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Mechanical & Mechanics Engineering

Effect of Compression Ratio

Super Duplex Stainless Steel

Highlights

Analysis of an NACA 4311

Light and Soft Armour Materials

Discovering Thoughts, Inventing Future

VOLUME 14 ISSUE 7 VERSION 1.0

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By M. Anandan, S. Sampath & Natteri M. Sudharsan
Sri Venkateswara College of Engineering, India

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Keywords: *compression ratio, exhaust gas recirculation, biodiesel blends, combustion, emission.*

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I. Introduction

An alternate fuel resource for IC engines is in great demand owing to various criteria. Usage of fossil fuel inhibits a scarcity of fossils and creates a complication for renewal. In such a case, the use of biodiesel is growing at a rapid rate to replace the diesel fuel. Biodiesel is a term that describes a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable or animal oils. The vegetable oil based biodiesel has found a prominent place as an alternate fuel due to the depletion in the conventional fossil fuels [1], [2], [3]. The esterification of biodiesels from its major crude vegetable oil was used as a well-known biofuel. Early scientists have also conducted experiments on vegetable oils like (Thevetia Peruviana, Neem oil) etc [4], [5]. In India, the large availability of Jatropha and Pongamia makes them a prime raw material for the production of biodiesel. Jatropha, is being spread across India as a vital crop to be cultivated due to the extensive advantages it inhibits [6]. Due to the similar fuel properties of biodiesel with the conventional diesel oil, it can be blended in varying proportions and used as an alternate fuel in Diesel engines [7]. Fuel consumption of biodiesel is slightly higher than conventional diesel due to lesser calorific value [8]. The exhaust gas of a diesel engine consists of a high level of NOx along with HC, CO, CO_2 and particulate matter [9]. All these gases pollute the atmosphere to a great extent that results in serious health hazards to human beings and also in the advent of precarious natural phenomenon like acid rain and greenhouse effect. One of the key method to overcoming this problem in engines is the use of an EGR system. Exhaust gas recirculation system is used as a hot mode by suffusing the varying percentage of burnt gases into the inlet port for reducing NOx emissions [10]. Exhaust gases resulting in lowering the emission of NOx by reduction of combustion temperature and excess oxygen [11]. As the working of this system is in direct concern to the environment, this system may be called an eco-friendly system. The methodology of EGR system is as follows.

Author α: Associate Professor, Department of Marine Engineering, Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India. e-mail: anandanmoothy@gmail.com

Author σ: Professor, Department of Automobile Engineering, Rajalakshmi Engineering College, Chennai, Tamilnadu, India.

Author ρ: Professor, Department of Mechanical Engineering, Rajalakshmi Engineering College, Chennai, Tamilnadu, India.

II. Egr System

EGR is one of the efficacious methods in reducing NO_x emissions in diesel engines. EGR has got its own limitations as at higher EGR rates the combustion is affected due to less availability of oxygen and hence increase in smoke emissions results in higher fuel consumption [12]. Hence a by-pass for the exhaust gas is provided along with the manually controlled EGR valve. The exhaust gas comes out of the engine during the exhaust stroke at a high pressure and is pulsating in nature. It is desirable to remove these pulses in order to make the volumetric flow rate measurements of the recirculating gas possible. For this purpose, smaller air box with a diaphragm is installed along the EGR route. A U-tube manometer is mounted across the orifice in order to measure the EGR flow rate. Suitable instrumentation is provided to acquire useful data from various locations. Thermocouples are placed in intake manifold and exhaust manifold at various points along the EGR route. A matrix of test conditions is used to investigate the effect of EGR on exhaust gas temperature and exhaust smoke opacity. The schematic diagram of exhaust gas recirculation (EGR) system attached with the diesel engine is as shown in Fig. 1. Increasing the exhaust pipe line length (15 metres) and placing the EGR system far away from the diesel engine reduces the exhaust gas temperature through natural convection. Manually controlled EGR valve was attached to pass the required amount of exhaust gas into the engine cylinder to combine with the intake air and is thus controlled accurately. Percentage of EGR was calculated using the following equation

$$\text{Percentage of EGR} = \frac{\text{volume of air without EGR} - \text{volume of air with EGR}}{\text{volume of air without EGR}} \times 100$$

III. Transesterification Process

Transesterification is a suitable method for utilizing vegetable oils in DI diesel engine for long term applications without any major modifications and durability problems. Transesterification of vegetable oil enhances the quality of biofuel by reducing its viscosity. Transesterification is influenced by the reaction temperature, catalyst and stirring speed [13]. A two-step acid base process was used to prepare the biodiesel. In the first step acid pre-treatment was used to extract the biodiesel from crude Jatropha and Pongamia oil followed by base transesterification using Methanol as a regeant; H_2SO_4 and KOH used as a catalyst. The physical and chemical properties of JME-Diesel; PME-Diesel was evaluated as per the IS 15607-2005 standards. The conversion of methyl esters from triglycerides with the presence of catalyst as represented in the following equation [14].

$$\begin{array}{lll} CH_2OCOR_1 & & CH_2OH \quad + \quad R_1COOCH_3 \\ CHOCOR_2 + \quad 3CH_3OH & \underset{\Delta \ \text{Catalyst}}{\overset{H_2SO_4;\ KOH}{\rightleftharpoons}} & CHOH \quad + \quad R_2COOCH_3 \\ CH_2OCOR_3 & & CH_2OH \quad + \quad R_3COOCH_3 \\ \text{Triglycerides} \quad \text{Methanol} & & \text{Glycerol} \quad \text{Methyl esters} \end{array}$$

a) Fuel Properties

Jatropha Methyl Ester (JME) and Pongamia Methyl Ester (PME) were mixed separately with diesel in varying proportions (10%, 20% and 30% by volume) and test fuels J10, J20, J30, P10, P20 and P30were prepared. The properties of neat diesel and biodiesel blends are presented in Table 1. Density and viscosity of biodiesel blends increases with increase in percentage volume of biodiesel due the higher molecular weight of fatty acids in biodiesel [15]. Respectively the density of biodiesel blends is higher than neat diesel oil. Density of higher jatropha and Pongamia blends is found to be 874 kg/m^3 and 891 kg/m^3. Kinematic viscosity of Jatropha and Pongamia blends is higher at J30 and P30 compared with diesel. Flash point of biodiesel blend is higher when compared with diesel. This is due to high vaporization temperature of biodiesel in air for combustion. Higher flash point enables storage of biodiesel blends safer than diesel and within the IS 5607-2005 standard limits [16]. Cetane number of biodiesel blends is higher when compared to diesel. Higher Cetane values of fuel enhance the combustion quality and hence smooth operation of the engine is guaranteed [17].

IV. Experimental Setup

The experimental investigation were conducted on a single cylinder air cooled DI diesel engine. The maximum power extracted by an engine was 4.4 kW at a rated speed of 1500rpm. The specification of the engine is shown in Table 2. The experimental setup is as shown in Fig. 1. Cylinder pressure is measured using AVL GH14D Pressure Transducer. The pressure transducer is located in a hole drilled through the cylinder head into the combustion chamber. The sensing element consists of metal diaphragm, which deflects under pressure. AVL 365C angle encoder is used to convert the Analog signal into a digital electrical signal. DAQ card was connected to the encoder to evaluate the electrical signals and determine the crank angular position. AVL 3066A02 Piezo Charge Amplifier is used to convert the electrical charge output of the pressure transducer into voltage. K type thermocouple was attached with diesel engine to measure the exhaust gas temperature. Electrical dynamometer is coupled to the engine by flexible coupling for measuring the brake power of the engine. It consists of a 5KVA AC alternator (220V, 1500rpm) mounted on the bearings and on the rigid frame for the swinging field type loading. The output power is directly obtained by measuring the reaction torque. Reaction force (torque) is measured by using a strain gauge type load cell. Panel board consists of Ammeter, Voltmeter switches and fuse, load cell indicator and temperature indicator. MRU delta 1600L Exhaust Gas Analyser was used to measure NO_x, HC, CO and CO_2 emissions. The emissions of CO (carbon monoxides) and HC (hydrocarbons) were measured by means of infrared measurement. AVL 415 Smoke meter is used to measure the percentage of smoke present in the exhaust gas. A fraction of the exhaust gas was sampled by means of a probe in the exhaust line and drawn through a filter paper. The resultant blackening of the filter paper was measured by a reflectometer and hence the opacity in the exhaust gas was determined. The list of instrumentation details is shown in Table 3. Exhaust gas recirculation (EGR) system externally fixed with diesel engine analysis the engine combustion and emission characteristics.

a) Testing Procedure

The single cylinder direct injection diesel engine was initially operated with neat diesel oil to maintain the wall temperature of the engine for proper combustion of biodiesel. Tests were performed for different loading conditions (0%, 25%, 50%, 75% and 100%) using JME and PME blends and for each loading condition the engine was allowed to run for 15minutes. Three sets of readings were taken for each test fuel. Varying compression ratio is attained in a constant compression ratio diesel engine through the modification of the bowl in piston as shown in Fig. 2 using aluminium alloy as an additive material by a low temperature CMT welding process. Compression ratio of 17.5:1, 19:1 and 20:1 were chosen for the present study. Exhaust gas recirculation is used in varying percentage by volume (10%, 20% and 30%). These three parameters were optimized by design of experiments (orthogonal array) and are shown in Fig. 3 and Table 3. Through this matrix approach the following conditions were selected for the optimized parameters: fuel blends (JME 20% and PME 20%), compression ratio 20:1 and Exhaust gas recirculation 20%.

V. Error Analysis

The maximum possible error in various measured parameters namely pressure, temperature, exhaust gas emissions, time, flow and speed estimated from the minimum values of output and accuracy of the instrument is calculated using the method proposed by (Moffat 1985). This method is based on careful specification of the uncertainties in the various experimental measurements. Instruments used for measuring various engine parameters as shown in Table 4.

If an estimated quantity S, depends on independent variables like (x1, x2, x3 …………xn) then the error in the value of S is given by

$$\frac{\partial S}{S} = \left\{ \left(\frac{\partial x_1}{x_1} \right)^2 + \left(\frac{\partial x_2}{x_2} \right)^2 + \ldots\ldots\ldots + \left(\frac{\partial x_n}{x_n} \right)^2 \right\}^{\frac{1}{2}}$$

Where, $\left(\frac{\partial x_1}{x_1}\right), \left(\frac{\partial x_2}{x_2}\right)$, are the errors in the independent variables.

= square root of ((uncertainty of pressure transducer)^2 + (uncertainty of angle encoder)^2 + (uncertainty of charge amplifier)^2 +(uncertainty of smoke meter)^2 + (uncertainty of NO)^2 + (uncertainty of UBHC)^2 + (uncertainty of CO)^2 + (uncertainty of CO2) + (uncertainty of thermocouple)^2 + (uncertainty of burette)^2 + (uncertainty of load cell)^2)

= square root of $(((0.20)^2 + (2)^2 + (0.15)^2 + (0.9)^2 + (1.74)^2 + (0.31)^2 + (0.67)^2 + (4.4) + (0.4)^2 + (0.15)^2 + (0.21)^2)$ =square root of (8.831) =2.971%.

VI. Results and Discussion

a) Combustion

i. *Cylinder Pressure*

The variation of cylinder pressure with respect to crank angle (CA) for diesel, biodiesel blends with different compression ratio and effect of EGR is shown in Fig. 4. for full load conditions. The peak cylinder pressure for diesel, J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% was obtained as 75.729bar at 7°CA after TDC, 75.194bar at 7°CA after TDC, 77.987bar at 7°CA after TDC, 76.501bar at 7°CA after TDC, 75.523bar at 7°CA after TDC, 75.201bar at 7°CA after TDC and 74.511barat 7°CA after TDC respectively. For all engine loads, cylinder pressure gradually increases for compression stroke. It attains the peak value at 7°CA after top dead centre (TDC). The quantity of fuel burned was increased with increasing the engine load. If a peak pressure occurs very close to TDC that cause severe knock and affects the engine durability [18]. In this experiment, while operating with biodiesel blends the peak pressure takes place after TDC and ensures safe and efficient operation. It is observed from the figure that the peak cylinder pressure with J20 CR20 blend was 2.53 bar higher than that of diesel. The reason for maximum cylinder pressure of J20 CR20 is increase in compression ratio. While engine was operated with EGR system, the peak cylinder pressure was found to decrease due to the increase in intake air temperature [19]. This in turn shortens the ignition delay period and hence results in lower peak pressure.

ii. *Heat release rate theoretical consideration*

Rate of heat release developed inside the cylinder during the combustion stroke was analyzed based on the in-cylinder pressure for various engine loads. The formula used to calculate the rate of heat release is given in Eq (1),

$$\frac{dQ_n}{d\theta} = \frac{\gamma}{\gamma-1} p \frac{dV}{d\theta} + \frac{1}{\gamma-1} V + \frac{dp}{d\theta} \qquad (1)$$

Where, γ-is the ratio of specific heats (C_p/C_v) (Heywood 1988). The appropriate range of γ (for diesel) heat release analysis is 1.3 to 1.35. $\frac{dQ_n}{d\theta}$ is the heat transfer in kJ/m^3.degree, P-is the instantaneous cylinder pressure (bar), V-is the instantaneous cylinder volume (m3).

iii. *Rate of Heat Release*

The change of heat release rate with respect to crank angle (CA) for diesel and biodiesel blends with different compression ratio and the effect of EGR as shown in Fig. 5. for full load conditions. The peak heat release rate for diesel, J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% was obtained as 69.854 kJ/m^{3}deg, 65.326 kJ/m^{3}deg, 62.481 kJ/m^{3}deg, 64.427 kJ/m^{3}deg, 79.791 kJ/m^3.deg, 76.478 kJ/m^3.deg and 70.079 kJ/m^3.deg respectively. Maximum heat release rate for biodiesel blends occurs earlier than for diesel due to its shorter ignition delay period [20]. It is observed from the figure that, heat release rate gets reduced as the percentage of biodiesel blends increases. The reason for reduced heat release rate of biodiesel blends with EGR is due to higher temperature of intake air.

iv. *Cumulative Heat Release Rate*

The change of cumulative heat release rate with respect to crank angle (CA) for diesel and biodiesel blends with different compression ratio and the effect of EGR as shown in Fig. 6. The CHRR values were evaluated from the end of compression stroke to the beginning of expansion stroke. It is observed from the figure that JME blends shows higher cumulative heat release rate compared to diesel because of the presence of oxygen molecules in the biodiesel fuel. Meanwhile, CHRR gets lowered for biodiesel fuels with EGR operation because of the reduction in combustion temperature.

v. *Ignition Delay*

Ignition delay is the delay period between the start of injection and the start of combustion. The ignition delay period of DI diesel engine was calculated by Eq (2).

$$\tau_{id} = Ap^{-n} \exp\left(\frac{E_A}{\hat{R}T}\right) \qquad (2)$$

τ_{id}- Ignition delay, E_A- apparent activation energy, $\hat{R}$- universal gas constant, A, n-constants (depend on fuel injection and air-flow characteristics). The ignition delay for Jatropha, Pongamia methyl ester blends and diesel at full load condition is shown in Table 5. The ignition delay period in a diesel engine has an influence on both the engine design and its performance [21]. Ignition delay of Diesel, J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% is 14.18°, 13.62°, 12.62°, 11.24°, 13.1°, 13.92° and 11.59° (CA) respectively. The ignition delay for biodiesel blends decreases with the increase in percentage of biodiesel due to the higher Cetane number of biodiesel compared with diesel.

b) Emission

The emission and performance characteristic of the IC engine is shown in Table 6.

i. *NO_x formation mechanism*

Thermal NOx is produced by the reaction of atmospheric oxygen and nitrogen at elevated temperatures and is reported to contribute about 20% of the total NOx. Nitric oxide is the predominant oxide of nitrogen produced inside the engine cylinder. Nitric oxide (NO) and Nitrogen oxide (NO_2) are grouped together as a NOx emission [22]. Mechanism of NO_x formation is proposed by Zeldovich was given by,

$$O + N_2 = NO + N \qquad (3)$$

$$N + O_2 = NO + O \qquad (4)$$

$$N + OH = NO + H \qquad (5)$$

ii. *NO_x emission*

The change of NO_x emission for Diesel, J20 CR17.5, J20 CR20, J20 CR20 EGR20%, and P20 CR17.5, P20 CR20 and P20 CR20 EGR20% with brake power was shown in Fig. 7. At lower temperatures, nitrogen exists as a stable diatomic molecule but at higher temperature it becomes reactive. Hence higher temperature and availability of excess oxygen are two main factors which facilitate the formation of NO_x [23]. The concentration of NO_x emission increases with increase in engine loads. The NO_x formation is higher with biodiesel blends than diesel oil. The NO_X formation value for the Jatropha and Pongamia blends was found

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to be 668 and 721ppm for J20 and 678 and 741ppm for P20 as optimum blend for 17.5 and 20 CR. This is due to higher Cetane number and availability of excess oxygen in the biodiesel inducing proper combustion [24]. NO_x level decreases with the use of EGR system due to the higher specific heat of recirculated exhaust gas and reducing the excess oxygen in the intake charge. The NO_x level of Jatropha and Pongamia with EGR system was found to be 534ppm and 612ppm.

iii. *HC Emission*

The variation of hydrocarbon (HC) for diesel and blends J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% with brake power is shown in Fig. 8. Hydrocarbon emission from diesel engine acts as irritants and odorants while some are toxic carcinogenic. HC emission is due to the insufficiency of oxygen level to consume all the fuel during combustion. This is because of non-homogeneity of fuel-air mixture [25]. The HC emission varies from 13 ppm at part load to 30 ppm at rated load for diesel, while for J20 CR17.5 it varies from 4 ppm at part load to 24.59 ppm at rated load. For J20 CR20 it varies from 5.89 ppm at part load to 21.77 ppm at rated load, for J20 CR20 EGR20%, it varies from 5.32 ppm at part load to 32.34 ppm rated load, for P20 CR17.5 it varies from 12ppm at part load to 28.17 ppm at rated load, for P20 CR20 it varies from10.9 ppm at part load to 25.2 ppm at rated load and forP20 CR20 E20% it varies from 14.16 ppm at part load to 36.7 ppm at rated load. It is also observed from the figure that J20 CR20 has the lowest HC emission compared to other test fuel blends. Further it is perceived from the figure that, Increase in percentage of biodiesel blends and compression ratio decreases the HC emission due to complete combustion and availability of O_2 in the biodiesel blends. Meanwhile inverse trends were detected with EGR system i.e. the HC emission increased with increase in percentage of EGR.

iv. *CO Emission*

The variation of carbon monoxide (CO) for diesel, J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% with brake power was shown in Fig. 9. CO emission varies from 0.06% at part load to 0.154% of full load for diesel, while for biodiesel blends it varies from 0.07% at part load to 0.139% at full load condition for J20 CR17.5, for J20 CR20 it varies from 0.08% at part load to 0.121% at full load, for J20 CR20 EGR20 it varies from 0.085% at part load to 0.163% at full load, for P20 CR17.5 it varies from 0.05% at part load to 0.1% at full load, for P20 CR20 it varies from 0.066% at part load to 0.147% at full load, for P20 CR20 E20% it varies from 0.05% at part load to 0.124% at rated load. It is noted from the figure that, biodiesel blends produces lower CO emission when compared to diesel. It is concluded that increase in biodiesel blends and compression ratio results in reduction in CO emission. However, CO emission increases with increase in the percentage of EGR. This is due to the overall reduction of excess oxygen resulting from EGR [26].

v. *CO_2 Emission*

The variation of carbon dioxide (CO_2) for diesel, J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% with brake power is shown in Fig. 10. CO_2 emission varies from 4% at part load to 8.7% at rated load for diesel, as for biodiesel blends 3.6% at part load to 8.1% at full load for J20 CR17.5, 3.8% at part load to 8.7% at rated load for J20 CR20, 4.2% at part load to 9% at full load for J20 CR20 EGR20%, 3.8% at part load to 8.6% at rated load for P20 CR17.5, 3.7% at part load to 8.8% at rated load for P20 CR20, 4.1% at part load to 9.2% at full load for P20 CR20 E20%. The increasing of CO_2 emission with load is might be due to the higher fuel consumption of biodiesel blended and due to the excess presence of oxygen in biodiesel molecular structure [27].

vi. *Smoke Opacity*

The variation of smoke opacity for diesel, J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% with brake power is shown in Fig. 11. The smoke opacity varies from 0.35FSN at part load to 3.61FSN at rated load for diesel, 0.25FSN at part load to 2.24FSN at rated load for J20 CR17.5 and 0.39FSN at part load to 3.31FSN at rated load J20 CR20, 0.4FSN at part load to 3.49FSN at rated load for J20 CR20 EGR20%, 0.26FSN at part load to 2.8FSN at rated load for P20 CR17.5, 0.33FSN at part load to 2.62FSn at rated load for P20 CR20, 0.32FSN at part load to 4.24FSN at rated load for P20 CR20 E20%. It is observed from the figure that, smoke opacity decreases with increase of biodiesel in blends and compression ratio due to availability of O_2 in fuel during diffusion combustion phase [29]. Meanwhile smoke opacity increases with increase in percentage of EGR this is due to present of carbon content.

c) Performance

i. *Brake Thermal Efficiency*

Brake thermal efficiency is the efficiency of the diesel engine in which chemical energy of the fuel is extracted in the form of heat and utilized for mechanical work. The variation of brake thermal efficiency for J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20, P20 CR20 EGR20% and diesel with brake power is shown in Fig. 12. It can be seen that the brake thermal efficiency increased with increase in engine loads for all test fuels. It is observed from figure that the thermal efficiency of diesel is 28.81% at rated power and for J20CR17.5; P20CR17.5 is 27.9%, 27% respectively. It shows that efficiency of J20, P20 blends is slightly less compare with diesel this is due to lower calorific value. Brake thermal efficiency for J20 CR20, P20 CR20 is

31.7%, 30% due to the effect of increase in compression ratio. For J20 CR20 EGR20%, P20 CR20 EGR20%, the BTE is 30.89%, 29.37% which is reduced with the use of EGR. This is because of reduced amount fresh oxygen content present in the combustion chamber [29].

ii. *Exhaust Gas Temperature*

The variation of exhaust gas temperature for J20 CR17.5, J20 CR20, J20 CR20 EGR20%, P20 CR17.5, P20 CR20 and P20 CR20 EGR20% and diesel with brake power is shown in Fig. 13. The EGT varies from 263°C at part load to 456°C at rated load condition for diesel. 263°C at part load to 456°C at rated load condition for J20 CR17.5, 270°C at part load to 464°C at rated load condition and for J20 CR20, 244°C at part load to 430°C at rated load condition. For J20 CR20 E20, 271°C at part load to 470°C at rated load condition and for P20 CR17.5, 283°C at part load to 477°C at rated load condition for P20 CR20 and 243°C at part load to 435°C at rated load condition for P20 CR20 E20 respectively. Exhaust gas temperature gets decreased continuously as the percentage of exhaust gas recirculated into the engine is increased. It can be observed from the figure that exhaust gas temperature gets reduced considerably with EGR; resulting in lower combustion temperature and NO_x emission.

