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CORRESPONDENCE and COMMUNICATION:

Istanbul Gelisim University Faculty of Engineering and Architecture
Cihangir Mah. Şehit P. Onb. Murat Şengöz Sk. No: 8
34315 Avcilar / Istanbul / TURKEY
Phone: +90 212 4227020 **Ext.** 221
Fax: +90 212 4227401
e-Mail: ijet@gelisim.edu.tr
Web site: http://ijet.gelisim.edu.tr
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E-mail: ankamatbaa@gmail.com

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Dear Colleagues,

On behalf of the editorial board of International Journal of Engineering Technologies (IJET), I would like to share our happiness to publish the eighth and ninth issues of IJET. My special thanks are for members of editorial board, publication board, editorial team, referees, authors and other technical staff.

Please find the eighth and ninth issues of International Journal of Engineering Technologies at http://ijet.gelisim.edu.tr or http://dergipark.gov.tr/ijet. We invite you to review the Table of Contents by visiting our web site and review articles and items of interest. IJET will continue to publish high level scientific research papers in the field of Engineering Technologies as an international peer-reviewed scientific and academic journal of Istanbul Gelisim University.

Thanks for your continuing interest in our work,

Professor Mustafa BAYRAM
Istanbul Gelisim University
mbayram@gelisim.edu.tr

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Numerical and Experimental Investigation of Aerodynamics Characteristics of NACA 0015 Aerofoil

Robiul Islam Rubel*‡, Kamal Uddin**, Zahidul Islam**, M.D. Rokunuzzaman**

* Department of Mechanical Engineering, Bangladesh Army University of Science & Technology, Saidpur Cantonment, Saidpur-5311, Bangladesh

**Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Rajshahi-6204, Bangladesh

(rubel.ruet10@gmail.com, kamaluddin.me10@yahoo.com, jahid10ruet@gmail.com, rzaman.mte@ruet.ac.bd)

‡ Corresponding Author; Robiul Islam Rubel, Department of Mechanical Engineering, Faculty of Mechanical & Production Engineering, Bangladesh Army University of Science & Technology, Saidpur Cantonment, Saidpur-5311, Bangladesh , Tel: +880-1749-399 082, rubel.ruet10@gmail.com

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Abstract- An aerofoil is a streamline body. Symmetric aerofoil (NACA 0015) is used in many applications such as in aircraft submarine fins, rotary and some fixed wings. The ultimate objective of an aerofoil is to obtain the lift necessary to keep an airplane in the air. But construction of the blade with proper angle of attack and implementation has significant effect on lift force. Insufficient lift force might cause fail of airplane flying, especially at high speed. Modern technologists use different simulation techniques to avoid costly model testing. But simulation is based on some assumption. Thus practically results are not fully authentic and have a deviation. In this work numerical and experimental investigation of NACA 0015 is studied at different angle of attack (degree) at different velocity of air by determining the forces at every two degrees from 0^0 to 18^0. The experiment is conveyed in a low speed wind tunnel. The numerical analysis is conducted using ANSYS (combined with CFD and FLUENT FLOW). The use of the CFD technology greatly reduces the overall investment and efforts for aerofoil design. CFD method contributes to visualize the flow pattern inside aerofoil and takes less time and comparatively faster than experiment. After completing the experimental, numerical data is compared. Therefore, the objective of this paper is to find the deviation and validation of aerodynamics characteristics of NACA 0015 aerofoil for experimental and numerical method.

Keywords CFD fluent flow, Lift and drag force, Experimental analysis, Numerical analysis, Comparison.

1. Introduction

An aerofoil is defined as the cross section of a body that is placed in an airstream in order to produce a useful aerodynamic force in the most efficient manner possible. It is an aerodynamic shape moves through air when applied. When it is applied as wing air is split in two streams. Among them one passes above and the other passes below the wing. The wing's upper surface is so shaped that air rushing over the top, speeds up and stretches out. This phenomenon produces a pressure reduction above the wing. Comparatively air flows in straighter line below the wing. Thus speed and air pressure remains the same for the shape [1]. Angle of attack, leading edge, trailing edge, span length, chord length, lift force, drag force and thickness all of them have to be clearly defined and be calculated from geometry of aerofoil [2]. The aerodynamics characteristic of an aerofoil is mainly depended on the flow characteristic [3]. Because a wing which is actually an aerofoil generates lift due to its characteristics shape. Lift acts on the centre of pressure at the perpendicular of relative wind flow where drag is parallel to relative wind flow which opposes the motion of aerofoil. Resultant force with X-axis at the centre of pressure is produced by the pressure difference between upper and lower surfaces. It is experimentally and theoretically noticed that asymmetrical aerofoil generates more lift than the symmetrical aerofoil. This performance will have an impact on the manoeuvrability [4]. The cross sections of wings, propeller blades, windmill blades, compressor and turbine blades in a jet engine, hydrofoils, aircraft vertical stabilizers, submarine fins, rotary and some fixed wings are examples of aerofoil [5,6]. The basic geometry of an aerofoil is shown in Fig. 1. Since an aerofoil is stream line body it may be symmetrical or unsymmetrical in shape characterized by its chord length (C), angle of attack (α), and span length (L) [7]. The basic forces on an aerofoil are shown in Fig. 2. The drag force and lift force significantly depends on its geometrical shape [8]. The proper designing of the aerofoil can minimize the produced drag on the aerofoil. The lift on the aerofoil is due to negative pressure created on the upper part of aerofoil [9]. Low Reynolds number aerofoil is important in civilian, technical or military applications. This may include propellers, high-altitude vehicles, sailing aircraft, light or heavy man carrying aircraft, blades of wind turbine, and micro or unman air vehicles (MAVs) [10]. Flow control over aerofoils is primarily directed at increasing the lift and decreasing the drag produced by the aerofoil [11]. Srinivosan et al. [12] studied on an oscillating aerofoil for evaluation of turbulence models for unsteady flows. He works on NACA 0015 aerofoil by using different turbulence models. Results found experimentally have good consistency with Spalart Allmaras turbulence model for lift, drag and moment coefficient. Lianbing's et al. [13] investigated on the performance of wind turbine NACA 0012 aerofoil using FLUENT (CFD) simulation techniques. With the rapid increase in computer performance, computational fluid dynamics (CFD) is possible in three dimensions at reasonably low costs. This can be employed to investigate complex dynamic three-dimensional effects [14]. Bacha et al. [15] works on prediction of drag over two-dimensional aerofoils in case of transitional flow. Chervonenko at el. [16] studied the effect of AOA on the non-stationary aerodynamic characteristics. Ramdenee et al. [17] investigated on modeling of aerodynamic flutter on a NACA 4412 aerofoil with application to wind turbine blades. Johansen [18] worked on the transition of flow from laminar to turbulent in aerofoil. Launder et al. [19] showed the numerical computation of turbulent flows. Kevadiya et al. [20] did 2D analysis and Saraf [21] of NACA 4412 aerofoil blade. By Bensiger et al. [22] CFD analysis of a bi-convex aerofoil was performed at supersonic and hypersonic speed. Turbulence models for the simulation of the flow over NACA 0012 aerofoil was evaluated by Eleni [23]. Low speed wind tunnel experiment is conducted by Şahin [24] et al. and using CFD (FLUENT) the numerical analysis was performed. A comparison was made between results obtained from experiment and numerical analysis. Study determines that, stall angle has dependency on turbulent that occur behind the aerofoil. As result, effect of the stall angle of aerofoil performance was investigated. CFD enable the engineers to see the aerodynamic effect of changing the geometry and to examine the airflow over an automobile or a particular part such as a wing or hood [25]. This work also focuses on Spalart Allmaras turbulence model for at 3× 106 Reynolds number for lift, drag force performance and stall angle. This paper is evaluated for finding the aerodynamics characteristics using CFD method. This method has contributed to visualize the flow pattern inside an aerofoil quickly than experiment.

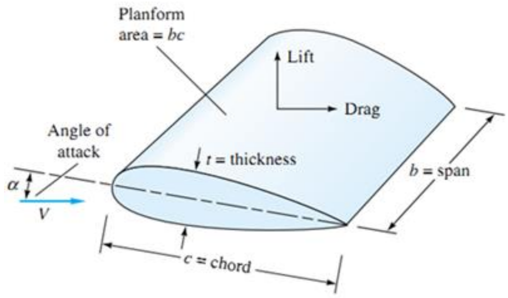


Fig. 1. Geometry of an aerofoil blade.

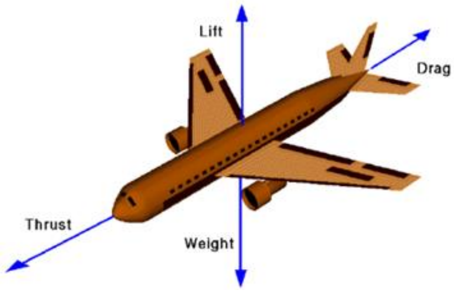


Fig. 2. Forces on a flooding body in air.

Lift and drag force is measured for the projected model of NACA 0015 at different velocity by inclined tube manometer. Lift coefficient (C_L), drag coefficient (C_D) and drag polar (C_L/C_D) is also measured and compared with experimental results.

2. Methodology

The experiment is conducted by an open channel wind tunnel having cross section of 0.3 m×0.3 m (aspect ratio 1) and length 0.4 m at 8.5-9.65 m/s wind velocity. The model is first prepared by casting followed by other machining process to obtain desired model. The model is placed in the open wind tunnel having an operating motor of 2800 rpm driving tunnel fan and tested. Lift and drag force are measured from balanced arm and velocity of air determined from inclined tube manometer after placing the model at an angle of attack (2 degree), which is increased after 2 degree-interval. A model is developed by ANSYS 14.0 workbench modeler and boundary conditions are applied on the aerofoil using FLUENT. A fine mesh body of the airfoil is needed in order to model the flow field accurately. Flow for this Reynolds number can be labeled as incompressible.

2.1. Experimental Arrangement

After settling the aerofoil blade specimen (Al) in the shaper machine table, it was feed across the single point cutting tool and removes metal from specimen. For making an aerofoil blade two supporter are needed to support the aerofoil blade. It is also useful for the freely movement of clapper part inside the supporter from top and upper portion. It is very complex to make. Drill bit is feed on the work piece by holding it by bench vise. Drilling operation is done in five points on the aerofoil specimen for entering screw in four holes and one hole for pushing small shaft bar which helps to stands the aerofoil blade upon the protractor.

Fig. 3. Preparation of an aluminum NACA 0015 blade.

Additional metal is also removed by using hand grinder. Filling operation is done by using flat file and fine grinding machines, sometimes in machine vise and sometimes in magnetic vice for an operating condition. Figure 3 shows some steps for fabrication of the blade.

Fig. 4 is the diagram of an open type wind tunnel with the following components numbered by (1) Base, (2) Moving carrier, (3) Balance Arm, (4) Speed Controller, (5) Inclined tube manometer, (6,7) Drive section (Motor, fan), (8) Diffuser, (9) Model, (10) Test Section, (11,13) Contraction Cone. The whole setup is shown in Fig. 5.

3. Theoretical Background

3.1. Lift and Drag force

The force that works normal to the body is referred as lift force. When fluid incorporates a circulatory flow about the body then lift will create as velocity above the object is increased and static pressure is reduced. The slowing of velocity beneath the body gives an increase in static pressure. Consequently, a normal or upwards lift force is created. The drag on a body is also a force as lift force but works in the direction parallel to the flow. Both of them are expressed in dimensionless terms called lift and drag coefficient. Lift force is a component of total force F perpendicular to the stream of Fcosα. So for the drag in the direction of the stream, which is Fsinα. The lift coefficient (C_L) and drag coefficient (C_D) is defined as mathematically by Eq. (1) and Eq. (2).

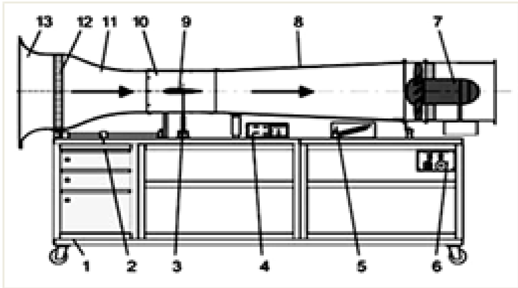


Fig. 4. Diagram of open type wind tunnel.

Fig. 5. Experimental setup.

$$C_L = \frac{2F_L}{\rho V^2 A} \quad (1)$$

$$C_d = \frac{2F_D}{\rho V^2 A} \quad (2)$$

Where, F_L= Lift produced, F_D= Drag produced, ρ = density of air, V = velocity of the air and A = (C×L) = area of the aerofoil. The magnitude of the coefficient differs with the angle of attack. Lift force is high at small angles of attack but drag force is low for a certain angle of attack. After that lift force decreases where drag forces increases.

3.2. Reynolds number

The Reynolds number is dimensionless number which is defined as following-

$$Re_L = \frac{\rho V L}{\mu} \quad (3)$$

Where, density of air ρ= 1.17 kg/m^3, kinematic viscosity, μ = 1.973 kg.m^{-1} s^{-1}, span length, L = 26 cm.

3.3. Mach number

It is defined as the ratio of the speed of the flow to that of the speed of sound. Again ratio of inertia forces in the fluid to the force resulting from compressibility is also interpreted as Mach number. Mathematically it is written as M = U/a. Pressure disturbances propagate through the air at the speed of sound given by $a = \sqrt{\gamma RT}$. For the experimental set up Mach number ≤ 0.15. Thus entire range of air flow remains subsonic and incompressible.

3.4. Design Criteria

In this paper, the NACA 0015 aerofoil from the 4-digit series of NACA aerofoil is utilized. The NACA 0015 airfoil is symmetrical is nature. The first two digits '00' indicate that it has no camber. The '15' indicates that the airfoil has a 15% thickness to chord length ratio (t/c). Ordinates for the NACA 0015 aerofoil can be describe by the following formula.

$$\frac{y}{c} = a_0\left(\frac{x}{c}\right)^{0.5} + a_1\left(\frac{x}{c}\right)^1 + a_2\left(\frac{x}{c}\right)^2 + a_3\left(\frac{x}{c}\right)^3 + a_4\left(\frac{x}{c}\right)^4 \quad (4)$$

The following co-efficient a_0, a_1, a_2, a_3, and a_4 are determine to find the required terms. Thus the parameters of the NACA 0015 aerofoil blade are the following-

Chord length of the aerofoil, C = 0.06 m

Maximum chamber, m = first digit × % C = $0 \times \frac{1}{100} \times 0.06$

Distance from leading edge to maximum wing thickness, p = second digit × 10% C = $0 \times \frac{1}{100} \times 0.06 = 0$

Maximum wing thickness, t = last two digit × % C = $15 \times \frac{1}{100} \times 0.06$ = 0.009 m

3.5. Computational fluid dynamics equations

The physics of fluid flow are described by equations mathematically. Navier-Stokes equation (Continuity equation and the momentum equation) describe the state of any type of flow and are generally solved for all flows in CFD modeling. Practically the governing equations for flows are complicated. Therefore an exact solution is unavailable and it is necessary to seek a computational solution method. The governing partial differential equations are replaced by algebraic equations in computational technique. The governing equation may have the form like this.

$$\frac{\partial U}{\partial t} + \frac{\partial F}{\partial x} + \frac{\partial G}{\partial y} + \frac{\partial H}{\partial z} = J \quad (5)$$

This is also termed as panicking differential equation or a system of equations. They are namely: (a) continuity equation, (b) three dimensional momentum equation, and (e) energy equation. If U, F, G, H. and J are considered functions with column vector then they take the form given

$$U = \begin{pmatrix} \rho \\ \rho u \\ \rho v \\ \rho w \\ \rho\left(e+\frac{V^2}{2}\right) \end{pmatrix} \quad (6)$$

$$F = \begin{pmatrix} \rho u \\ \rho u^2 + p - \tau_{xx} \\ \rho uv - \tau_{xy} \\ \rho wu - \tau_{xz} \\ \rho\left(e+\frac{V^2}{2}\right)u + pu - k\frac{\partial T}{\partial x} - u\tau_{xx} - v\tau_{xy} - w\tau_{xz} \end{pmatrix} \quad (7)$$

$$G = \begin{pmatrix} \rho v \\ \rho uv - \tau_{yx} \\ \rho v^2 + p - \tau_{yy} \\ \rho wv - \tau_{yz} \\ \rho\left(e+\frac{V^2}{2}\right)w + pv - k\frac{\partial T}{\partial y} - u\tau_{yx} - v\tau_{yy} - w\tau_{yz} \end{pmatrix} \quad (8)$$

$$H = \begin{pmatrix} \rho w \\ \rho uw - \tau_{zx} \\ \rho vw - \tau_{zy} \\ \rho w^2 + p - \tau_{zz} \\ \rho\left(e+\frac{V^2}{2}\right)w + pw - k\frac{\partial T}{\partial z} - u\tau_{zx} - v\tau_{zy} - w\tau_{zz} \end{pmatrix} \quad (9)$$

$$J = \begin{pmatrix} 0 \\ \rho f_x \\ \rho f_y \\ \rho f_z \\ \rho(uf_x + vf_y + wf_z) + q \end{pmatrix} \quad (10)$$

In Eq. (5), the column vectors F, G, and H are denoted flux terms, and J represents a source term. The continuity equation can be derived by putting the first vector in Eq. (5).

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} + \frac{\partial \rho w}{\partial z} = 0 \quad (11)$$

Where ρ stands for density. The mass fluxes in the x, y, z directions are ρu, ρv, and ρw respectively. The momentum and the energy equation can be found following the same procedure. Both steady state and transient state solutions will be satisfied by Eq. (5). The fluxes considered are (a) mass flux = ρV, (b) flux of x, y, and z component of momentum are ρuV, ρvV, ρwV, (c) flux of internal energy = ρeV, (d) flux of total energy = $\rho\left(e+\frac{V^2}{2}\right)$. The CFD codes contain all the necessary equations to be solved. All that is needed is to define computational domain in time and space. Also this need to initialize the solution process by defining the boundary values as a common process in numerical solutions. The computer runs the solution process and solves the required unknowns for each element of fluid or more precisely, for each point in the computational grid.

4. Results and Discussion

4.1. Lift Coefficient and Drag Coefficient vs Angle of Attack

Lift coefficient depends on angle of attack. The experimental results obtained from our model NACA 0015 are plotted on graph. The Fig. 6 shows that lift coefficient increases with increasing angle of attack and after a certain angle of attack it is decreased and this angle is called stall angle.

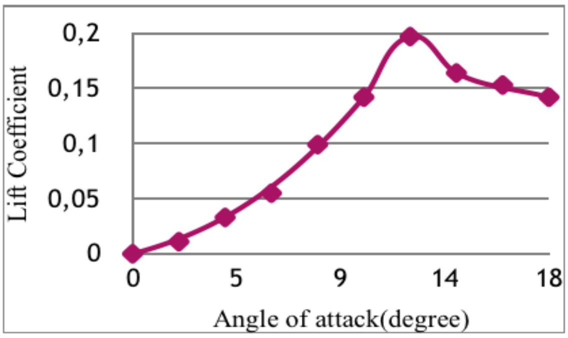


Fig. 6. Variation of Lift Coefficient w.r.to angle of attack.

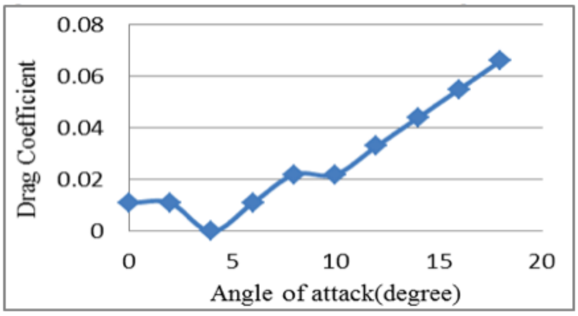


Fig. 7. Variation of Drag Coefficient w.r.to angle of attack.

C_L is maximum (0.197) at 12 degrees. The stall angle is caused transition from laminar to turbulence flow. Drag coefficient also depends on angle of attack. It is clear from Fig. 7 that the value drag coefficient is increased as angle of attack is increased. Drag coefficient is maximum (0.066) at 18 degrees.

4.2. Performance curve for NACA 0015

From Fig. 8 it is clearly noticed that C_L/ C_D is gradually increases as the value of AOA is increased. C_L/C_D is maximum (6.45) at 10 degrees. After these values C_L/ C_D ratio start decreases with the increases of angle of attack.

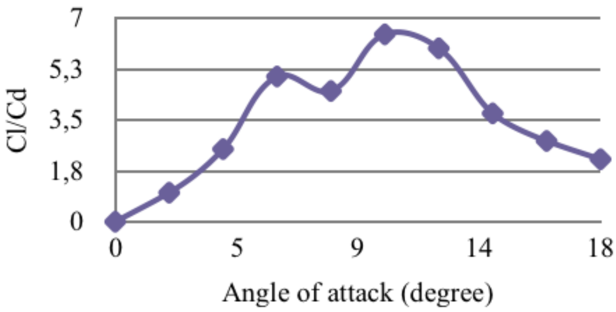


Fig. 8. Variation of C_L/C_D w.r.to Angle of attack

5. Simulation with ANSYS and CFD

5.1. Problem Specification

This section shows how to simulate a NACA 0015 aerofoil at different angle of attack placed in a subsonic wind tunnel. FLUENT is used for creating an environment for simulation of this experiment. Afterwards, comparison is made for the values from the simulation and experiment. The coordinates are tabulated from which the following profile is drawn as in Fig. 9 and Fig. 10. In this step the coordinates for NACA 0015 aerofoil were imported to create the geometric shape that will be used for the simulation process.

5.2. C-Mesh Domain

After generation of aerofoil profile, it is needed to create the mesh able surface to specify boundary conditions. A coordinate system is created at the tail of the aerofoil to begin C-Mesh. The computational domain is set from tailing edge to inlet and outlet 12.5L (L= Chord length) V4= =H3=R5=12.5L presented in Fig. 10 where H3=R5=12.5L presented in Fig. 11.

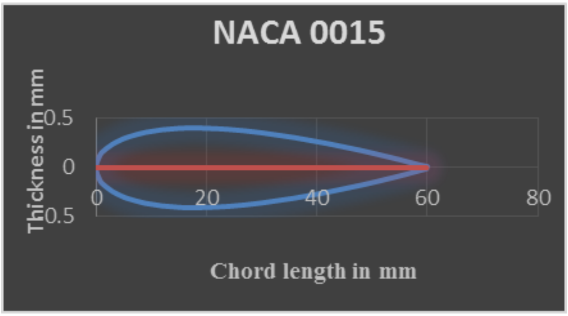


Fig. 9. Aerofoil profile drawn by Microsoft Excel.

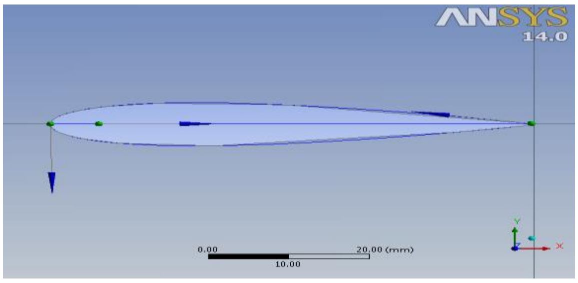


Fig. 10. Geometry of NACA 0015 in ANSYS.

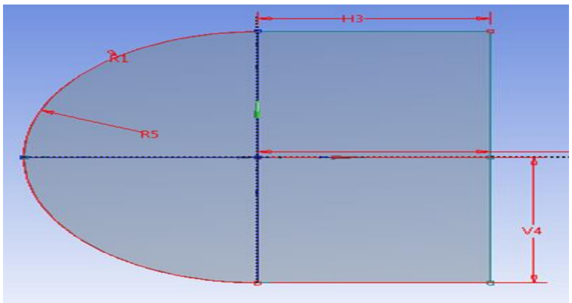


Fig. 11. Setup of a C mesh domain.

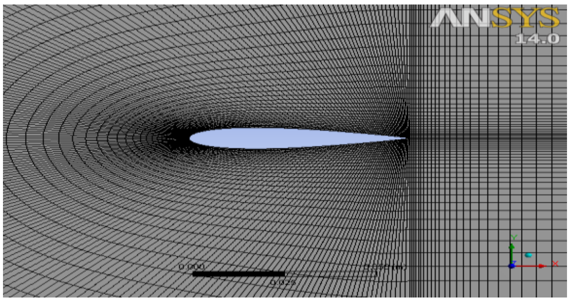


Fig. 12. Mesh generation for NACA 0015.

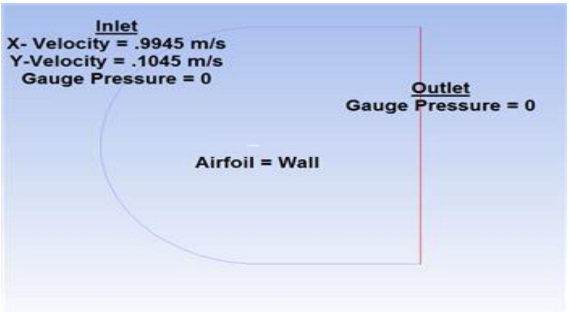


Fig. 13. Setting boundary conditions.

5.3. Mesh generation

The flow domain is mandatorily split into smaller subdomains in order to analyze the fluid flows. These are each mesh elements. The mesh mode is shown in Fig. 12. After mesh analysis it is found that total nodes 15300 totals elements 15000. Mesh analysis was done by assuming relevance center is fine and smoothing is high.

5.4. Inputs and Boundary condition

Boundary conditions are a set of physical properties or conditions on surfaces of the domains. The flow simulation is defined completely by the boundary conditions. The equations relating to fluid flow can be closed (numerically) by the specification of conditions on the external boundaries of a domain.

Table 1. Boundary conditions for CFD analysis

Input Parameter	Magnitude	Input Parameter	Magnitude
Solver type	Density based	AOA	0°-8°
Time	Steady	Kinematic viscosity	1.46e-5
Velocity of flow	8.5-9.65 m/s	Reynolds number	Vary with air velocity
Operating temperature	300 k	Number of iteration	1500
Operating pressure	1 atm	Angle of Attack	0° to 18°
Viscous model	Laminar	Solution method	Second order upwind
Density of fluid(Ideal air)	1.23 kg/m^3	Length	0.06 m

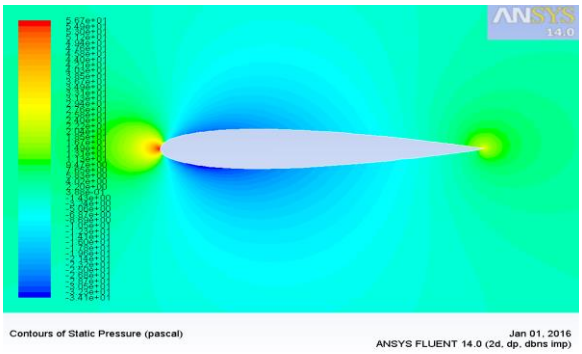
Therefore, it is prime important to establish boundary conditions to accurately imitate practical situation that would allow obtaining accurate results. In this work C-mesh is intended to use as it is the most popular mesh for simulating an aerofoil. At the inlet of the system velocity is defined at a 6 degrees angle of attack having total magnitude of one. The gauge pressure at the inlet is defined zero and at outlet the gauge pressure is assumed zero. When all pre-calculations are set, the simulation is ready to perform in ANSYS Workbench. FLUENT is used to simulate completely. The problem considers flow around the Aerospatiale an aerofoil at 0º - 18º angles of attack. Some initial inputs and boundary condition for the problems which are set shown in the Table 1 and Fig. 13. Before running the simulation it must configure the software environment according to the following checklists or in other words it classifies the job according to the physical phenomena involved.