VII. Conclusion

It is concluded from the results that,

- The effect of increase in compression ratio increase the brake thermal efficiency, exhaust gas temperature, NO_x emission and reduces the smoke opacity, CO emission and Unburned hydrocarbon emission.
- NO_x emission was higher for biodiesel and its blends due to higher in-cylinder temperature and availability of free oxygen in the fuel.
- Smoke emission decrease due to availability of O_2 in fuel during diffusion combustion phase.
- Both HC and CO Emission decreases due to complete combustion and availability of excess oxygen in biodiesel blends.
- Effect of EGR, Decreases NO_x, EGT, thermal efficiency and increases Smoke, UBHC and CO.
- NO_x, Brake thermal efficiency, EGT gets reduced considerably by adopting EGR; meanwhile it slightly increases the Smoke, HC and CO emissions

Thus the usage of EGR to the optimum biodiesel blends reduces NO_x emission and improves combustion characteristics providing an energy based fuel economy in diesel engines.

VIII. Abbreviation

J10, J20, J30 - Jatropha 10%, Jatropha 20%, Jatropha 30%

P10, P20, P30 - Pongamia 10%, Pongamia 20%, Pongamia 30%,

J20 CR17.5 - Diesel 80%-Jatropha 20% and compression ratio 17.5:1

J20 CR20 - Diesel 80%-Jatropha 20% and compression ratio 20:1

J20 CR20 EGR 20% - Diesel 80%-Jatropha 20% and compression ratio 20:1, Exhaust gas recirculation 20%

P20 CR17.5 - Diesel 80%-Pongamia 20% and compression ratio 17.5:1

P20 CR20 - Diesel 80%-Pongamia 20% and compression ratio 20:1

P20 CR20 EGR 20% - Diesel 80%-Pongamia 20% and compression ratio 17.5:1, Exhaust gas recirculation 20%

EGT - Exhaust gas Temperature

FSN - Filter smoke number

BTE - Brake thermal efficiency

CMT - Cold metal transfer

IX. Acknowledgement

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References Références Referencias

1. Gerhard Knothe, Biodiesel and renewable diesel: A comparison, Progress in Energy and Combustion Science xxx, 2009, 1–10.
2. Daming Huang, Haining Zhou, Lin Lin, Biodiesel: an Alternative to Conventional Fuel, Energy Procedia 16, 2012, 1874 – 1885.
3. Constantine Arcoumanis, Choongsik Bae, Roy Crookes, Eiji Kinoshita, The potential of di-methyl ether (DME) as an alternative fuel for compression-ignition engines: A review. Fuel 87, 2008, 1014–1030.
4. T. Kandasamy Kannan, Marappan Rakkiyanna Gounder, Thevetia Peruviana biodiesel emulsion used as a fuel in a single cylinder diesel engine reduces NO_x and smoke. Thermal Science Vol. 15, No. 4, 2011, 1185-1191.
5. Md. Hasan Ali, Mohammad Mashud, Md. Rowsonozzaman Rubel, Rakibul Hossain Ahmad, Biodiesel from Neem oil as an alternative fuel for Diesel engine. Procedia Engineering 56, 2013, 625 – 630.
6. Dulari Hansdah, S. Murugan, L.M. Das, Experimental studies on a DI diesel engine fueled with bioethanol-diesel emulsions. Alexandria Engineering Journal 52, 2013, 267–276.

7. A. Murugesan, C. Umarani, R. Subramanian, N. Nedunchezhian, Biodiesel as an alternative fuel for diesel engines- A review. Renewable and Sustainable Energy Reviews Volume 13, 3, 2009, 653–662.
8. Kian Hee Kay, Suhaimi Md Yasir, Biodiesel Production from Low Quality Crude Jatropha Oil Using Heterogeneous Catalyst. APCBEE Procedia 3, 2012, 23 – 27.
9. Ming Zheng, Graham T. Reader, J. Gary Hawley, Diesel engine exhaust gas recirculation-a review on advanced and novel concepts. Energy Conversion and Management 45, 2004, 883–900.
10. G.H. Abd-Alla, Using exhaust gas recirculation in internal combustion engines: a review. Energy Conversion and Management 43, 2002, 1027–1042.
11. Deepak Agarwal, Shailendra Sinha, Avinash Kumar Agarwal, Experimental investigation of control of NO_x emissions in biodiesel-fueled compression ignition engine. Renewable Energy 31, 2006, 2356–2369.
12. Haiyong Peng, Yi Cui, Lei Shi, Kangyao Deng, Effects of exhaust gas recirculation (EGR) on combustion and emissions during cold start of direct injection (DI) diesel engine. Energy 33, 2008, 471–479.
13. Eman N. Ali, Cadence Isis Tay, Characterization of Biodiesel Produced from Palm Oil via Base Catalyzed Transesterification. Procedia Engineering 53, 2013, 7 – 12.
14. Deepak Agarwal, Lokesh Kumar, Avinash Kumar Agarwal, Performance evaluation of a vegetable oil fuelled compression ignition engine. Renewable Energy Volume 33, 6, 2008, 1147–1156.
15. Parag Saxena, Sayali Jawale, Milind H Joshipura, A review on prediction of properties of biodiesel and blends of biodiesel. Procedia Engineering 51, 2013, 395 – 402.
16. Hifjur Raheman, Sweeti Kumari, Combustion characteristics and emissions of a compression ignition engine using emulsified jatropha biodiesel blend. Biosystems engineering 123, 2014, 29-39.
17. F. Lujaji, A. Bereczky, Cs. Novak, and M. Mbarawa, Cetane Number and Thermal Properties of Croton Oil, Biodiesel, 1-Butanol, and Diesel Blends. Proceedings of the World Congress on Engineering 2010 Vol III.
18. P.K. Sahoo, L.M. Das, Combustion analysis of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine. Fuel 88, 2009, 994–999.
19. A. Tsolakis, A. Megaritis, M.L. Wyszynski, K. Theinnoi, Engine performance and emissions of a diesel engine operating on diesel-RME (rapeseed methyl ester) blends with EGR (exhaust gas recirculation). Energy 32, 2007, 2072–2080.
20. M. Shahabuddin, A.M. Liaquat, H.H. Masjuki, M.A. Kalam, M. Mofijur, Ignition delay, combustion and emission characteristics of diesel engine fueled with biodiesel. Renewable and Sustainable Energy Reviews 21, 2013, 623–632.
21. Mohammed EL-Kasaby, Medhat A. Nemit-allah, Experimental investigations of ignition delay period and performance of a diesel engine operated with Jatropha oil biodiesel. Alexandria Engineering Journal 52, 2013, 141–149.
22. Avinash kumar agrawal, Shrawan kumarsingh, Shailendra sinha and Mritunjay kumar Shukla, Effect of EGR on the exhaust gas temperature and exhaust opacity in compression ignition engines. Sadhana Vol. 29, 3, 2004, 275–284.
23. K. Sureshkumar, R. Velraj, R. Ganesan, Performance and exhaust emission characteristics of a CI engine fueled with Pongamia pinnata methyl ester (PPME) and its blends with diesel. Renewable Energy 33, 2008, 2294–2302.
24. S.S. Gill, A. Tsolakis, J.M. Herreros, A.P.E. York, Diesel emissions improvements through the use of biodiesel or oxygenated blending components. Fuel 95, 2012, 578–586.
25. Gunfeel Moon, Yonggyu Lee, Kyonam Choi, Dongsoo Jeong, Emission characteristics of diesel, gas to liquid, and biodiesel-blended fuels in a diesel engine for passenger cars. Fuel 89, 2010, 3840–3846.
26. H. Raheman, A.G. Phadatare, Diesel engine emissions and performance from blends of karanja methyl ester and diesel. Biomass and Bioenergy 27, 2004, 393–397.
27. Syarifah Yunus, Amirul Abd Rashid, Nik Rosli Abdullah, Rizalman Mamat, Syazuan Abdul Latip, Emissions of Transesterification Jatropha-Palm Blended Biodiesel. Procedia Engineering 68, 2013, 265 – 270.
28. Jaffar Hussain, K. Palaniradja, N. Alagumurthi, R. Manimaran, Effect of Exhaust Gas Recirculation (EGR) on Performance and Emission characteristics of a Three Cylinder Direct Injection Compression Ignition Engine. Alexandria Engineering Journal 51, 2012, 241–247.
29. Ameya Vilas Malvade, Sanjay T Satpute, Production of Palm fatty acid distillate biodiesel and effects of its blends on performance of single cylinder diesel engine. Procedia Engineering 64, 2013, 1485 –1494.

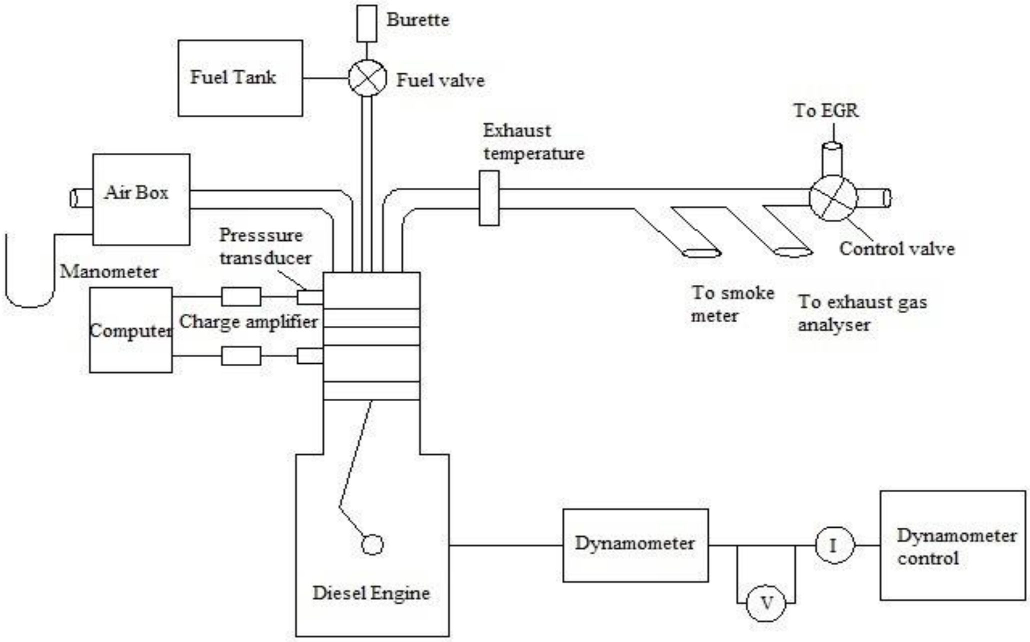

Figure 1 : Experimental Setup

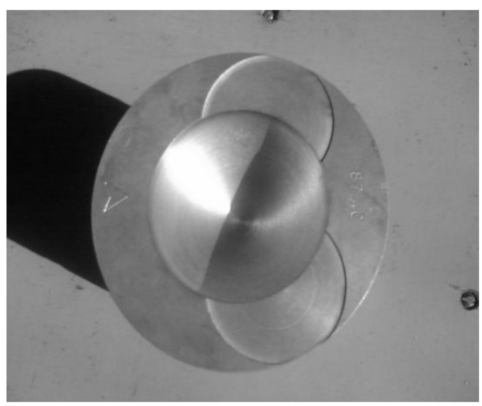

Figure 2 : Piston after machining 23

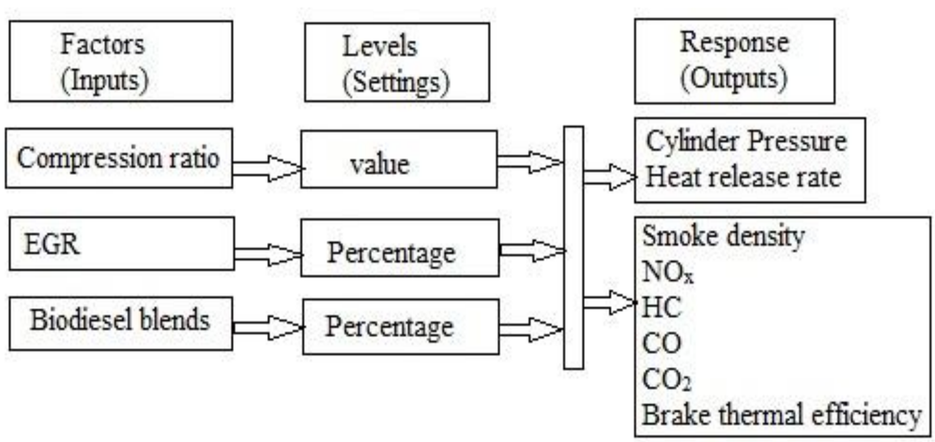

Figure 3 : Design of experiments

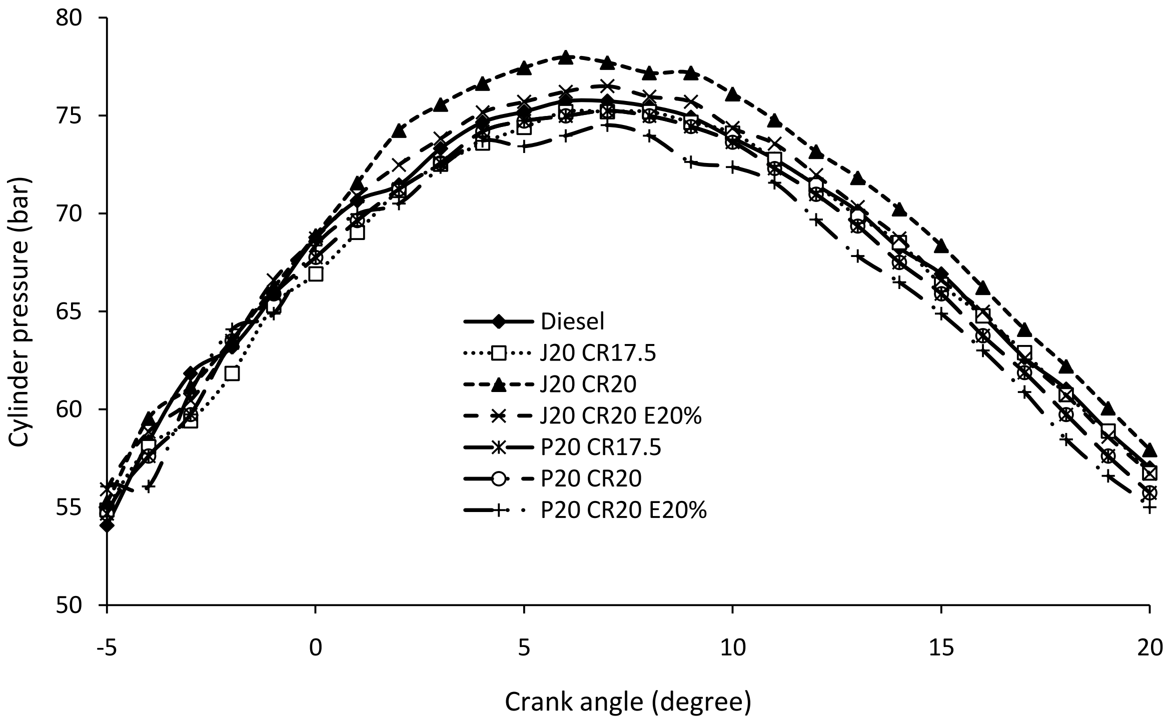

Figure 4 : Crank angle vs. Cylinder pressure 24

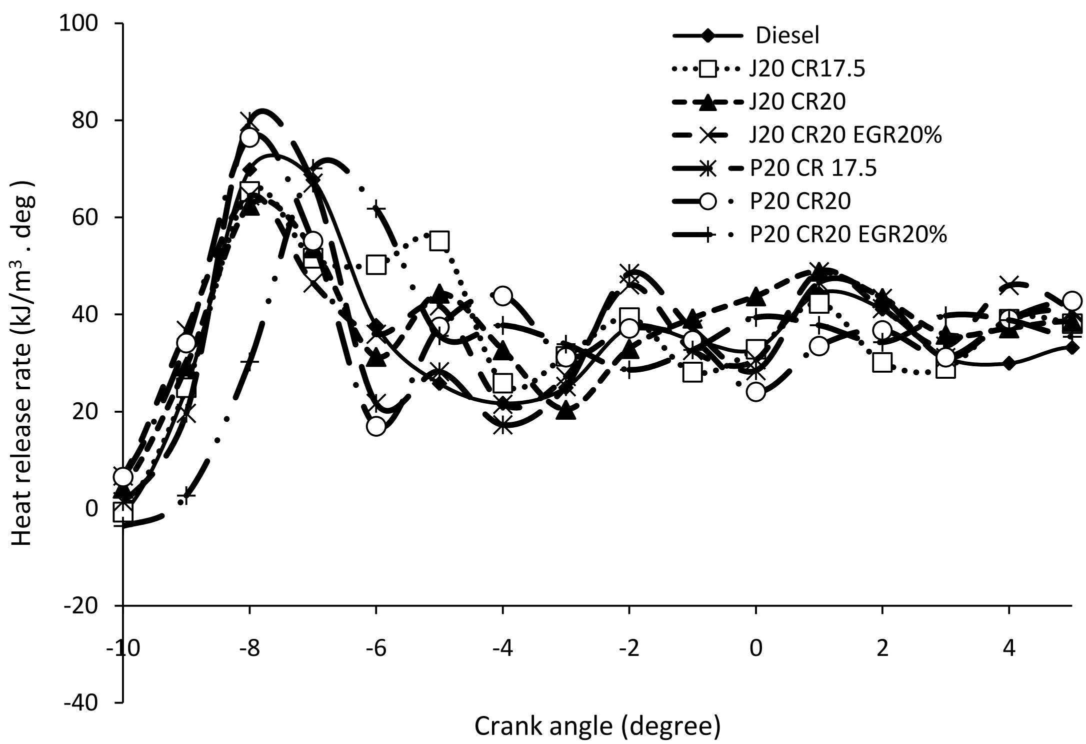

Figure 5 : Crank angle vs. heat release rate

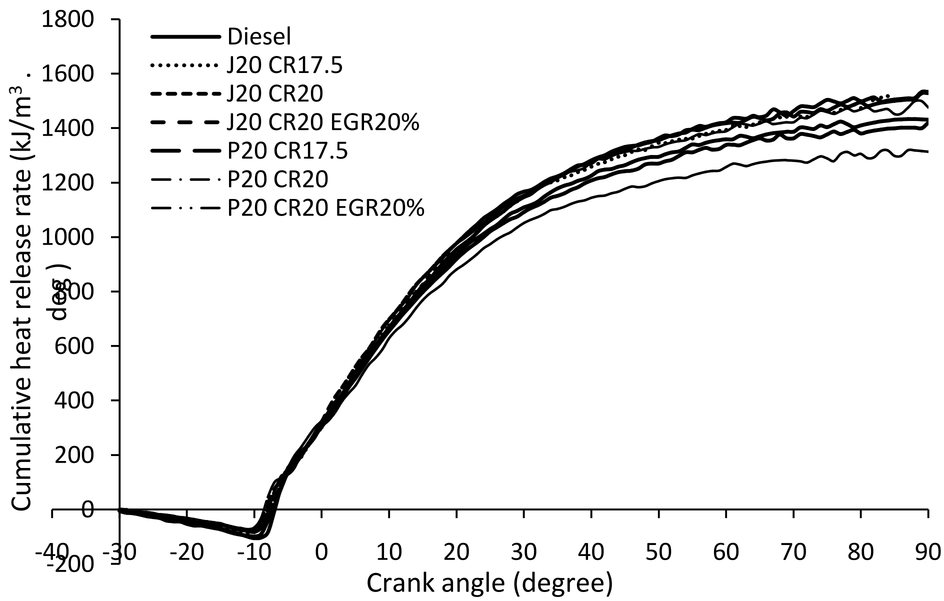

Figure 6 : Crank angle vs. cumulative heat release rate

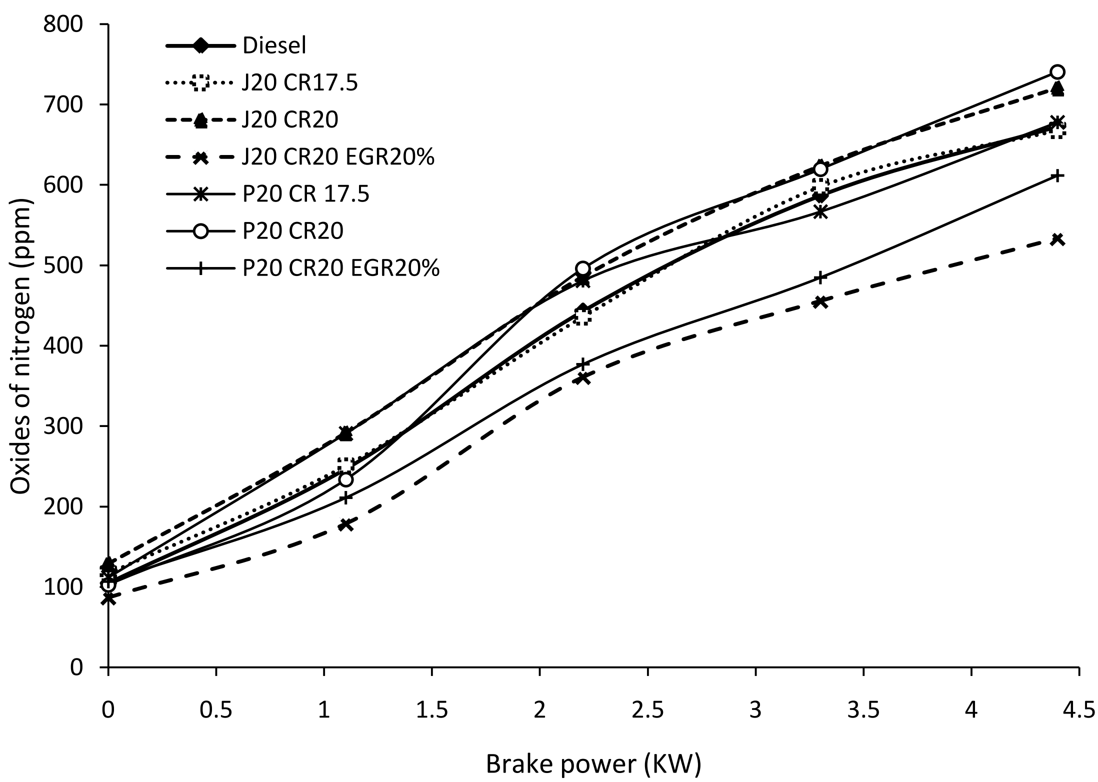

Figure 7 : Brake power vs. Oxides of nitrogen

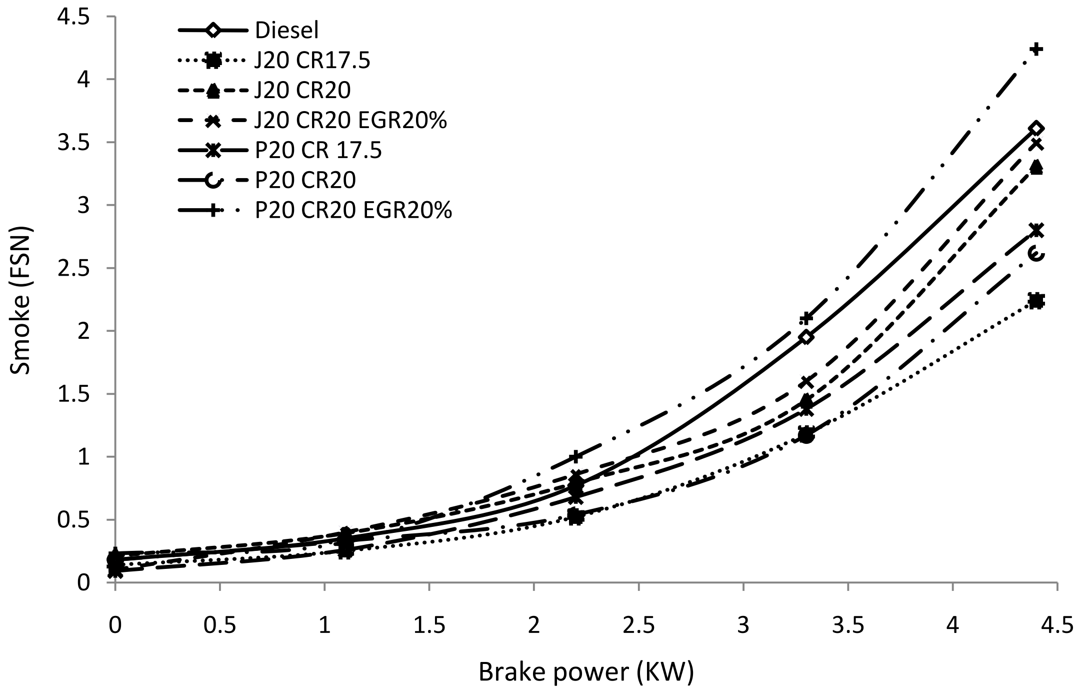

Figure 8 : Brake power vs. Smoke (FSN) 26

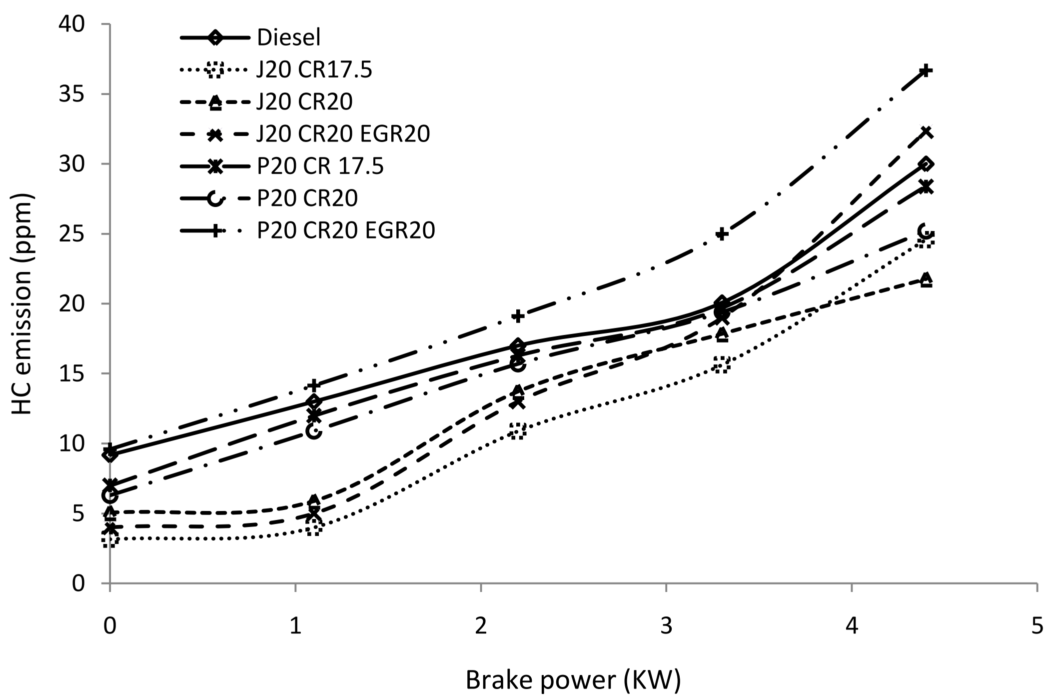

Figure 9 : Brake power vs. HC emission (ppm)

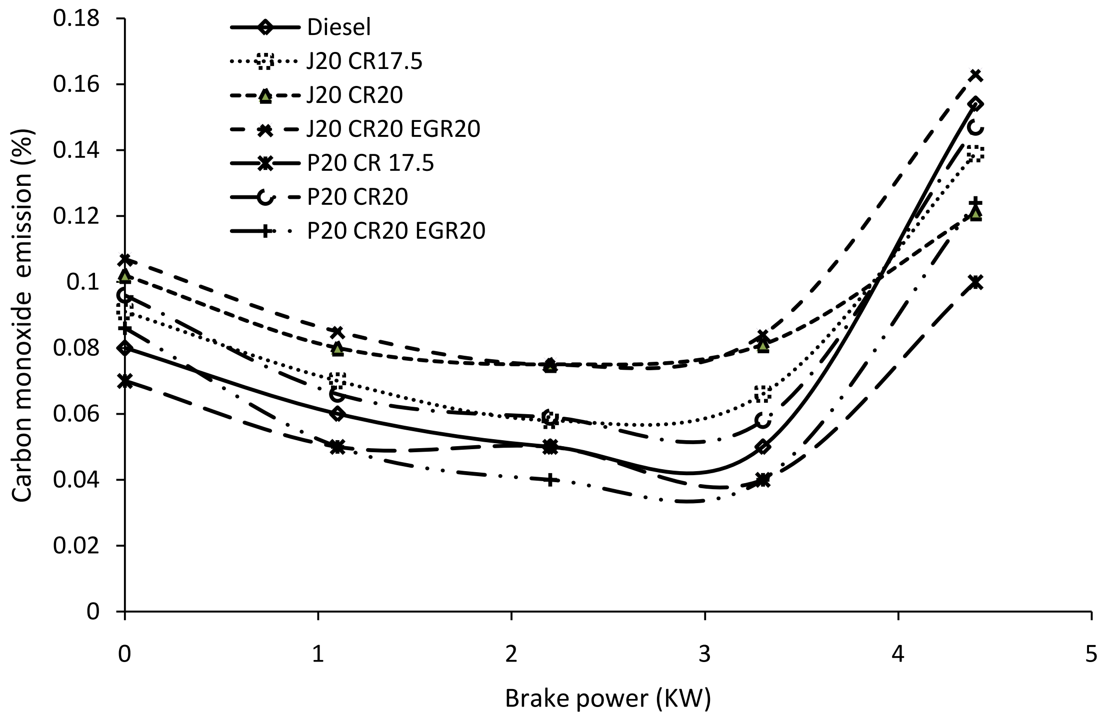

Figure 10 : Brake power vs. Carbon monoxide emission

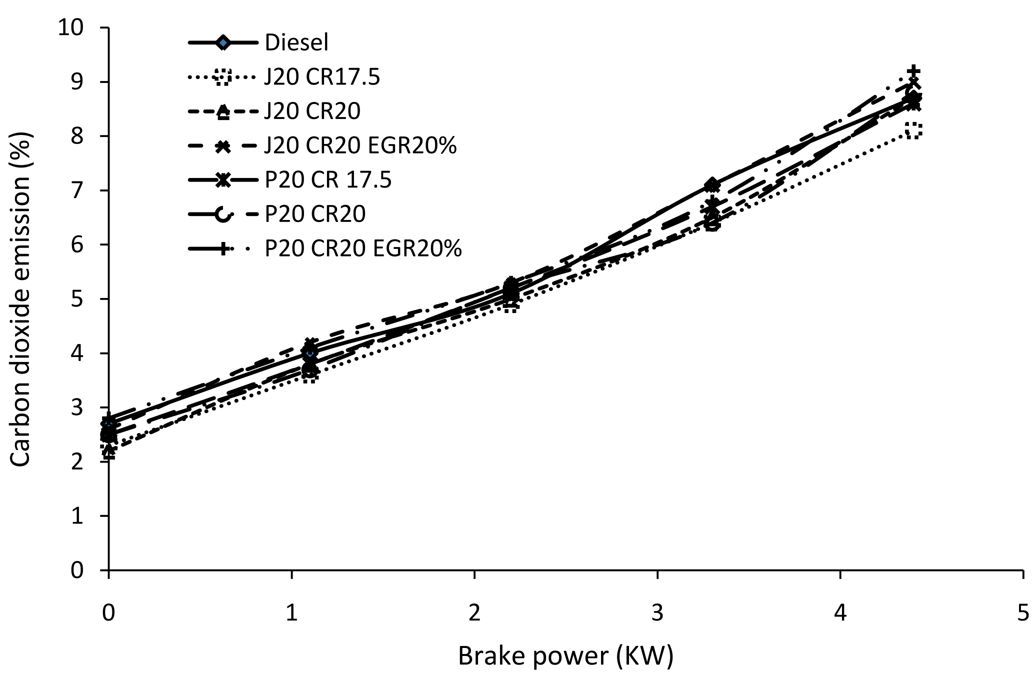

Figure 11 : Brake power vs. carbon dioxide emission

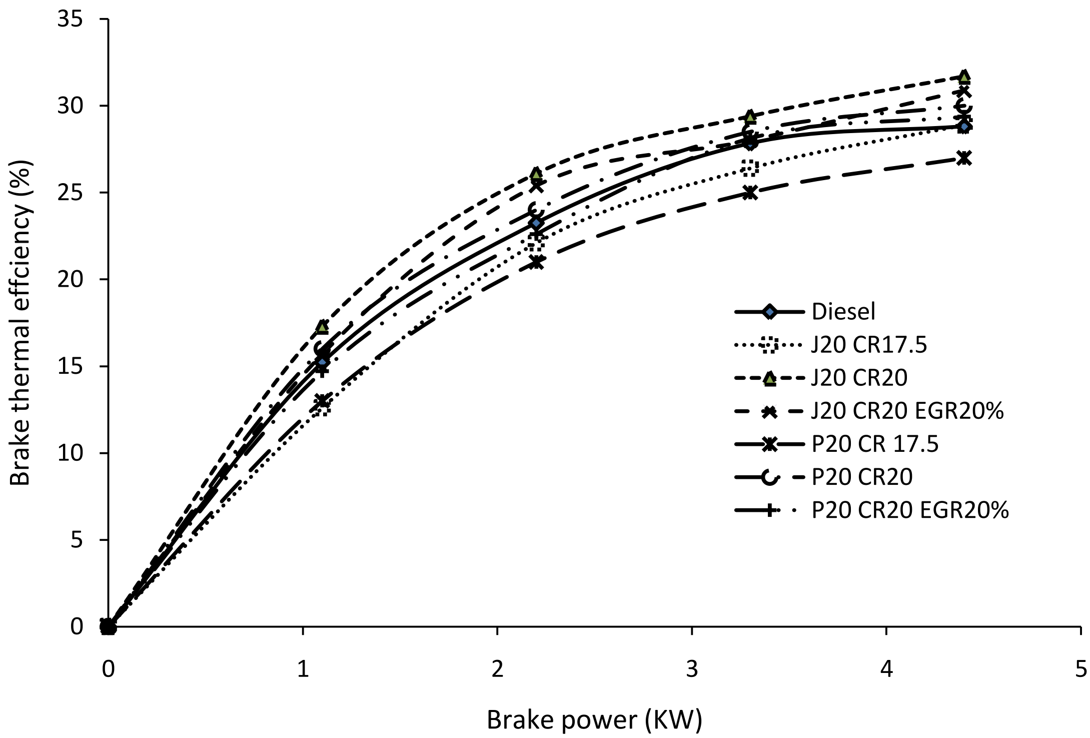

Figure 12 : Brake power vs. brake thermal efficiency 28

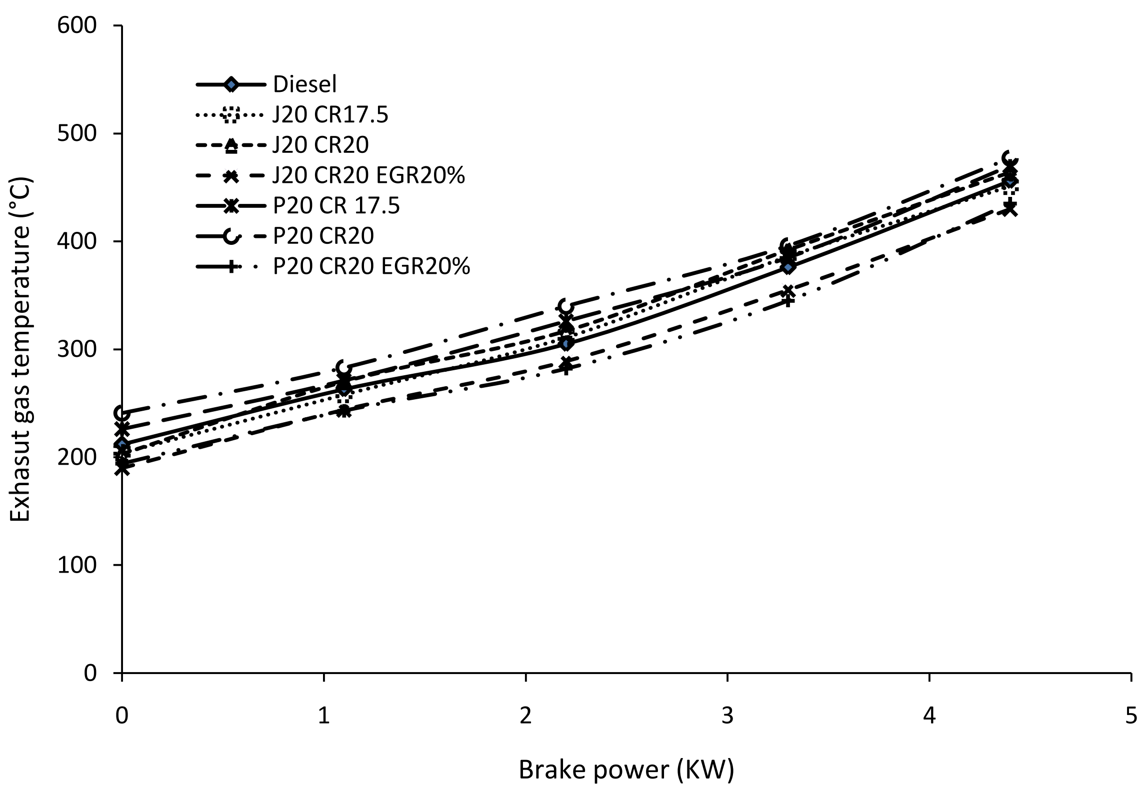

Figure 13 : Brake power vs. Exhaust gas temperature

Table 1 : Properties of Diesel, JME and PME blends

S.No	Fuel blend	Density (kg/m^3)	Calorific value (kJ/kg)	Kinematic viscosity at 40^0C (cSt)	Flash point (^0C)	Cetane number
1	Diesel	840	43000	3.90	50	48
2	JME 10	868	37956	5.17	162	52.70
3	JME 20	870	38450	5.43	169	53.01
4	JME 30	874	39423	5.62	171	53.4
5	PME 10	882	35412	5.21	160	46.17
6	PME 20	897	36010	5.64	163	46.48
7	PME 30	891	37675	5.97	166	46.80
IS for Biodiesel (IS15607:2005)		860-900	-	2.5-6.0	120 min	46 min

Table 2 : Technical specifications Diesel engine

Particulars	Specifications
Manufacture& model	Kirloskar-TAF1
Fuel injection type	Direct injection
Number of cylinder	1
Bore × stroke (mm)	87.5× 110
Displacement volume (cc)	661.45
Compression ratio	17.5:1
Cooling system	Air -cooled
Fuel Injection time	23.4 degree bTDC
Injector opening pressure (bar)	200
Loading type	Eddy current dynamo meter
Rated speed (rpm)	1500
Maximum power (kW)	4.4
Maximum torque (Nm)	28

Table 3 : Analysis of biodiesel test matrix for study on DI diesel engine

Variables	Fuels used	Details of fuel studied
Maintaining constant speed and varying loads 0%, 25%, 50%, 75% & Full load. Compression ratio 17.5, 19& 20 EGR- 10%, 20% &30%.	Diesel- Baseline fuel Jme- Diesel blends (10, 20 & 30% Jme) PME- Diesel blends (10, 20 & 30% Pme)	Evaluation of combustion, emission and performance characteristics of the diesel engine with diesel and biodiesel blends.
optimum values		
Maintaining constant speed and varying loads 0%, 25%, 50%, 75% & Full load. Compressionratio 20. EGR-20%.	Diesel-baseline fuel Optimum JME20-Diesel blend. Optimum PME20-Diesel blend.	study on combustion, emission and performance characteristics of the diesel engine with optimum blends, compression ratio and Exhaust gas recirculation