5.5 Results of Simulation

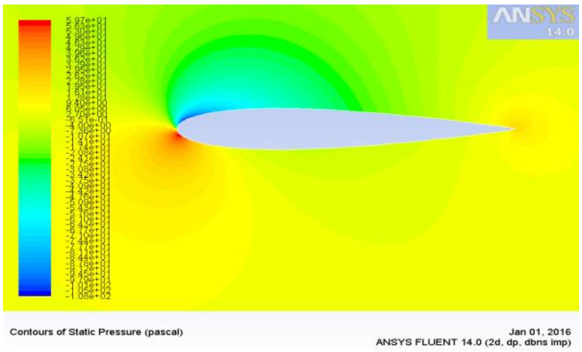
The following figure shows the result of simulation after completing the total iteration. The analysis is visualized in the following plots.

5.5.1. Contours of Static Pressure

Contours of static pressure show that static pressure increases at the lower surface of the aerofoil with increasing angle of attack.

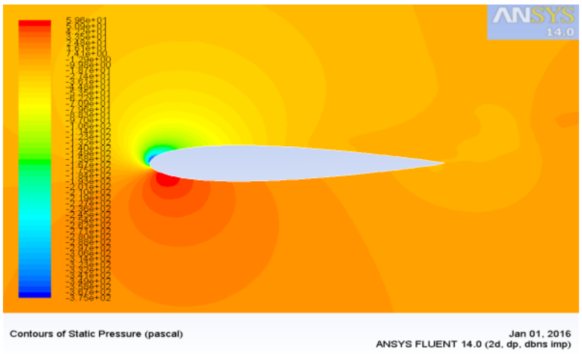


(a) 0 degrees angle of attack



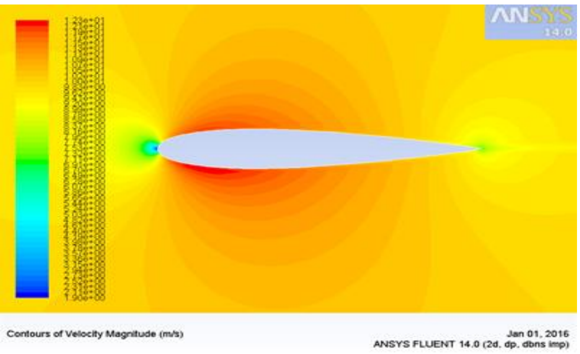
(b) 6 degrees angle of attack

(c) 12 degrees angle of attack

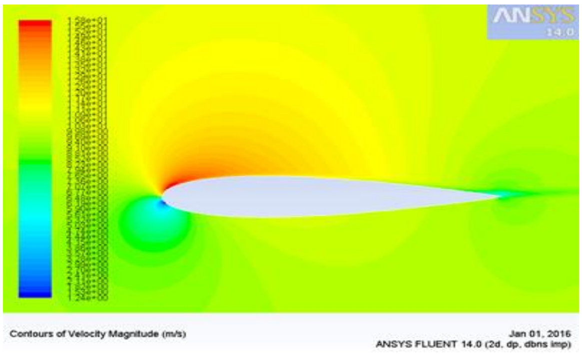


(d) 18 degrees angle of attack

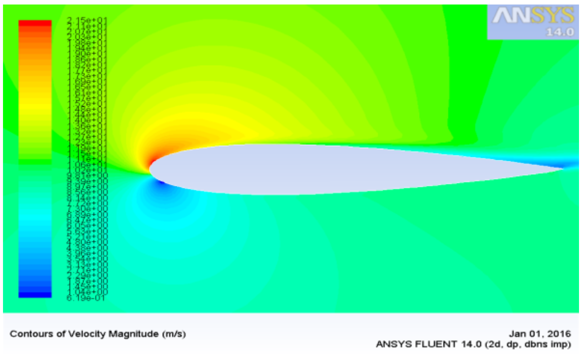
Fig. 14. Static Pressure contours for NACA 0015.



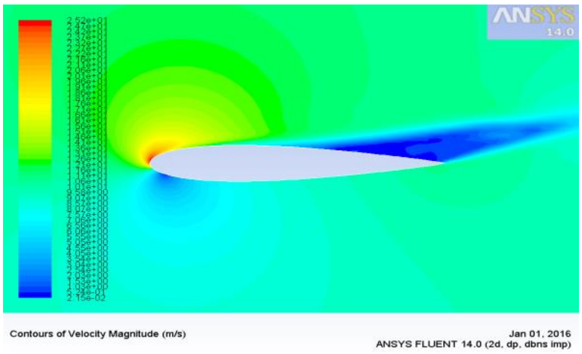
(a) 0 degrees angle of attack



(b) 6 degrees angle of attack



(c) 12 degrees angle of attack



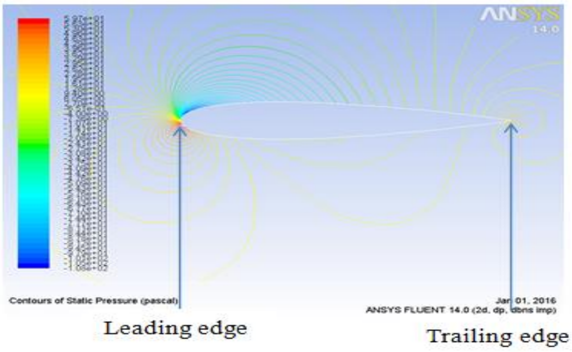
(d) 18 degrees angle of attack

Fig. 15. Contours of velocity magnitude for NACA 0015.

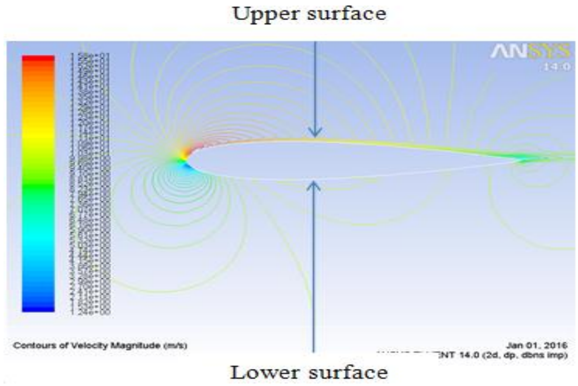
Fig. 14 shows the outcomes of static pressure at angles of attack 0°-18° with the viscous model. It is depicted from the figure that, magnitude of pressure on the aerofoil is more in lower surface than that of the incoming flow stream. As a result an effective upward push called lift is obtained, perpendicular to the incoming flow stream. Static pressure increases with increasing angle of attack but at 12 degrees angle (Maximum 6.14e=01 Pa) of attack it decreases slightly. Between 0° to 12° angle of attack flow pattern is laminar around the NACA 0015 airfoil. Laminar flow becomes go through transition turbulence flow for more than 16° AOA. Therefore, pressure distribution also changed and lift coefficient began to decrease.

5.5.2. Contours of Velocity Magnitude

Contours of velocity magnitude show that static pressure increases at the lower surface of the aerofoil with increasing angle of attack but reversely velocity magnitude increases at the upper surface. Contours of velocity components at angles of attack 0°-18° are also shown in Fig. 16. The stagnation point at the trailing edge moves slightly forward at low AOA. At stall angle it jumps rapidly to the leading edge. Higher velocity is experienced in the upper surface compare to lower surface and increase with AOA as expected from the nature of pressure distribution. The Fig. 16(a) demonstrates that leading edge of NACA 0015 experiences higher static force than telling edge. It is clearly noticed from the Fig. 16(b) that velocity at the upper surface is increased than lower surface of the aerofoil. Low velocity at lower surface generates more lift.



(a)



(b)

Fig. 16. At 6° angle of attack (a) Static pressure contours without filled, (b) Velocity magnitude contours without filled for NACA 0015.

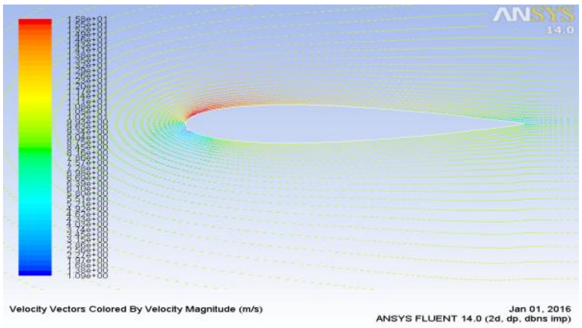


Fig. 17. Velocity vector colored by velocity magnitude.

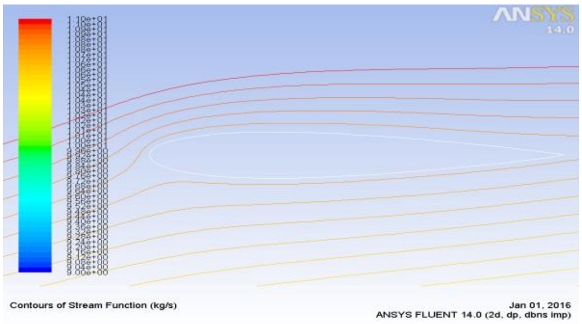


Fig. 18. Stream function for NACA 0015.

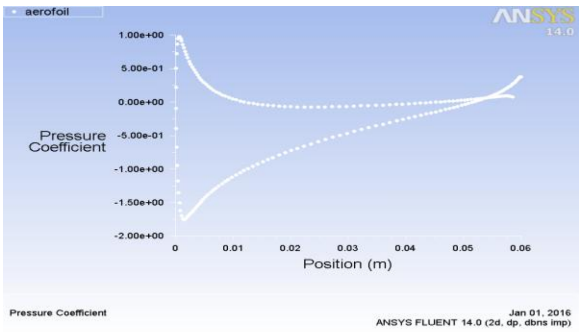
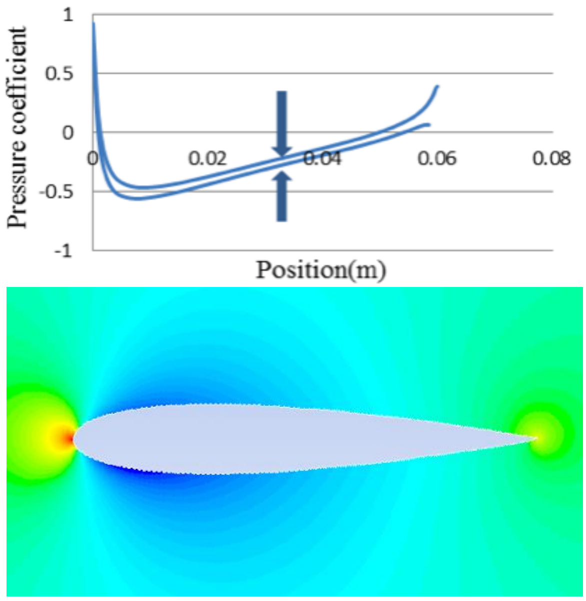


Fig. 19. Pressure coefficient vs position of chord length curve for NACA 0015.

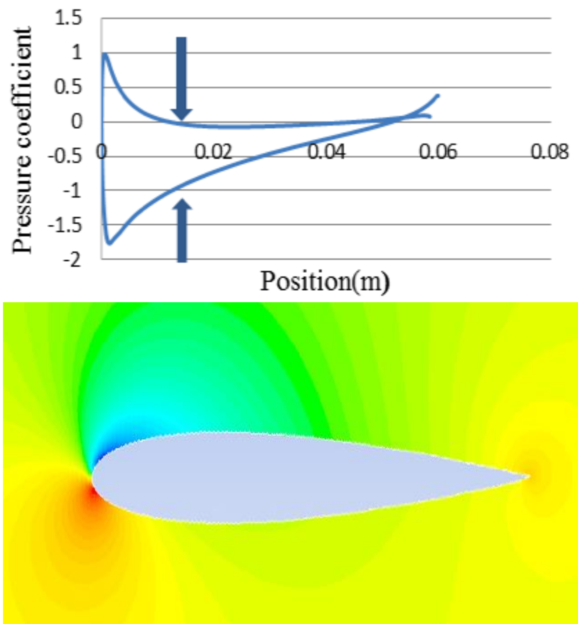
5.5.3. Velocity Vector and Stream Function at 6° Angle of Attack

After analysis it is found that velocity vector is 15.8 m/s for NACA 0015. The pressure distribution parallel to the stream line of the incoming flow tends to slow the velocity of the incoming flow presented in Fig. 17 and Fig 18. Pressure Coefficient vs Position of Chord Length curve at 6° angle of attack is presented in Fig. 19. The two curves show that negative pressure at the lower surface of the aerofoil is greater than positive surface.

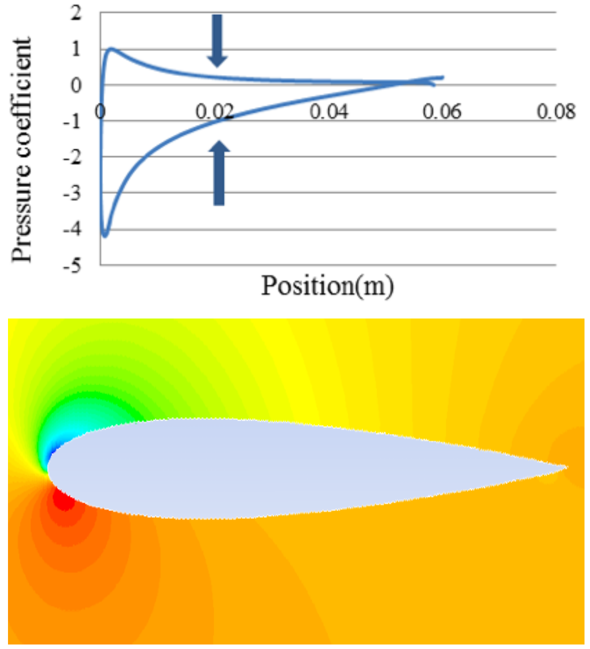
It is clearly observed from Fig. 20 (a) that pressure coefficient is very low experienced only at leading edge of the aerofoil due to its lower angle of attack. Fig. 20(b) shows that with increasing angle of attack, the area between positive Cp and negative Cp is increased and this high pressure coefficient generates lift on the airfoil to turn around or to fly. Further angle of attack is increased (12°), Cp is increased at the lower surface of the aerofoil greater than 6° angle of attack which shown at contours of pressure coefficient also at the area of graph shown in Fig 20(c).



(a) 0° angle of attack



(b) 6° angle of attack



(c) 12° angle of attack

Fig. 20. Pressure coefficient (Cp) vs position of chord length (m) and contours of pressure coefficient for NACA 0015 at different AOA.

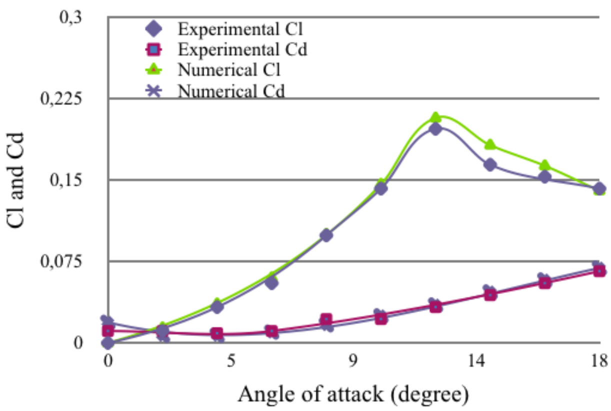


Fig. 21. Variation of C_L and C_D w.r.to angle of attack.

6. Comparison of the Experimental and Numerical Data

Fig. 21 is the comparable curve between numerical and experimental data. In Fig. 21 it is seen that lift coefficient increases with the increases of angle of attack up to a certain limit then it decreases experimentally but numerically lift coefficient stay some nearer to the value obtained from experimentally. Drag coefficient increases with the increases of angle of attack experimentally and also numerically value of drag coefficient remains very closest. It is shown in the above figure that lift coefficient is 0.197 for NACA 0015 numerically which is very closer to the value obtained in experimentally 0.207.

7. Conclusions

Preparing a NACA 0015 aerofoil blade, experimental and numerical measurement of lift and drag force is performed. The experiment is compensated for NACA 0015 by an open type wind tunnel. CFD study of airfoils is performed to predict its lift and drag characteristics, visualization and surveillance of flow field pattern around the body. It shows distribution of turbulence, distribution of pressure and total pressure velocity contour around NACA 0015 aerofoil blade. Both lift and drag coefficient increases as angle of attack (degree) is increased. The drag coefficient gradually is decreased as Reynolds's number increases. But with the increase of Reynolds's number lift coefficient increases slightly and after a certain point it decrease. There is large negative pressure created on the aerofoil, which accounts for most of the lift. Pressure is maximum and velocity is zero at stagnation point. Distinct red point on the velocity contour plots characterized this zone. With positive AOA, stagnation point transfers in the direction of trailing edge on the lower surface of the aerofoil. This deviation of pressure between upper and lower surface of the airfoil principally creates significant amount of positive lift. Numerical modeling can be good practice for determining the aerofoil properties instead of costly wind tunnel model tests.

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References

[1]K. S. Patel, S. B. Patel, U. B. Patel, and A. P. Ahuja, "CFD Analysis of an Aerofoil", International Journal of Engineering Research, vol. 3, issue. 3, pp. 154-158, March 2014.

[2]I. B. Llorca, "CFD Analysis and Assessment of the Stability and Control of a Supersonic Business Jet", Royal Institute of Technology (KTH), Stockholm, Sweden, March 2015.

[3]Y. T. Chuen, M. Z. Abdullah, and Z. Husain, "The Effects of Turbulence Intensity on the Performance Characteristics of NACA 0015 and Eagle 150 Airfoils", Proc. NSF Seminar 2002.

[4]W. L. Siauw, J. P. Bonnet, and J. Tensi, "Physics of Separated Flow Over a NACA 0015 Airfoil and Detection of Flow Separation", 47th AIAA Aerospace Sciences Meeting Including The New Horizons Forum and Aerospace Exposition, 5 - 8 January 2009, Orlando, Florida.

[5]M. R. Islam, M. A. Hossain, M. N. Uddin, and M. Mashud, "Experimental Evaluation of Aerodynamics

Characteristics of a Baseline Aerofoil", American Journal of Engineering Research, vol. 4, Issue. 1, pp. 91-96, 2015.

[6]S. Kandwal, and S. Singh, "Computational Fluid Dynamics Study of Fluid Flow and Aerodynamic Forces on an Aerofoil", International Journal of Engineering Research & Technology, vol. 1, Issue. 7, 2012.

[7]Dr. R. K. Bansal, Fluid Mechanics and Hydraulic Mechunes, 9th ed., Laxmi Publication (P) Ltd, 2010, pp. 686- 687.

[8]M. Morshed, S. B. Sayeed, S. A. A. Mamun, and J. Alam, "Investigation of Drag Analysis of Four Different Profiles Tested at Subsonic Wind Tunnel", Journal of Modern Science and Technology, vol. 2, No. 2, pp. 113-126, 2014. (Article)

[9]E. H. Lewitt, Hydraulics and Fluid Mechanics, 10th ed., Sir Isaac Pitman & Sons Ltd, 1963, pp. 382-383.

[10] M. S. Selig, and J. J. Guglielmo, "High-Lift Low Reynolds Number Airfoil Design", Journal of Aircraft, vol. 34, No. 1, 1997.

[11] Z. Yang, H. Igarashi, M. Martin, and Hui Hu, "An Experimental Investigation on Aerodynamic Hysteresis of a Low-Reynolds Number Aerofoil", American Institute of Aeronautics and Astronautics, AIAA-2008-0315, 2008.

[12] G. R. Srinivasan, J. A. Ekaterinaris, and W. J. McCroskey, "Evaluation of Turbulence Model for Unsteady Flows of an Oscillating Aerofoil", Elsevier Science Ltd., Computers & Fluids, vol. 24, No. 7, 1995, pp. 833-861.

[13] L. B. Li, Y. W. Ma, and L. Liu, "Numerical Simulation on Aerodynamics Performance of Wind Turbine Aerofoil", Conf. on World Automation Congress (WAC), Puerto Vallarta, Mexico, Publisher by IEEE, pp. 1-4, 2012.

[14] M. Gaunaa, J. N. Sørensen, P. S. Larsen, "Unsteady Aerodynamic Forces on NACA 0015 Airfoil in Harmonic Translatory Motion", Technical University of Denmark, (MEK-FM-PHD; No. 2002-02, 2002.

[15] W. Bacha, and W. Ghaly. "Drag Prediction in Transitional Flow Over Two-Dimensional Airfoils", 44th AIAA Aerospace Sciences Meeting and Exhibit, Aerospace Sciences Meetings, Reno, Nevada, 2006.

[16] A. G. Chervonenko, "Effect of attack Angle on the Nonstationary Aerodynamic Characteristics and Flutter Resistance of a Grid of Bent Vibrating Compressor Blades", Ukrainian Academy of Sciences, Plenum Publishing Corporation, Ukraine, vol. 39, No. 10, pp. 78-81. 1991.

[17] D. Ramdenee, H. Ibrahim, N. Barka, and A. Ilinca, "Modeling of Aerodynamic Flutter on A NACA 4412 Airfoil Wind Blade", International Journal of Simulation and Process Modeling, Inderscience Publishers, Canada, vol. 8, No. 1, pp. 79-87, 2013.

[18] J. Johansen, "Prediction of Laminar/Turbulent Transition in Airfoil Flows", Journal of Aircraft, Aerospace Research Central, Denmark, vol. 36, No. 4, pp. 731-734, 1997.

[19] B. E. Launder, and D. B. Spalding, "The Numerical Computation of Turbulent Flows", Computer Methods in Applied Mechanics and Engineering, vol. 3, No. 2, pp. 269-289, 1974.

[20] M. Kevadiya, H. A. Vadiya, "2D Analysis of NACA 4412 Airfoil", International Journal of Innovative Research in Science Engineering and Technology, vol. 2, No. 5, pp. 168-1691, 2013.

[21] A. K. Saraf, M. Singh, and A. Kumar, "Analysis of the Spalart-Allmaras and k-ω standard models for the simulation of the flow over a National Advisory Committee for Aeronautics (NACA) 4412 airfoil", International Journal of Scientific & Engineering Research, vol. 3, Issue 8, pp. 1-7, August-2012.

[22] S. S. B. Bensiger, and N. Prasanth, "Analysis of Bi-Convex Airfoil Using CFD Software at Supersonic and Hypersonic Speed", Elixir International Journal, vol. 53, pp. 11695-11698, 2012.

[23] D. C. Eleni, T. I. Athanasios, and M. P. Dionissios, "Evaluation of the Turbulence Models for the Simulation of the Flow over an Aerofoil", Journal of Mechanical Engineering Research, vol. 4, No. 3, pp. 100-111, 2012.

[24] I. Şahin, and A. Acir, "Numerical and Experimental Investigations of Lift and Drag Performances of NACA 0015 Wind Turbine Aerofoil", International Journal of Materials, Mechanics and Manufacturing, vol. 3, No. 1, pp. 22-25, 2015.

[25] S. Chandra, A. Lee, S. Gorrell, and C. G. Jensen, "CFD Analysis of PACE Formula-1 Car", Computer-Aided Design & Applications, PACE (1), 2011, 1-14.

Using Five Machine Learning for Breast Cancer Biopsy Predictions Based on Mammographic Diagnosis

David Oyewola*‡; Danladi Hakimi*; Kayode Adeboye*, Musa Danjuma Shehu*

*Department of Mathematics, Federal University of Technology, Minna, Nigeria

(davidakaprof01@yahoo.com)

‡ Department of Mathematics, Federal University of Technology, Minna, Nigeria , davidakaprof01@yahoo.com

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Abstract- Breast cancer is one of the causes of female death in the world. Mammography is commonly used for distinguishing malignant tumors from benign ones. In this research, a mammographic diagnostic method is presented for breast cancer biopsy outcome predictions using five machine learning which includes: Logistic Regression (LR), Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), Random Forest (RF) and Support Vector Machine (SVM) classification. The testing results showed that SVM learning classification performs better than other with accuracy of 95.8% in diagnosing both malignant and benign breast cancer, a sensitivity of 98.4% in diagnosing disease, a specificity of 94.4%. Furthermore, an estimated area of the receiver operating characteristic (ROC) curve analysis for Support vector machine (SVM) was 99.9% for breast cancer outcome predictions, outperformed the diagnostic accuracies of Logistic Regression (LR), Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), Random Forest (RF) methods. Therefore, Support Vector Machine (SVM) learning classification with mammography can provide highly accurate and consistent diagnoses in distinguishing malignant and benign cases for breast cancer predictions.

Keywords Logistic regression, Linear discriminant analysis, Random forest, Quantitative discriminant analysis, Support vector machine, Breast cancer.

1. Introduction

Breast cancer is a malignant tumor that starts in the cells of the breast. A malignant tumor is a set of cancer cells that grow into surrounding tissues or spread to distance areas of the body. Breast cancer can occur in both men and women, although it is much more common in women. [1] .Breast cancer was rated second highest among women in the United States. Some women are at higher risk for breast cancer than others because of their personal or family medical history or because of certain changes in their genes [2].A patients using mammograms regularly can lower the risk of dying from breast cancer. Preventive Services Task Force in the United States recommends that average-risk women who are 50 to 74 years old should have a screening mammogram every two years**.** Average-risk women who are 40 to 49 years old should talk to their doctor about when to start and how often to get a screening mammogram.

Machine learning is a type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed. Machine learning have been used in cancer detection and diagnosis for a score [4-6]. Nowadays machine learning techniques are being used in a wide range of applications ranging from detecting and classifying tumors via X-ray and CRT images [7-8] to the classification of malignancies from proteomic and genomic (microarray) assays [9-10]. According to the latest PubMed statistics,more than 1500 papers have been published on the subject of machine learning and cancer. However, the vast majority of these papers are concerned with using machine learning methods to identify, classify, detect, or distinguish tumors and other malignancies. In other words machine learning has been used primarily as an aid to cancer diagnosis and detection [12]. Breast Cancer data can be useful to discover the genetic behaviour of tumors and to predict the outcome of some diseases. There are many techniques to predict and classify breast cancer pattern. This paper compares performance of five machine learning techniques classifiers.

2. Materials and Methods

In this study, the Wisconsin Breast Cancer Database an UCI Machine Learning Repository was analysed which was located in breast-cancer Wisconsin sub-directory, filenames root: breast-cancer-Wisconsin having 568 instances, 2 classes (malignant and benign), and 32 attributes (ID, diagnosis, 30 real-valued input features) (see Table 1). Our methodology involves use of machine learning techniques such as; Logistic regression (LR), Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), Random Forest (RF) and Support Vector Machine (SVM).

Table 1. Wisconsin Diagnostic Breast Cancer Attributes

Number	Attributes
1	ID number
2	Diagnosis (M = malignant, B = benign)
3-32	ten real-valued features are computed for each cell nucleus:
a)	Radius (mean of distances from center to points on the perimeter)
b)	Texture (standard deviation of gray-scale values)
c)	Perimeter
d)	Area
e)	Smoothness (local variation in radius lengths)
f)	Compactness (perimeter^2 / area - 1.0)
g)	Concavity (severity of concave portions of the contour)
h)	Concave points (number of concave portions of the contour)
i)	Symmetry
j)	Fractal dimension ("coastline approximation" -1)

2.1. Logistic Regression (LR)

Logistic regression is a generalized linear model that can be binomial or multinomial. Binomial or binary logistic regression can have only two possible outcomes: for example, "chronic disease" vs. "non-existence of chronic disease". The outcome is usually coded as "0" or "1", as this leads to the most straightforward interpretation. If possible outcome is success then it is coded as “1” and the contrary outcome referred as a failure is coded as "0". Logistic regression is used to predict the odds of a case based on the values of the independent variables (predictors). The odds are the probability that a particular outcome occuring divided by the probability that it is not occuring.

2.2. Linear Discriminant Analysis (LDA)

Linear Discriminant Analysis is a technique developed by Roland Fisher. It can also be called Fisher Discriminant Analysis (FDA). The main objective of LDA is to separate samples of distinct groups. Essentially, it transforms data to a different space which optimally distinguishes classes which can be referred to as the "between class" and "within class".

2.3. Quadratic Discriminant Analysis (QDA)

Quadratic Discriminant Analysis (QDA) is much like Linear discriminant analysis. QDA classifier results from assuming that the observations from each class are drawn from a Gaussian distribution and plugging estimates for the parameters in order to perform prediction. QDA assumes that each class has its own covariance matrix which leads to the number of parameters increases significantly.

2.4. Random Forest (RF)

Random forest provide an improvement over bagged trees by way of small tweak that decorates the trees.

In Breiman’s approach, each tree in the collection is formed by first selecting at random, at each node, a small group of input coordinates to split on and, secondly, by calculating the best split based on these features in the training set. The tree is grown using CART methodology (Breiman et al., 1984) to maximum size, without pruning. This subspace randomization scheme is blended with bagging (Breiman, 1996; Buhlmann and Yu, 2002; Buja and Stuetzle, 2006; Biau et al., 2010) to resample, with replacement, the training data set each time a new individual tree is grown.

2.5. Support Vector Machine (SVM)

Support vector machine (SVM) is a powerful machine learning technique for classification. SVM is becoming popular in pattern recognition in bioinformatics, cancer diagnosis, and more. SVM is a maximum margin classification algorithm rooted in both machine and statistical learning theory. It is the method for classifying both linear and non-linear data. Basically the method involves finding a hyper plane that separates the examples of different outcomes. Being primarily designed for two-class problems, it find a hyper plane with a maximum distance to the closest point of the two classes; such a hyper plane is called the optimal hyper plane. A set of instances that is closest to the optimal hyper plane is called a support vector.

In this study, logistic regression, linear discriminant analysis, quadratic discriminant analysis, random forest and support vector machine algorithm can be assessed by confusion matrix which is shown in Table 2 below. Confusion matrix provides a detailed layout which represents the performance of the two algorithm. The row of this matrix represents the predicted class instances while each of column of the matrix represents the actual class instances as shown below. This matrix is also used to show the correct and incorrect instances.

Table 2. Confusion Matrix

	Actual Class		
Predicted Class		Positive(P)	Negative(N)
	True(T)	True Positive(TP)	True Negative (TN)
	False(F)	False Positive (FP)	False Negative (FN)

True Positive(TP): This instance indicates benign samples that were classify as benign.
True Negative(TN): This instance indicates malignant samples that were classify as malignant.
False Positive(FP): This instance indicates benign samples that were classify as malignant.
False Negative: It indicates malignant samples that were classify as benign.

2.6. Performance Metrics

Performance metrics such as accuracy, sensitivity and specificity is the most widely used medicine and biology. The performance metrics are presented in Table 3.

Table 3. Performance Metrics

Measure	**Formula**
Accuracy	$\frac{TP+TN}{TP+TN+FP+FN}$
Sensitivity	$\frac{TP}{TP+FN}$
Specificity	$\frac{TN}{TN+FP}$

3. Result and Discussion

The experimental results of the breast cancer disease for prediction using Logistic regression, linear discriminant analysis, quadratic discriminant analysis, random forest and support vector machine are analysed in this section. The data related to breast cancer diseases are collected from 568 patients who are provided by National Cancer Institute.

In order to visually compare profiles from the two groups such as benign and malignant cancer patients. The Figure 1 below consists of patients that have benign cancer which is represented as B and malignant patients is represented by M as displayed below.

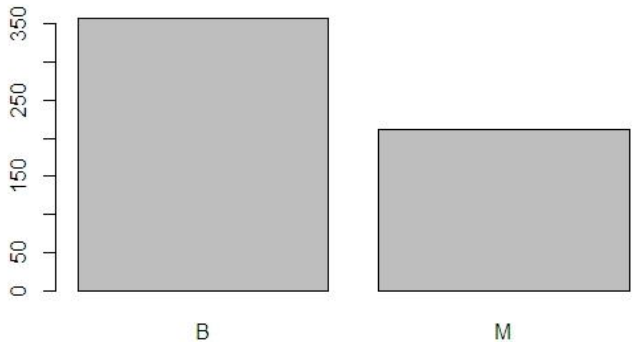

Fig. 1. Benign and Malignant cancer patients.

Table 4. Results for diagnosing of breast cancer

Techniques	**LR**	**LDA**	**QDA**	**RF**	**SVM**
TN	346	349	346	341	354
TP	191	182	180	194	190
FP	20	29	31	17	21
FN	11	8	11	16	3
TN+TP+FP+FN	568	568	568	568	568
TP+FN	202	190	191	210	193
TN+FP	366	378	377	358	375
Accuracy	94.5	93.5	92.6	94.2	95.8
Sensitivity	94.6	95.8	94.2	92.4	98.4
Specificity	94.5	92.3	91.8	95.3	94.4

The correctly classified data for diagnosis of breast cancer has been observed and its accuracy is calculated for the five machine learning are shown in Table 4 above. After completing the training of the five machine learning classification model. Using 568 clinical instances of the mammographic mass dataset. From Table 4 above, the testing results shows that Support Vector Machine (SVM) in terms of accuracy performs better than other remaining four machine learning.

Figure 2 is called a Receiver Operating Characteristic curve (or ROC curve) it is a useful technique for organizing classifiers and visualizing their performance. ROC graphs are two-dimensional graphs in which true positive rate is plotted on the Y axis and false positive rate is plotted on the X axis. Figure 2 displays an ROC graph with five classifiers that were used in this paper which was plotted on the same graph. The diagonal line, from (0,0) to (1,1), is an indicative of an independent variable that discriminates no different from guessing (50/50 chance). ROC space is better than another if it is to the northwest (TP rate is higher, FP rate is lower, or both) of the first. From the Figure 2 above the perfect curve was obtained from SVM since it is closer to the northwest of True positive rate.

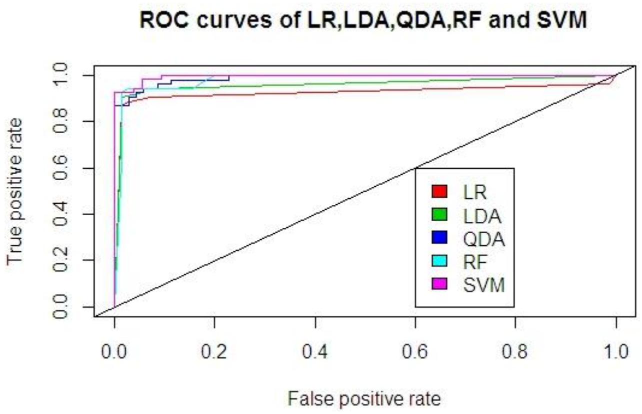

Fig. 2. ROC curves of LR, LDA, QDA, RF and SVM.

The AUC is a measure of the discriminality of a pair of classes. Table 5 above shows the AUC results obtained from ROC curve. From the table 5 above SVM has the highest predicted value.

Table 5. Area under the curve (AUC)

Techniques	Area Under the curve (AUC)(%)
SVM	99.9%
RF	98.07%
QDA	98.89%
LDA	96.06%
LR	92.51%

References

[1] Department of Health and Human Services Centers for Disease Control and Prevention, World Cancer Day, February 3, 2015.

[2] Department of Health and Human Services Centers for Disease Control and Prevention, United States Cancer Statistics, Technical Notes 2007.

[3] American Cancer Society, Cancer Facts & Figures 2016, Atlanta, Georgia, American Cancer Society, pp. 1–63, 2016.

[4] Simes RJ. Treatment selection for cancer patients: application of statistical decision theory to the treatment of advanced ovarian cancer. J Chronic Dis, 38:171-86, 1985.

[5] Maclin PS, Dempsey J, Brooks J, et al. Using neural networks to diagnose cancer J Med Syst, 15:11-9, 1991.

[6] Cicchetti DV. Neural networks and diagnosis in the clinical laboratory: state of the art. Clin Chem, 38:9-10, 1992.

[7] Petricoin EF, Liotta LA. SELDI-TOF-based serum proteomic pattern diagnostics for early detection of cancer. Curr Opin Biotechnol, 15:24-30, 2004.

[8] Bocchi L, Coppini G, Nori J, Valli G. Detection of single and clustered micro calcifications in mammograms using fractals models and neural networks. Med Eng Phys, 26:303-12, 2004.

[9] Zhou X, Liu KY, Wong ST. Cancer classification and prediction using logistic regression with Bayesian gene selection. J Biomed Inform, 37:249-59, 2004.

[10] Dettling M. Bag Boosting for tumor classification with gene expression data. Bioinformatics, 20:3583-93, 2004.

[11] Wang JX, Zhang B, Yu JK, et al. Application of serum protein finger printing coupled with artificial neural network model in diagnosis of hepatocellular carcinoma. Chin Med J (Engl), 118:1278-84, 2005.

[12] McCarthy JF, Marx KA, Hoffman PE, et al. Applications of machine learning and high-dimensional visualization in cancer detection, diagnosis, and management. Ann N Y Acad Sci, 1020:239-62, 2004.

[13] L. Breiman. Bagging predictors. Machine Learning, 24:123–140, 1996.

[14] P. Buhlmann and B. Yu. Analyzing bagging, The Annals of Statistics, 30:927–961, 2002.

[15] A. Buja and W. Stuetzle. Observations on bagging. Statistica Sinica, 16:323–352, 2006.

[16] G. Biau, F. Cerou, and A. Guyader. On the rate of convergence of the bagged nearest neighbor estimate. Journal of Machine Learning Research, 11:687–712, 2010.

Fractional Distillation & Characterization of Tire Derived Pyrolysis Oil

Makhan Mia*, Ariful Islam*, Robiul Islam Rubel**‡, Mohammad Rofiqul Islam*

* Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Rajshahi-6204, Bangladesh

** Department of Mechanical Engineering, Bangladesh Army University of Science & Technology, Saidpur Cantonment-5311, Bangladesh

(almamunme10ruet@gmail.com, arif.ruet92@gmail.com, rubel.ruet10@gmail.com, mrislam1985@yahoo.com)

‡ Corresponding Author; Robiul Islam Rubel, Saidpur Cantonment-5311, Bangladesh, Tel: +088-1749-399-082, rubel.ruet10@gmail.com

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Abstract- Energy is extracted recently from the waste products. Environmental pollutions are being minimized along with the addition of considerable amount of energy beside the conventional sources. The energy extracted from the waste leads a hope of alternative fuel for internal combustion engines as well as to meet other requirement. Common energy conversion method uses tire, wood, rubber to derived energy through pyrolysis. About 9.25% gaseous, 43% liquid, and 47% solid product are obtained from tire pyrolysis process at around 450°C temperature. The liquid fuel is directly used in the engines and that phase is a mixture of complex hydrocarbon. In this work Fractional Distillation, oxidative desulfurization and de-colorization for upgrading liquid product has been conducted. In fractional distillation 30%, 20%, 6.35%, 6%, 4.5%, and 1.3% by volume oils are obtained at over the temperature ranges- 121-180°C, 211-260°C, 71-120°C, 191-210°C, 181-190°C, and 40-70°C. Then by desulfurization around 54-58% sulphur was removed. For desulfurization hydrogen peroxide and formic acid (2:1 ratio) are used at constant temperature and magnetic stirring rate. The obtained fraction was characterized by elemental analyses, FT-IR techniques and compared with conventional diesel fuel. Sludge oil parts may be used as furnace oil which has higher calorific value than that of other conventional furnace oils. The rest of 40-70°C and 71-120°C oil parts may be used as alternative fuel like kerosene. Thus, the aim of the present study is to investigate the suitability of pyrolysis oil as an alternative fuel for IC engine.

Keywords Pyrolysis, Fractional distillation, Tire pyrolysis oil, Upgrading and characterization.

1. Introduction

The energy crisis and environmental degradation are the main problems in the present days due to growing population and rapid industrialization. Around the world, there are initiatives to replace gasoline and diesel fuel due to the impact of fossil fuel crisis and hike in oil price. Millions of dollars are being invested in the search for alternative fuels. The scrap tire is one of the common and important solid wastes all over the world including developing and semi developing country. Scrap tire production shows increasing trend due to increasing number of vehicle in both developed and underdeveloped countries [1]. Nearly one billion of waste vehicle tires are accumulated each year [2]. On the other hand, the disposal of waste tires from automotive vehicles appears complex. Degrading of scrap tires in the nature is difficult for many years. There are studies and available literature on pyrolysis of waste vehicles tires. Scrap tire disposing methods like landfill, reusing and burning can create serious hazards, especially in terms of human and environmental health. Thus, waste tire is required to keep under control without damaging the environment. One of the most favorable and effective disposing method is pyrolysis, which is environmental friendly and efficient way. Therefore, these valuable carbon compounds should be utilized by converting new and clean energies. Pyrolysis is the thermal fragmentation of solid substances in an airless environment. The products obtained with this process can be easily handled, stored and easy to transportation which increases the applicability of this method. Pyrolysis fluid can be used directly as fuel in boilers and can be used in internal combustion engines after modifications such as sulphur reduction and blending with diesel fuel. It is reported that pyrolysis oil of automobile tires contains 85.54% C, 11.28%

H_2, 1.92% O_2, 0.84% S, and 0.42% N_2 components [3]. Pyrolysis produces three principal products, such as pyrolytic oil, gas and char. The quality and quantity of these products depend upon the reactor temperature and design. In the pyrolysis process, larger hydrocarbon chains break down at certain temperatures in the absence of oxygen that gives end products usually containing solids, liquids and gases.

Many studies have been done using systems such as thermo-gravimetric analysis, fixed bed reactor, fluidized bed pyrolysis unit, vacuum pyrolysis reactor and jet bed reactor, among which vacuum pyrolysis reactor is easier and effective. In addition, chemical products such as benzene, toluene, xylene and limonene can be obtained from waste vehicle tire pyrolysis liquid products [4-7]. The use of tire pyrolysis oil as a substitute of diesel fuel is an opportunity in minimizing the utilization of the natural resources. Isabel de Marco Rotriguez et al. [8] studied the behaviour and chemical analysis of tire pyrolysis oil. In their work it is reported that tire oil is a complex mixture of organic compounds of 5-20% carbons and with a higher proportion of aromatics. The percentage of aromatics, aliphatic, nitrogenized compounds, benzothiazol are also determined in the tire pyrolysis oil at various operating temperatures of the pyrolysis process [9]. Aromatics are found to be about 34.7% to 75.6% when the operating temperature is varied between 300°C and 700°C, while aliphatic are about 19.8% to 59.2 %. In the same work, an automatic distillation test is carried out at 500 °C to analyze the potential use of tire pyrolysis oil as petroleum fuels. It is observed that more than 30% of the tire pyrolysis oil is easily distillable fraction with boiling points between 70°C and 210°C, which is the boiling point range specified for commercial petrol. On the other hand, 75% of the pyrolytic oil has a boiling point under 370°C, which is the upper limit specified for 95% of distilled product of diesel oil. It was mentioned that distillation carried out between 150°C and 370°C has a higher proportion of the lighter and heavier products and a lower proportion of the middle range of products than commercial diesel oil structure. The influences of the distillation process on raw pyrolytic fuel properties and on engine performance are studied in a DI diesel engine by using different test fuels which actually a blends of different pyrolytic tire oil and diesel fuel.

The distillation process improved the fuel properties of raw pyrolytic tire fuel, and the engine test results. The viscosity and sulphur content of crude TPO are the two parameters that influence the engine performance and emissions. The high viscosity of the fuel will lead to problems in the long run which include carbon deposit, oil ring sticking etc. The high viscosity is due to its large molecular mass and chemical showed that engine performance and emissions can be improved by the distillation process. The previous experimental works by the authors [10-11] studied the effect of lower and higher concentrations of the tire pyrolysis oil/diesel fuel blends on the performance, emission and combustion characteristics of a single cylinder, 4-stroke and water cooled, DI diesel engine running. They reported that HC, NOX, CO and smoke emissions usually increased with the increasing tire derived fuel content in the diesel fuel blends. Furthermore, they found that the increasing tire derived fuel content in the diesel fuel blends increased the maximum combustion pressure, rate of pressure rise and ignition delay. To investigate a new source of petrol, kerosene and diesel like fuel, study about the chemical and physical property of TPO (Tire Pyrolytic Oil) is done. In this work a simplified fractionation distillation column is used to drive oil from waste tire. Again desulfurize, decolorize of pyrolysis oil is done to prepare eco-friendly energy source compare to the conventional diesel fuel.

2. Working Plant

A previously set pyrolysis plant shown in Fig. 1 is used to collect the oil following the process chart in Fig. 2. Major parts of the pyrolysis plant are:- (a) Reactor, (b) Fractionating column, (c) 1st condenser, (d) CTPO-Reservoir, (e) 2nd condenser, and (f) HQO-Reservoir.

2.1. Temperature distribution of tire pyrolysis plant

The temperature distribution is very important factor for pyrolysis plant. Initially reactor temperature is 18ºC. Then after every 30 minutes, temperature reading is recorded during heating of the reactor. The reactor is heated at an increasing rate up to first 120 minutes of running operation. Then the next 120 minutes was maintained at constant temperature near about 455ºC (± 5ºC). Then the portable parts of the insulated side wall of reactor shield are removed for cooling. Temperature distribution during the reactor heating operation is presented in Fig. 3.

2.2. Performance of the plant

The performance data is collected during operating time of pyrolysis plant presented in Table 1. The reactor temperature becomes stagnant at 455ºC. The condenser outlet is fixed at 20 Lit/min.

2.3. Pyrolysis products from pilot plant

In tire pyrolysis system liquid, char and gases products are obtained. Pyrolytic liquid is the main products in pyrolysis process. Char and gases are two by products which may be used as fuel for reactor heating purpose. Several runs are carried out by using prepared tire waste samples.

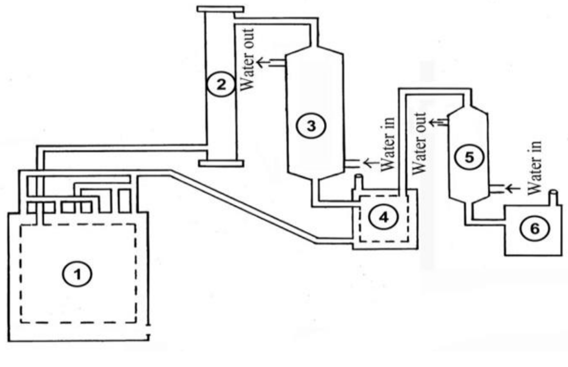


Fig. 1. Pyrolysis plant (for 200 kg scrap tire).

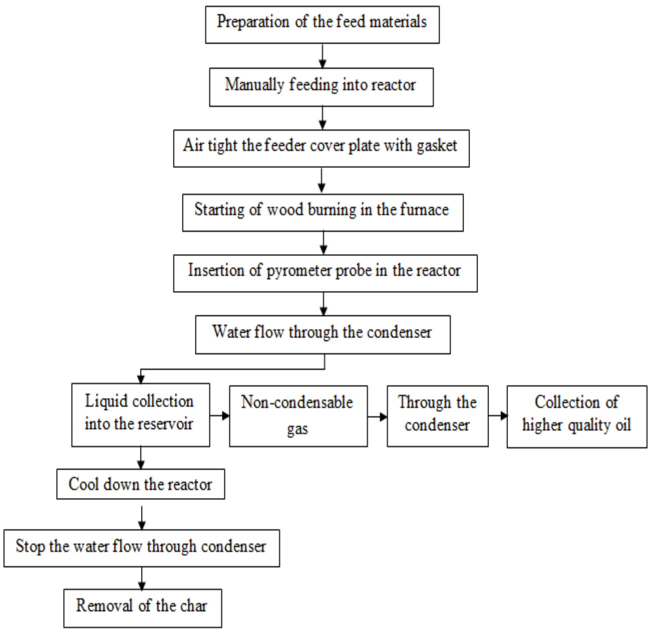


Fig. 2. Process flow chart.

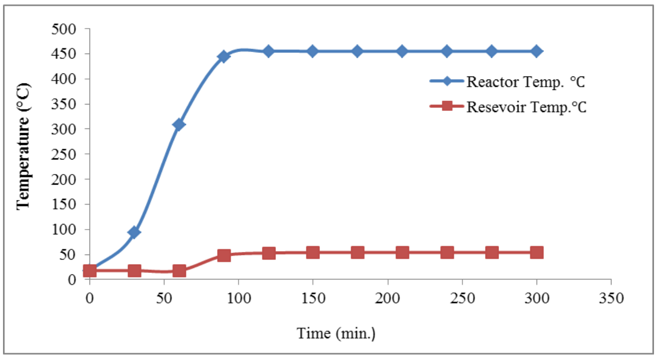


Fig. 3. Temperature distribution in reactor and reservoir with time.

Table 1. Data collected from pyrolysis unit during operation

Reactor tempt. (°C)	Reservoir tempt. (°C)	Water Inlet tempts. (°C)	Water outlet tempts. (°C)	Condenser water flow rate (Lit./min.)
18	18	18	18	20
93	18	18	18	20
309	18	18	21	20
444	48	19	22	20
455	53	20	24	20
455	54	20	25	20
455	54	20	25	20
455	54	20	25	20
455	54	20	25	20
455	54	20	25	20
455	54	20	25	20

The product distributions obtained from the pilot plant experiments are presented in Table 2. In Table 3 the properties of TPO is shown and comparison results is given in Table 4.

Table 2. Product yields distribution of tire pyrolysis for different sizes

Feed size (cm)	Tire feed (Kg)	Product yield			
		Liquid	Char	Higher quality oil	Gas
15×15×3	200	66 kg (33%)	112 kg (56%)	1.1kg (0.55%)	10.45%
20×20×3	200	86 kg (43%)	94 kg (47%)	1.5kg (0.75%)	9.25%

Table 3. Properties of diesel, crude TPO, TPO

Property	Conventional diesel	Crude TPO	TPO
Density (kg/ m^3)	872.3	942.6	848.69
Viscosity (centi poise) (at 30(°C)	4	4.2	1.4
Calorific value (MJ/kg)	44.832	41.5	42.37
Flash point (°C)	65	40	45.7
Pour point (°C)	-30 to -40	-2	-6

Table 4. Comparing the properties of our TPO with a reference book [12]

Property	Conventional Diesel	Crude TPO	TPO
Density (kg/ m^3)	830	935	871
Viscosity (centi poise)(at 40°C)	2	3.2	1.7
Calorific value (MJ/kg)	46.5	42.83	45.78
Flash point (°C)	50	43	36

3. Fractional distillation

In common industrial jargon, distillation is used sometimes to mean fractional, and not merely simple distillation. Fractional distillation or fractionation however, is in fact a special type of distillation, and as a separation technique, is much more effective than simple distillation and more efficient. In effect, fractionation is equivalent to a series of distillations, where the separation is achieved by successive distillations or repeated vaporization-condensation cycles. Each vaporization-condensation cycle makes for an equilibrium stage, commonly known as a theoretical stage. A number of such theoretical stages may be required for the efficient fractionation and separation of the vapor or liquid mixture. Fig. 4 shows a simple fractional distillation column and its major parts are a. Electric heater, b. Round cylindrical reactor, c. Column, d. Thermometer adaptor, e. Condenser, and f. Oil collector.

Electric Heater: Electric heater was made by 3000 watt nicrome wire.

Round Cylindrical Reactor: The distillation column uses 8500 ml round cylindrical reactor. The height of the reactor is 34.29 cm, inner diameter is 17.78 cm.

Column: Height of hollow column is 83.82 cm. A number of general rules of thumb are used as a general guide before carrying out the actual calculations, but these rules often have exceptions.
Such rules as related to column diameter include the following four rules given below [13].
a. The length to diameter ratio should be less than 30, preferably below 20, and tower height is to be limited to 60 meters because of wind load and foundation concerns. If the tower is higher than 60 m, then a design with smaller tray spacing should be considered [14].
b. The ratio of tower diameter to random packing size is greater than 10.
c. The tower diameter should be maintained at 1.2 meters at the top for vapor disengagement.
d. The tower diameter should be maintained at 2 meters at the bottom for liquid level and re-boiler return. In normal practice, however, only one diameter is calculated for the whole column. Different column diameters would only be used where there is a considerable change in flow-rate. Changes in liquid rate can be allowed for by adjusting the liquid down comer areas [15]. If two or more diameters are calculated, say for the top and bottom sections of the column, then roughly speaking, when the difference in the calculated diameters exceeds 20%, different diameters for the top and bottom sections are likely to be economical and sections having different diameters should be at least 600 cm (20 ft.) in length. Otherwise the diameter should be uniform. The preliminary column diameter would then be the larger of the two calculated diameters [16].

Thermometer adopter: A small scale degree Celsius thermometer is used in this column. A thermometer holder holds this thermometer appropriate position which can give appropriate result. For proper holding the thermometer M-seal gum is used.

Condenser: For proper condensing purpose, a condenser is used as libig condenser where tap water is passing through it at moderate flow rate. During water flow tap water pipe is connected below the condenser and exhaust water pipe is above. The total length of condenser is 71.12 cm, outer diameter is 7.62 cm and inner diameter is 2 cm.

Oil collector: For different oil fraction collection, a special oil collector which can give out the non-condensable gases is used.

Insulation: Glass wool is an insulating material made from fibers of glass arranged using a binder into a texture similar to wool. The process traps many small pockets of air between the glass, and these small air pockets result in high thermal insulation properties. Glass wool is produced in rolls or in slabs, with different thermal and mechanical properties. It may also be produced as a material that can be sprayed or applied in place, on the surface to be insulated [17].

3.1. Collection of crude TPO

TPO is collected from the university inventory as in Fig. 5. The pyrolysis was done in a fixed bed pyrolysis reactor in a temperature range 350-400˚C. The setup includes a condenser and fractionating column. Nitrogen gas was used to maintain an inert environment. In this pyrolysis, an automobile tire was cut into a number of pieces and the bead, steel wires and fabrics were removed. Thick rubber portion at the periphery of the tire is made into small chips like piece.

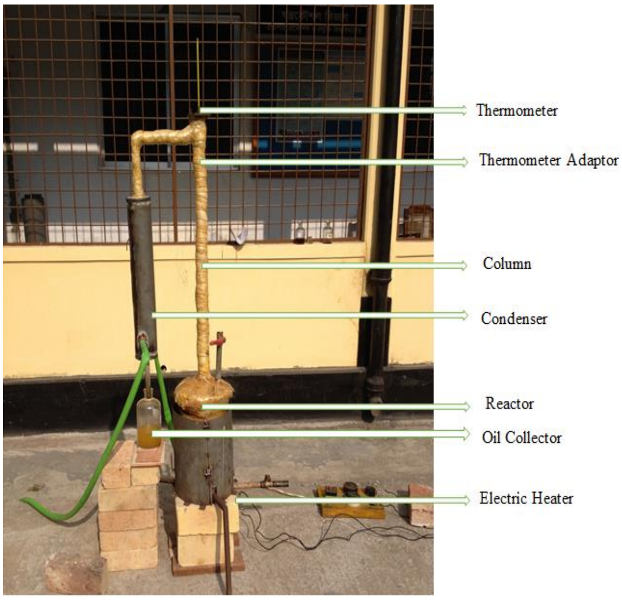


Fig. 4. Experimental set up for fractional distillation.