Table 4 : Lists of instruments details

Instrument	Measurement	Range	Accuracy	Percentage of uncertainties
AVL GH14D Pressure Transducer	Cylinder pressure	0-110 bar	±1 bar	0.20
AVL 365C angle encoder	Crank angle	--	±1	2
AVL3066A02 Piezo Charge Amplifier	Combustion pressure	0-700 bar	±0.01%	0.15
AVL 415 Smoke meter	Smoke opacity	0-10 FSN	±0.1	0.9
MRU delta 1600L Exhaust Gas Analyzer				
	NO	0-5000 ppm	±50 ppm	1.74
	UBHC	0-10000 ppm	±10 ppm	0.31
	CO	0-15 %vol	±0.06%	0.67
	CO_2	0-20 %vol	±0.5%	0.4
K type Thermocouple	EGT	0-1500°C	±1°C	0.4
Burette	Fuel consumption	1-30 cc	±0.1cc	0.15
Load cell	Load	250-600 W	±1 W	0.21

Table 5 : Combustion parameters of Diesel, JME and PME fuels on diesel engine at full load condition

Fuel	Start of injection (°) bTDC	Start of combustion (°) bTDC	Ignition delay	Peak pressure (bar)	Peak heat release rate (kJ/m^3.deg)
Diesel	23.4	9.22	14.18	75.729	69.65.326
J20 CR17.5	23.4	10.3	13.1	75.194	65.326
J20 CR20	23.4	10.78	12.62	77.987	62.481
J20 CR20 EGR20	23.4	12.16	11.24	76.501	64.427
P20 CR17.5	23.4	9.78	13.62	75.253	79.791
P20 CR20	23.4	10.48	12.92	75.201	76.478
P20 CR20 EGR20	23.4	11.89	11.59	74.511	70.079

Table 6 : Performance and emission output values at full load

Parameters	Diesel	J20 CR17.5	J20 CR20	J20 CR20 EGR20	P20 CR17.5	P20 CR20	P20 CR20 EGR20
NO_x (ppm)	673	668	721	534	678	741	612
HC (ppm)	30	24.59	21.77	32.34	28.17	25.2	36.7
CO (%)	0.154	0.139	0.121	0.163	0.1	0.147	0.124
CO_2 (%)	8.7	8.7	8.7	9	8.6	8.8	9.2
Smoke (FSN)	3.61	2.24	3.31	3.496	2.8	2.62	4.24
EGT (°C)	456	451	464	430	470	477	435
BTE (%)	28.81	28.9	31.7	30.89	27	30	29.37

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Study of Combustion and Performance Characteristics on a Single Cylinder DI Diesel Engine with Jatropha and Pongamia Methyl Ester Blends

By M. Anandan, S. Sampath & Natteri M. Sudharsan
Sri Venkateswara College of Engineering, India

Abstract- Biodiesels are produced from various organic materials such as plants, fossils and bio wastes etc. The present work is a proposal for the study of combustion characteristics in a single cylinder DI diesel engine with a bio-fuel derived from Jatropha and Pongamia seed oil for supporting industrial aspects in India. Tests were conducted to study the engine characteristics such as heat release rate, peak pressure, ignition delay and brake thermal efficiency were studied for part load and rated load with different compression ratios 17.5:1, 19:1 and 20:1. Experimental results conclude that engine operating at a compression ratio 20:1 is found to be more effective with Jatropha and Pongamia blends. Combustion characteristics reveals maximum cylinder pressure occurs at PME20% as an optimal blend ratio. Ignition delay were reliable for shorter angle at 12.6° for PME20% blend. Performance characteristics suggests that brake thermal efficiency was increased for JME30% blend ratio.

Keywords: compression ratio, biodiesel blends, combustion, ignition delay, brake thermal efficiency.

GJRE-A Classification : FOR Code: 290501

STUDYOFCOMBUSTIONANDPERFORMANCECHARACTERISTICSONASINGLECYLINDERDIDIESELENGINEWITHJATROPHAANDPONGAMIAMETHYLESTERBLENDS

Strictly as per the compliance and regulations of:

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Abstract- Biodiesels are produced from various organic materials such as plants, fossils and bio wastes etc. The present work is a proposal for the study of combustion characteristics in a single cylinder DI diesel engine with a bio-fuel derived from Jatropha and Pongamia seed oil for supporting industrial aspects in India. Tests were conducted to study the engine characteristics such as heat release rate, peak pressure, ignition delay and brake thermal efficiency were studied for part load and rated load with different compression ratios 17.5:1, 19:1 and 20:1. Experimental results conclude that engine operating at a compression ratio 20:1 is found to be more effective with Jatropha and Pongamia blends. Combustion characteristics reveals maximum cylinder pressure occurs at PME20% as an optimal blend ratio. Ignition delay were reliable for shorter angle at 12.6° for PME20% blend. Performance characteristics suggests that brake thermal efficiency was increased for JME30% blend ratio.

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I. Introduction

Supplement to the petroleum fuels becomes a common practice and needful for reducing the usage of fossil fuel resources. Enhancing the production of vegetable oil supports the fuel demands. Biodiesel is methyl or ethyl ester of fatty acid derived from vegetable oils (both edible and non-edible) and animal fat. The main resources for biodiesel production can be non-edible oils obtained from plant species such as Jatropha curcas, Pongamia pinnata, Calophyllum inophyllum, hevea brasiliensis (Rubber) etc. Biodiesel can be blended in any proportion with mineral diesel to produce a biodiesel blend or can be used in its pure form like petroleum diesel [1]. Biodiesel operates in compression ignition (diesel) engine, and essentially require very little or no engine modifications because biodiesel has properties similar to neat diesel [2]. It can be easily stored and transported because of its higher flash point temperature [3]. The use of biodiesel in conventional diesel engines results in substantial reduction in emission of unburned hydrocarbons, carbon monoxide and particulate matters [4]. Environmental factor is the major concern for an alternate fuel. In India adoption of Euro V equivalent emission norms are under consideration. Implementation of emission norms will focus on to reduce the sulphur content and increase the Cetane number of the fuel [5]. Biodiesel derived from rice bran oil, Mahua oil, Neem oil, Jatropha oil, Pongamia oil etc.are suitable alternative fuels for DI diesel engine. The performance of diesel engine depends on blends percentage, Ignition timing and it reduced with increasing the blends percentage beyond 50% [6], [7]. The performance and emission characteristics study was carried out for non-edible vegetable oil such as linseed oil, rice bran oil and its methyl ester. Operational and durability problems were occurred because of high viscosity, low volatility and poly unsaturated character to overcome this vegetable oil methyl ester blends were used instead of straight vegetable oil [8]. Higher viscosity of vegetable oil affects the atomization results in poor combustion and it is prevented by transesterification process. 25 percentage of cotton seed methyl ester blends performance almost same as the neat diesel while used as a fuel in diesel engine [9]. Processed cooking oil was used as a biodiesel through transesterification process. The effect of cooking oil diesel blends like B20, B50, and B100 was compared with neat diesel. 20% of blends produce the lowest carbon monoxide emission than 50 percentage of blends exclude at high engine speed [10]. Straight vegetable oil (Jatropha) used in diesel engine reduce the brake thermal efficiency and increase the smoke. Use of vegetable oil blend with methanol increase the brake thermal efficiency similarly smoke was significantly reduced [11]. Ignition delay, peak pressure and heat release rate were studied compression ignition diesel engine was operated with duel fuel such as karanja methyl ester and hydrogen fuel. Ignition delay increased at full load and it decrease considerably with lower loads. During the combustion process, karanja methyl ester burns with hydrogen results it increase the

Author α: Associate professor, Department of Marine Engineering, Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India. e-mail: anandanmoothy@gmail.com
Author σ: Professor, Department of Automobile Engineering, Rajalakshmi Engineering College, Chennai, Tamil Nadu, India.
Author ρ: Professor, Department of Mechanical Engineering, Rajalakshmi Engineering College, Chennai, Tamilnadu, India.

heat release rate. Low viscosity of fuel with hydrogen burns quickly and produces high pressure [12]. A cold pressed cashew nut shell liquid blend with diesel was used as an alternative fuel in internal combustion engine. 20 percentages of CNSL blends produce closer value of brake thermal efficiency as neat diesel. Cylinder pressure and heat release rate gets reduced with increasing the Cashew Shell Nut Liquid (CSNL) proportions. Operating engine with 40 percentage of CSNL blends engine knocking was observed [13]. Mahua oil and its blend were used as a fuel in direct injection diesel engine and the performance, emission and combustion characteristics was studied. Ignition delay, cylinder pressure and heat release rate was taken for combustion analysis. The output results for Mahua blends almost comparable with diesel hence; it can be used in diesel engine without any modifications [14]. The present work was approached to study the effect of increase in compression ratio (CR) of a conventional diesel engine operated with different percentage of Jatropha methyl ester and Pongamia methyl ester blends with neat diesel. Peak pressure, heat release rate and ignition delay characteristics for different compression ratio and different biodiesel blends were studied. Also the effect CR with brake thermal efficiency was studied for different percentage of biodiesel blends.

a) Esterification Process

Transesterification is a suitable method of utilizing vegetable oils in Compression Ignition engine without any long-term operational and durability problems. Vegetable oils can play a vital role in power generation for developing countries. Esterification is a chemical treatment process performed for treating vegetable oils [15]. Crude Jatropha and Pongamia seed oil was used for Transesterification process to convert crude oil into methyl ester oil. The Esterification process parameters such as reaction condition, type of alcohol, amount of catalysts, reaction time and temperature were controlled by manual mode. Single stage base catalyzed Transesterification was used for Jatropha and Pongamia. Methanol used as a regeant; H2SO4 and KOH used as a catalyst for base reaction.

b) Biodiesel Properties

The fuel properties of Jatropha methyl ester (JME) and Pongamia oil methyl esters (PME) blends with diesel are shown in Table1.The biodiesel properties such as density (kg/m3), calorific value (kJ/kg), viscosity (cSt), flash point (0C) was improved by Transesterification process. The property of biodiesel was tested as per IS15607:2005 standards. The methyl esters of Jatropha and Pongamia oil properties relatively closer with neat diesel. From the experimental results, these bio fuels can be used to operate the existing engine without any modifications. Compare with diesel, Jatropha and Pongamia blends contain oxygen molecules in the fuel. Hence complete combustion of fuel in the engine inhibits with the presence of oxygen ions in the biodiesel. Flash point for biodiesel was high, so it is safe to store compare with diesel. Small amount of biodiesel (Jatropha and Pongamia) added with the diesel increase the flash point of diesel blends.

II. Experimental Setup and Procedure

AVL software and data acquisition system was used to analyze the combustion characteristics of an engine as shown in Fig. 1. AVL 365C angle encoder was used to measure the crank angle position. AVL GH14D Pressure transducer was used to convert cylinder pressure value into analog signal form to the data acquisition system. Specification of the DI diesel engine was shown in Table 2. Experimental investigations of Jatropha methyl ester and Pongamia methyl ester were carried out in a four stroke single cylinder air cooled direct injection 4.4 kW at 1500 rpm diesel engine as a bore of 87.5 mm and stroke length of 110 mm as shown in Fig. 2 and Fig. 3. Engine test was performed with neat diesel; biodiesel blends (10%, 20% and 30%) for different compression ratios of 17.5:1, 19:1 and 20:1. Electric Dynamometer consists of electrical power bank it applies loads 0%, 25%, 50%, 75%, 100% on engine and it is controlled with the aid current and voltage values. The performance of biodiesel blends experimental values are compared with neat diesel.

III. Error Analysis

Error analysis was performed to indentify the accuracy of the measuring instruments. The percentage of uncertainties of a measuring instruments as given in Table. 3 Percentage of uncertainties present in experiments is = square root of ((uncertainty of pressure transducer)2 + (uncertainty of angle encoder)2 + (uncertainty of K-type thermocouple)2 + (uncertainty of stop watch)2 + (uncertainty of manometer)2 + (uncertainty of burette)2)+ (uncertainty of load cell)2 = square root of ((0.20)2 + (1)2 + (0.4)2 + (0.2)2 + (0.5)2 + (0.15)2+ (0.21)2) = square root of (1.566) = ±1.25%.

IV. Results and Discussion

a) Cylinder Pressure

i. Pongamia Methyl Ester Blends

The variation of cylinder pressure with crank angle for PME blends at different compression ratio as shown in Fig. 4a-c. For compression ratio of 17.5, peak pressure occurs at 67.49 bar at CA of 50 after TDC for diesel and 67.9 bar at CA of 60after TDC for PME10%, 67.67 bar at CA of 60 after TDC for PME20%, 67.68 bar at CA of 70 after TDC for PME30%. For 19 compression ratio, peak pressure occurs at 75.72 bar at CA of 70 after TDC for diesel and 75.78 bar at CA of 60 after TDC, 75.25 bar at CA of 60 after TDC, 76.94 bar at CA of 70 after TDC for PME10%, PME20%, PME30% respectively. For 20 compression ratio, peak pressure occurs at 75.61 bar at CA of 60 after TDC for diesel and 76.62 bar at CA of 60 after TDC, 75.83 bar at CA of 70 after TDC, 75.63 bar at a CA of 70 after TDC for PME10%, PME20%, PME30% correspondingly. It is observed from the figure that biodiesel blends had a higher peak pressure than diesel. The Combustion peak pressure increased with increasing the compression ratio.

ii. *Jatropha Methyl Easter Blends*

The variation of cylinder pressure with crank angle for JME blends at different compression ratio as shown in Fig. 6a-c.For compression ratio of 17.5, JME10%, JME20%, and JME30% combustion pressure of 69.28 bars at CA 70 after TDC, 70.67 bar at CA of 70 after TDC, 69.42 bar at CA of 60 after TDC respectively. For compression ratio of 19, JME10%, JME20%, J30% combusts pressure of 77.12 bar at CA 60 after TDC, 79.19 bar at CA of 80 after TDC, 78.85 bar at CA of 60 after TDC respectively. For compression ratio of 20, JME10%, JME20%, JME30% combustion pressure of 76.76 bar at CA 70 after TDC, 77.98 bar at CA of 60 after TDC, 77.83 bar at CA of 50 after TDC respectively. The peak pressure forJME20%, atCR of 20 was 3.57bar, for PME30% at CR of 19 was 1.82bar higher than diesel. The peak pressure takes place after TDC for safe and efficient operation. If it occurs close to TDC or before that causes severe engine knock thus affects engine durability [16]. It is concluded from the results JME 20% with Compression ratio of 20:1 achieves maximum peak pressure of 3.46 bar higher than diesel and JME20% blend was the optimum fuel blends as far as peak cylinder pressure concerned.

b) Heat Release Rate

The variation of heat release rate with crank angle for PME and JME blends at different compression ratio as shown in Fig. 5a-c and Fig. 7a-c. Heat release rate indicates that ignition delay for biodiesel blends was shorter compared with neat diesel. Neat diesel produces maximum heat release of 91.93 kJ/m3deg for CR of 17.5, 87.72 kJ/m3deg for CR of 19, and 79.85 kJ/m3deg for CR 20 respectively. It is observed from figure that maximum heat release rate of biodiesel blends are lower than diesel because of their shorter ignition delay compared with diesel. It is also observed from the obtained values that, JME 20% blend produces minimum heat release rate of 62.53 kJ/m3deg at compression ratio of 20:1 among the biodiesel blends tested.

c) Ignition Delay

The variation of ignition delay fordiesel, biodiesel blends at different compression ratio as shown in Fig.8. Ignition delay is one of the important parameters in determining the knocking characteristics of diesel engines. It is a period between start of injection and start of combustion and it depends upon many factors such as compression ratio, the inlet pressure, injection parameters and the properties of the operating fuel. Higher the cetane number (CN), the shorter is the ignition delay, and vice versa [17]. Table. 4 show the ignition delay for biodiesel blends for different compression ratio.It is observed from figure that the ignition delay of methyl esters and its blends is significantly lower than that of diesel and decreases with increase in the percentage of methyl ester in the blend and compression ratio. As the temperature of air in the cylinder is fairly high at the time of injection, esters undergo chemical reactions and polymerization, which result in injection characteristics that are different from those of diesel. A decrease in ignition delay results in smaller amount of fuel accumulation to ignition which results in lower heat release rate during premixed combustion phase.

V. Effect of Biodiesel Blends on Brake Thermal Efficiency

The variation of the brake thermal efficiency with compression ratio for diesel, biodiesel blends at full load were shown in Fig. 9. Brake thermal efficiency (BTE) mainly depends on the operating fuel properties such as density and viscosity. In general, BTE was lower for methyl ester derived biodiesels compared to diesel. To achieve better brake thermal efficiency of biodiesel blends, compression ratio of diesel engine was increased. At full load conditions BTE of diesel, PME10, PME20, PME30, JME10, JME20, JME30 are 28.1%, 26%, 27%, 30%, 30.3%, 33.5%, 35.6% respectively. It is observed from the figure that BTE gets increased proportionally with engine loads. JME30% blend produces 7.5% higher brake thermal efficiency than diesel. Increase in compression ratio of engine enhance the complete combustion of fuel in the combustion chamber with the presence of oxygen and hence better thermal efficiency.

VI. Conclusion

The experiments reveals that biodiesel from unrefined Jatropha and Pongamia seed oil is quite suitable as an alternative to diesel. Following results were obtained from the bio fuel operated single cylinder diesel engine operation.

- The ignition delay was shorter for PME blends (10%, 20%, and 30%) varying between 12.6 to 14.2 CA for different compression ratios 17.5:1, 19:1, 20:1 compared with diesel.
- The ignition delay was shorter for JME blends (10%, 20%, and 30%) varying between 12.9 to 14.28 CA for different compression ratios 17.5:1, 19:1, 20:1compared with diesel.

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- It is concluded that biodiesel (JME and PME) blendsreleases maximum peak pressure compared with diesel and peak pressure increases while increasing the compression ratio.
- It is also concluded that Heat release rate is less for biodiesel fuel blends compared with diesel fuel. Among the tested blends JME 20% blend produce minimum heat release rate of 62.48 kJ/m3deg at 20:1 compression ratio.
- Brake thermal efficiency increases with increase in compression ratio for biodiesel blends.

VII. Acknowledgement

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References Références Referencias

1. Gerhard Knothe, Biodiesel and renewable diesel: A comparison. Progress in Energy and Combustion Science xxx (2009) 1–10.
2. C. Carraretto, A. Macor, A. Mirandol, A. Stoppato, S. Tonon, Biodiesel as alternative fuel: Experimental analysis and energetic evaluations. Energy 29 (2004) 2195–2211
3. R. Altin, S. Cetinkaya, H.S. Yucesu, Potential of using vegetable oil fuels as fuel for diesel engines, Energy Conversion Manage. 42 (2001) 529–538.
4. Avinash Kumar Agarwal, Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science 33 (2007) 233–271.
5. Fangrui Ma, Milford A. Hanna, Biodiesel production: a review. Bio resource Technology 70 (1999) 1-15.
6. Md. Hasan Alia, Mohammad Mashud, Md. Rowsonozzaman Rubel, Rakibul Hossain Ahmad, Biodiesel from Neem oil as an alternative fuel for Diesel engine. Procedia Engineering 56 (2013) 625 – 630.
7. Shailendra Sinha, Avinash Kumar Agarwal, Sanjeev Garg, Biodiesel development from rice bran oil: Transesterification process optimization and fuel characterization. Energy Conversion and Management, Volume 49, Issue 5, May 2008, Pages 1248–1257.
8. Qi, D.H, Chen, H., Mattews, R.D, Bian., Y. Z., Ren, X.CH., 2010. Performance and Combustion characteristics of biodiesel-diesel-methanol blend fuelled engine, Applied Energy 87, p. 1679.
9. Luis Felipe Ramirez-Verduzco, Javier Esteban Rodriguez-Rodriguez, Alicia del Rayo Jaramillo-Jacob, Predicting cetane number, kinematic viscosity, density and higher heating value of biodiesel from its fatty acid methyl ester composition. Fuel Volume 91, Issue 1, January 2012, 102–111.
10. K. Nantha Gopal, Arindam Pal, Sumit Sharma, Charan Samanchi, K. Sathyanarayanan, T. Elango, Investigation of emissions and combustion characteristics of a CI engine fueled with waste cooking oil methyl ester and diesel blends. Alexandria Engineering Journal (2014) 53, 281–287.
11. Zhu L, Cheung CS, Zhang WG, Huang Z. Combustion, performance and emission characteristics of a DI diesel engine fueled with ethanol–biodiesel blends. Fuel 2011; 90:1743–1750.
12. Mohammed EL-Kasaby, Medhat A. Nemit-allah, Experimental investigations of ignition delay period and performance of a diesel engine operated with Jatropha oil biodiesel. Alexandria Engineering Journal (2013) 52, 141–149.
13. V. Palvannan, K. Balagurunathan, Technical Sustainability of Cashew Nut Shell Liquid as a Renewable Fuel in Compression Ignition Engine. European Journal of Scientific Research Vol.76 No.4 (2012), pp.614-627.
14. Effect of injection timing on performance, combustion and emission characteristics of a diesel engine using mahua oil methyl ester as fuel. journal of scientific & Industrial research vol. 71, January 2013, pp.69-74.
15. Meher, L.C. Sagar, D.V. Naik, Technical aspect of biodiesel production by Transesterification- a review, Renewable and Sustainable Energy Review 10, 2006. p. 248.
16. P.K. Sahoo, L.M. Das, Combustion analysis of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine. Fuel 88 (2009) 994-999.
17. John B Heywood. 1988. Internal Combustion Engine Fundamentals. McGraw Hill Book Company.