Fig. 5. Crude pyrolysis oil.

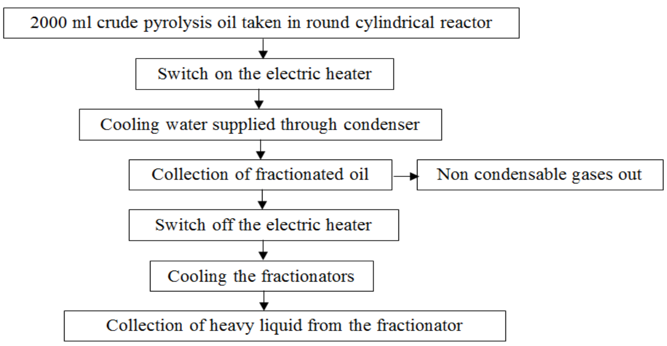
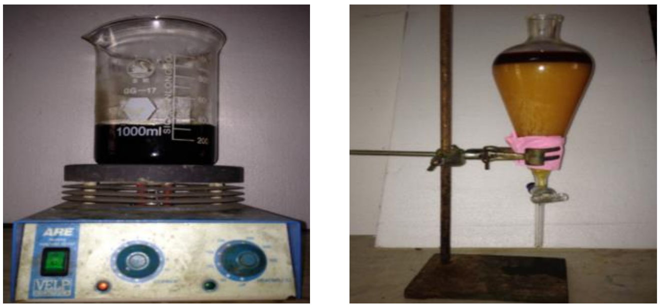


Fig. 6. Process flow chart of Fractional distillation.



(a) (b)

Fig. 7. (a) Desulfurization of oil**; (b)** Separation of oil.

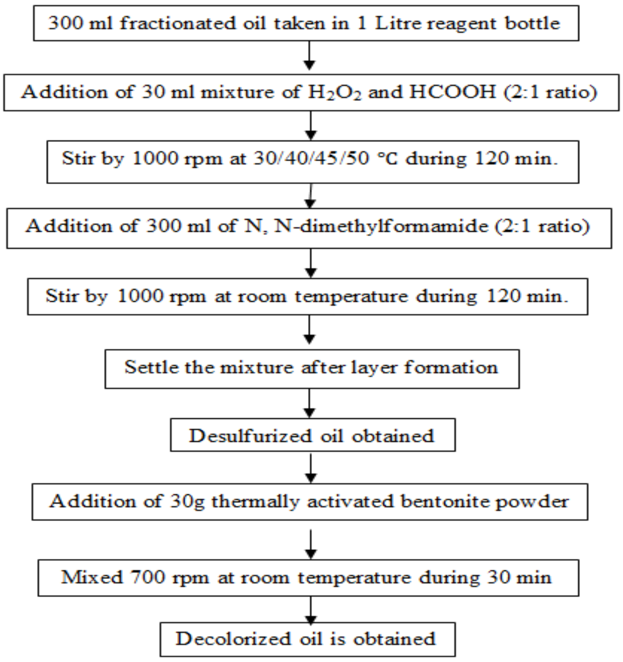


Fig. 8. Desulfurization and De-colorization of Fractionated oil.

The tire chips are washed and dried before feeding in the reactor unit. The chips feed is heated externally in absence of oxygen in the reactor. During the pyrolysis, large molecules of liquefied tires were converted into steam and rose out of the rector at high temperature. Vapor of these products is liquefied with the help of reactor condenser to obtain liquid product.

3.2. Desulfurization of Fractionated oil

The desulfurization as presented in Fig. 7 of fractionated oil has the following stages as mentioned in Fig. 8.

Oxidation stage: In this step 10% solution of a mixture hydrogen peroxide and formic acid (2:1) is used. This mixture has mild oxidizing effect and oxidized the sulfur, which existing in the form of complex aromatic compound. In this step major of sulfur compound is oxidized. Another de-oxidation method may also be used but they have negative effect on the hydrocarbon mixture of pyrolysis oil.

Extraction stage: Extraction step is another most important step because in this step the oxygenated sulfur compound is extracted by suitable solvent.

Fig. 9. Total upgraded oil yields from tire pyrolysis oil (TPO).

Fig. 10. Upgraded oil from tire pyrolysis oil (TPO).

The solvent may be ethanol, methanol, acetone, N, N-dimethyl formamide. But among this N, N-dimethyl formamide is most effective for extraction of oxygenated compound.

3.3. De-colorization of Fractionated oil

For further de-colorization thermally activated bentonite powder is used by suitable 10g weighed per 100 ml oil sample. Magnetic stirrer is used for mixing the oil with bentonite powder. After filtration the filtrate oil color is developed.

4. Results and Discussions

4.1. Upgrading by fractional distillation

During upgrading process pyrolytic liquid is fractionated into seven parts by using distillation column as depicted in Fig. 9. Here pyrolytic liquid was classified as 40-70°C, 71-120°C, 121-180°C, 181-190°C, 191-210°C, 210-260°C, and non-fractionated residue oil by using their boiling point difference. Several successful runs were carried out by using prepared raw pyrolysis liquid samples to obtain sufficient amount of fractionated oil. The product distributions obtained from the fractional distillation process are presented in Table 5 and Fig. 10.

4.2. Characterization of upgraded pyrolysis oil

Pyrolytic liquids obtained under the maximum liquid yield conditions are well mixed and homogenized prior to analysis being made. Some physical properties of pyrolytic liquids are density, viscosity, flash point, pour point and GCV is determined by using proximate analysis that satisfies following ASTM D189, ASTM D445, ASTM D92, ASTM D97 and ASTM D240 international standards. Proximate analysis of a fuel provides a simple breakdown of the components volatile matter, moisture and ash, thereby giving an indication of the combustion characteristics of the fuel. The proximate analysis of crude, upgrade tire pyrolysis oil and conventional diesel fuel are shown in Table 6. This table also presents the fuel properties of the pyrolytic liquids in comparison to commercial automotive diesel, which is mostly consumed in Bangladesh. Elemental analysis of liquids is determined with an elemental analyzer of model EA 15137078, which followed the quantitative "dynamic flash combustion" method.

Thus, the functional group compositions of the product liquids are analyzed by Fourier Transform Infra-Red FT-IR (Fourier Transform Infrared Spectrometer) spectroscopy. FT-IR spectrometers are widely used in organic synthesis, polymer science, petrochemical engineering, pharmaceutical industry and food analysis. In addition, since FT-IR spectrometers can be hyphenated to chromatography, the mechanism of chemical reactions and the detection of unstable substances can be investigated with such instruments [18]. FT-IR spectra analysis results for upgraded pyrolysis oil over temperature range of 40-260 °C are given in Table 7 to Table 12.

Table 5. Oil obtained at different temperature range by fractional distillation for 2000 ml crude pyrolytic oil

Temp. Range (°C)	40-70	71-120	121-180	181-190	191-210	211-260	Residue oil	Distillation loss
Oil obtained in volume (ml)	23.4	110	578	100	130.6	395	643	26
Oil obtained in (%)	1.17	5.5	28.9	5	6.53	19.5	32.15	1.5

Table 6. Comparison the properties of crude tire pyrolytic oil, fractionated oil with conventional diesel fuel

Properties	Crude tire oil	Upgrading fractionated oil °C						Conventional Diesel Fuel
		40-70	71-120	121-180	181-190	191-210	211-260	
Density(kg/m^3) at 20°C	942.6	791.5	802.98	848.69	876.276	892.863	931.94	831
Viscosity (at 20°C, Centri poise)	3.5	-	-	1.4	-	-	3.5	4
Flash point (°C)	69	42.3	45.7	53.4	69.2	71.5	78.5	65
Fire point (°C)	95	72.1	81	130.5	155.2	167.5	174.2	228
Pour point (°C)	<-23	<-23	<-23	<-23	<-23	<-23	<-23	-30-40
Calorific value	41.5	42.3	42.37	42.37	42.37	42.37	42.37	44.832
Color	Brownish black	Black tea liquor	Blackish red	orange	Black tea liquor	Blackish red	Brownish black	Green tea liquor

Table 7. FT-IR spectra for upgraded pyrolysis oil over temperature range of 40-70 ^{0}C

Functional group	Theoretical frequency range(cm^{-1})	Actual peak	Class of compounds
C-H stretching	near 3000	-	Alkanes
CH_2 and CH_3 bending	1475-1365	1456.26 and 1375.25	
C-H bending (oop)	1000-650	891.11, 825.53, 723.31, 677.01	Alkenes
C=C stretching	1600-1450	1456.26	Aromatic rings
C=C (oop)	900-690	891.11, 825.53, 723.31, 677.01	
C=O stretch	1850-1650	1670.35	Carbonyl group
C-H	2850-2750	-	Aldehydes (doublet)
C=O	1680-1630	-	Amides
C-Cl N=O asymmetric stretch	730-550 1600-1530	-	Acid chlorides Nitro group(aliphatic)
S=O asymmetric stretch	1375	1375.25	Sulfonyl chlorides
N-H bend	1550	-	Sulfonamides

Table 8. FT-IR spectra for upgraded pyrolysis oil over temperature range of 71-120 ^{0}C

Functional group	Theoretical frequency range (cm^{-1})	Actual peak	Class of compounds
C-H stretching	near 3000	2958.80	Alkanes
CH_2 and CH_3 bending	1475-1365	1456.26 and 1377.17	
C-H stretching	greater 3000	-	Alkenes
C-H bending (oop)	1000-650	817.82, 813.36, 677.01	
C=C stretching	1600-1450	1494.83	Aromatic rings
C=C (oop)	900-690	817.82, 813.36, 677.01	
C=O stretch	1850-1650		Carbonyl group
C-H	2850-2750	-	Aldehydes (doublet)
C-Cl	730-550	-	Acid chlorides
N-H bend	1640-1560	1558.48	Secondary amines
N-H (oop)	near 800	-	Amines
N=O asymmetric stretch	1550-1490	1494.83	Nitro group (aromatic)
S=O asymmetric stretch	1375	1377.17	Sulfonyl chlorides

Table 9. FT-IR spectra for upgraded pyrolysis oil over temperature range 121-180 ^{0}C

Functional group	Theoretical frequency range (cm^{-1})	Actual peak	Class of compounds
C-H stretching	near 3000	2973	Alkanes
CH_2 and CH_3 bending	1475-1365	1456.26 and 1377.17	
C-H stretching	greater 3000	3026.31	Alkenes
C-H bending (oop)	1000-650	889.18, 694.37	-
C=C stretching	1600-1450	1456.26	Aromatic rings
C=C (oop)	900-690	889.18, 694.37	
C=O stretch	1850-1650	-	Carbonyl group
C-H	2850-2750	-	Aldehydes (doublet)
C=O	1680-1630	-	Amides
C-Cl	730-550	-	Acid chlorides
N-H bend	1640-1560	-	Secondary amines
N-H (oop)	near 800	-	Amines
N=O asymmetric stretch	1600-1530	-	Nitro group (aliphatic)
N=O asymmetric stretch	1550-1490	-	Nitro group (aromatic)
S=O asymmetric stretch	1375	1377.17	Sulfonyl chlorides
N-H bend	1550	-	Sulfonamides
S=O asymmetric	1350	-	Sulfonic acids

Table 10. FT-IR spectra for upgraded pyrolysis oil over temperature range 181-190 ^{0}C

Functional group	Theoretical frequency range (cm^{-1})	Actual peak	Class of compounds
C-H stretching	near 3000	2960.73	Alkanes
CH_2 and CH_3 bending	1475-1365	1456.26 and 1375.25	
C-H stretching	greater 3000	3016.67	Alkenes
C-H bending (oop)	1000-650	891.11, 823.60, 725.23	
C=C stretching	1600-1450	1506.41	Aromatic ring
C=C (oop)	900-690	891.11, 823.60, 725.23	
C=O stretch	1850-1650	1683.86	Carbonyl group
C-H	2850-2750	-	Aldehydes (doublet)
N-H stretch	3475-3150	-	Amides
C=O	1680-1630	-	
C-Cl	730-550	725.23	Acid chlorides
N-H bend	1640-1560	1616.36	Secondary amines
N-H (oop)	near 800	-	Amines
N=O asymmetric stretch	1600-1530	-	Nitro group(aliphatic)
N=O asymmetric stretch	1550-1490		
S=O asymmetric stretch	1375	1375.25	Sulfonyl chlorides
N-H bend	1550	1506.41	Sulfonamides

Table 11. FT-IR spectra for upgraded pyrolysis oil over temperature range 191-210 ^{0}C

Functional Group	Theoretical frequency range (cm^{-1})	Actual peak	Class of compounds
C-H stretching	near 3000	2973	Alkanes
CH_2 and CH_3 bending	1475-1365	1456.25 and 1377.17	
C-H stretching	greater 3000	3016.67	Alkenes
C-H bending (oop)	1000-650	891.11, 821.68, 740.67, 690.52	Aromatic rings
C=C stretching	1600-1450	1506.41, 1456.26	
C=C bending (oop)	900-690	891.11, 690.52	Carbonyl group
C=O stretch	1850-1650	1670.35	
C-H	2850-2750	-	Aldehydes (doublet)
C=O	1680-1630	-	Amides
N-H stretch	3475-3150	-	Acid chlorides
C-Cl stretch	730-550	-	
N-H bend	1640-1560	-	Secondary amines
N-H (oop)	near 800	-	Amines
N=O asymmetric stretch	1600-1530	1558.48	Nitro group (aliphatic)
N=O asymmetric stretch	1550-1490	1506.41	Nitro group (aromatic)
S=O asymmetric stretch	1375	1377.17	Sulfonyl chlorides
N-H bend	1550	-	Sulfonamides

Table 12. FT-IR spectra for upgraded pyrolysis oil over temperature range 211-260 ^{0}C

Functional group	Theoretical frequency range (cm^{-1})	Actual peak	Class of compounds
C-H stretching	near 3000	2956.87	Alkanes
CH_2 and CH_3 bending	1475-1365	1456.26 and 1375.25	
C-H stretching	greater 3000	3400	Alkenes
C-H bending (oop)	1000-650	-	
C=C stretching	1600-1450	1558.48, 1506.41, 1456.2	Aromatic rings
C=C (oop)	900-690	730	
C-O stretch	1260-1000	1197.79, 1122.57	Phenols
C=O stretch	1850-1650	1670.35	Carbonyl group
C-H	2850-2750	-	Aldehydes (doublet)
C=O	1680-1630	1670.35	Amides
C-Cl	730-550	-	Acid chlorides
C-O stretch	1300-900	11197.79, 1122.57	Anhydrides
N-H stretch	3500-3300	-	Amines
N-H bend	1640-1560	1558.48	Secondary amines
N-H (oop)	near 800	-	Amines
N=O asymmetric stretch	1600-1530	1558.48	Nitro group(aliphatic)
N=O asymmetric stretch	1550-1490	1506.41	
S=O asymmetric stretch	1375	1375.25	Sulfonyl chlorides
N-H bend	1550	-	Sulfonamides

5. Conclusions and Recommendations

The physical and chemical characterizations of the raw pyrolysis oil derived from light automotive tire waste has been carried out and compared with conventional fuels. The pyrolytic liquids obtained from pyrolysis of automotive tire wastes, which are oily organic compounds, appears dark-brown-color with a strong acrid smell. Careful handling of the liquids is required since it reacts easily with human skins, leaving permanent yellowish brown marks and an acrid smell for a few days, which is difficult to remove by detergent. No phase separation was found to take place in the storage bottles. Experimental consequences are summarized below-

a. Improved pyrolysis system is designed, so that higher quality oil possible to separate from crude tire pyrolysis oil reservoir.

b. Fractional distillation yields more pyro-oil in the temperature range of 121-180°C.

c. The density of fractionated pyrolytic liquids is found lower than that of the commercial diesel fuel and also lower than that of heavy fuel oil.

d. The density of 40-70°C, 71-120°C, 121-180°C, 181-190°C, 191-210°C, 211-260°C are 791.5, 802.98, 848.69, 876.276, 892.863, 931.94 (kg/m^3) at 20 °C. Where conventional diesel fuel has density 831 (kg/m^3).

e. The viscosity of fractionated liquid products from tire wastes is slightly lower than that of the diesel but also much lower than that of heavy fuel oil. Low viscosity of the liquids at 121-180°C and 211-260°C are 1.4 and 3.5 Centri poise at 20°C and conventional diesel fuel has viscosity 4.0 Centri poise at 27°C is a favorable feature in the handling and transporting of the liquid.

f. The flash point of the tire-derived crude liquid at 40-70°C, 71-120°C, 121-180°C, 181-190°C, 191-210°C, 211-260°C oils are 42.3°C, 45.7°C, 53.4°C, 69.2°C, 71.5°C 78.5°C obtained at 20°C and for conventional diesel fuel 65°C obtained at 27°C. The flash point is low when compared with petroleum-refined fuels.

g. The fire point at 40-70°C, 71-120°C, 121-180°C, 181-190°C 191-210°C and 211-260°C oils are 72.1°C, 81°C, 130.5°C, 155.2°C, 167.5°C, 174.2°C and conventional diesel fuel is 228°C, which is greater than fractionated oil.

h. The pour point of the tire-derived liquids is -6 °C. The calorific value of the upgraded tire oil is 42.37 MJ/Kg. The calorific value is high and comparable with that of a diesel fuel oil, indicating the potential for the use of tire derived oils as fuel.

i. The upgraded fractionated oil has lower viscosity, good spray quality and proper combustion with compared to conventional fuel.

j. The pyrolytic liquids abundantly contain olefins, specially limonene and light aromatics, whose have higher market values as chemical feedstock than their use as fuels.

Some steps may be taken to improve the oil grade. The foregoing recommendations are-

a. Special glass made fractional column is recommended for smooth or perfect operation as metal has conductivity higher than glass.

b. The TPO has many impurities and odor, which causes its use difficult. Further chemical and physical treatment is required to remove this.

c. The color of TPO is not stable, it changes with time as there some sludge remains. To prevent this problem some further steps should be taken.

d. The unit production cost of pyrolysis oil and upgrading by suitable method is analyzed suitably for large scale production.

e. Finally, it may be concluded that the fractional distillation can be run only under continuous monitoring and consultancy support of a tire pyrolysis specialist team.

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References

[1] Scrap tire markets in the United States, 9th Biennial Report, Rubber Manufacturers Association, May 2009.

[2] Rubber Manufacturers Association (RMA), Scrap Tire Markets in the United States; 2005.

[3] A. M. Mastral, R. Murillo , M. S. Callen, and T. Garcia, “Optimisation of scrap automotive tyres recycling into valuable liquid fuels”, Resources, Conservation and Recycling, Vol. 29, Issue 4, pp. 263–272, June 2000.

[4] A. M. Cunliffe, and P. T. Williams, “Composition of oils derived from the batch pyrolysis of tyres”, Journal of Analytical and Applied Pyrolysis, Vol. 44, Issue 2, pp. 131–152, January 1998.

[5] P. T. Williams, and A. J. Brindle, “Temperature selective condensation of tyre pyrolysisoils to maximise the recovery of single ring aromatic compounds”, Fuel, Vol. 82, Issue 9, pp. 1023–1031, June 2003.

[6] S. Ucar, S. Karagoz, A. R. Ozkan, and J. Yanik, “Evaluation of two different scrap tires ash hydrocarbon source by pyrolysis”, Fuel, Vol. 84, Issues 14–15, pp. 1884–1892, October 2005.

[7] C. Berrueco, E. Esperanza, F. J. Mastral, J. Ceamanos, and P. Garcı´a-Bacaicoa, “Pyrolysis of waste tyres in a atmospheric static-bed batch reactor”, Journal of Analytical and Applied Pyrolysis, Vol. 74, Issues 1–2, pp. 245–253, August 2005.

[8] Isabel de Marco Rodriguez, M. F. Laresgoiti, M. A. Cabrero, A Torres, M. J. Chomón, and B. Caballero, “Pyrolysis of scrap tyres”, Fuel Processing Technology, Vol. 72, Issue 1, pp. 9–22, August 2001.

[9] M. R. Islam, M. N. Islam, N. N. Mustafi, M. A. Rahim, and H. Haniu, “Thermal recycling of solid tire wastes for alternative liquid fuel: the first commercial step in Bangladesh”, Procedia Engineering Vol. 56, pp. 573-582, 2013.

[10] S. Murugan, M. C. Ramaswamy, and G. Nagarajan, A comparative study on the performance, emission and combustion studies of a DI diesel engine using distilled tire pyrolysis oil–diesel blends, Fuel, Vol. 87, Issues 10–11, pp. 2111–2121, August 2008.

[11] S. Murugan, M. C. Ramaswamy, and G. Nagarajan, The use of tire pyrolysis oil in diesel engines, Waste Management, Vol. 28, Issue 12, pp. 2743–2749, December 2008.

[12] J. L. Humphrey, and G. E. Keller, Separation Process Technology, New York: McGraw-Hill, 1997, ch. 1.

[13] K. Kolmetz, W. K. Ng, S. H. Lee, T. Y. Lim, D. R. Summers, and C. A. Soyza, “Optimize distillation column design for improved reliability in operation and maintenance”, 2nd Best Practices in Process Plant Management, Kuala Lumpur, Malaysia, March 14-15, 2005.

[14] Distillation Column Selection and Sizing. KLM Technology group, Available at: www.klmtechgroup.com, 2011.

[15] R. K. Sinnott, Coulson & Richardson’s Chemical Engineering, 4th ed., Vol. 6. Elsevier, 2006, pp. 564-565.

[16] H. Z. Kister, Distillation design. New York: McGraw-Hill Book Co., 1992, ch. 3.

[17] Uses and Benefits of Glass Wool, https://storify.com/VarunSharma123/uses-and benefits-of-glass-wool, 2016.

[18] How an FTIR Spectrometer Operates. Available at:http://chemwiki.ucdavis.edu/Core/Physical_Chemistry/Spectroscopy/Vibrational_Spectroscopy/Infrared_Spectroscopy/How_an_FTIR_Spectrometer_Operates, 2016.

Layout Effect of Manufacturing Workplace to Illumination of Working Position

Darina Dupláková*‡, Marián Flimel*

*Department of Manufacturing Management, Faculty of Manufacturing Technologies with a seat in Presov, Technical University of Kosice, Bayerova 1, 080 01 Presov, Slovakia

(darina.duplakova@tuke.sk)

‡ Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Bayerova 1, 080 01 Presov, Slovakia, Tel: 004210556026402, darina.duplakova@tuke.sk

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Abstract- Layout of manufacturing workplace is demanding process which has to take into consideration the technical knowledge, ergonomic rules and factors. One of these factors is illumination, too. The optimization of working position illumination is significant element of working environment and it has strong effect on safety at the work, well-being, health, motivation and performance of workers. Presented article is focused on effect consideration of layout and operational layout of workplace to illumination of working position by software modelling in the stage of workplace design.

Keywords Layout, Illumination, Dialux, Manufacturing workplace.

1. Introduction

At the present time it is one of issues the method of machines and devices layout during the design of manufacturing workplaces. Designers and managers have to observe the standards so that the layout met the demanding criterions. Studies have established that natural lighting is more conducive to a productive and healthy working environment than is artificial lighting. [1] From the point of view of acceptable light climate provision at the workplace, it is necessary to comprehensive perspective on solution of illumination system for day, artificial or compound illumination. From the evaluated 12 criterions of illumination: intensity, evenness, directivity, shadiness, glare, colour, safety, aesthetics, economy, environmental friendliness, maintenance and flexibility, subject of this article is the evaluation of illumination intensity E_m [lx] for artificial illumination and daylight factor D [%] for day illumination. The development of modern computing technology has provided a strong means of analysing the mathematical models of metallurgical processes. [2] The suitability of illumination for various variants of layout will be declared by application of simulation software Dialux and Wdls 4.1.

2. Methodical procedure of illumination system suggestion in relation to layout

In the manufacturing halls, the illumination of workplaces is conditioned by various factors [3]:

a) shape of hall, reflectance of surfaces,

b) size and placement of transparent constructions,

c) kind, power and arrangement of lights, height of light above the work surface,

d) type of manufacturing has effect on layout in relation to material flows, maintenance, etc.,

e) operation

At the design stage of workplace by software modelling, it is suitable to observe the following methodical procedure:

1) assignment of geometrical characteristics and features of space

2) to determine the necessary machines and devices (sizes) according to manufacturing requirements

3) to compile the possible alternatives of layout

4) to suggest the alternatives of artificial illumination (e.g. by Dialux)

5) to select the suitable alternatives of layout in relation to the achievement of required intensity of working position illumination

6) to model the day illumination for selected alternatives with the suggestion variation of transparent constructions

7) to select of optimal solution (alternative) and its finishing by final model of artificial illumination

This presented methodical procedure is suitable for sort of manufacturing when there is not frequent transfer of machines (e.g. piece production). The presented procedure was verified in example of manufacturing hall with fixed position of 5-axis CNC machine (DMU 340P) with variableness possibility of four other machines.

3. Solved example of illuminating system of manufacturing hall

According to point No. 1, 2 and 3 it was suggested the (4!) = 24 alternatives of machine arrangement for concrete conditions. Individual arrangements are presented in the following figure.

Fig. 1. Arrangement variants of manufacturing workplace.

It was assigned the input data to the software Dialux on the basis of the fourth point of methodical procedure and the results are presented in the following table. The requirements were evaluated on the basis of STN EN 12 464 -1. [4] This standard was written by Work Group 2 of the Technical Committee TC 169 of the European Committee for Standardisation (CEN). The standard governs indoor workplace lighting. As with most standards, minimum requirements are laid down. In other words, it concerns a minimum that workplace lighting and the direct environment needs to meet. EN 12464-1 is an application standard. In this document the standard is described with a view to developing a lighting solution:

- gathering the necessary project data and laying down the preconditions;
- considering different alternatives (determining the most suitable lighting concept, choice of luminary type, choice of lamp, ...);
- calculating and documenting

Table 1. Results – average values of illumination (AVI) in lux (at the work surface 0.85 m near machines)

Option	AVI of hall	AVI of FNG machine	AVI of Hermle machine	AVI of MCV machine	AVI of Matec machine	Satisfaction of requirements STN EN 12 464 – 1[4]
1.	312	530	424	473	426	not comply
2.	300	471	331	459	416	not comply
3.	311	487	459	473	426	comply
4.	299	394	391	458	416	not comply
5.	308	501	416	465	427	not comply
6.	311	529	458	469	394	not comply
7.	309	481	452	469	431	comply
8.	301	396	455	423	418	not comply
9.	299	491	390	357	417	not comply
10.	310	523	433	438	424	not comply
11.	301	469	444	358	418	not comply
12.	313	509	468	456	444	not comply
13.	310	503	461	488	396	not comply
14.	309	503	456	467	386	not comply
15.	305	469	447	462	422	not comply
16.	309	501	425	485	434	not comply
17.	309	501	469	451	436	not comply
18.	305	499	446	429	420	not comply
19.	310	476	451	479	437	comply
20.	313	509	432	494	445	not comply
21.	299	491	330	424	416	not comply
22.	312	504	451	495	399	not comply
23.	307	499	446	481	372	not comply
24.	307	520	446	465	377	not comply

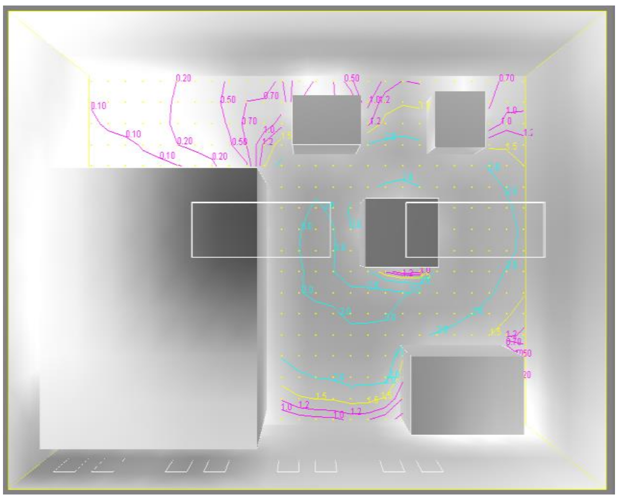

Fig. 2. Course of daylight factor (isophote D=1.5%) [5] – final solution - layout No 19.