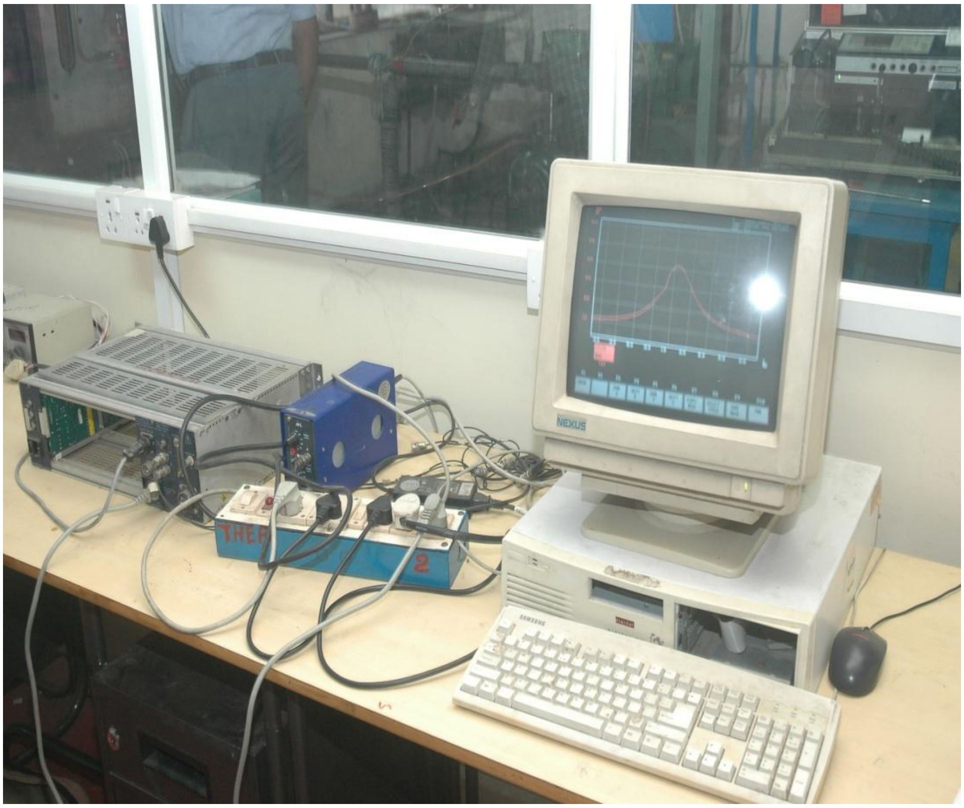
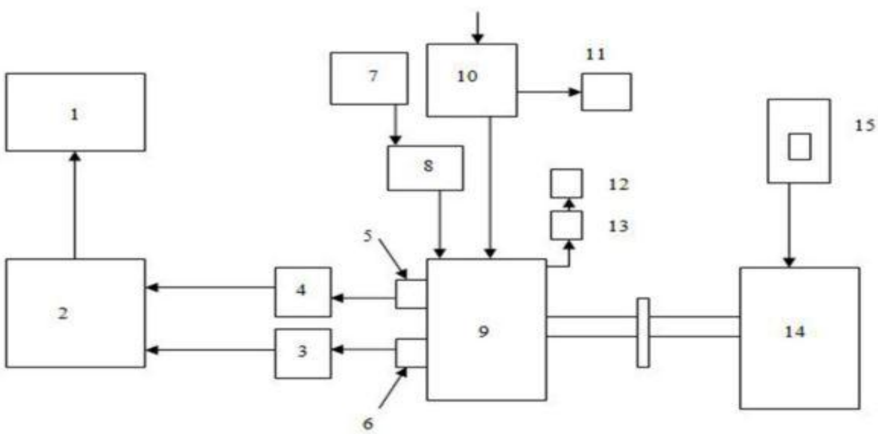


Figure 1 : AVL Data acquisition system



1. Computer	9. Diesel engine
2. A/D card	10. Air box
3. TDC amplifier circuit	11. U-tube manometer
4. Charge amplifier	12. Exhaust gas analyzer
5. Pressure transducer	13. AVL smoke meter
6. TDC position sensor	14. Electric dynamometer
7. Fuel tank	15. Dynamo meter control
8. Fuel flow meter	

Figure 2 : Layout of diesel engine setup

Figure 3 : Test engine setup

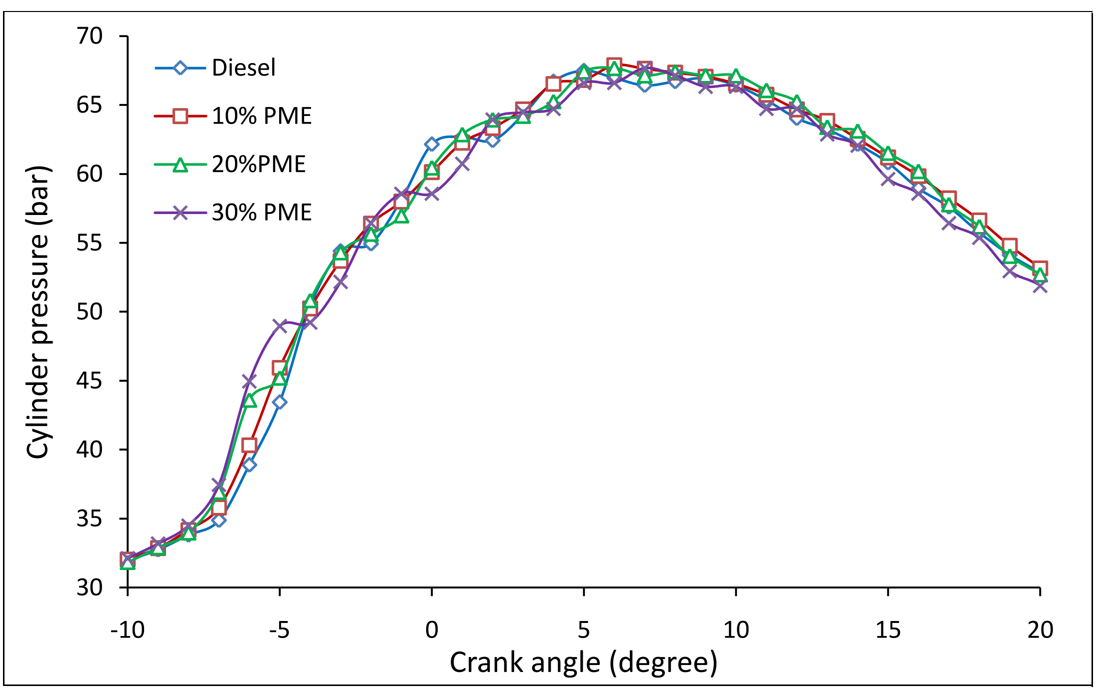


Figure 4a: Crank angle vs. cylinder pressure for compression ratio of 17.5

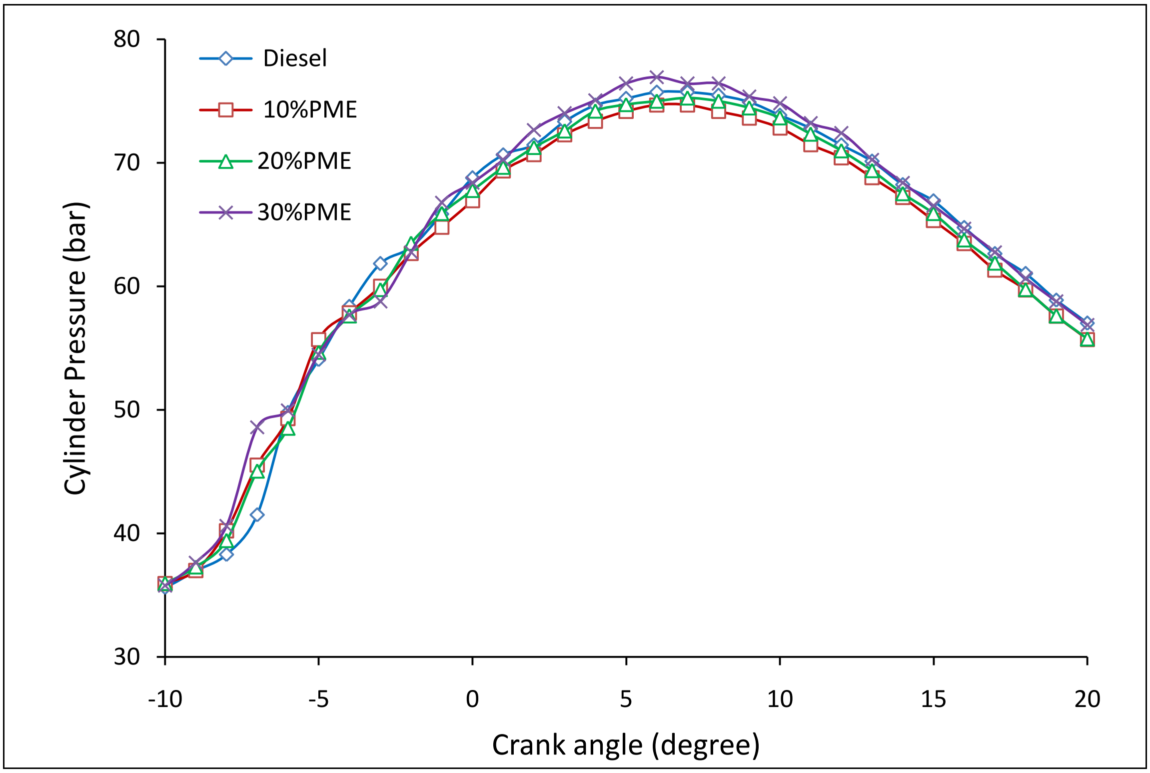


Figure 4b : Crank angle vs. cylinder pressure for compression ratio of 19

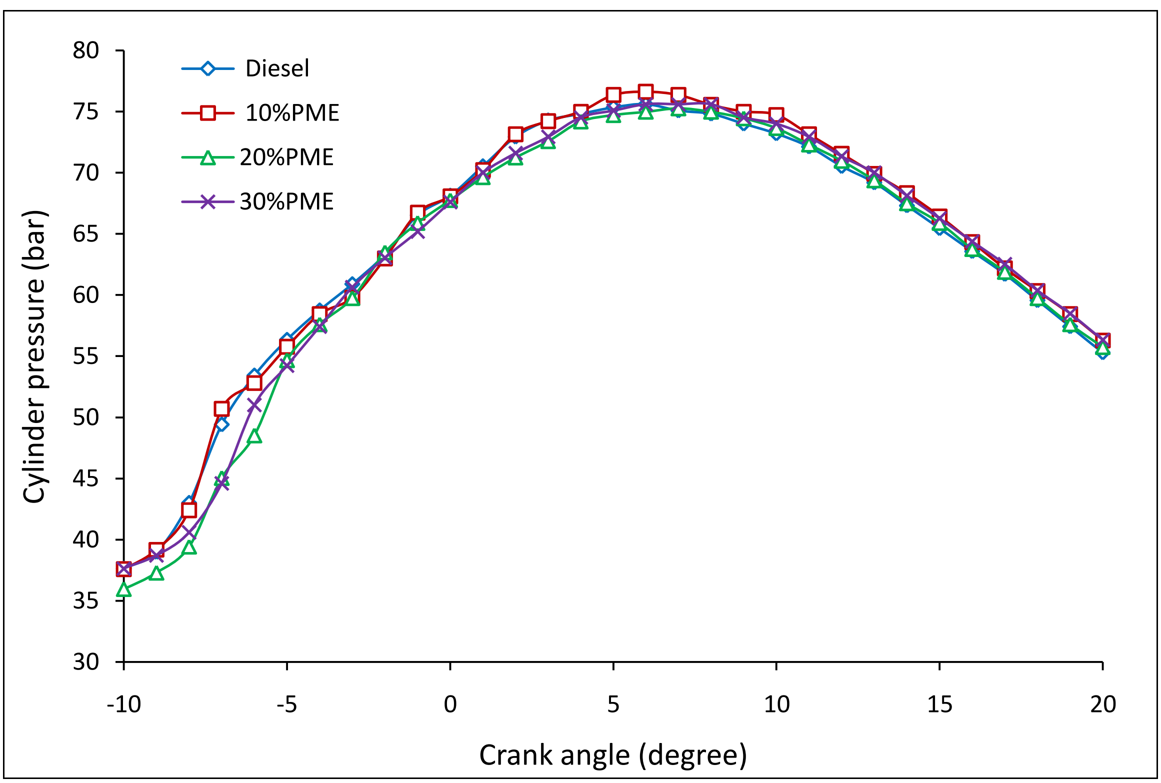


Figure 4c : Crank angle vs. cylinder pressure for compression ratio of 20

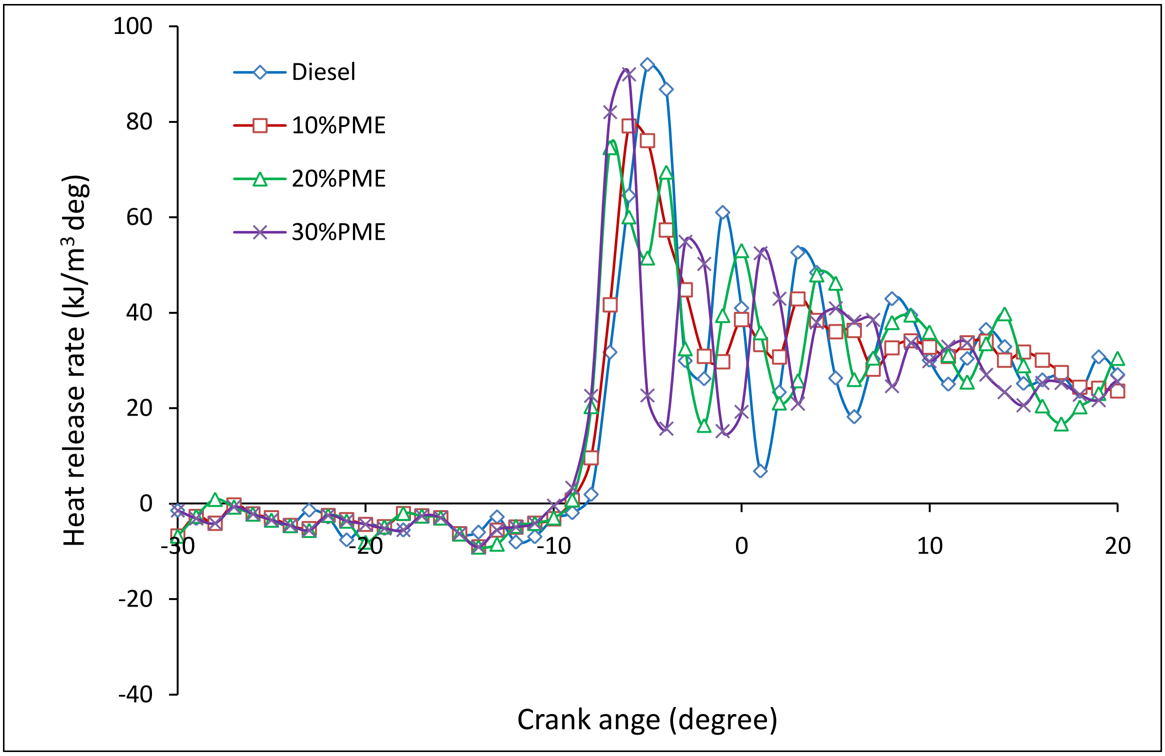


Figure 5a : Crank angle vs. heat release rate for compression ratio of 17.5

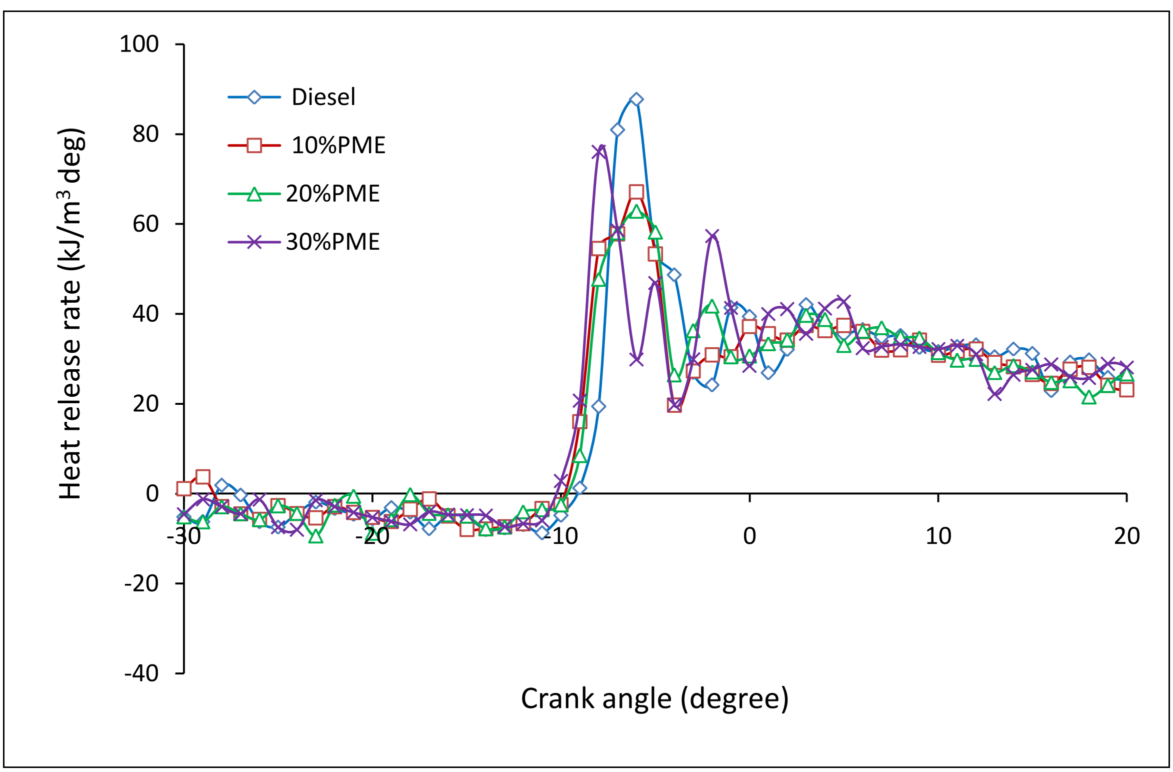


Figure 5b : Crank angle vs. heat release rate for compression ratio of 19

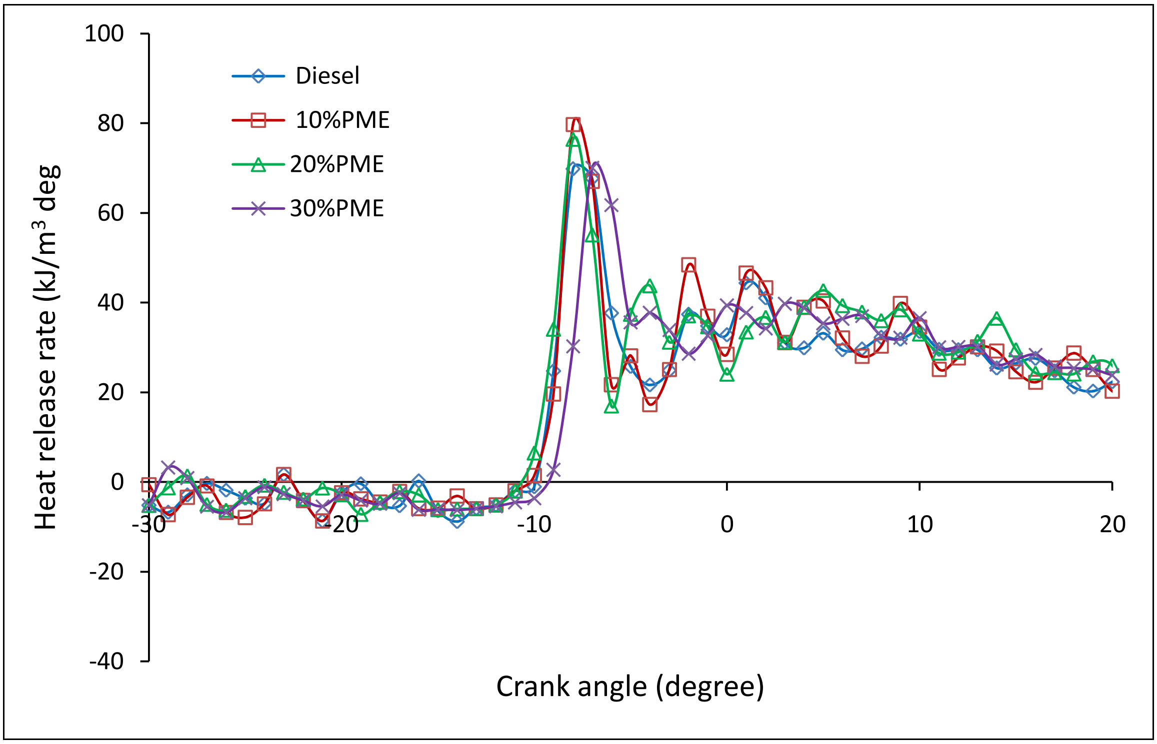


Figure 5c : Crank angle vs. heat release rate for compression ratio of 20

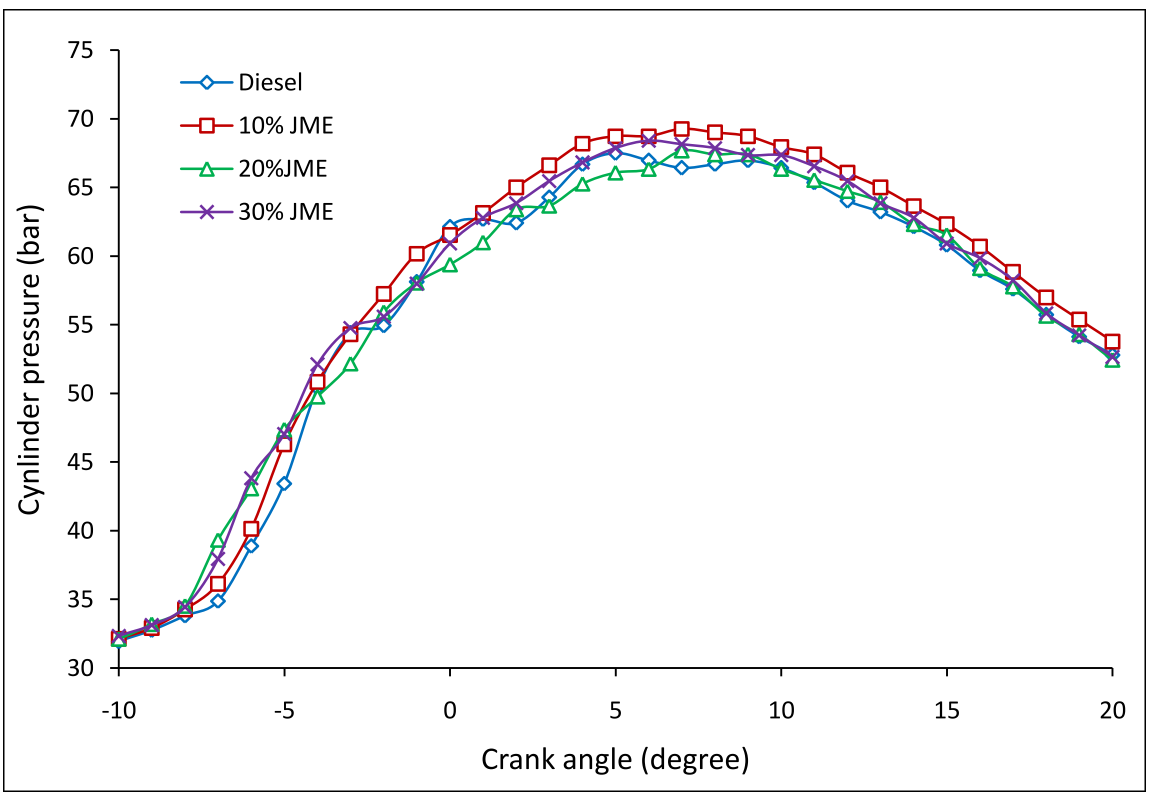


Figure 6a : Crank angle vs. cylinder pressure for compression ratio of 17.5

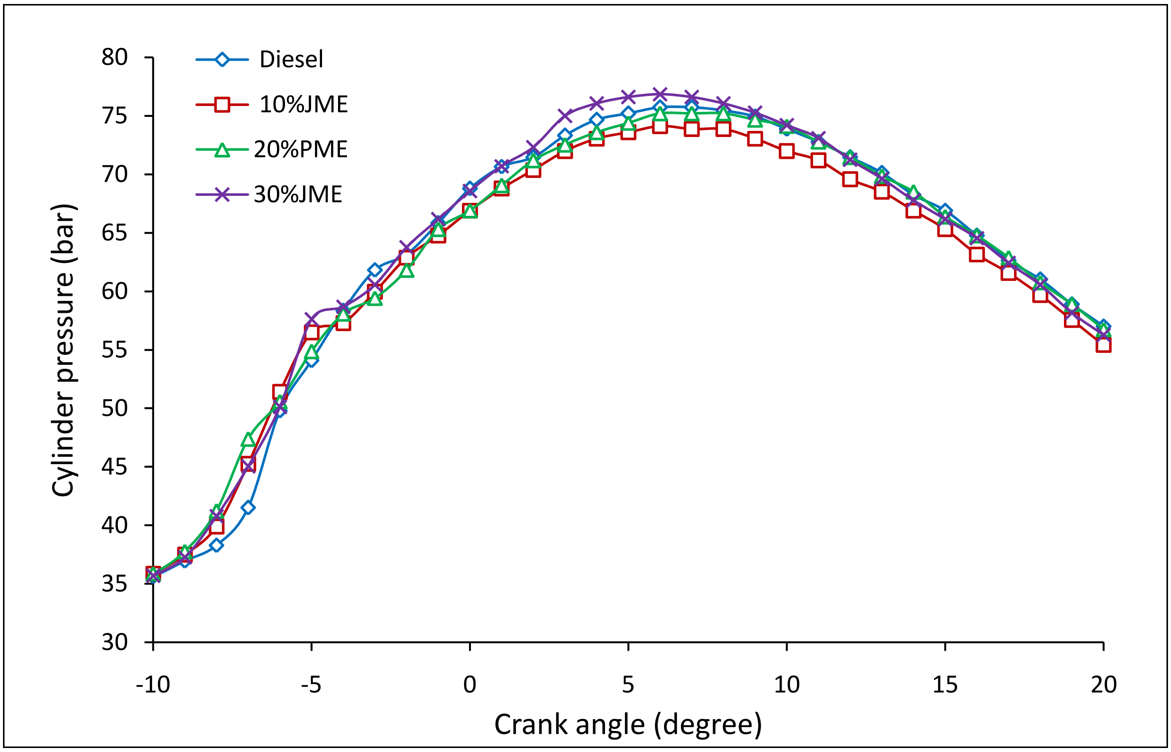


Figure 6b : Crank angle vs. cylinder pressure for compression ratio of 19

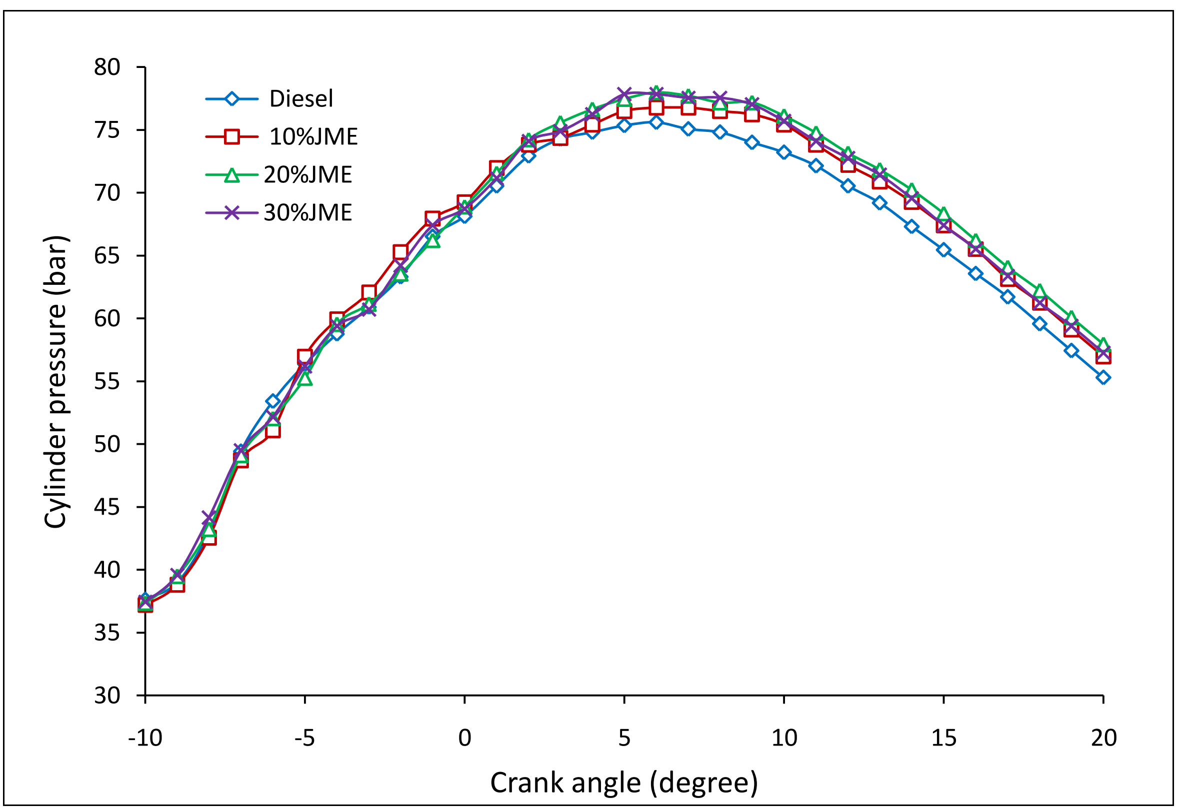


Figure 6c : Crank angle vs. cylinder pressure for compression ratio of 20

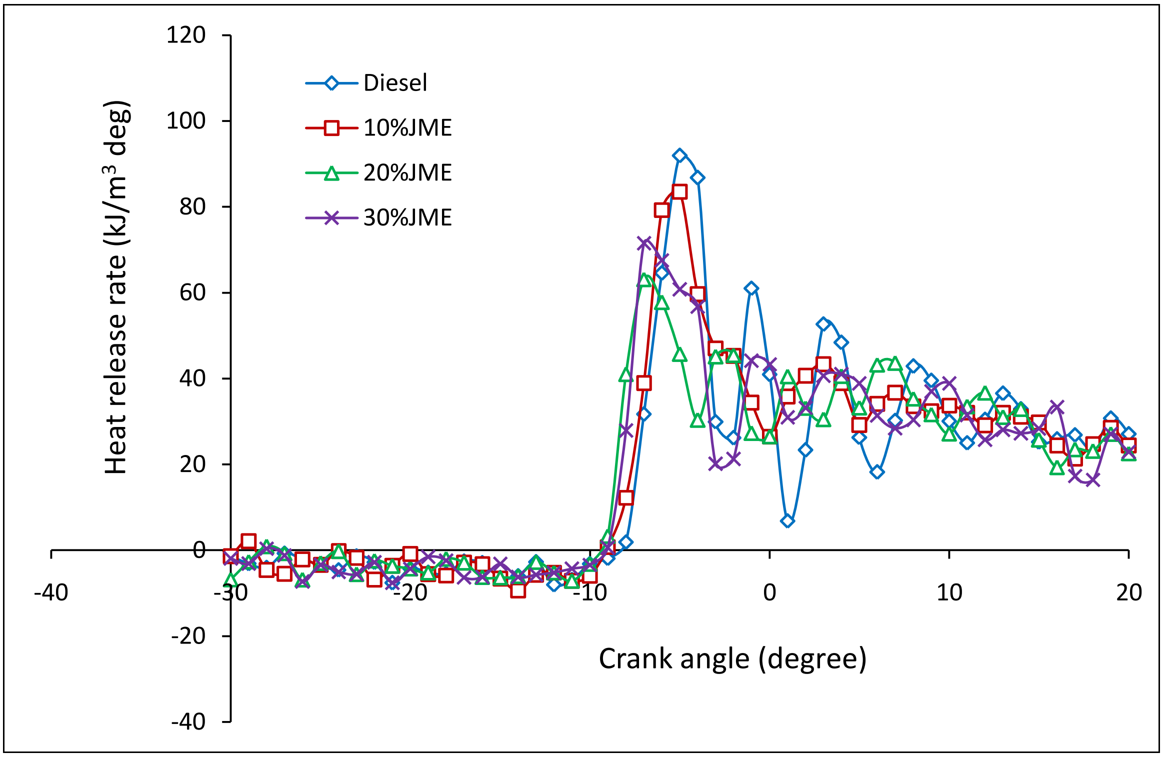


Figure 7a : Crank angle vs. heat release rate for compression ratio of 17.5

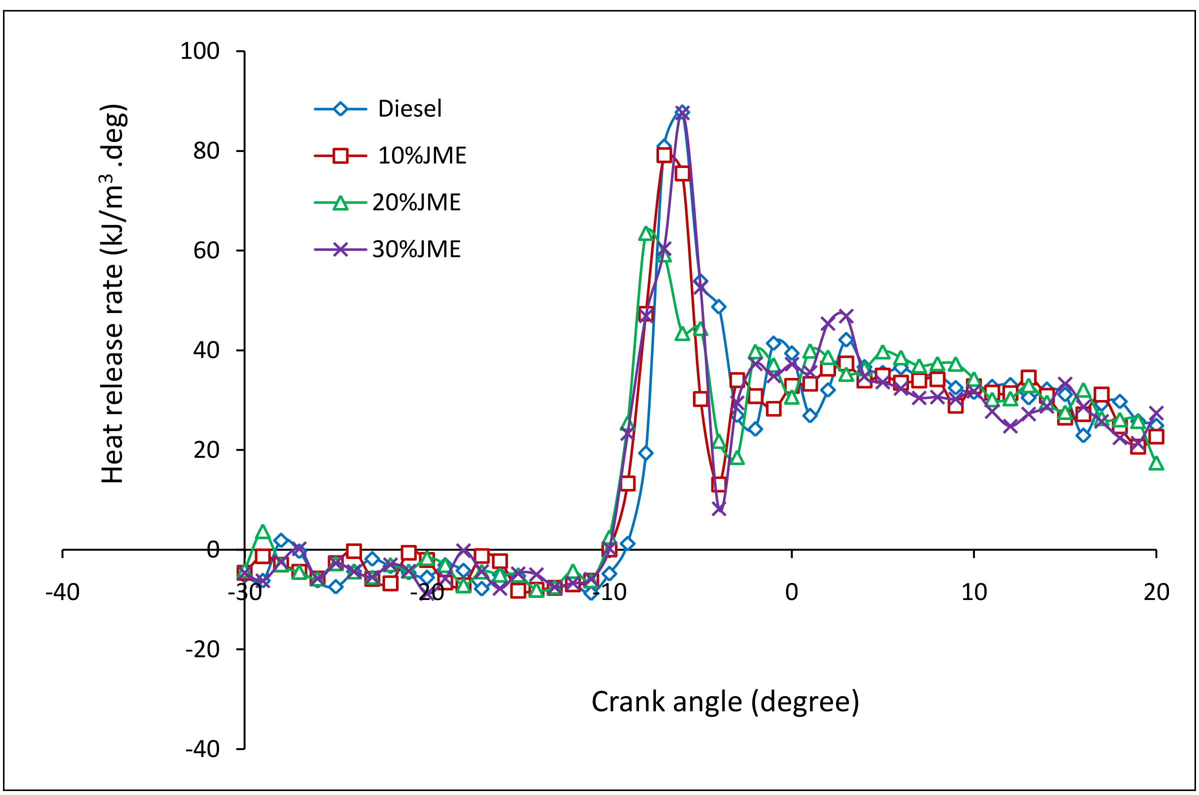


Figure 7b : Crank angle vs. heat release rate for compression ratio of 19

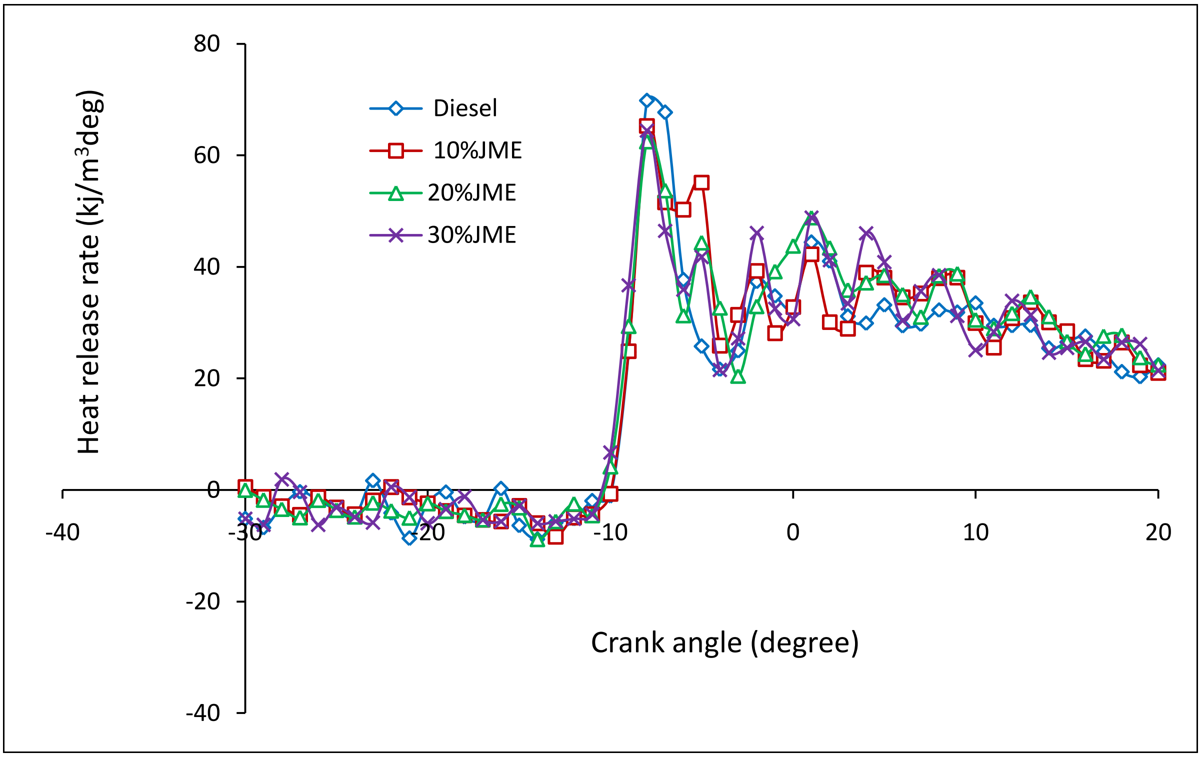


Figure 7c : Crank angle vs. heat release rate for compression ratio of 20

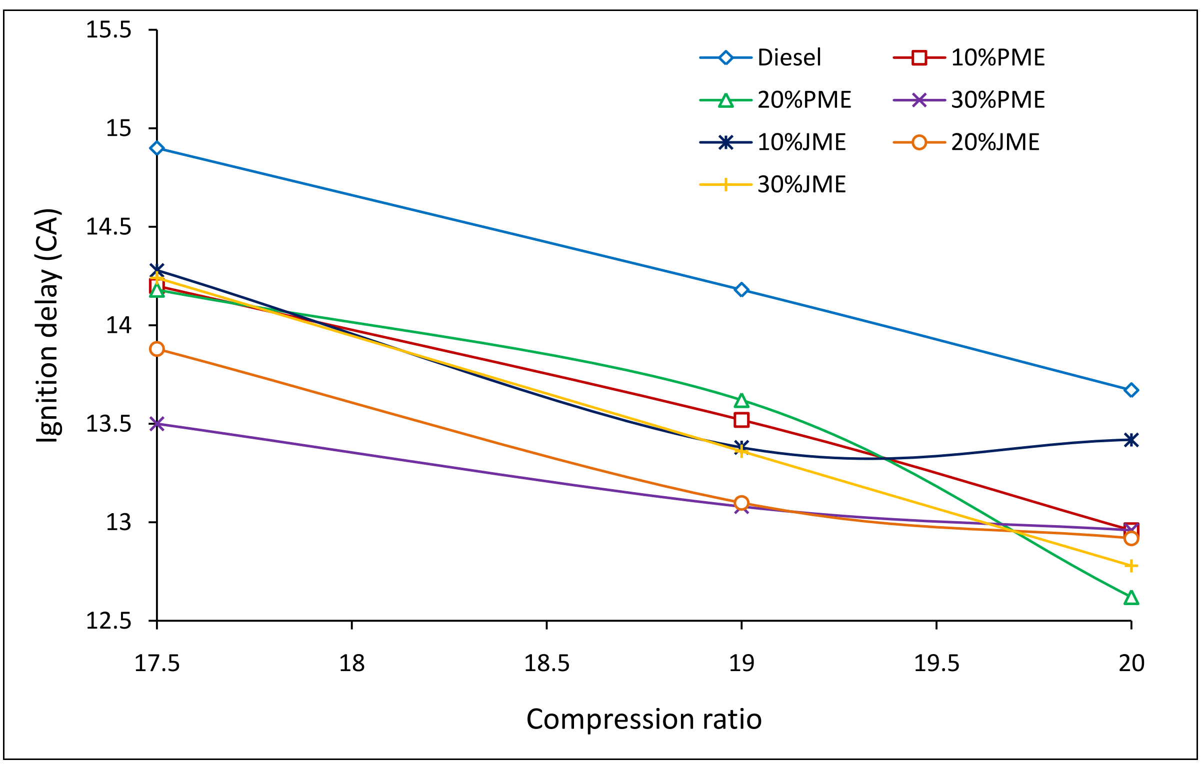


Figure 8 : Compression ratio vs. Ignition delay

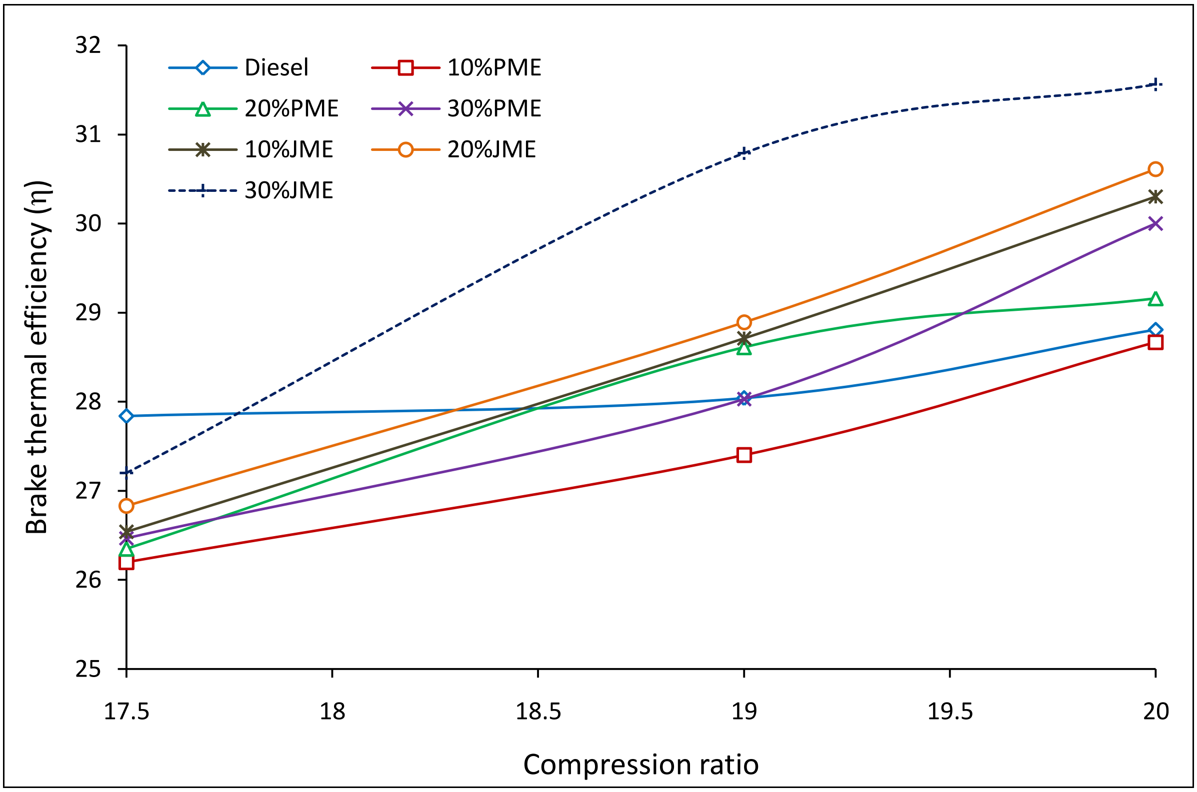


Figure 9 : Brake thermal efficiency vs. compression ratio at full loads

Table 1 : Diesel and biodiesel blends

Fuel blend	Density (kg/m^3)	Calorific value (kJ/kg)	Kinematic viscosity at 40^{0}C (cSt)	Flash point (^{0}C)	Cetane number
DIESEL	840	43000	3.90	50	48
PME10	868	37956	5.17	162	52.70
PME20	870	38450	5.43	169	53.01
PME30	874	39423	5.62	171	53.4
JME10	882	35412	5.21	160	46.17
JME20	897	36010	5.64	163	46.48
JME30	891	37675	5.97	166	46.80
IS for biodiesel (IS15607:2005)	860-900	-	2.5-6.0	120 min	46 min

Table 2 : Diesel engine Specifications Particulars

Particulars	Specifications
Engine model	Kirloskar TAF-1
Fuel injection type	Direct injection
No of cylinder	1
Bore & Stroke	87.5mm & 110mm
Compression ratio	17.5:1
Cooling system	Air –cooled

Fuel injection time	23.4 degree bTDC
Injection pressure	200 bar
Loading type	Eddy current dynamometer
Maximum power	4.4 kW@1500rpm
Maximum torque	28 N-m@1500rpm
IVO	4.5 degree bTDC
IVC	35.5 degree aBDC
EVO	35.5 degree bBDC
EVC	4.5 degree aTDC

Table 3 : Instruments used for engine test

Instrument	Measurement	Range	Accuracy	Percentage of uncertainties
AVL GH14D Pressure Transducer	Cylinder pressure	0-110 bar	±1 bar	0.20
AVL 365C angle encoder	Crank angle	--	±1	1
K type Thermocouple	EGT	0-1500°C	±1°C	0.4
Burette	Fuel consumption	1-30 cc	±0.1cc	0.15
U-tube Manometer	Inlet flow rate	-	±1 mm	0.5
Stopwatch	Time	-	±0.2sec	0.2
Load cell	Load	250-600 W	±1 W	0.21

Table 4 : Ignition delay, Peak pressure, heat release rate for diesel and biodiesel blends

Fuel	Start of combustion (^{0}) bTDC			Ignition delay			Peak pressure (bar)			Heat release rate (kJ/m^{3}deg)		
	17.5	19	20	17.5	19	20	17.5	19	20	17.5	19	20
Diesel	8.5	9.3	10	14.9	14.1	13.4	67.49	75.12	75.61	91.93	87.72	79.85
PME 10	9.2	9.9	10.5	14.2	13.5	12.9	67.88	75.68	76.62	79.17	67.12	78.79
PME 20	9.22	9.8	10.8	14.18	13.6	12.6	67.67	75.25	75.33	74.58	62.83	76.47
PME 30	9.9	10.4	9.5	13.5	13.0	13.9	67.67	76.94	75.61	89.92	76.07	70.07
JME 10	9.12	10.1	10	14.28	13.3	13.4	69.28	77.12	76.76	83.50	79.11	65.32
JME 20	9.52	10.3	10.5	13.88	13.1	12.9	70.67	77.98	79.18	63.10	63.53	62.48
JME 30	9.16	9.8	10.5	14.24	13.6	12.9	69.42	78.85	77.83	71.47	84.61	64.42

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Analysis of an NACA 4311 Airfoil for Flying Bike

By Amit Singh Dhakad, Pramod Singh & Arun Singh
Chhattisgarh Swami Vivekanand University, India

Abstract- The development of the wing has been always such that it should be able to produce the maximum lift due to the high pressure on the bottom surface and low pressure on the top surface of an airfoil. And these concepts clears that the flow of air/velocity of air will be low on the lower surface and higher on the upper surface of an airfoil. So, due to these differences in pressures and velocity the aerial can produce lift. Here to let fly the Bike in the air the Flat bottomed Airfoil has been chosen and usually the flat bottomed airfoil is called as the Clark Y and this has the feature as Maximum thickness of 11.7% at 28% chord and maximum camber of 3.4% at 42% chord.

Keywords: NACA 4311 airfoil, flat bottomed airfoil, javafoil, clark Y.

GJRE-A Classification : FOR Code: 091399p

ANALYSISOFANNACA4311AIRFOILFORFLYINGBIKE

Strictly as per the compliance and regulations of:

Analysis of an NACA 4311 Airfoil for Flying Bike

Amit Singh Dhakad [α], Pramod Singh [σ] & Arun Singh [ρ]

Abstract- The development of the wing has been always such that it should be able to produce the maximum lift due to the high pressure on the bottom surface and low pressure on the top surface of an airfoil. And these concepts clears that the flow of air/velocity of air will be low on the lower surface and higher on the upper surface of an airfoil. So, due to these differences in pressures and velocity the aerial can produce lift. Here to let fly the Bike in the air the Flat bottomed Airfoil has been chosen and usually the flat bottomed airfoil is called as the Clark Y and this has the feature as Maximum thickness of 11.7% at 28% chord and maximum camber of 3.4% at 42% chord.