After the evaluation (point No. 5) was suitable the tree alternatives No. 3, 7 and 19 which was evaluated according to point No. 6. It was calculated the daylight factors of illumination suitable alternatives by simulation software Wlds 4.1. Then it was evaluate the alternative with the most advantageous ratio of suitable day illumination surface (Point No. 7). In Figure 2 and Figure 3 there are the graphical outputs of layout optimal solution for alternative No. 19.

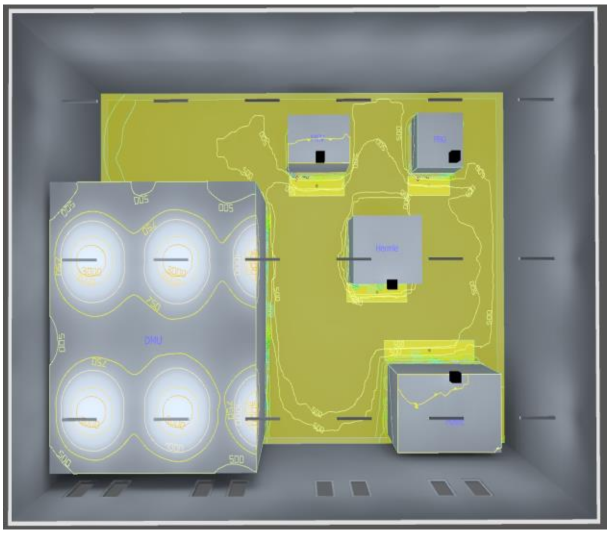

Fig. 3. Course of isophote Em = 300 lx - layout No. 19.

It was established that given hall is not suitable for day illumination because current side lighting or with the required 1/3 of the acceptable day illumination. From this reason it was suggested two upper skylights (sizes 6 x 2 m) and these skylights ensure the required values at the working zones around the machines. The artificial illumination it will be suitable in realization: 24 lights, 4 x 80W power, 7 m height.

4. Conclusion

One of the most widely use fields of electricity is lighting. [6] A lots of simulation software are used for various fields of manufacturing. [7] Model solutions of workplaces illumination are significant tool for optimization of workplace layout. The presented methodical procedure is only the solution fragment of comprehensive optimization of workplace design when it will be necessary to allow for other relevant factors of the environment and working activities.

References

[1] T. Joseph, A. Dutta,"Estimating the annual range of global illuminance on a vertical south facing building façade", International Journal of Energy and Environment, vol. 6, no. 3, pp. 265-272, 2015.

[2] X. Shen, et al."Numerical simulation and analyses for sinter cooling process with convective and radiative heat transfer", International Journal of Energy and Environment, vol. 7, no. 4, pp. 303-316, 2016.

[3] M. Flimel, "Možnosti optimalizácie denného osvetlenia na výrobných pracoviskách", Zborník zo seminára Slovalux 2015 [online]. Bratislava: Slovenská svetelnotechnická spoločnosť, 2015.

[4] STN EN 12464-1:2012 Light and lighting - Lighting of work places - Part 1: Indoor work places.

[5] Vyhláška 541/2007 Z.z. o podrobnostiach a požiadavkách na osvetlenie pri práci, 2007.

[6] I. Aliskan, R. Keskin, "Fluorescent Lamp Modelling and Electronic Ballast Design by the Support of Root Placement, International journal of engineering technologies, vol. 2, no. 3, pp. 118-123, 2016.

[7] L. Knapčíková, "Using of simulation software in the field of reverse logistics" Trendy v podnikání 2012 : mezinárodní vědecká konference : 15. - 16.11.2012, Plzeň. - Plzeň : Západočeská univerzita, pp. 1-5, 2012.

Evaluation and Scheduling of the Car Manufacturing Factory's Employers' Work Shifts

Erhan Baran*‡

*Industrial Engineering Department, Faculty of Engineering, Hitit University, 19030

(erhanbaran@hitit.edu.tr)

‡Erhan Baran,Industrial Engineering Department, Hitit University, Tel:+90 364 227 4533,

Fax: +90 364227 4535, erhanbaran@hitit.edu.tr

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Abstract-This study is made an application related to the regulation of working hours of workers in car factory. This factory has thick to work 24 hour shifts need to work with the system as needed. In this study, which is open 24 hours a day and 7 days in a car factory, it has made application serving with 3 shifts. The attention of employees serving in this industry and are crucial to productivity. Mistakes will be made, which can lead to irreparable consequences. The working hours of workers at the factory scheduling process is usually carried out by personnel chief in the factory. In this study, in consultation with the chief engineer in charge of drafting the schedule and made relevant studies were identified by examining the constraints to be considered. Then it established a mathematical model that can be used in a general sense with integer linear programming techniques. Established model applies to data in a unit of a car factory and has been found to be optimal solutions with the help of LINGO software. Unlike other shift scheduling problems in the literature, this study aimed to run for a minimum of additional workers outside the factory. There is also a model that defined the mathematical model and skillful workers to shift some concessions to be assigned any number of workers in particular experience has been established.

Keywords Mathematical programming, Integer linear programming, Scheduling, Optimization.

1. Introduction

For many organizations, the ability to have the right employee on work at the right time is a critically important factor when attempting to satisfy their costumers' requirements. Computational methods for rostering and personnel scheduling has been a subject of continued research and commercial interest since thee 1950s. Personnel scheduling rostering is defined as the process of constructing optimized work timetables for staff.

Staff scheduling problems deal with the issue of assigning employees to shifts in a certain time period (usually, a week or one month) such that several regulations are satisfied, qualifications and preferences of the employees are taken into account, level of service is maximized and costs are minimized [1].

Personnel scheduling and rostering problems tackle the difficult problem of building employee rosters respecting legal and organizational constraints to satisfy personnel requirements [2]. To fit the minimum-cost shift schedule is also required [3].

To use resourcesoptimally, the structure of the work must be; shift types, holidays, hard and soft constraints to be satisfied, etc.) [4]. Feasible schedules are used if we succeed [5]. These problems involve a great deal of constraints that derive from the usual complexity of regulations on the work relationship employer/employee [6]. Personnel scheduling (PS) is defined as the process of constructing optimized work schedules for staff [7].

In this study, have been studied to find a solution with mathematical programming approach to employee scheduling problems. In literature, the limitations identified in the results of the bilateral talks held in relevant areas of the work done and expressed factory unit with a constraint equations in the model. The fact that patients or authorized personnel working, does not distribute so as to respond to the needs of any shift engineer of the existing obligation, makes it extremely difficult problem making scheduling updates.

When the inadequate number of available workers from outside is needed as the company's short-term help some workers from other units. In these cases, the workers from the another unit to run as soon as possible the work will make it more healthy.

2. Literature Review

Some studies in the literature relating to personnel shift scheduling problems over the years has been in operation in Ernst et al. (2004)[8]. Subsequent studies since 2004 are detailed in the study of Van Den Berghe et al. (2013)'s[9]. When the works are examined since 2013, heuristic approaches can be seen in work shift scheduling. In some studies, heuristic and analytical approaches are used together. Some of the most commonly used methods in mathematical programming techniques are linear programming and integer programming.

If the literature is searched, it can be seen that models and algorithms for specific situations are studied by Burke et al. [10], airline crew scheduling by Kohl and Karisch [11], staff scheduling in postal service by Bard et al. [12], and also call centers optimization by Mehrotra [13]. And also cyclic patterns is studied (cf.,e.g. Beaumont [14] or Mason et al. [15]). Shift scheduling is studied by Vakharia et al. [16] and Lauer et al. [17]. Ernst et al. also work same subjects[8] and Blöchliger [18] who gives a tutorial on modeling staff scheduling problems also work. De Causmaecker et al. [19] classified personnel scheduling problems. Meisels and Schaerf [20] considered a general employee scheduling problem with local search algorithm. Integer linear programming formulation solved by column generation of Sarin and Aggarwal [21]. And also in Baran and Erol's study [22], there has been a mathematical model to select the suppliers. It has many similarities with the scheduling problems.

In this study; the purpose of constraints and can be solved in an analytical approach is not needed to use the heuristic approach. Within this aim and constraints, optimal results were obtained. In this study, optimal results are obtained by mathematical programming techniques.

This study has a very different character from other studies in the literature. For example, in this study, the hours of operation on a volume edited workers, workers are also taken into account in another section. There are no studies in the literature in this direction.

Also a constraint is added to the model skillful workers. Some concessions to the working master is provided with this constraint. This is provided to be different from other models in the model of the literature.

3. Application

In this study, will benefit in the event of insufficient number of workers assigned to each shift is intended to operate with a minimum duration of 8 workers considered in other units. In the study, interviews with responsible personnel unit prepares years in the factory scheduling, scheduling is performed using the data concerning the unit. In consultation with other scientists and engineers working on the issue, opinions and findings are taken. The basis of this assessment, the objective function of the mathematical model and constraints are identified.

Information from workers in the motor car manufacturing unit and analyzing the studies in the literature, the information necessary for regulation model is organized as follows:

i) The weekly working time is taken as 40 hours.

ii) The working hours are organized as three 8-hour shifts.

1st shift; daily shift between 08:00-16:00,

2nd shift; evening shift between 16:00-24:00,

3rd shift; night shift between 24:00-08:00.

iii) When the desired number of first, second and third shift workers can be changed by the workload, the number of workers who will work in shifts are taken as separate constraints.

iv) At the weekend, the number of workers in the first and third shifts, taken separately to run different according to the different workload and the number of workers of different assumptions in this study, charts were prepared by running a different number of workers.

v) They are not able to work at the same time the existing employee (reports, such as annual leave) are set out in interviews that facilitates application changed the number of workers able to work in the model.

vi) These findings and the results of the evaluations taking into account the review of studies in the literature, the purpose of the established model functions and constraints are identified.

4. Mathematical Model

When studies in scheduling field workers examined were found to be the most widely used method of mathematical programming. Thus, mathematical programming approach has been applied to employee scheduling problems in this study.

In this study, according to the motor unit usually applied study system, skillful workers are working on the day shift on weekdays. According to the density of the number of workers to be working the night shift during the week to be changed, the number of shifts in generated mathematical models were taken as separate constraints.

In this study, the additional workers work outside of working hours will be needed if service is intended to be minimized. In some periods of increased work intensity, the number of available workers if insufficient number of workers with insufficient service or other reasons, this model will be very useful. In addition, according to the experience of assignment status, unlike other studies in the literature is limited to restrictions.

Mathematical representation of the mathematical model of the objective function and constraints are as follows:

Indices:

i=1,2,…..,8 (The total number of workers)

j=1,...…,3 (Number of shifts)

k=1,……7 (The number of working days)

e=1,…....,8 (The number of additional workers)

a=1,….,3 (Skillful group of workers)

i=1 (The foreman worker)

Parameters and Variables:

DS_I: The number of workers who must work in first shift,

DS_II: The number of workers who must work in second shift,

DS_III: The number of workers who must work in third shift,

DS_I_hs: The number of workers who must work in first shift at weekends,

DTCSi: The total weekly working time of the worker i.

$$X_{ijk} = \begin{cases} 1, & \text{if worker } i \text{ works at shift } j \text{ in day } k \\ 0, & \text{otherwise} \end{cases}$$

$$XK_{ajk} = \begin{cases} 1, & \text{if worker } a \text{ works at shift } j \text{ in day } k \\ 0, & \text{otherwise} \end{cases}$$

$$YK_{aj} = \begin{cases} 1, & \text{if worker } a \text{ works at shift } j \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{ij} = \begin{cases} 1, & \text{if worker } i \text{ works at shift } j \\ 0, & \text{otherwise} \end{cases}$$

$$Z_{ejk} = \begin{cases} 1, & \text{if worker } e \text{ works at shift } j \text{ in day } k \\ 0, & \text{otherwise} \end{cases}$$

S_i: The maximum idle time during the scheduling period of worker I,

Sa: During a scheduling period, the worker a, how is that working less than 40 hours,

M: A large number.

Assumptions:

In case of need, it was assumed additional workers can be operated externally as required. In the literature, it is not working in this manner. In addition, different constraints are taken into account seniority. Accordingly, it will work day shifts and are assigned to each shift of workers in particular experience is limited to certain constraints. Specific experience of workers in the same day, desired to study the same shift case was also taken into consideration. There are three different groups of the mathematical model. These are: skillful working group, working group in relevant departments and in an additional group of freelance workers.

Objective Function Model:

The aim of this study is to do the minimum work time availability roll scheduling of additional workers will be used outside. In this case, the objective function is a mathematical model will be as follows;

$$Max\ 8\sum_{e=1}^{8}\sum_{j=1}^{3}\sum_{k=1}^{7} Z_{ejk} \qquad (1)$$

Constraints of the Mathematical Model:

Factory benefiting from bilateral talks at the appropriate unit is arranged below constraints;

- Any shifts will work from that unit total number of workers, it should not exceed the number of units formed working groups;

$$\sum_{i=1}^{8} X_{ijk} \leq 8 \qquad \text{Aj,k} \qquad (2)$$

$$\sum_{a=1}^{3} XK_{ajk} \leq 3 \qquad \text{Aj,k} \qquad (3)$$

- Each shift and the experience of more than one group of workers to work day, the same day and you do not wish to work in the same shift;

$$\sum_{a=1}^{3} XK_{ajk} \leq 1 \qquad \text{Aj,k} \qquad (4)$$

- There is a foreman and the foreman workers working in the service under consideration is only required to work in the first shift on weekdays;

Xijk=1 i=1;j=1;k≠6,7 (5)

- The number of workers on weekdays to work in the first shift is DS I;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 5 \quad j=1;k\neq 6,7 \qquad (6)$$

- Number workers to work in the second shift during the week is DS_II;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 4 \quad j=2,\ k=1.,7 \qquad (7)$$

- Number workers to work in the third shift during the week is DS_III;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 4 \quad j=3,\ k=1,.,7 \qquad (8)$$

- At the weekend, the number of workers to work in the first shift is DS_I_hs;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 4 \quad j=1,\ k=6,7 \qquad (9)$$

- Weekly working time must not exceed 40 hours for each worker;

$$\sum_{j=1}^{3}\sum_{k=1}^{7} 8X_{ijk} + S_i \leq 40 \quad i=1,..,8 \tag{10}$$

- Weekly working time must not exceed 40 hours per skillful workers;

$$\sum_{j=1}^{3}\sum_{k=1}^{7} 8X_{ijk} + S_a \leq 40 \quad i=1,....,8 \tag{11}$$

- Weekly working time must not exceed 40 hours for each additional employee;

$$\sum_{j=1}^{3}\sum_{k=1}^{7} 8Z_{ejk} + S_i \leq 40 \quad e=1,....,8 \tag{12}$$

- Negative values are not receiving condition;

$$S_i \geq 0 \quad i=1,....,8 \tag{13}$$

$$S_a \geq 0 \quad a=1,....,3 \tag{14}$$

- Each worker will work at the most one shift on the same day;

$$\sum_{j=1}^{3} X_{ijk} \leq 1 \quad i=1,....,8;\ k=1,....,7 \tag{15}$$

$$\sum_{j=1}^{3} XK_{ajk} \leq 1 \quad a=1,...,3;\ k=1,...,7 \tag{16}$$

- The total weekly working hours for all workers and skillful working group;

$$HTÇS_i = 8\sum_{j=1}^{3}\sum_{k=1}^{7} X_{ijk} \quad i=1,...,8 \tag{17}$$

$$HTÇS_a = 8\sum_{j=1}^{3}\sum_{k=1}^{7} X_{ijk} \quad a=1,...,3 \tag{18}$$

- Each worker, throughout the week, will only operate in a kind of shift;

$$1 - \sum_{k=1}^{7} X_{ijk} \leq (1 - Y_{ij}) \times M \quad i=1,..,8;\ j=1,2,3 \tag{19}$$

$$\sum_{k=1}^{7} X_{ijk} \leq Y_{ij} \times M \quad i=1,....,8;\ j=1,2,3 \tag{20}$$

$$1 - \sum_{k=1}^{7} XK_{ajk} \leq (1 - YK_{aj}) \times M \quad a=1,..,3;\ j=1,2,3 \tag{21}$$

$$\sum_{k=1}^{7} XK_{ajk} \leq YK_{aj} \times M \quad a=1,...,3;\ j=1,2,3 \tag{22}$$

5. Computational Results

In this study, the LINGO program is used for solving the mathematical model. The obtained results are summarized in Table1.

In this study, unlike the literature, assigning additional workers to the schedule status is concerned. Moreover, no previous studies restrict where they can be assigned any number of shifts of workers in particular experience is added to the model.

Table 1. Computational Results

	k=1	k=2	k=3	k=4	k=5	k=6	k=7
j=1	X_{111} X_{611} X_{811} Z_{111} Z_{511}	X_{112} X_{812} Z_{212} Z_{612} Z_{812}	X_{113} X_{613} X_{713} XK_{113} Z_{813}	X_{114} X_{714} XK_{314} Z_{114} Z_{814}	X_{115} X_{315} XK_{115} Z_{315} Z_{515}	X_{616} XK_{116} Z_{316} Z_{516}	X_{317} X_{417} XK_{317} Z_{317}
j=2	X_{721} Z_{221} Z_{621} Z_{821}	X_{222} X_{422} X_{522} XK_{322}	X_{323} XK_{323} Z_{123} Z_{723}	X_{324} Z_{224} Z_{424} Z_{724}	X_{725} XK_{225} Z_{225} Z_{625}	X_{826} XK_{226} Z_{726} Z_{826}	X_{227} XK_{127} Z_{427} Z_{627}
j=3	Z_{331} Z_{431} Z_{631} Z_{731}	X_{332} X_{632} X_{732} XK_{232}	X_{533} XK_{233} Z_{133} Z_{233}	X_{234} X_{634} X_{834} XK_{134}	X_{235} X_{535} XK_{335} Z_{335}	X_{236} X_{436} Z_{136} Z_{736}	X_{537} X_{837} XK_{237} Z_{537}

In this study, which will be the number of workers in skilled workers per shift or unit can be determined. In this model, the working hours of additional workers from outside is minimized. Unlike the literature, the experience the group has been created and is made with scheduling constraints associated with it.

6. Conclusion

Taking into accountthe different approaches and practices, optimal solution with integer linear programming methods of the mathematical model was found. LINGO software solution by the mathematical model has been implemented. The resulting solution is expressed in the table above. As can be seen from the table; 37 of them coming from outside is assigned the task shifts from a total of 89 additional workers. All eight workers who will be appointed as additional items are assigned. Consequently, the workers must study in shifts in the engine unit 8 in addition to the outside.3 skillful worker is assigned 5 shift duty. Similarly, in its own working unit, it was assigned to 5 shift duty. All workers worked 40 hours per week to be worked.

References

[1] Sigrid Knust, Elisabeth Schumacher, “Shift scheduling for tank trucks”, Omega, 513-521, 2011.

[2] Tanguy Lapegue, Odile Bellenguez-Morineau, Damien Prot, “A constraint-based approach for the shift design personnel task scheduling problem with equity”, Computers & Operations Research, 40, 2450-2465, 2013.

[3] MiekeDefraeye, Inneke Van Nieuwenhuyse, “A branch and bound algorithm for shift scheduling with stochastic non-stationary demand”, Computers & Operations Research, 65, 149-162, 2016.

[4] Javier Puente, Alberto Gomez, Isabel Fernandez, Paolo Priore, “Medical doctor rostering problem in a hospital emergency department by means of genetic algorithms”,

Computers & Industrial Engineering, 56, 1232-1242, 2009.

[5] Edmund K. Burke, Jingpeng Li, Rong Qu, "A hybrid model of integer programming and variable neighbourhood search for highly-constrained nurse rostering problems", European Journal of Operational Research, 203, 484-493, 2010.

[6] Joao Telhada, "Alternative MIP formulations for an integrated shift scheduling and task assignment problem", Discrete Applied Mathematics, 164, 328-343, 2014.

[7] ŞeydaTopaloğlu, "A shift scheduling model for employees with different seniority levels and an application in healthcare", European Journal of Operational Reserch, 198, 943-957, 2009.

[8] A.T. Ernst, H. Jiang, M. Krishnamoorthy, B. Owens, D. Sier, "An annotated bibliography of personnel scheduling and rostering", Annals of Operations Research, 127, 21-144, 2004.

[9] Jorne Van Den Bergh, JeroenBelien, Philippe de Bruecker, Erik DEmeulemeester, Liesje De Boeck, "Personnel scheduling a literature review", European Journal of Operational Research, 226, 367-385, 2013.

[10] Edmund K. Burke, DeCaumaecker P., Van Den Bergh G., Van LAndeghem H., "The state of the art of nurse rostering", Journal of Scheduling, 7, 99-441, 2004.

[11] Kohl N., Karisch S.E., " Airline crew rostering: problem types, modelling and optimization", Annals of Operations Research, 127, 57-223, 2004.

[12] Bard J. F., Bibici C., De Silva A.H., "Staff scheduling at the United States postal service", Computers & Operations Research, 30, 71-745, 2003.

[13] Mehrota A.J., "Ringing up business", OR/MS Today, 24, 1997.

[14] Beaumont N., "Scheduling staff using mixed integer programming", European Journal of Operational Research, 98, 84-473, 1997.

[15] Mason A.J., Ryan D.M., Panton D.M., "Integrated simulation, heuristic and optimization approaches to staff scheduling", Operations Research, 46, 75-161, 1998.

[16] Vakharia A.J., Selim H.S., Husted R.R., "Efficient scheduling of part-time employees", Omega, 20, 13-201, 1992.

[17] Lauer J., Jacobs L.W., Brusco M.J., Bechtold S.E., "An interactive, optimization-based decision support system for scheduling part-time computer lab attendants", Omega, 22, 26-613, 1994.

[18] Blöchliger I., "Modelling staff scheduling problems", European Journal of Operational Research, 158, 42-553, 2004.

[19] DeCausMaecker P., Demeester P., Van Den Berghe G., Verbeeke B., "Analysis of real world personnel scheduling problems", Proceedings of the Fifth International Conference on Practice and Theory of Automated Timetabling in Pittsburgh, 97-183, 2004.

[20] Meisels A., Schaerf A., "Modeling and solving employee timetabling", Annals of Mathematics and Artificial Intelligence, 39, 41-59, 2003.

[21] Sarin S.S., Aggarwal S., "Modelling and algorithmic development of a staff scheduling problem", European Journal of Operational Research, "128, 69-558, 2001.

[22] Baran E., Erol S., "A Model suggestion to determine the order quantity in supplier selection problems", Gazi University Journal of Science Part A: Engineering and Innovation, 3, 45-50, 2014.

Light Wavelength and Power Quality Characteristics of CFL and LED Lamps under Different Voltage Harmonic Levels

Kamran Dawood*‡, Bora Alboyaci*, Mehlika Sengul**, Ibrahim Gursu Tekdemir*

* Department of Electrical Engineering, Kocaeli University, Umuttepe Campus 41380 Izmit, Kocaeli, Turkey

** Civil Aviation College, Arslanbey Yerleskesi 41285 Kartepe, Kocaeli, Turkey

(kamransdaud@yahoo.com, alboyaci@kocaeli.edu.tr, mehlika@kocaeli.edu.tr, gursu.tekdemir@kocaeli.edu.tr)

‡Corresponding Author; Kamran Dawood, Department of Electrical Engineering, Kocaeli University, Umuttepe Campus 41380 Izmit, Kocaeli, Turkey, Tel: +905060663676, kamransdaud@yahoo.com

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Abstract- Conventional light sources are less efficient as compared to the light emitting diode and compact fluorescent lamps. Conventional incandescent filament lamps are resistive and therefore do not depend on power quality parameters. In the electric power system, nonlinear loads are increasing rapidly and the high content of harmonic due to the nonlinear loads cannot be neglected. Harmonic generation from the light emitting diode and the compact fluorescent lamp is one of the main problems for power quality. In this study, the light efficiency and electrical characteristics of the light emitting diode lamps and compact fluorescent lamps are evaluated under various voltage harmonic levels. The results show that light emitting diode, produces more harmonics as compared to the compact fluorescent lamps, with the increase of the voltage harmonic distortion from 0.7% to 3.52% in the light emitting diode, current harmonic increased from 140% to 192%. The results also show that increase in voltage harmonic distortion just not only increase current harmonics distortion but also affect the light wavelength of the lamp.

Keywords LED lamps, CFL, Total harmonic distortion, Light intensity, Power quality.

1. Nomenclatures

LED	Light Emitting Diode
CFL	Compact Fluorescent Lamp
I	Luminous Intensity
W	Watt
THD	Total Harmonic Distortion
RMS	Root Mean Square
V_H	RMS Voltage of the hth Harmonic
V_1	RMS Voltage of the fundamental Harmonic
I_H	RMS Current of the hth Harmonic
I_1	RMS Current of the fundamental Harmonic
THD_V	Total harmonic distortion of voltage (%)
THD_I	Total harmonic distortion of current (%)

2. Introduction

Since last few years energy saving lamps, LED lamps and CFLs are replacing incandescent light bulb due to the power saving. The average efficiency of the standard incandescent bulbs is about 2.2% [1] almost 97.8% of the total energy is converted into heat. Many governments have introduced directives to replace the incandescent light bulbs with energy saving lamps, such as CFLs and LED lamps [2-4].

Several studies have been conducted on the highly distorted current of the CFL lamps [5-9]. LED lamps also produce highly distorted current and many different studies have been conducted on the electrical characteristics of LED [9-10].

There are many advantages of using CFL and LED lamps over using of incandescent bulbs. Luminous efficacy of the LED lamps and CFLs are high as compared to the luminous efficacy of the incandescent bulbs. Efficacy of the typical incandescent bulb is about 16 lumens per watt and efficacy of the CFL and white LED lamps are 60 lm/W and 150 lm/W respectively [11] But the main concern about LED lamps and CFLs are the generation of current harmonic distortion. Different types of LED lamps and CFLs generate different levels of the harmonic distortion. As nonlinear loads, LED lamps produce highly distorted currents [12]. LED lamps and CFLs require less active power as compared to the incandescent bulb; however, a large number of the consumer using CFLs and LED lamps in one location may give rise to significant power problems [13]. Over the years, many types of researches are also conducted on the internal ballast circuit and harmonic characters of the CFL and LED lamps [13-17].In this paper, CFLs and LED lamps are categorized on the colour temperature and colour type to analyze their light wavelength and electrical characteristics.