Keywords: NACA 4311 airfoil, flat bottomed airfoil, javafoil, clark Y.

I. Introduction

The wing considered is the flat Bottom (NACA 4311) which is a Clark Y type usually called just because it comes under the Flat bottomed surface airfoil and has the features of maximum thickness (t/c): 11.63% @ 30.81%and maximum camber of 3.54% @ 34.52% (when plotted for 81 points) And as in order to provide the maximum lift with minimum drag we will analyze the various kinds of airfoil using the airfoil analysis software called JAVAFOIL. And the main purpose of JAVAFOIL is to determine the lift, drag and the moment characteristics of airfoils. For this reason it uses a potential flow analysis module which is based on the higher order panel method (linear varying vorticity distribution), Since the drag force is referred as the energy loss property, so to minimize it, we will choose various airfoils to compare the best one. So, with the help of JAVAFOIL we will look over the various properties and characteristics of an airfoil.

a) Reason for the choosing of Clark Y type Airfoil is as follows:

i. *Characteristics of Clark Y:*

- Clark Y has a flat bottomed profile of an airfoil and is usually safe for gliding with lower pitch in the air.

Author α: Department of Mechanical Engineering, Christian College of Engineering and Technology, Chhattisgarh Swami Vivekanand University, Bhilia (Durg), C. G, India. e-mail: innovaamit@yahoo.co.in
Author σ: Department of Mechanical Engineering, Siddhaganga Polytecnic, Tumkur, Board of Technical Education, Bangalore-Karnataka, India. e-mail: licchi85@yahoo.co.in
Author ρ: Department of Mechanical Engineering, Sendur Polytecnic, Yashwant Nagar, Board of Technical Education, Banglore-Karnataka, India. e-mail: arun.mars5@gmail.com

Fig 1 : (Clark YH wingroot of a Yak-18T)

b) Applications

Some representative aircraft that used the Clark Y and Yh are listed below:

Clark Y

- Ace Baby Ace
- Aeronca 50 Chief
- Avia B.122
- Curtiss P-6 Hawk
- Fleet Fawn
- Heath Parasol
- Lockheed Vega
- Long Henderson Longster
- Monocoupe 90
- Polikarpov R-5
- Spirit of St. Louis
- Stinson Reliant
- Waco UPF-7

Clark YH

- Currie Wot
- Hawker Hurricane
- Ilyushin Il-2
- Mikoyan-Gurevich MiG-3
- Miles Magister
- Nanchang CJ-6
- Polikarpov I-153
- Stolp SA-900 V-Star
- Yakovlev Yak-18T

Here with the help of an Airfoil tool generator we can construct any profile of required data and can be experimented for results. The five Flat bottom airfoil (NACA-4311, 3310, 3310 with P= 38.6%), 2306, 2206 and Symmetrical airfoil NACA 2412 are generated through this software (Airfoil tool generator) Source: http://www.airfoiltools.com/airfoil/naca4digit

II. Methodology

a) Considering the type of airfoil for analysis on

- NACA 4311 (Flat Bottomed Airfoil)
- NACA 3310 with thickness: 38.6%, (Flat Bottomed Airfoil)
- NACA 3310 with thickness: 31.8%, (Flat Bottomed Airfoil)
- NACA 2306, (Flat Bottomed Airfoil)
- NACA 2206, (Flat Bottomed Airfoil)
- NACA 2412, (symmetrical Airfoil)

On analyzing the above airfoil (a-f) in JAVAFOIL, we have the result as

Table 1

Sl. no	Airfoil	Coefficient Of Lift	Coefficient Of drag	Coefficient Of moment
1.	NACA 4311	0.48101	0.01089	-0.09216
2.	NACA 3310 (p=38. 6%)	0.41505	0.00978	-0.08836
3.	NACA 3310 (p=31. 8%)	0.39486	0.01063	-0.07784
4.	NACA 2306	0.22477	0.00958	-0.04518
5.	NACA 2206	0.21175	0.00955	-0.03669
6.	NACA 2412	0.25889	0.01032	-0.05525

WHILE FOR CLARK Y (from JAVAFOIL) we have the result as:

Table 2 : (Javafoil analysis)

Sl.no	Airfoil	Coefficient Of Lift	Coefficient of drag	Coeff Of moment
1.	Clark Y (NACA 3411)	0.44560	0.01231	-0.09714

Table 3 : (Result from Gedser Simulation), A textbook on the thesis in Aeronautical Engineering

Airfoil	Operational	No roughness	Roughness	Difference	TSR	$C_{P,\ max}$	Wind speed m/s
Operational	200 kW				4.4	0.32	8.5
NACA 4312		235 kW	210 kW	15 %, 5 %	4.4, 4.4	0.36, 0.34	8.5, 8.5
CLARK Y		218 kW	202 kW	9 %, 1 %	4.4, 4.4	0.33, 0.33	8.5, 8.5

Thus, on comparing the above table 1, 2 and 3, we have the best result from NACA 4311 due to the modification of Clark Y type airfoil for maximum lift and minimum drag.

b) Analysis of NACA 4311

Therefore, to analyze the airfoil for its characteristics and performance, a JAVAFOIL has been used which is an Aerodynamic software Source: (http://www.airfoiltools.com/airfoil/naca4digit) for the illustration of various aerodynamic properties.

c) Geometry

This is the first step in JAVAFOIL to obtain the required shape of an airfoil by giving the details of airfoil or by giving the coordinates and the airfoil will be developed selecting the create airfoil option.

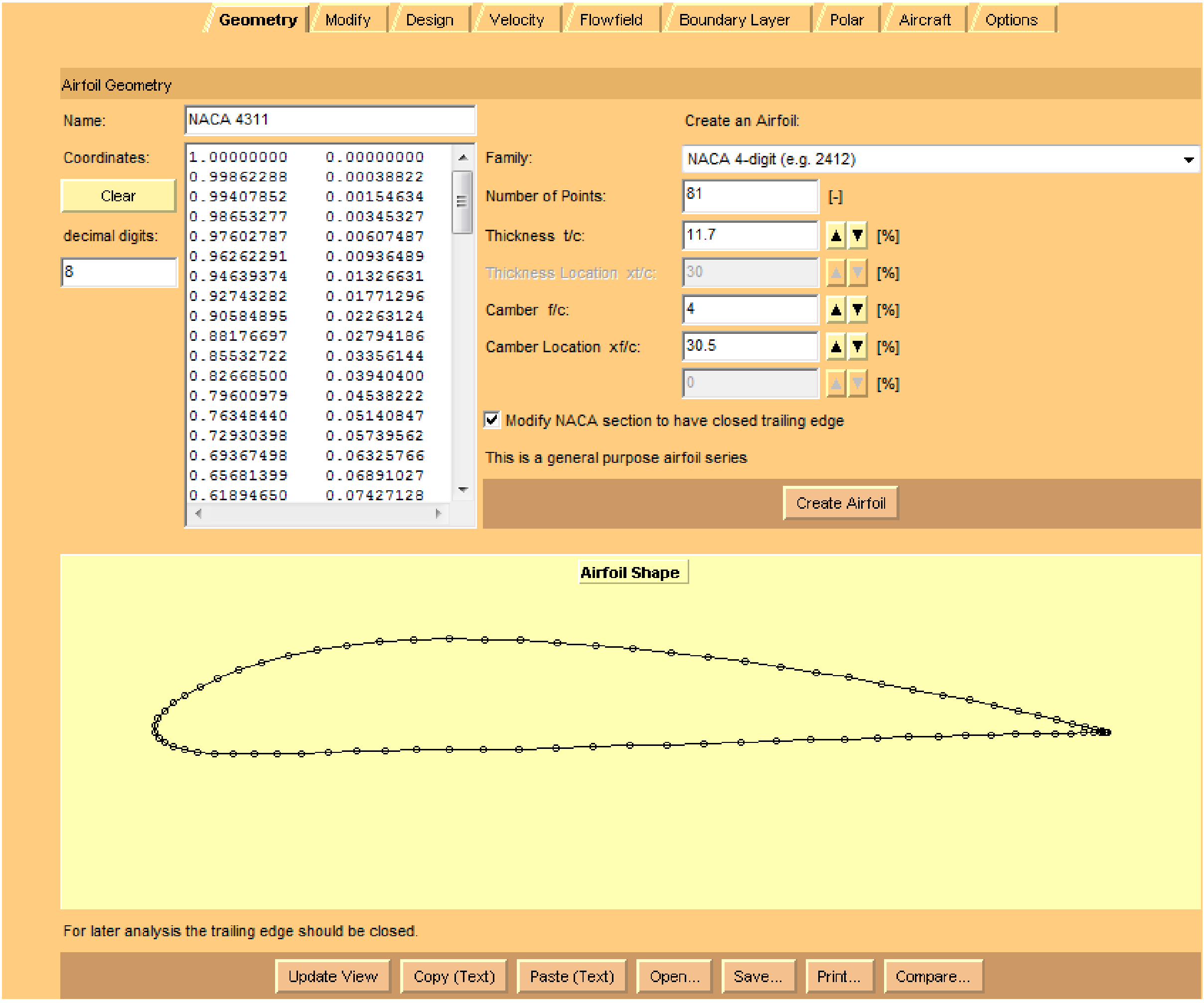


Fig 2 : Geometry card: (here we observe the required airfoil in 2d view in a scale of 1/1)

Modification

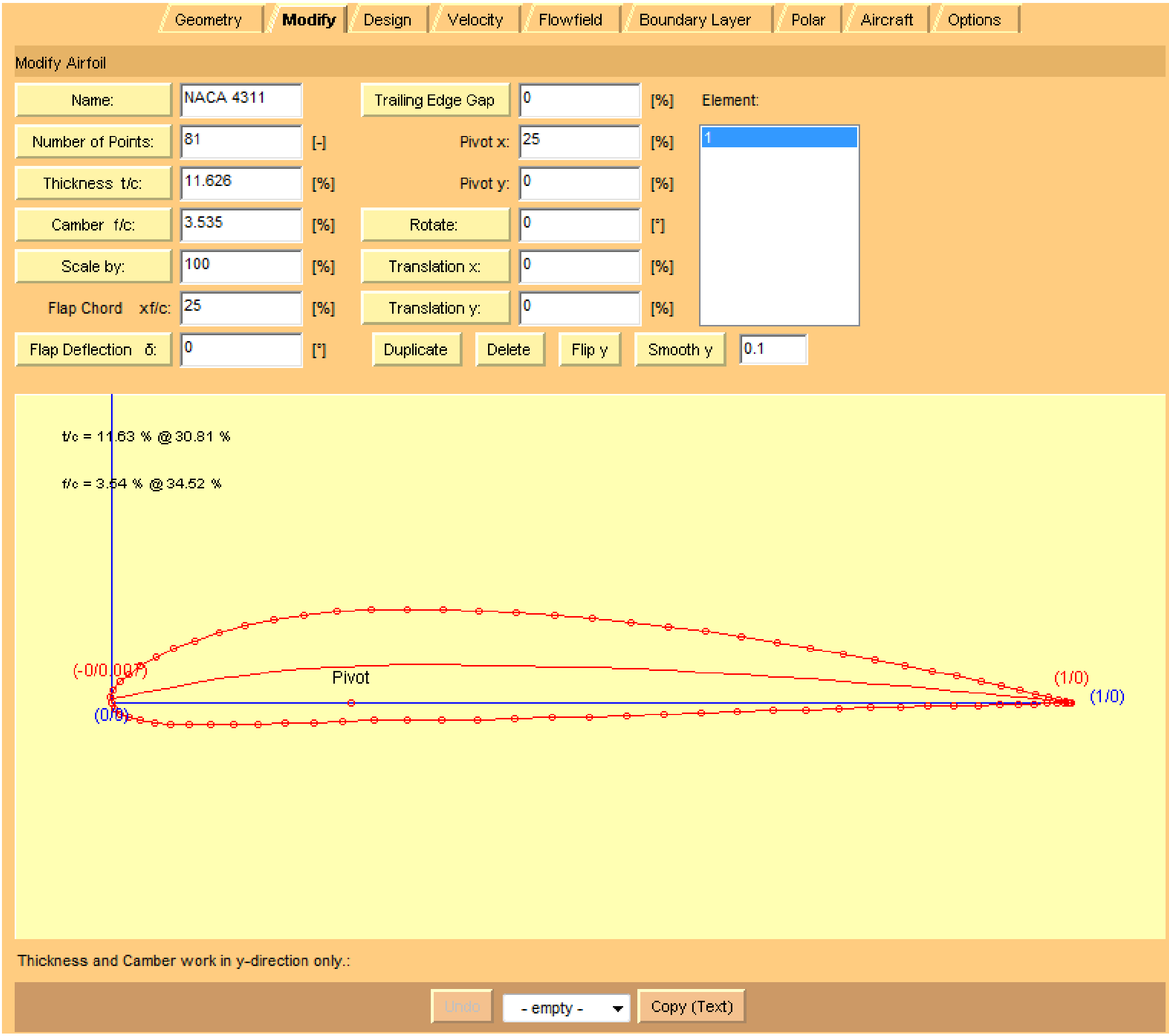


Fig 3 : (Here in the second part of the analysis we have the modified 2D Dimensional view of the Clark Y Airfoil in a scale of 100mm with the trailing edge gap as zero in order to get the smooth aerodynamic nature and named as NACA 4311. This card can be used to perform various modifications to the airfoil geometry. Where we can see the center red line which is called camber line, while the upper and lower dotted line are upper and lower surfaces. Also upper and lower surface forms maximum thickness, which is given as t/c = 11.63 % @ 30.81 % and the maximum camber of f/c =3. 54 is located at 34.52 % of the chord length. While the points at trailing edge are intersecting with the ground)