In this study, the light efficiency and electrical characteristics of the LED and CFL are evaluated under various voltage harmonic levels. Two CFLs of 23 W and two LED lamps of 18.7W were used and all of the lamps have same luminous flux. To see the effect of colour temperature of armature hot and cold colour type lamps were used. CFLs and LED lamps were tested under different conditions i.e. without harmonic voltage and with different levels of harmonic voltages. The experiments were conducted to see the harmonic current and light intensity response of the CFLs and LED lamps. The experiment results were also compared with the IEC 61000-3-2.

3. Basic Photometric Quantities

Optical measurements techniques can be subdivided into photometry and radiometry. The main problem with photometry is that the determination of optical quantities is directly related to the sensitivity of the human eye. The measurement of energy per time emitted by the light source is commonly known as radiometry. Some photometric quantities are given below.

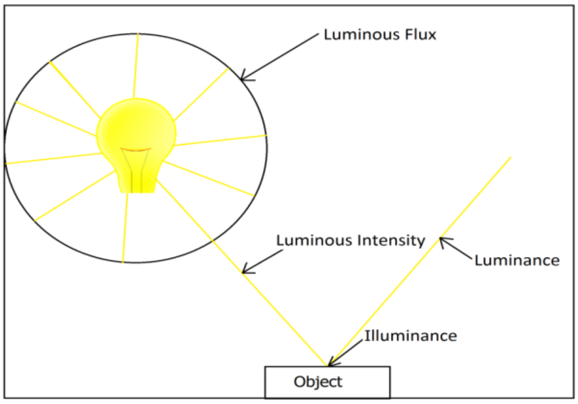

Fig. 1. Photometric Quantities.

3.1. Luminous Intensity

The luminous intensity is a photometric quantity, represents the light intensity of an optical source, as perceived by the human eye. The symbol of luminous intensity is I.

The S.I unit of luminous intensity is candela, it is defined as the luminous intensity of a light source emitting a monochromatic light having an optical power of (1/683) watt per steradian in a given direction at a wavelength of 555 nm, that the source will emit one candela in the specified direction.

3.2. Luminous Flux

The quantity of the energy of the light emitted per second in all directions is known as luminous flux. Figure 2 shows the luminous efficiency function for both scotopic and photopic vision, it describes the average spectral sensitivity of human visual perception of brightness.

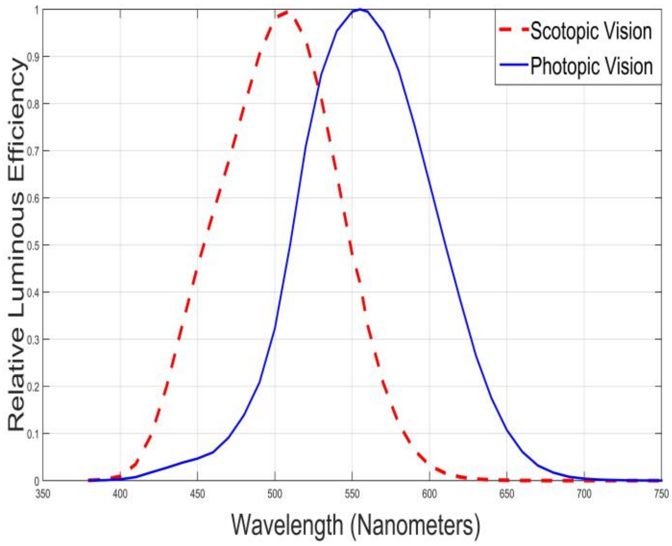

Fig. 2. Spectral sensitivity of the human eye.

Human eyes have different sensitivities within the spectrum with respect to the wavelength. Greenish-yellow light at a wavelength of 555 nm is most sensitive to the human eyes. SI unit of luminous flux is lumen (lm). Lumen is defined as the luminous power of a light source emitting a monochromatic light having the power of (1/683) watt at a wavelength of 555 nm. It defines that at the wavelength of 555nm, 1watt of radiant light is equal to 683 lumens.

3.3. Luminous

Luminous intensity per unit area of light traveling in a given direction is known as luminous. It is used to characterize the reflection and emission from particular area. The SI unit of luminous is candela per square meter (cd/m^2).

3.4. Illuminance

The illuminance is the perpendicular component of the luminous flux that falls on the surface. S.I unit of illuminance is lux. Table 1 is showing illuminance for the different illuminance conditions.

Table 1 Typical illuminance in different environments [18]

Illumination condition	Illuminance [lux]
Full moon	1
Street lighting	10
Home lighting	30 to 300
Office desk lighting	100 to 1000
Surgery lighting	10000
Direct sunlight	100000

4. Power Quality

Power systems are operating in the range of 50-60Hz Frequencies. However, sometimes loads create current and voltages with frequencies that are normally integer multiples of the fundamental frequency. These multiple integers of frequencies are known as power system harmonics and these frequencies are a form of electrical pollution. There are many studies conducted on the impact of CFL and LED lamps on the power quality [20-22]. Harmonics are normally added by the non-linear loads. Use of the semiconductor in the switching part of the electronic equipment is the main reason of non-linearity in the load. Some of the equipment causing harmonics are computers, TVs, printers, CFL bulbs, and motors [19].

The Total Harmonic Distortion (THD) is defined as the ratio of the RMS value of the waveform (without fundamental) and the RMS value of the fundamental. Total harmonic distortion of the voltage is defined by:

$$[THD]_V = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \quad (1)$$

Total harmonic distortion of the current is defined by:

$$[THD]_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \quad (2)$$

It is found that most of the new design of LEDs with lower power rating (<25 Watt) have a power factor (PF) up to 0.6 and current total harmonic distortion (THDI) between 100-140 % [13], [23].

IEC 61000-3-2 gives the limits for the equipment that draws the input current less than 16A per phase [24]. Lightning equipment harmonic emission is divided into two categories i.e. having active power up to 25W and active power greater than 25W. Lightning equipment having active power up to 25W must follow the one of the following condition [24].

In the first condition, 3^{rd} and 5^{th} Harmonic current should not be greater than 86% and 61% of the fundamental current respectively. According to the first condition, the maximum limit of the current total harmonic distortion is approximately 105%.

According to the second condition, 3^{rd} harmonic should not be greater than 30% of the power factor. Detail of the second condition is given in Table 2.

Table 2 Limits for lightning equipments ($P \leq 25W$)

Harmonics [h]	Percentage of fundamental
2	2
3	30 x Power Factor
5	10
7	7
9	5
$11 \leq n \leq 39$ (odd harmonics only)	3

5. Experimental Setup

This section illustrates the experimental setup and the experimental results of the current harmonic and performance of CFL and LED lamps.

A Tektronix DPO5034 digital oscilloscope[3], Everfine spectrum coating integrating sphere[2], Chroma programmable AC source 61704[4], Newport optical spectrometer OSM-100[1] and two computers were used in the experimental setup as given in figure 3. Tektronix DPO5034 digital oscilloscope is used to find the current response of the lamps. Wavelength and light intensity of the lamps are measured from Newport optical spectrometer. Different levels of the voltage harmonics are generated from Chroma programmable AC source 61704. Technical data of the experimented CFLs and LED lamps are given in Table 3.

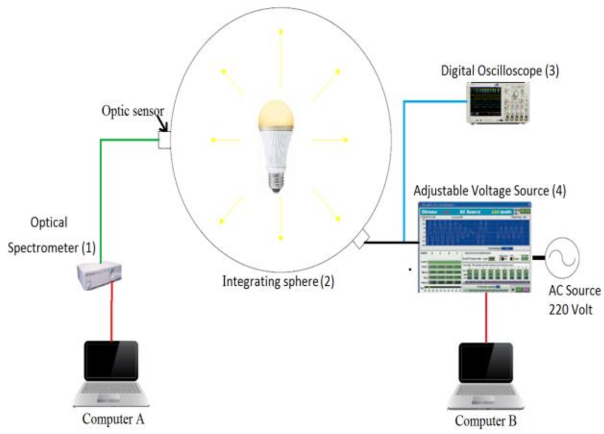

Fig. 3. Experimental Setup.

Table 3. Technical data of lamps

Rated Value	CFL-1	CFL-2	LED-3	LED-4
Nominal RMS Voltage	220	220	220	220
Lamp Power (W)	23	23	18.7	18.7
Luminous Flux (Lm)	1600	1600	1600	1600
Color Type	Warm	Cool	Cool	Warm
Color Temperature (k)	2700	6500	6500	4000
Average Lifetime (hrs)	10000	10000	25000	25000

To see the wavelength and electrical characteristics of the CFLs and LED lamps in different harmonic levels three different conditions of the THD_V are used in the experiment. All the conditions are taken within the range of TS EN 50160 i.e. THD_V must not be more than 8%. In condition 1, the supply voltage is pure sinusoidal with a fundamental frequency of 50 Hz without any harmonic component. In condition 2, 50% of the TS EN 50160 THD_V limit is applied. However, for the condition-3, the value of the THD_V is taken near to the maximum limit of the TS EN 50160. Detail of the applied voltage THD_V is given in Table 4.

Table 4. Used THD value of the voltage

Conditions	Harmonic Number (h)			Total Harmonic Distortion (THD)
	5.	7.	11.	
Condition 1	0%	0%	0%	0%
Condition 2	3%	2%	1%	3.74%
Condition 3	6%	5%	1%	7.87%

5.1. Current Harmonic measurement procedure

As listed in table 3 and table 4; four different lamps are tested for three different conditions. Lamps have same luminous flux. The power consumption of LED lamps is approximately 19W and Compact Fluorescent Lamp is 23 W. All the conditions have been tested at 220 V and 50 Hz Frequency.

Each lamp is tested 20 times for each condition and average is taken from obtained results to minimize the error and increase the reliability and sensibility of the output. Furthermore, total current harmonic distortion is taken from obtained current waveform by using MATLAB software.

6. Measurements and Results

The measurement of Light Intensity and current harmonic distortion are analyzed and discussed in this section.

6.1 Measurement of Light Intensity

This section shows the output of light intensity of the lamps measured by using Newport optical spectrometer OSM-100.

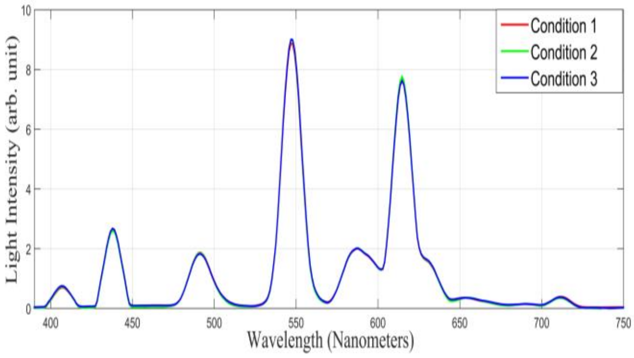

Fig. 4. Light Intensity of CFL-1.

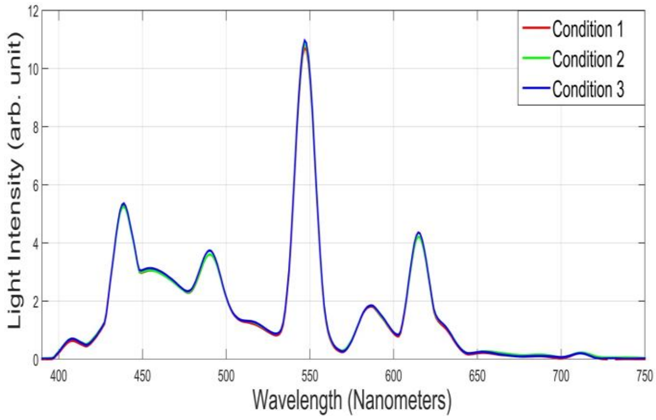

Fig. 5. Light Intensity of CFL-2.

Figure 4 and 5 is showing that the both CFL have the highest peak of light intensity on the wavelength of the 550 nm. However for the second highest peak, both lamps are showing different wavelength, in the case of CFL-1 it lies on the 620 nm wavelength and for CFL-2 second highest peak lies on the 440 nm.

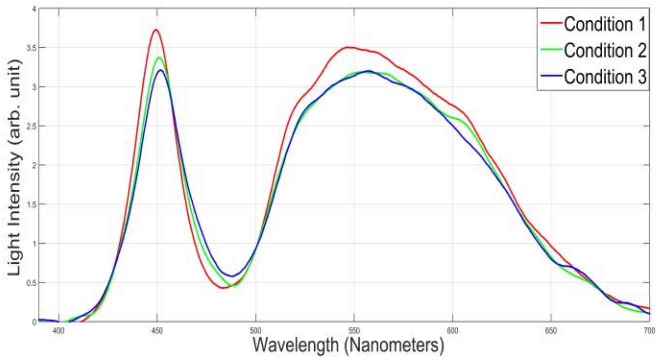

Fig. 6. Light Intensity of LED-1.

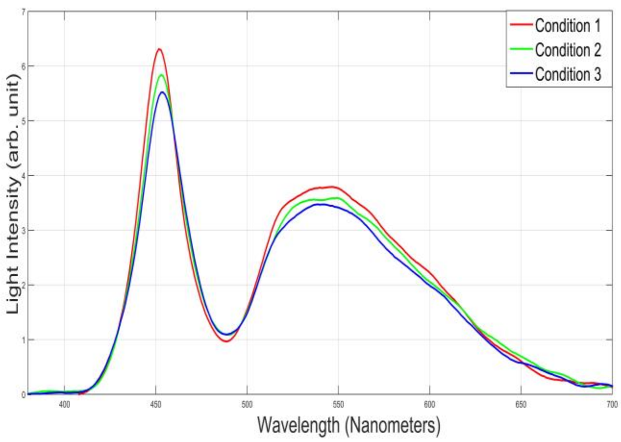

Fig. 7. Light Intensity of LED-2.

Figure 6 and 7 is showing that the both LED have the highest peak of light intensity on the wavelength of the 450nm. The second highest peak of the light intensity for both of the LED is also same, which lies on the 550 nm.

The experiment shows that light intensity of the CFL is more stable as compared to the light intensity of the LED lamp. Results also show that area of the light intensity of the

LED lamps is inversely proportional to the total harmonic distortion of voltage and CFL is directly proportional to the value of total harmonic distortion of voltage.

6.2. Current Harmonic Distortion of lamps

The Current waveform is used to find the total harmonic distortion of current. It is obtained by performing frequency domain analysis on MATLAB.

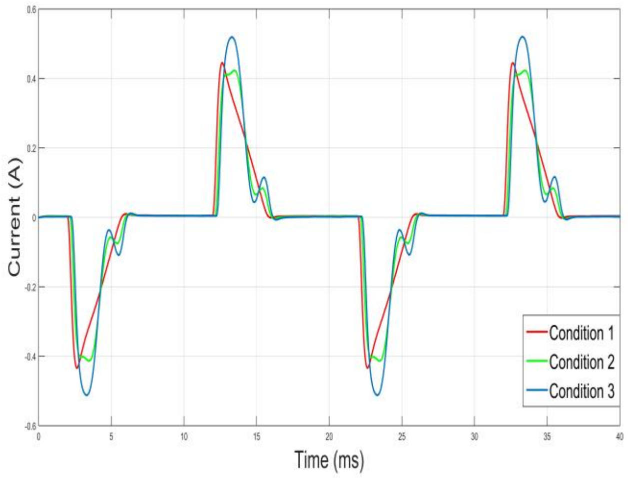

Fig. 8. CFL-1 Current waveform.

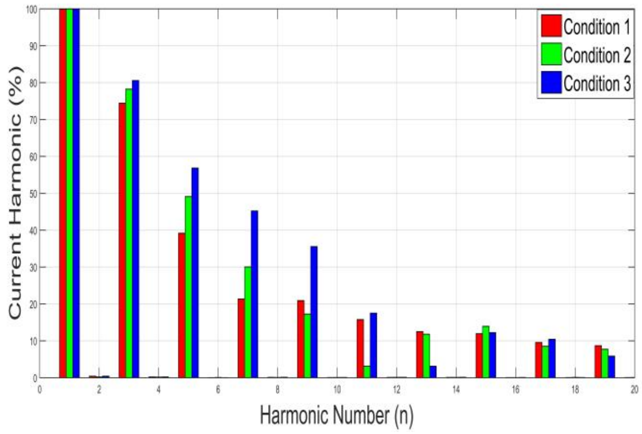

Fig. 9. CFL-1 Harmonic spectrum of current.

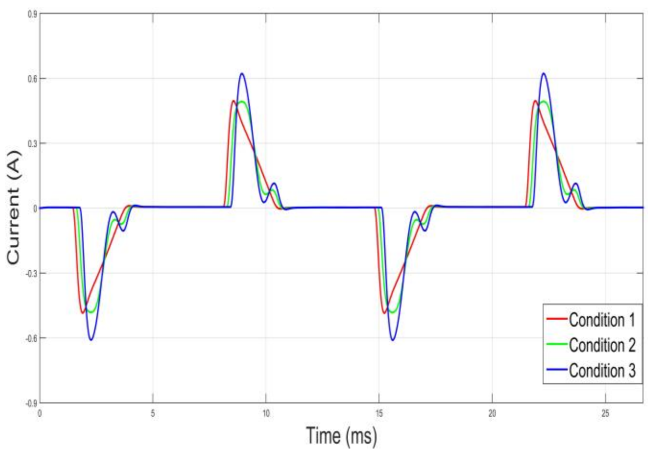

Fig. 10. CFL-2 Current waveform.

Figure 8 and 9 is showing that with the increase in voltage harmonic distortion, current harmonic distortion is also increasing, especially in the 5th, 7th and 9th harmonic.

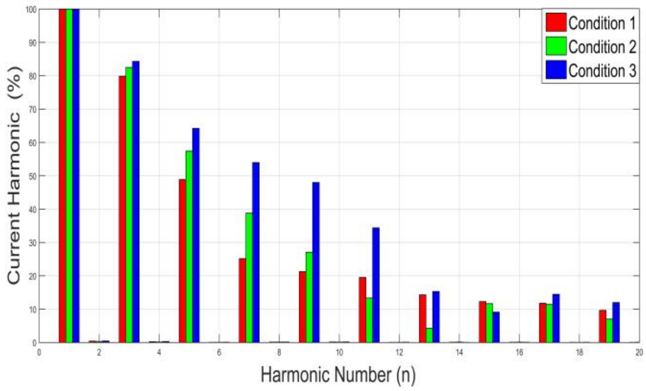

Fig. 11. CFL-2 Harmonic spectrum of current.

Figure 10 and 11 is also showing that with the increase of voltage harmonic distortion, current harmonic distortion also increases. However, results show that 11th harmonic of the CFL-2 is higher as compared to the CFL-1.

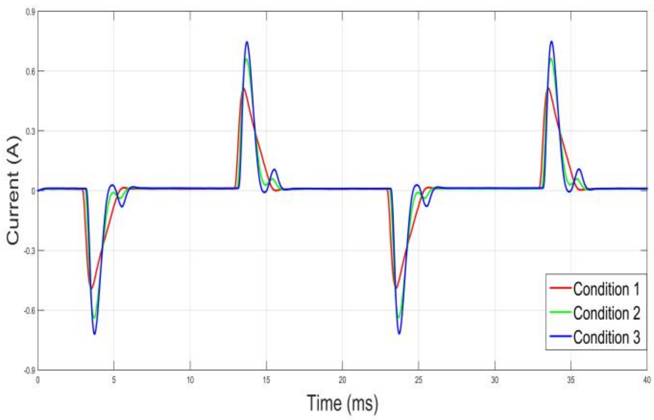

Fig. 12. LED-1 Current waveform.

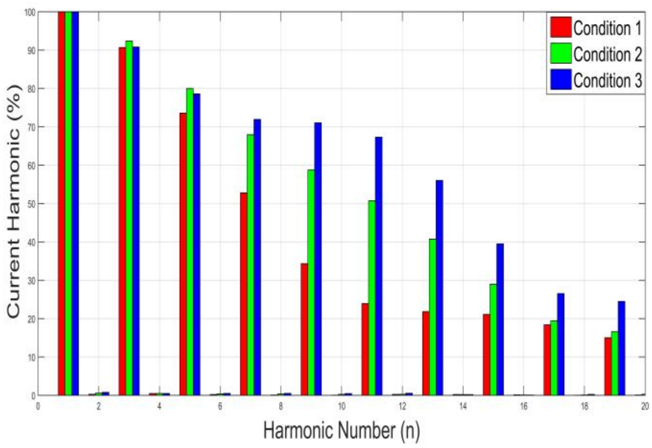

Fig. 13. LED-1 Harmonic spectrum of current.

Figure 12 and 13 is showing the current waveform and harmonic spectrum of the current. Results show that LED is producing more current harmonic distortion; even 11th, 13th

and 15th harmonics are producing harmonic distortion in the large quantity.

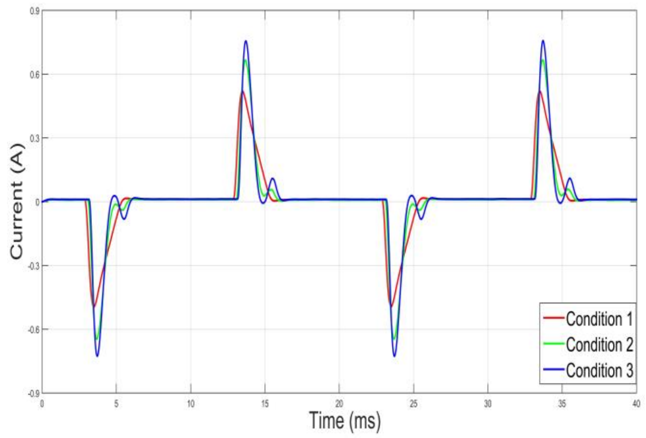

Fig. 14. LED-2 Current waveform.

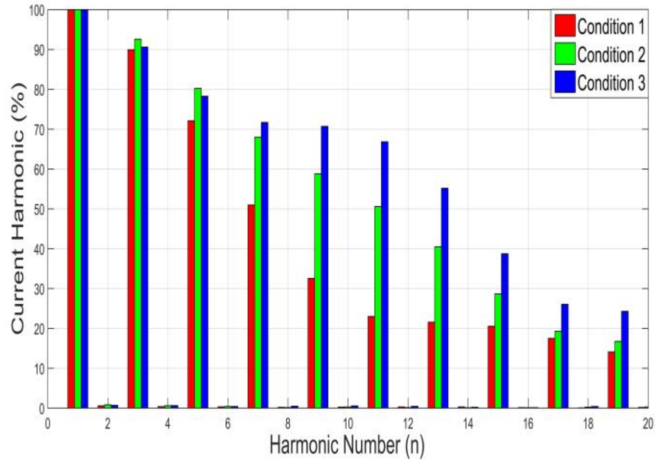

Fig. 15. LED-2 Harmonic spectrum of current.

Figure 15 and 16 are showing the current waveform and harmonic spectrum of the current of the LED-2. Results show that the effect of the voltage harmonic distortion on the LED-2 is same as LED-1.

Table 5 is showing the measured value of the lamps. Results show that all the lamps are producing non-sinusoidal waveform, indicating that lamps are producing harmonics into the power system. For each lamp, THD_I is increasing with the increase in THD_V. Total current harmonic distortions for both lamps are presented in Table 5. As shown in Table 5 just the first condition of CFL-1 produced THD_I value less than 100, whereas all other tested conditions produced THD_I value greater than 100.

These both lamps are producing high levels of harmonic distortion and these values are not acceptable according to the IEC 61000-3-2 standard. Furthermore, results are showing that LED is producing more harmonic current as compared to the CFL lamp.

Change in THD_I in cool color type LED lamp and warm color type LED lamp is approximately same for each condition. However cool color type CFL lamp produces more THD_I as compared to the warm color type CFL lamp.

Table 5 is also showing light intensity area of the CFL and LED lamps with different conditions. Results show that area of the CFL is directly proportional to the harmonic voltages, however, light intensity area of the LED lamp is decreasing with the increased in harmonic voltages. Results also show that light intensity of the CFL lamps is more stable as compared to the LED lamps.

Table 5. Measured Values of the lamps

Lamp	Condition	Voltage				Current			Area of the light intensity
		RMS (V)	THD (%)	Fundamental (V)	RMS Value of the voltage harmonics (V)	THD (%)	Fundamental RMS current (mA)	RMS Value of the Current harmonics (mA)	
CFL-1	1	220	0.76	215.9	1.6	94.52	125.4	118.5	400
	2	220	3.35	216	7.2	102.17	120.2	122.8	402
	3	220	7.53	215.4	16.2	117.7	117.3	138	410
CFL-2	1	220	0.77	215.8	1.7	105.4	120.7	127.2	574
	2	220	3.31	215.8	7.2	114.4	118.8	135.9	591.2
	3	220	7.56	215.4	16.3	136.5	112.2	153.2	595.3
LED-1	1	220	0.75	215.9	1.6	142.9	86.7	123.7	529
	2	220	3.32	215.9	7.2	172.8	86.2	149	497
	3	220	7.51	215.1	16.2	193.3	83.5	161.4	496
LED-2	1	220	0.73	215.9	1.6	139.8	89.9	125.7	599.8
	2	220	3.3	215.7	7.1	172.96	87.2	150.8	587.7
	3	220	7.52	215.2	16.2	192.08	85.3	163.9	562.8

7. Conclusion

In this study, light efficiency and electrical characters of the compact fluorescent lamps and LED lamps are investigated under different voltage harmonic levels. Experiments were carried out on a number of lamps in a laboratory environment. Experiments have shown that CFL and LED lamps are a serious source of harmonic distortion. It has been observed that the current harmonics of the LED lamps have increased significantly as the harmonic components are added to the supply source. Furthermore, wavelength characters of the CFL and LED lamps are also investigated. It is seen that under the distorted voltage source CFL and LED lamps also affects the light wavelength of the lamp. The features of the lamps are also important factor as result shows that warm color type lamps produce fewer harmonic as compare to the cool color type lamps.

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References

[1] N. Armaroli, and V. Balzani, Towards an electricity-powered world: Energy and Environmental Science 4, pp 3193-3222, 2011.

[2] C. DiLouie, Advanced Lighting Controls: Energy Savings, Productivity, Technology and Applications, The Fairmont Press, Inc., 2006.

[3] B.J. Huang, P.C. Hsu, M.S. Wu and C.W. Tang, "Study of system dynamics model and control of a high-power LED lighting luminaire", Energy, Vol. 32, No. 11,pp 2187–2198, 2007.

[4] S. Uddin, H. Shareef, and A. Mohamed. "Power quality performance of energy-efficient low-wattage LED lamps", Measurement, Vol.46, No.10, pp 3783-3795, 2013.

[5] Matvoz D., and M. Maksic. " Impact of compact fluorescent lamps on the electric power network ",In Harmonics and Quality of Power, ICHQP,pp 1-6, 13th International Conference IEEE, 2008.

[6] A. Gil-de-Castro, S. K. Ronnberg, M. H. Bollen and A. Moreno-Munoz, "Harmonics from household equipment and different lamp technologies", Compatibility and Power Electronics 8th International Conference, pp. 1-6, 2013.

[7] R.M Remy, R. K. Rayudu, M. S. Witherden, and E. M. Lai, "Power quality indices of compact fluorescent lamps for residential use—A new zealand study", TENCON 2010 IEEE Region 10 Conference, pp. 647-652, 2010.

[8] S. Elphick, P. Ciufo and S. Perera, "The electrical performance of modern compact fluorescent lamps", Australian Journal of Electrical and Electronics Engineering, vol. 7, pp. 43-51, 2010.

[9] S. K Rönnberg, M. H. J. Bollen, and M. Wahlberg, "Harmonic emission before and after changing to LED and CFL—Part I: Laboratory measurements for a domestic customer", 14th International Conference Harmonics and Quality of Power, pp. 1-7, 2010.

[10] C. Jettanasen and C. Pothisarn, "Analytical study of harmonics issued from LED lamp driver", Proceedings of the International Multi Conference of Engineers and Computer Scientists, 2014.

[11] V. Balzani, G. Bergamini, P. Ceroni, Light, "A Very Peculiar Reactant and Product", Angewandte Chemie International, Vol. 54, No. 39, pp 11320–11337, 2015.

[12] V. Cuk, J.F.G. Cobben, W.L. Kling, R.B. Timens, "An analysis of diversity factors applied to harmonic emission limits for energy saving lamps", Proceeding 14th International Conference on Harmonics and Quality of Power, Italy, pp. 1–6, 2010.

[13] R. Dwyer, A.K. Khan, M. McGranaghan, L. Tang, R.K. McCluskey, R. Sung, and T. Houy, "Evaluation of harmonic impacts from compact fluorescent lights on distribution systems", IEEE Transaction on Power System, vol. 10 , Issue 4, pp. 1772–1779, 1995.

[14] S. Choi and T. Kim, "Symmetric current-balancing circuit for LED backlight with dimming", IEEE Transaction on Industrial Electron, vol. 59, No. 4, pp. 1698–1707, 2012.

[15] R. R. Verderber, O. C. Morse, and W. R. Alling, "Harmonics from compact fluorescent lamps", IEEE Transaction on Industry Application, vol. 29, No. 3, pp. 670-674, 1993.

[16] F. V. Topalis, " Efficiency of Energy Saving Lamps and Harmonic Distortion in Distribution System", IEEE Transactions on Power Delivery, vol. 8, No.4, pp. 2038-2042, Oct.1993.

[17] M. Ponce, A. J. Marinez, J. Correa, M. Cotorogea, and J. Arau, "High– Efficient Integrated Electronic Ballast for Compact Fluorescent Lamps", IEEE Transactions on Power Delivery, vol. 21, No.2, pp. 532-542, 2006.

[18] E. Fred Schubert, Light-Emitting Diodes:Cambridge University Press,Ed. 2, pp.278, 2006.

[19] F.D. Wijaya, A. N. Widiastuti, and Z.F. Wibowo, "Pengaruh Beban Harmonik Terhadap Putaran Piringan KWh Meter Induksi", CITEE. Indonesia: Department Of Electrical Engineering and Information Tech.,UGM 124, 2011.

[20] Rana A.J., M. Ai-Dabbagh, ,A. Muhammad. "Impact of compact fluorescent lamp on power quality", Australasian Universities Power Engineering Conference, pp.1-5, 2008.

[21] N. Charles , J. Nderu, and L. Ngoo. " Effects of Compact Fluorescence Light (CFL) Bulbs on Power Quality", Journal of Energy Technologies and Policy,Vol. 2 , Issue 3, pp. 2224-3232, 2012.

[22] A.M. Blanco, R. Stiegler, and J. Meyer, "Power quality disturbances caused by modern lighting equipment (CFL and LED)", PowerTech IEEE Grenoble, pp. 1-6, 2013.

[23] Blanco A.M., Parra E.E.,"Effects of High Penetration of CFLs and LEDs on the Distribution Networks", 14th International Conference on Harmonics and Quality of Power, pp. 1-5, 2010.

[24] IEC Standard 61000-3-2, Limits for Harmonic Current Emissions (Equipment Input Current ≤ 16A Per Phase), Ed. 3.2, 2009.

A Case Study for Estimation of Heating Energy Requirement and Fuel Consumption in a Prototype Building Using Degree-Day Method in Kocaeli

Cenker Aktemur‡

‡ Department of Mechanical Engineering, Eastern Mediterranean University, via Mersin 10, Famagusta, N.Cyprus

(cenkeraktemur_41@hotmail.com)

‡ Corresponding Author; Cenker Aktemur, Department of Mechanical Engineering, Eastern Mediterranean University, via Mersin 10,

Famagusta, N.Cyprus, Tel: +95382660367,

cenkeraktemur_41@hotmail.com

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Abstract- Energy is a requirement of all industrialised nations, and variations in its availability can be dangerous and disruptive. The majority of the energy consumed in buildings is spent for heating and cooling to ensure the thermal comfort of human beings in all parts of the world. Energy analysis plays a vitally important in the design of heating, ventilation and air conditioning (HVAC) systems at affordable and efficient cost in residential areas. Buildings are in need of heating in cold weather. The mean daily outside air temperature is an important guide in predicting the amount of fuel needed to heat residential buildings. The amount of fuel required to heat an area, a city or a region can be accurately forecasted based on the outside air temperature. One of the well-accepted methods internationally is the heating degree-day (HDD) method, which is employed for the energy analysis. This paper considers for İzmit, the capital district of Kocaeli province, which is located on the western coast of Turkey and aims to calculate the annual heating energy requirement and natural gas consumption at a base temperature of 15oC by considering different type of glass, glazing area percentage (GAP), air exchange rate (ACH), and the number of people (n) living in a prototype building. It was predicted that in the worst condition (single-glazing), natural gas consumption would be about fourfold higher than the best condition (triple-glazing) if it is thought that 60 people live in an apartment building.

Keywords Energy analysis, heating degree-day, heating energy requirement, natural gas consumption, prototype building.

1. Introduction

Energy is fundamental to meet many human needs, including lighting, cooking, heating and traveling. The swiftly growing world population, escalating energy demands and industrialisation of countries have resulted in high energy costs and environmental problems; therefore, studies that focus on cutting unnecessary costs have been gaining prominence. Energy consumption can be generally examined in four major sectors, namely industry, building, transportation and agriculture. In almost all countries, energy consumption in buildings constitutes a substantial part of total energy consumption. Roughly 25 - 30% of the total energy consumption in Turkey occurs in residential buildings. The energy in buildings is mainly employed in heating, domestic water preperation and cooking. Heating is the largest part of energy consumption in the buildings with 40 %. Therefore, the amount of energy required to heat buildings is a very important step and must be focused it on painstakingly [1-3].

The seasonal energy requirements for the heating of buildings and the associated fuel consumption can be determined depending on the predetermined architectural design, the material characteristics of the buildings and meteorological temperature measurements. Design of conditioning systems, energy analysis in buildings, heating and cooling load calculations are mainly based on climate data [4].

Various energy estimation methods have been developed for buildings and climate systems. One of the methods of predicting the energy requirement for heating building in a given time of period is the degree-day (DD) method [5]. The method assumes that the energy requirement of a building is directly proportional to the difference between the outdoor and indoor air temperatures. Heating calculations are performed for periods of time provided that the outdoor temperature is lower than a base temperature [6].

2. Literature review

The first work in the sense of degrees-days (DDs) in the world was conducted in the 1700's and studies in this direction accelerated in the 20th century. In Turkey, however, a number of studies be on this subject after the 1980s. The first DD study is based on the relationship between plant growth and temperature. The first serious study related to DD was carried out by French scientist Reaumur in the 18th century. Today, DD technique has been further developed and been continued to be employed incessantly for many purposes by researchers. Some of these are energy demand, fuel consumption, and cost analysis which are substantial parameters for the energy management of the buildings [7].

Durmayaz et al. (2000) [8] conducted a study on Istanbul's energy needs and fuel consumption using heating degree-hours technique. In the study, a prototype apartment was planned in Göztepe province of Turkey and they assumed that 20-65 people live in the apartment. Basic parameters such as heating energy demand and fuel consumption, the number of hourly air changes, the number of people in the apartment and the population of the city were used. They explained that this method can easily be used in similar applications for any part of the world.

Dagsoz (1995) [9] utilized for heating and cooling purposes using degree-day method. He calculated HDD at base temperatures of 12 and 18 °C using the 10-year average temperature data for 67 provinces in Turkey and tried to determine the heating fuel requirement of the buildings.

Sarak and Satman (2003) [10] tried to estimate natural gas demand using heating degree day (HDD) method that is required for the heating of buildings in Turkey. Daily temperatures of cities, population and settlement records of buildings were obtained to predict Turkey's natural gas demand. They estimated that the maximum amount of potential natural gas consumption would be 14.92 Gm3 in 2023.

Akbayir (2006) [11] aimed to calculate the daily heating and cooling degree days for Eskişehir province of Turkey. He determined that fuel consumption in Eskişehir is at most 18.2 % in January.

Kaynakli (2008) [12] calculated degree-hours (DH) values considering mean outside air temperature from 1992 to 2005 in İstanbul province of Turkey. Then, he investigated for different architectural design properties such as air infiltration rate, glazing type, and area to determine the heating energy requirement and fuel consumption calculations on single and double-glazing, various type of material used.

Durmayaz and Kadioglu (2003) [13] estimated the seasonal energy demand and fuel consumption in a building for the major cities of Turkey such as Istanbul, Ankara, Adana, Bursa and Konya by using degree-hour (DH) method. Since 50.8% of the total population in Turkey is thought to be in these big city centres, it was stated that the total amount of these estimates can be interpreted as a good indicator of the energy demand and fuel consumption of buildings in all major cities of Turkey.

3. Heating degree-day method

While climate data are presented in different ways for different purposes, the complexity and truthfulness of the methods developed are relied on the detailed climate data used. Accepted methods for estimating energy use of buildings in the early 1970s are developed for the need to forecast the energy usage at the macro level. One of the methods employed for the heating energy calculations is degree-day (DD) calculation method. It is the most common method since it gives very good results in energy consumption calculations for heating purposes. For several provinces it is possible to compile DD values calculated by different researchers at different base temperatures. Degree-days (DDs), the cumulative sum of the differences between the mean outdoor air temperature and base temperature, can be calculated for a specific period of time (e.g., day, week, month, or year), and they are determined only by the positive values of the temperature difference [14]. Countries employ several techniques to calculate DD. To create a comparable and common use, Statistical Office Of The European Communities (EUROSTAT) proposes the following equation (1) in terms of the entire heating season for the calculation of the total number of HDD [15].

$$\mathrm{HDD} = \sum_{j=1}^{N} (\mathrm{T_b} - \mathrm{T_{o,j}}) \text{ if } (\mathrm{T_o} < \mathrm{T_b}) \quad (1)$$

$$\mathrm{HDD} = 0 \text{ if } (\mathrm{T_o} > \mathrm{T_b}) \quad (2)$$

where T_b is base temperature, $T_{o,j}$ is daily mean outside air temperature recorded at a meteorology station, as indicated in the following equation (2), N is the number of days provided that $T_o < T_b$ in a heating season. Therefore, HDD values are calculated as $T_o < T_b$. As it can be seen from equation (2), HDD values only take on positive values.

The daily mean outdoor air temperature, T_o, is determined by taking the average of the measured maximum and minimum temperatures during a day.

$$\mathrm{T_o} = \frac{(\mathrm{T_{o,min}} + \mathrm{T_{o,max}})}{2} \quad (3)$$

where $T_{o,min}$ and $T_{o,max}$ are, in turn, minimum and maximum temperatures recorded during a day [°C].

4. Practical calculations and interprations

Thermal conductivities and thicknesses of the construction materials are determined for an insulated building. U-values of outside walls, single, double and triple glazed windows, floor and roof are calculated as 0.54, 5.8, 2.7, 0.85, 032 and 0.51 W/m^{2}K. A brief summary of physical and thermal properties of building construction materials is presented in **Table 1** below.

Table 1. Physical and thermal properties of building construction materials

Element	Area (m^2)	Material	Conductivity (W/m-K)	Thickness (m)	U-value (W/m^2-K)
Ceiling under the roof	504	Insulation (fiberglass)	0.038	0.07	0.51
		Concrete with sand and gravel aggregate	2.1	0.16	
		Cement plaster with sand aggregate	0.72	0.04	
Outside walls	2208 minus glazing area	Cement plaster with sand aggregate	0.72	0.02	0.54
		Brickwork	0.84	0.075	
		Insulation (Glass wool)	0.034	0.05	
		Brickwork	0.84	0.075	
		Cement plaster with sand aggregate	0.72	0.02	
Windows	15,20,25,30,35, 40,45,50% of outside walls	Single glass			5.8
		Double glass			2.7
		Triple glass			0.85
Basement	504	Laminate	0.13	0.007	0.32
		Cement mortar	1.73	0.05	
		Extrude polystren foam	0.035	0.1	
		Unreinforced concrete	1.65	0.2	

Daily means of external air temperatures over the heating season are indicated in **Fig.1**. The total number of heating degree-days is forecasted as 1407 at a base temperature of 15 ºC for the heating season in Kocaeli (latitude 40°47' N, longitude 29°58 E) by the aid of Figure 1 and equation (1).

According to TS 825 (Thermal Insulation Rules of Buildings) [16], Turkey is divided into four climatic zones depending on DD values determined according to the average temperatures for heating. Kocaeli, the reference province located in the second climate region, was inspected in detail to determine the mean outside air temperatures in 2016. The daily mean outdoor air temperature variation between 2015 and 2016, based on the records of İzmit meteorology station, is exemplified conjunction with a fitted polynomial function of the 4th order in Figure 1 below. It is possible to infer that parabolic DD alterations occur because Kocaeli transitions between Mediterranean and Black Sea climates. The base temperature is determined according to the comfort needs of human beings and is a major influence on the starting date of a building's heating season. **Fig. 2** below are employed for determination of the starting and end of the heating season. The 266th day (22 September) and 149th day (28 May) of the year appear as the beginning and end of the heating season if T_b = 15ºC is considered. It is seen that the heating season lasts 236 days within the year, which means that it encompasses approximately 55% of the heating season and it is clearly understood that there is no requirement for the heating between the 150th and 265th days of the year in Kocaeli. According to ASHRAE [17], it is necessary to properly and adequately ventilate the structure in order to meet the oxygen requirements for the maintenance of human life and to remove the air pollution that can occur for various reasons in the structure. Ventilation can be provided by the use of building systems or by natural means. Provision of natural ventilation on the buildings is more favorable than energy conservation, economy and health systems. However, in order to ventilate by means of natural methods, appropriate external air must reach the structure and this air must be absorbed into the structure through the building's shell and ensuring adequate and proper air circulation within the structure and then the polluted air is needed to be removed from the structure.

Let us assume I (ACH) for hourly average air exchange rate, I = 0.5 ACH, 1.0 ACH, 1.5 ACH, and 2.0 ACH depending on the ventilation spacings. Besides, we take the glazed area percentages as 15% (352.8 m^2), 20% (470.4 m^2), 25% (588 m^2), 30% (705.6 m^2), 35% (823.2 m^2), 40% (940.8 m^2), 45% (1058.4 m^2) and 50% (1176 m^2) with respect to the total outside wall area.

The prototype, 7-story apartment building, in which it is assumed that 40,45,50,55,60,65,70,75,80,85,90,95 or 100 people may live, is placed in İzmit (capital district of Kocaeli). The outside dimensions, widt×depth×height, of this building are taken into account as 28×18×24 m. It is thought to be 36 residences in this building. Area of roof, outside walls, and floor is 504 m^2, 2208 m^2 and 504 m^2, respectively and total building volume is V = 12096 m3. According to these, the building's total heat loss coefficient, L (W/K), various glazing area percentage of outside walls, GAP, and I is calculated through the following equation (4) [18]:

$$L = \sum \frac{UA + I(\rho c_p)_{air} V}{3.6} = \sum \frac{UA + IV}{3} \quad (4)$$

because the volumetric thermal capacity of air is $(\rho c_p)_{air}$ = 1.2 kJ/m^{3}K . Then, the results are tabulated in **Table 2.**

5. Determination of heating energy requirement and fuel consumption

Seasonal heating energy requirement, Q (J), for prototype building, located in Kocaeli is calculated adopting the following equation (5) in respect of HDDs and the total heat loss coefficients (L) [19].

$$Q = \frac{L \cdot HDD_y \cdot \frac{24h}{1\ day} \cdot \frac{3600s}{1h}}{(T_i - T_o)} \quad (5)$$

Equation (5) is simplified as follows:

$$Q = \frac{86400 \cdot L \cdot HDD_y}{(T_i - T_o)} \quad (6)$$

where Q is energy demand (J), L is the total heat loss coefficient of the building (W/°C), HDD is the total number of DDs in a year for the heating period (°C.day) and $T_i - T_o$ is design indoor and outdoor air temperature difference (°C).

Following the determination of the total heat coefficients, the heating energy requirements are given in GJ in **Table 3** below for single, double and triple glass, various GAP and I.

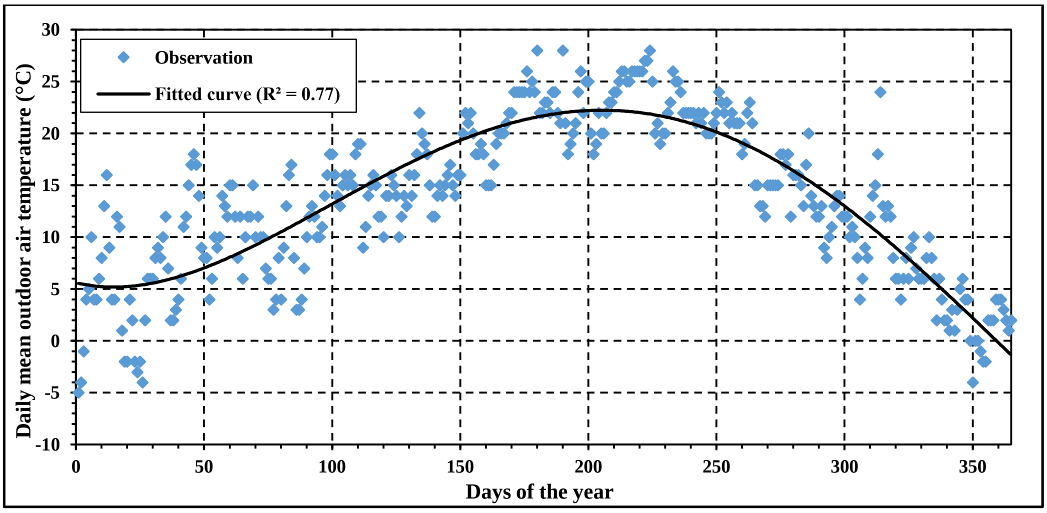

Fig. 1. Variation of daily outdoor air temperatures for Kocaeli in 2016.

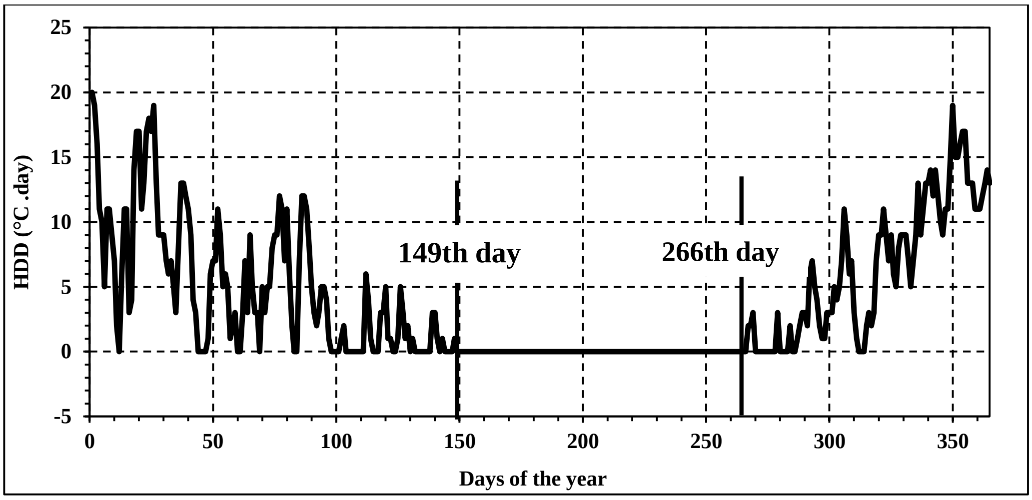

Fig. 2. Alteration of daily HDD at a base temperature of 15 °C in 2016.

Table 2. Building heat loss coefficient L (W/K) for various glazing type and surface area GAP, and air infiltration rate I.

Glass	ACH	GAP (%)							
		15	20	25	30	35	40	45	50
Single	0,5	5560,1	6178,7	6797,3	7415,9	8034,4	8653,0	9271,6	9890,2
	1	7576,1	8194,7	8813,3	9431,9	10050,4	10669,0	11287,6	11906,2
	1,5	9592,1	10210,7	10829,3	11447,9	12066,4	12685,0	13303,6	13922,2
	2	11608,1	12226,7	12845,3	13463,9	14082,4	14701,0	15319,6	15938,2
Double	0,5	4466,4	4720,5	4974,5	5228,5	5482,5	5736,5	5990,5	6244,6
	1	6482,4	6736,5	6990,5	7244,5	7498,5	7752,5	8006,5	8260,6
	1,5	8498,4	8752,5	9006,5	9260,5	9514,5	9768,5	10022,5	10276,6
	2	10514,4	10768,5	11022,5	11276,5	11530,5	11784,5	12038,5	12292,6
Triple	0,5	3813,8	3850,2	3886,7	3923,1	3959,6	3996,0	4032,5	4069,0
	1	5829,8	5866,2	5902,7	5939,1	5975,6	6012,0	6048,5	6085,0
	1,5	7845,8	7882,2	7918,7	7955,1	7991,6	8028,0	8064,5	8101,0
	2	9861,8	9898,2	9934,7	9971,1	10007,6	10044,0	10080,5	10117,0

Table 3. Estimations of the heating energy requirements of an apartment building

Glass	ACH	GAP (%)							
		15	20	25	30	35	40	45	50
Single	0,5	675,9	751,1	826,3	901,5	976,7	1051,9	1127,1	1202,3
	1	921,0	996,2	1071,4	1146,6	1221,8	1297,0	1372,2	1447,4
	1,5	1166,1	1241,3	1316,5	1391,7	1466,9	1542,1	1617,2	1692,4
	2	1411,1	1486,3	1561,5	1636,7	1711,9	1787,1	1862,3	1937,5
Double	0,5	543,0	573,8	604,7	635,6	666,5	697,4	728,2	759,1
	1	788,0	818,9	849,8	880,7	911,6	942,4	973,3	1004,2
	1,5	1033,1	1064,0	1094,9	1125,8	1156,6	1187,5	1218,4	1249,3
	2	1278,2	1309,1	1339,9	1370,8	1401,7	1432,6	1463,5	1494,3
Triple	0,5	463,6	468,1	472,5	476,9	481,3	485,8	490,2	494,6
	1	708,7	713,1	717,6	722,0	726,4	730,9	735,3	739,7
	1,5	953,8	958,2	962,6	967,1	971,5	975,9	980,4	984,8
	2	1198,8	1203,3	1207,7	1212,1	1216,6	1221,0	1225,4	1229,9

Fig. 3 shows the need for seasonal heating energy (GJ) in the prototype building in Kocaeli, together with the equations for both single, double and triple glasses, versus GAP. It can be seen how the seasonal heating energy requirement changes with GAP.

In a similar way, **Fig. 4** displays the seasonal heating energy requirement for the prototype building in Kocaeli for I=1.0 ACH versus different GAP. It is possible to infer that as the air exchange rate enhances, the need for seasonal heating energy also increases dramatically.

A point to be emphasized is the number of people living in an apartment, n, of course, when this value is taken, the number of apartments in the city must be detected. In this case study, necessary calculations were made considering that the population of the city lived utterly in the apartment.

For apartment buildings in the city, the total fuel consumption in a heating season can easily be calculated by aid of the following equation (7) [18].

$$F = \frac{Q \times P}{\eta \times H \times n} \tag{7}$$

where F is the total fuel consumption (m^3), Q is energy demand (J), P is population of the city, LHV is lower heating value of natural gas (J/m^3) and η is the heating-system efficiencies so-called the thermal efficiency of the burning equipments.

Some assumptions were made in this case study: The average population for Kocaeli city is 1,830,772, the heating value of natural gas is H = 34.526 J/m^3 , and the thermal efficiency is 0.88 [19].

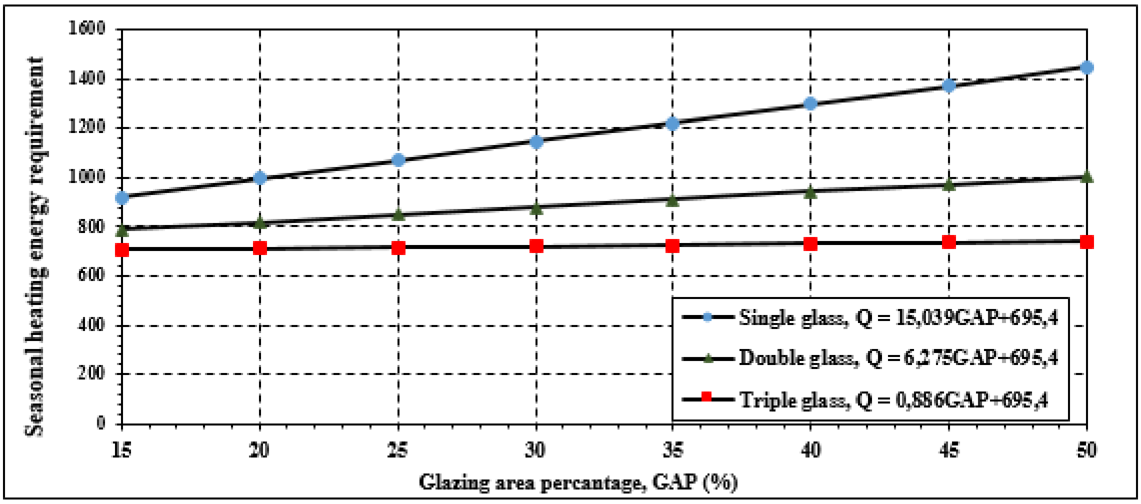

Fig. 3. Seasonal heating energy requirement for the prototype apartment building in Kocaeli for *I*=1.0 ACH versus different glazing area percentages.

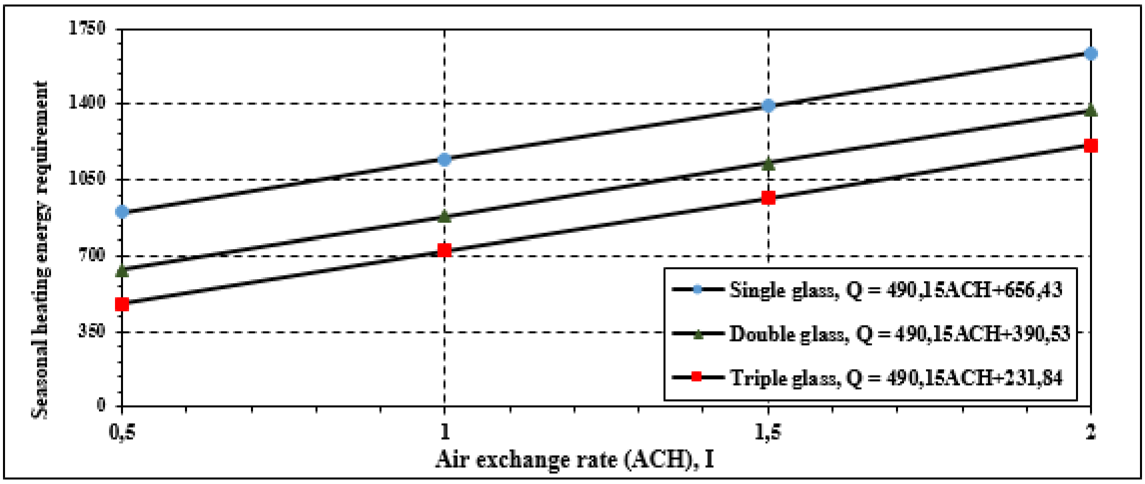

Fig. 4. Seasonal heating energy requirement for the prototype apartment building in Kocaeli for GAP=30% versus various air exchange rates.

Fig. 5 presents seasonal natural gas consumption considering single-, double-, and triple-glazed windows for GAP=35% and I=1.0 ACH versus number of people living in an apartment building. It is deduced from the **Fig. 5** that as the number of people living in apartment buildings increases, the amount of natural gas used for annual heating decreases gradually.

Fig. 6 shows the annual amount of natural gas used for heating purpose based on the number of people living in an apartment building considering the best, the average and the worst conditions. The best case is that the triple-glazing is to be air exchange rate (I=0.5) and glazing area percentage (GAP=15%). The average case is that double-glazing is to be air exchange rate (I=1.0) and glazing area percentage (GAP=30%). The worst case is that single-glazing is to be air exchange rate (I=2.0) and glazing area percentage (GAP=50%). To illustrate, natural gas consumption will be approximately 0.46, 0.86 and 1.9 billion m^3 (bcm), respectively, in an apartment building where 60 people live, taken into consideration these three cases. Natural gas consumption in the worst condition is nearly fourfold than the best condition.

Table 4 are created to forecast natural gas consumption for different GAP and I. If 85 people are considered to live in the best condition in an apartment building (triple glass; 0.5 ACH and GAP=15%), the natural gas consumption value is roughly 0.32 bcm, as demonstrated in **Fig. 6**. The actual consumption value taken from İZGAZ is between 0.3 and 0.4 bcm in 2015.

Table 4. Estimation for the natural gas consumption (bcm) during the heating season in Kocaeli if all heating energy requirements are provided by natural gas.

No. of people living in an apartmant building	GAP (%)	Single glass				Double glass				Triple glass			
		0.5 ACH	1.0 ACH	1.5 ACH	2.0 ACH	0.5 ACH	1.0 ACH	1.5 ACH	2.0 ACH	0.5 ACH	1.0 ACH	1.5 ACH	2.0 ACH
40	15	1.0	1,36	1,72	2,08	0,80	1,16	1,52	1,88	0,68	1,04	1,40	1,77
	20	1,11	1,47	1,83	2,19	0,85	1,21	1,57	1,93	0,69	1,05	1,41	1,77
	25	1,22	1,58	1,94	2,30	0,89	1,25	1,61	1,97	0,70	1,06	1,42	1,78
	30	1,32	1,69	2,05	2,41	0,94	1,30	1,66	2,02	0,70	1,06	1,42	1,79
	35	1,44	1,80	2,16	2,52	0,98	1,34	1,70	2,06	0,71	1,07	1,43	1,79
	40	1,55	1,91	2,27	2,63	1,03	1,39	1,75	2,11	0,72	1,08	1,44	1,80
	45	1,66	2,02	2,38	2,74	1,07	1,43	1,79	2,16	0,72	1,08	1,44	1,80
	50	1,77	2,13	2,49	2,85	1,12	1,48	1,84	2,20	0,73	1,09	1,45	1,81
45	15	0,89	1,21	1,53	1,85	0,71	1,03	1,35	1,67	0,61	0,93	1,25	1,57
	20	0,98	1,30	1,63	1,95	0,75	1,07	1,39	1,71	0,61	0,93	1,25	1,58
	25	1,08	1,40	1,72	2,04	0,79	1,11	1,43	1,75	0,62	0,94	1,26	1,58
	30	1,18	1,50	1,82	2,14	0,83	1,15	1,47	1,79	0,62	0,95	1,27	1,59
	35	1,28	1,60	1,92	2,24	0,87	1,19	1,51	1,84	0,63	0,95	1,27	1,59
	40	1,38	1,70	2,02	2,34	0,91	1,23	1,55	1,88	0,64	0,96	1,28	1,60
	45	1,46	1,80	2,12	2,44	0,95	1,27	1,60	1,92	0,64	0,96	1,28	1,60
	50	1,57	1,90	2,22	2,54	0,99	1,31	1,64	1,96	0,65	0,97	1,29	1,61
50	15	0,8	1,09	1,37	1,66	0,64	0,93	1,22	1,51	0,55	0,84	1,12	1,41
	20	0,89	1,17	1,46	1,75	0,68	0,96	1,25	1,54	0,55	0,84	1,13	1,42
	25	0,97	1,26	1,55	1,84	0,71	1,00	1,29	1,58	0,56	0,85	1,13	1,42
	30	1,06	1,35	1,64	1,93	0,75	1,04	1,33	1,62	0,56	0,85	1,14	1,43
	35	1,15	1,44	1,73	2,02	0,79	1,07	1,36	1,65	0,57	0,86	1,14	1,43
	40	1,24	1,53	1,82	2,11	0,82	1,11	1,40	1,69	0,57	0,86	1,15	1,44
	45	1,32	1,62	1,91	2,19	0,86	1,15	1,44	1,72	0,58	0,87	1,16	1,44
	50	1,42	1,71	1,99	2,28	0,89	1,18	1,47	1,76	0,58	0,87	1,16	1,45
55	15	0,72	0,99	1,25	1,51	0,58	0,84	1,11	1,37	0,50	0,76	1,02	1,28
	20	0,81	1,07	1,33	1,59	0,61	0,88	1,14	1,40	0,50	0,76	1,03	1,29
	25	0,89	1,15	1,41	1,67	0,65	0,91	1,17	1,44	0,51	0,77	1,03	1,29
	30	0,97	1,23	1,49	1,75	0,68	0,94	1,21	1,47	0,51	0,77	1,04	1,30
	35	1,05	1,31	1,57	1,83	0,71	0,98	1,24	1,50	0,52	0,78	1,04	1,30
	40	1,13	1,39	1,65	1,91	0,75	1,01	1,27	1,53	0,52	0,78	1,05	1,31
	45	1,21	1,47	1,73	1,99	0,78	1,04	1,31	1,57	0,53	0,79	1,05	1,31
	50	1,29	1,55	1,81	2,08	0,81	1,08	1,34	1,60	0,53	0,79	1,05	1,32
60	15	0,67	0,90	1,15	1,39	0,53	0,77	1,01	1,26	0,46	0,70	0,94	1,18
	20	0,74	0,98	1,22	1,46	0,56	0,80	1,04	1,29	0,46	0,70	0,94	1,18
	25	0,81	1,05	1,29	1,53	0,59	0,83	1,08	1,32	0,46	0,70	0,95	1,19
	30	0,89	1,13	1,37	1,61	0,62	0,86	1,11	1,35	0,47	0,71	0,95	1,19
	35	0,96	1,20	1,44	1,68	0,65	0,90	1,14	1,38	0,47	0,71	0,95	1,19
	40	1,03	1,27	1,51	1,75	0,68	0,93	1,17	1,41	0,48	0,72	0,96	1,20
	45	1,11	1,35	1,59	1,83	0,72	0,96	1,20	1,44	0,48	0,72	0,96	1,20
	50	1,18	1,42	1,66	1,90	0,75	0,99	1,23	1,47	0,49	0,73	0,97	1,21
65	15	0,61	0,83	1,06	1,28	0,49	0,71	0,94	1,16	0,42	0,64	0,86	1,09
	20	0,68	0,90	1,13	1,35	0,52	0,74	0,96	1,19	0,42	0,65	0,87	1,09
	25	0,75	0,97	1,19	1,42	0,55	0,77	0,99	1,21	0,43	0,65	0,87	1,09
	30	0,82	1,04	1,26	1,48	0,58	0,80	1,02	1,24	0,43	0,65	0,88	1,10
	35	0,89	1,11	1,33	1,55	0,60	0,83	1,05	1,27	0,44	0,66	0,88	1,10
	40	0,95	1,18	1,40	1,62	0,63	0,85	1,08	1,30	0,44	0,66	0,88	1,11
	45	1,02	1,24	1,47	1,69	0,66	0,88	1,10	1,33	0,44	0,67	0,89	1,11
	50	1,09	1,31	1,53	1,76	0,69	0,91	1,13	1,35	0,45	0,67	0,89	1,11
70	15	0,57	0,78	0,98	1,19	0,46	0,66	0,87	1,08	0,39	0,60	0,80	1,01
	20	0,63	0,84	1,04	1,25	0,48	0,69	0,90	1,10	0,39	0,60	0,81	1,01
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	30	0,76	0,97	1,17	1,38	0,53	0,74	0,95	1,15	0,40	0,61	0,81	1,02

	35	0,82	1,03	1,23	1,44	0,56	0,77	0,97	1,18	0,41	0,61	0,82	1,02
	40	0,89	1,09	1,30	1,50	0,59	0,79	1,00	1,21	0,41	0,62	0,82	1,03
	45	0,95	1,15	1,36	1,57	0,61	0,82	1,03	1,23	0,41	0,62	0,83	1,03
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75	15	0,53	0,72	0,92	1,11	0,43	0,62	0,81	1,00	0,36	0,56	0,75	0,94
	20	0,59	0,78	0,98	1,17	0,45	0,64	0,84	1,03	0,37	0,56	0,75	0,95
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	30	0,71	0,90	1,09	1,29	0,50	0,69	0,88	1,08	0,37	0,57	0,76	0,95
	35	0,77	0,96	1,15	1,34	0,52	0,72	0,91	1,10	0,38	0,57	0,76	0,96
	40	0,83	1,02	1,21	1,40	0,55	0,74	0,93	1,13	0,38	0,57	0,77	0,96
	45	0,89	1,08	1,27	1,46	0,57	0,76	0,96	1,15	0,39	0,58	0,77	0,96
	50	0,94	1,14	1,33	1,52	0,60	0,79	0,98	1,17	0,39	0,58	0,77	0,97
80	15	0,5	0,68	0,86	1,04	0,40	0,58	0,76	0,94	0,34	0,52	0,70	0,88
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	30	0,66	0,84	1,02	1,21	0,47	0,65	0,83	1,01	0,35	0,53	0,71	0,89
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	40	0,77	0,96	1,14	1,32	0,51	0,69	0,87	1,06	0,36	0,54	0,72	0,90
	45	0,83	1,01	1,19	1,37	0,54	0,72	0,90	1,08	0,36	0,54	0,72	0,90
	50	0,89	1,07	1,25	1,43	0,56	0,74	0,92	1,10	0,36	0,54	0,73	0,91
85	15	0,47	0,64	0,81	0,98	0,38	0,55	0,72	0,89	0,32	0,49	0,66	0,83
	20	0,52	0,69	0,86	1,03	0,40	0,57	0,74	0,91	0,32	0,49	0,66	0,83
	25	0,57	0,74	0,91	1,08	0,42	0,59	0,76	0,93	0,33	0,50	0,67	0,84
	30	0,62	0,79	0,96	1,13	0,44	0,61	0,78	0,95	0,33	0,50	0,67	0,84
	35	0,68	0,85	1,02	1,19	0,46	0,63	0,80	0,97	0,33	0,50	0,67	0,84
	40	0,73	0,90	1,07	1,24	0,48	0,65	0,82	0,99	0,34	0,51	0,68	0,85
	45	0,78	0,95	1,12	1,29	0,50	0,67	0,84	1,01	0,34	0,51	0,68	0,85
	50	0,83	1,00	1,17	1,34	0,53	0,70	0,87	1,04	0,34	0,51	0,68	0,85
90	15	0,44	0,60	0,76	0,92	0,36	0,52	0,68	0,84	0,30	0,46	0,62	0,78
	20	0,49	0,65	0,81	0,97	0,38	0,54	0,70	0,86	0,31	0,47	0,63	0,79
	25	0,54	0,70	0,86	1,02	0,40	0,56	0,72	0,88	0,31	0,47	0,63	0,79
	30	0,59	0,75	0,91	1,07	0,42	0,58	0,74	0,90	0,31	0,47	0,63	0,79
	35	0,64	0,80	0,96	1,12	0,44	0,60	0,76	0,92	0,32	0,48	0,64	0,80
	40	0,69	0,85	1,01	1,17	0,46	0,62	0,78	0,94	0,32	0,48	0,64	0,80
	45	0,74	0,90	1,06	1,22	0,48	0,64	0,80	0,96	0,32	0,48	0,64	0,80
	50	0,79	0,95	1,11	1,27	0,50	0,66	0,82	0,98	0,32	0,48	0,64	0,81
95	15	0,42	0,57	0,72	0,88	0,34	0,49	0,64	0,79	0,29	0,44	0,59	0,74
	20	0,47	0,62	0,77	0,92	0,36	0,51	0,66	0,81	0,29	0,44	0,59	0,75
	25	0,51	0,66	0,82	0,97	0,38	0,53	0,68	0,83	0,29	0,45	0,60	0,75
	30	0,56	0,71	0,86	1,02	0,39	0,55	0,70	0,85	0,30	0,45	0,60	0,75
	35	0,61	0,76	0,91	1,06	0,41	0,57	0,72	0,87	0,30	0,45	0,60	0,75
	40	0,65	0,80	0,96	1,11	0,43	0,58	0,74	0,89	0,30	0,45	0,61	0,76
	45	0,7	0,85	1,00	1,15	0,45	0,60	0,76	0,91	0,30	0,46	0,61	0,76
100	15	0,4	0,54	0,69	0,83	0,32	0,46	0,61	0,75	0,27	0,42	0,56	0,71
	20	0,44	0,59	0,73	0,88	0,34	0,48	0,63	0,77	0,28	0,42	0,56	0,71
	25	0,49	0,63	0,78	0,92	0,36	0,50	0,65	0,79	0,28	0,42	0,57	0,71
	30	0,53	0,68	0,82	0,96	0,37	0,52	0,66	0,81	0,28	0,43	0,57	0,71
	35	0,58	0,72	0,86	1,01	0,39	0,54	0,68	0,83	0,28	0,43	0,57	0,72
	40	0,62	0,76	0,91	1,05	0,41	0,56	0,70	0,84	0,29	0,43	0,57	0,72
	45	0,66	0,81	0,95	1,10	0,43	0,57	0,72	0,86	0,29	0,43	0,58	0,72
	50	0,71	0,85	1,00	1,14	0,45	0,59	0,74	0,88	0,29	0,44	0,58	0,72

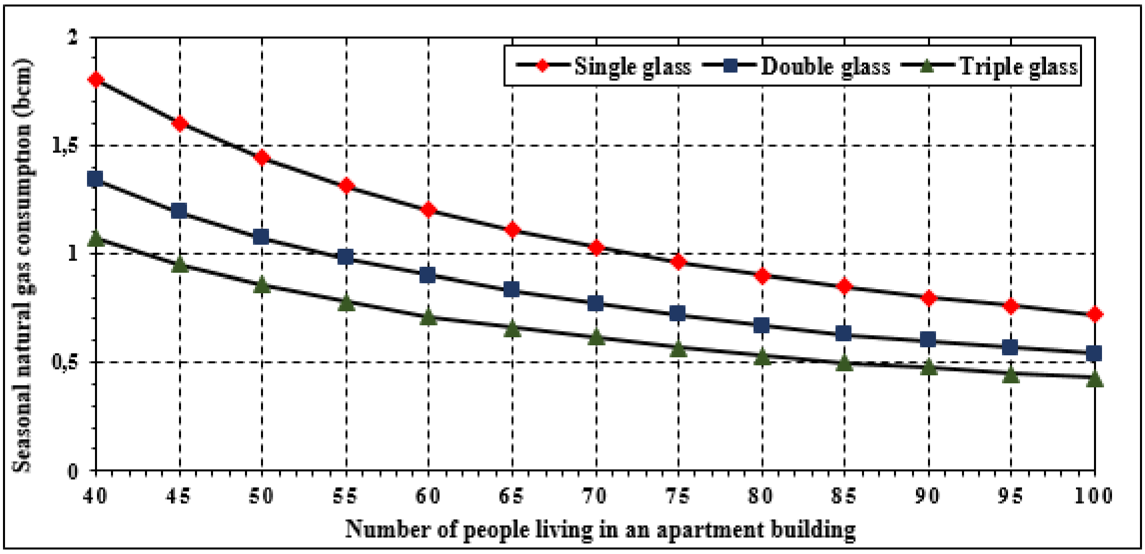

Fig. 5. Seasonal natural gas consumption in Kocaeli for GAP=35% and I=1.0 ACH versus number of people living in an apartment building.

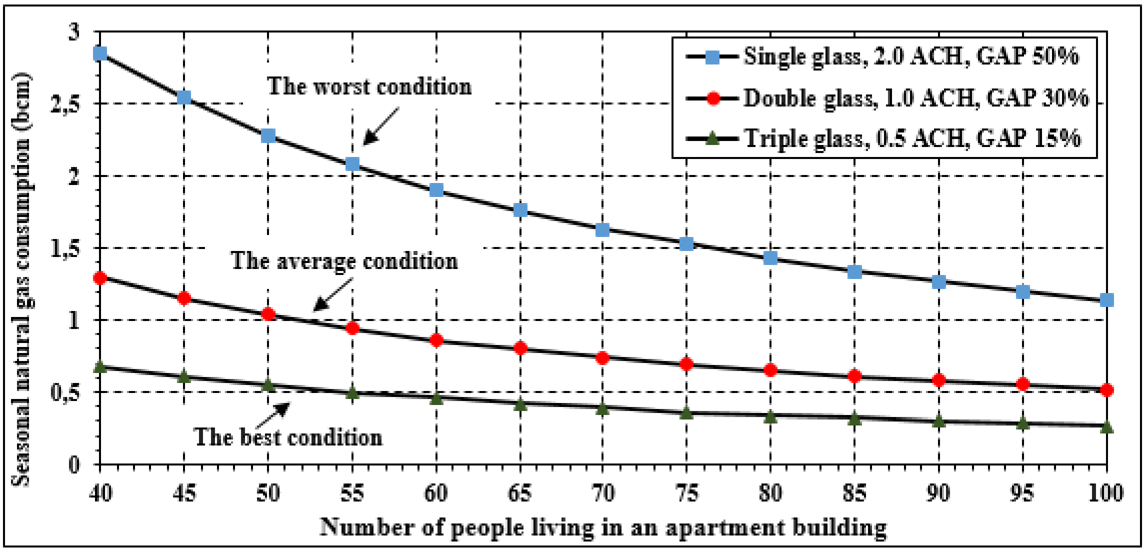

Fig. 6. Seasonal natural gas consumption in Kocaeli for the best, average and worst construction conditions vs number of people living in an apartment building.

6. Conclusion and future work

In this case study, the annual heating energy requirement and natural gas consumption were calculated for the building model with architectural design properties by using heating degree-day (HDD) method for the city of Kocaeli, based on temperature records at İzmit meteorology station located on the western coast of Turkey. It was observed that the 266th day (22 September) and 149th day (28 May) of the year appear as the beginning and end of the heating season if T_b =15°C is considered. After determining amount of the annual natural gas consumption for Kocaeli, it was investigated that how the building exterior wall area, the air exchange rate, the type of glass used, the number of people living in the buildings affect the amount of fuel to be consumed.

It was identified that approximately 40% savings in annual fuel consumption are achieved in case of employing triple glass instead of single glass in residential buildings. It was also observed that air exchange rate influences the heating energy requirement significantly. Another parameter is the amount of glazed surface area in the buildings. It was seen by approximately twofold augmentation in fuel consumption in case this variable is increased from 20 to 50%.

In addition to these, the architectural characteristics of the prototype building also significantly affect the energy demand. In the best conditions, the consumption for the example building model in Kocaeli is in the range of 0.27 bcm, while this value is nearly 2.85 bcm in the worst case.

The number of people living in an apartment building is moreover an substantial factor affecting the fuel consumption. Fuel consumption is positively affected by the increase in the number of people living in the building. If this value increases from 40 to 100, natural gas consumption is reduced by almost 1.5 times.

If one of the other energy sources other than natural gas is employed, the annual energy load of a building can also be determined. By using the method given in this study, the heating energy requirement and fuel consumption in other cities of Turkey can be easily and safely calculated. The simple and useful method presented can be implemented in any other region of the desired world.

References

[1] K. Bilen, O. Ozyurt, K. Bakirci, S. Karsli, S. Erdogan, M. Yilmaz & O. Comakli, "Energy production, consumption, and environmental pollution for sustainable development: A case study in Turkey ", Renewable and Sustainable Energy Reviews, vol. 12, pp. 1529-1561, 2008.

[2] T. Covert, M. Greenstone & C. R. Knittel, "Will we ever stop using fossil fuels?", The Journal of Economic Perspectives, vol. 30, pp. 117-137, 2016.

[3] E. Akyuz, "Turkey's energy profile and the importance of renewable energy sources." Academic Sight, vol. 49, pp. 494-504, 2015.

[4] M. Kadioglu & Z. Sen, "Degree-day formulations and application in Turkey", Journal of Applied Meteorology, vol. 36, pp. 837-846, 1999.

[5] O. Kaynakli, "A review of the economical and optimum thermal insulation thickness for building applications", Renewable and Sustainable Energy Reviews, vol. 16, pp. 415-425, 2012.

[6] A. K. Dagsoz & K. G. Bayraktar, "The number of degree-day in Turkey and energy politics", Journal of Sanitary Engineering, pp. 32-40, 1999.

[7] A. Arisoy, İklim Verileri, III. Uluslar arası Yapıda Tesisat Bilimi ve Teknolojisi Sempozyumu, 1998.

[8] A. Durmayaz, M. Kadioglu & Z. Sen, "An application of the degree-hours method to estimate the residential heating energy requirement and fuel consumption in Istanbul", Energy, vol. 25, pp. 1245-1256, 2000.

[9] A. K. Dagsoz, "Degree Day Values in Turkey, National energy saving policy, Heat insulation in buildings", Istanbul: Izocam, 1995.

[10] H. Sarak & A. Satman, "The degree-day method to estimate the residential heating natural gas consumption in Turkey: a case study", Energy, vol. 28, pp. 929-939, 2003.

[11] S. Akbayir, "Derece gün metodu ve Eskişehir için derece gün değerlerinin tespiti, Yüksek lisans tezi, O.G.Ü, 2006.

[12] O. Kaynakli, "A study on residential heating energy requirement and optimum insulation thickness", Renewable Energy, vol. 33, pp. 1164-1172, 2008.

[13] A. Durmayaz & M. Kadioglu, "Heating energy requirements and fuel consumptions in the biggest city centers of Turkey", Energy Conversion and Management, vol. 44, pp. 1177-1192, 2003.

[14] A. F. Emery & C. J. Kippenhan, "A long term study of residential home heating consumption and the effect of occupant behavior on homes in the Pacific Northwest constructed according to improved thermal standards", Energy, vol. 31, pp. 677-693, 2006.

[15] J. F. Kreider & A. Rabl, "Heating and cooling of buildings: design for efficiency McGraw-Hill", New York, 1994.

[16] S. Usta, "TS 825 "Binalarda Isı Yalıtım Kuralları" Standardına Göre İkinci Bölgede Bulunan Bir Binanın Yalıtımsız ve Yalıtımlı Durumlarının Enerji Verimliliği Bakımından Karşılaştırılması." Electronic Journal of ConstructionTechnologies, vol. 5, pp. 1-24, 2009.

[17] ASHRAE Handbook Fundamentals, "American society of heating, refrigerating and air-conditioning engineers", Inc. , 2009.

[18] A. Satman & N. Yalcinkaya, "Heating and cooling degree-hours for Turkey", Energy, vol. 24, pp. 833-840, 1999.

[19] J. A. Duffie & W. A. Beckman, "Solar engineering of thermal processes", John Wiley & Sons, 2013.

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Enter an abstract of up to 250 words for all articles. This is a concise summary of the whole paper, not just the conclusions, and is understandable without reference to the rest of the paper. It should contain no citation to other published work. Include up to six keywords that describe your paper for indexing purposes.

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Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). To make equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use an dash (–) rather than a hyphen for a minus sign. Use parentheses to avoid ambiguities in denominators. Punctuate equations with commas or periods when they are part of a sentence, as in

$$C = a + b \qquad (1)$$

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Books

[1] J. Clerk Maxwell*, A Treatise on Electricity and Magnetism,* 3rd ed., vol. 2. Oxford:Clarendon Press, 1892, pp.68-73.

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[2] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface", *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740-741, August 1987.

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Keywords- Keyword1; keyword2; keyword3; keyword4; keyword5.

2. Introduction

Authors should any word processing software that is capable to make corrections on misspelled words and grammar structure according to American or Native English. Authors may get help by from word processor by making appeared the paragraph marks and other hidden formatting symbols. This sample article is prepared to assist authors preparing their articles to IJET.

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$$\mathrm{C = a + b} \qquad (1)$$

Section titles should be written in bold style while sub section titles are italic.

3. Figures and Tables

3.1. Figure Properties

All illustrations must be supplied at the correct resolution:

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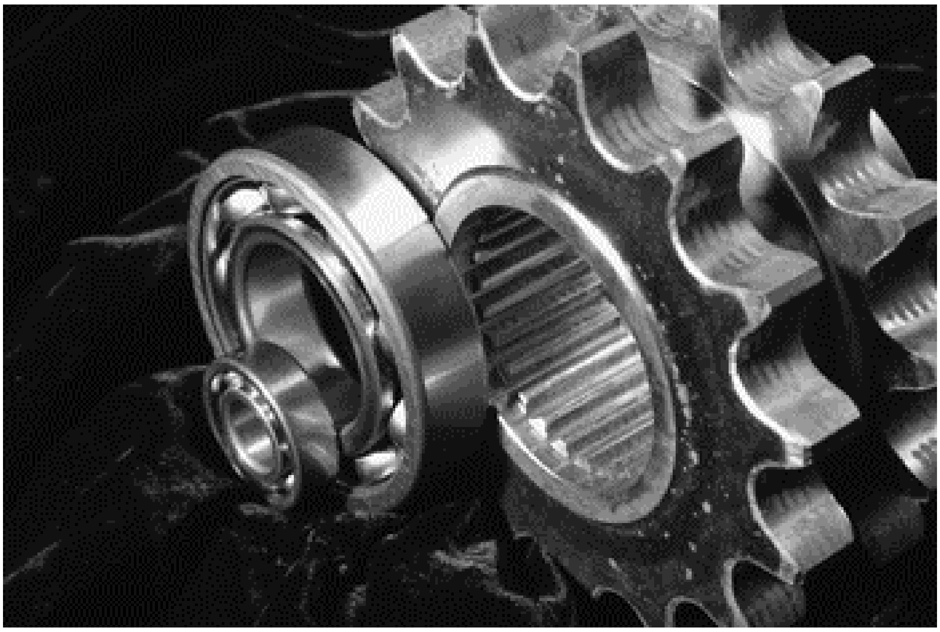

Figure 1. Engineering technologies.

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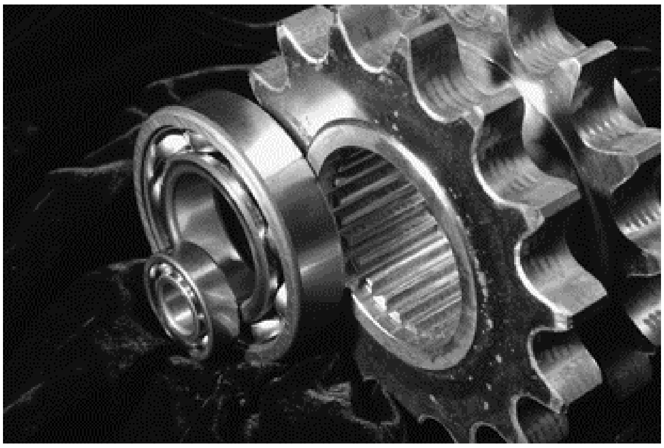

Fig. 1. Engineering technologies.

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