So, after modification we get properties of aifoil on modified screen are

- Smoothy Y = 0.1, which describes that the airfoil has a smooth spline curve.
- (Pivot x=25%) horizontally at red point describes that the angle of attack of the airfoil is always change by rotating the section around the pivot point specified on the Modify card.

d) Design

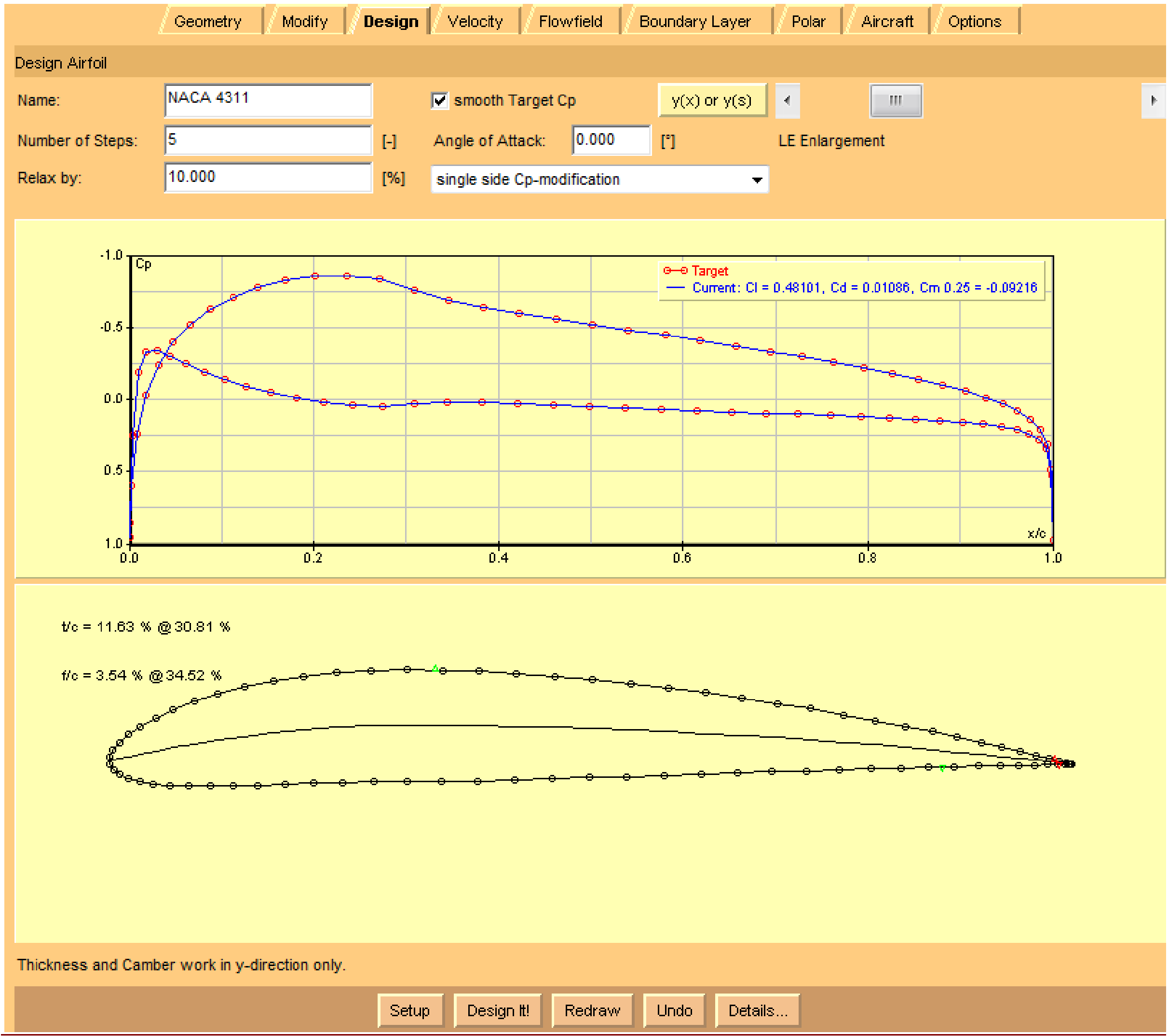
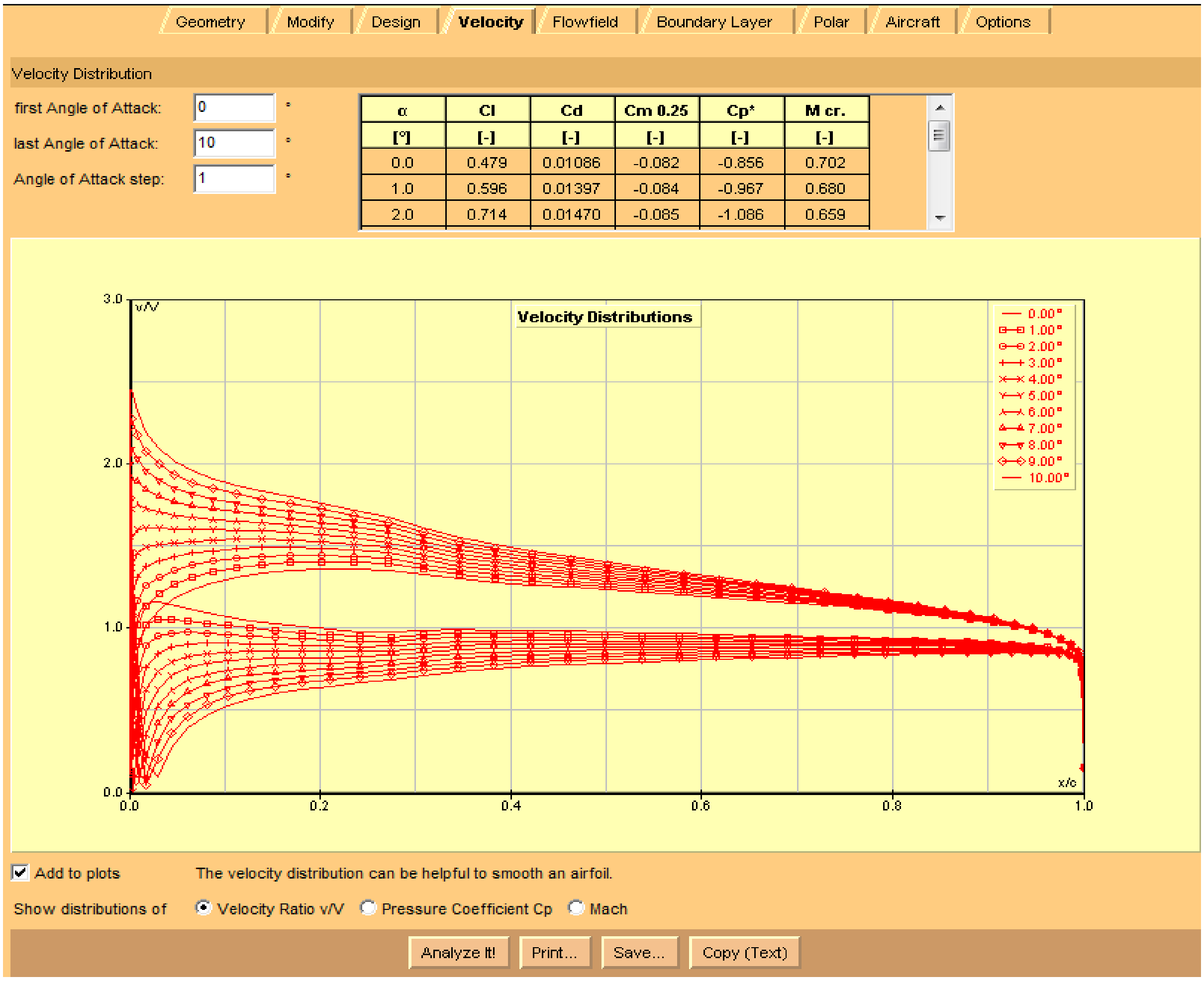


Fig 4 : (Here we can see the 2D Dimensional design of the NACA 4311 Airfoil, and it is delivering a lift of (Coefficient of lift) = 0.48101 and Coefficient of drag as 0.01086 at an angle of attack = 0º, while the graph shows the coefficient of pressure along the length of the chord(c))

- Here from the above (figure 4) we see that a graph is plotted for the airfoil and the upper surface is having the coordinates in negative mostly just because airfoil is experiencing a negative pressure and the lower surface is having a positive coordinates mostly just because it is experiencing a positive pressure which is responsible for the lift of an airfoil.

While, $\frac{L}{D} = \frac{Cl}{Cd}$ ratio gives Glide Ratio of the flight *e) Velocity*

After design first it will calculate the distribution of the velocity on the surface of airfoil which can be integrated to get the lift and the moment coefficient. Number for different angle of attack.



α	Cl	Cd	Cm 0.25	Cp*	M cr.
[°]	[-]	[-]	[-]	[-]	[-]
0.0	0.479	0.01086	-0.082	-0.856	0.702
1.0	0.596	0.01397	-0.084	-0.967	0.680
2.0	0.714	0.01470	-0.085	-1.086	0.659

Fig. 5 : (Velocity distribution past a NACA 4311 at an angle of attack of 10°. The results are for free flow.)

Therefore, the analysis on the velocity provides the information about the behavior of the airfoil which varies with the angle of attack. Hence from the above figure of Velocity distributions we can see that how it has behaved along the length of an airfoil for different angles, Also we can see the coefficient of lift $(C_l)$and Coefficient of drag (C_d) along with the pitching moment (C_m), coefficient of pressure (C_p) and Mach number (M_{cr}).

So, here we get the velocity distribution over airfoil (NACA 4311) for 10º of angle of attack in 10 steps which is shown by the ten upper line and ten lower line indicated on the right hand side top corner of the figure 5.While the (0-0) is the velocity distribution on the surface, where we can see that the velocity distribution is low at the stagnation point as it had dropped downwards due to the high pressure and again the velocity is much high in the upper surface than lower surface and it has again dropped down in the trailing edge without overlapping of upper and lower velocity distribution profile and also it suggest that it is a laminar flow since no overlapping of profile is noticed. And the coefficient of lift (C_l) and drag (C_d), pitching moment(C_m), and critical coefficient of pressure (C_p) are increasing for every 10º angle of attack. Rather the Mach number(M_{cr}) is decreasing for every 10º angle of attack.

While, $M_{0.25}$ (Nm) is the pitching moment at 25% chord point.

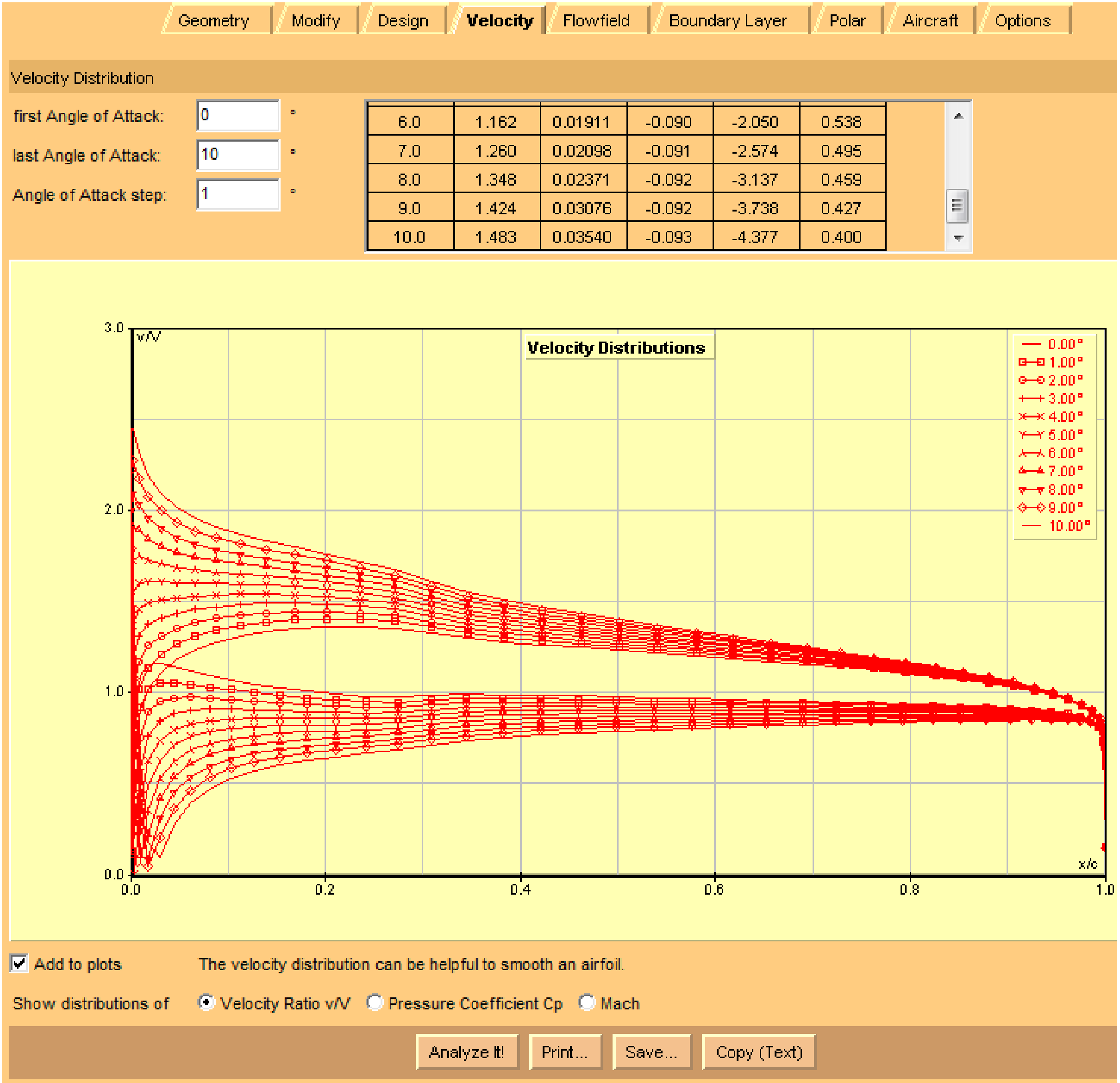


Fig 6 : (Velocity distribution for 10° angle of attack with different characteristics of (C_l), (C_d), (C_m) and Mach number

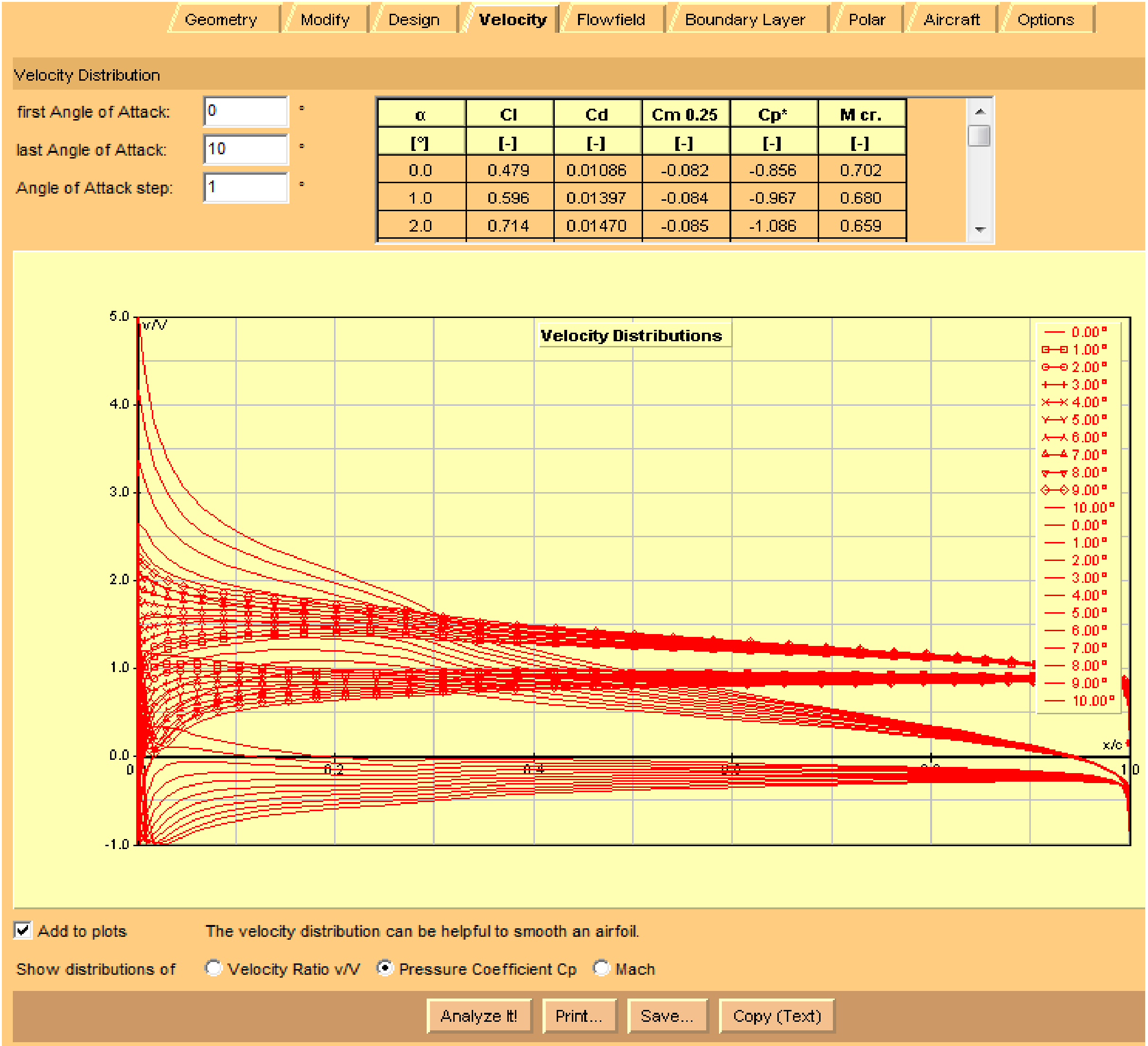


Fig 7 : (Velocity distribution profile with the pressure coefficient)

Therefore from the figure 7, we can see the pressure coefficient in a thin red lines for ten different angle of contact. And the Critical mach number for 0º is 0.702 and for the 10º the mach number 0.400. Hence the mach no is less than 0.8 so it concludes that the flight is subsonic. While the pressure are low in the upper surface of airfoil and high on the lower surface which creates the lift.

f) Mach Number

Mach number (*M* or *Ma*) is the ratio of speed of an object moving through a fluid and the local speed of sound.

$$\mathrm{M} = \frac{v_{\mathrm{object}}}{v_{\mathrm{sound}}}$$

Where, v is the velocity of the source relative to the medium and v_{sound} is the speed of sound in the medium.

Table 4 : (General Plane Characteristic)

Regime:	Mach	Mph	km/h	m/s	General plane characteristics
Subsonic	<0.8	<610	<980	<270	Most often propeller-driven and commercial turbofan aircraft with high aspect-ratio (slender) wings, and rounded features like the nose and leading edges.

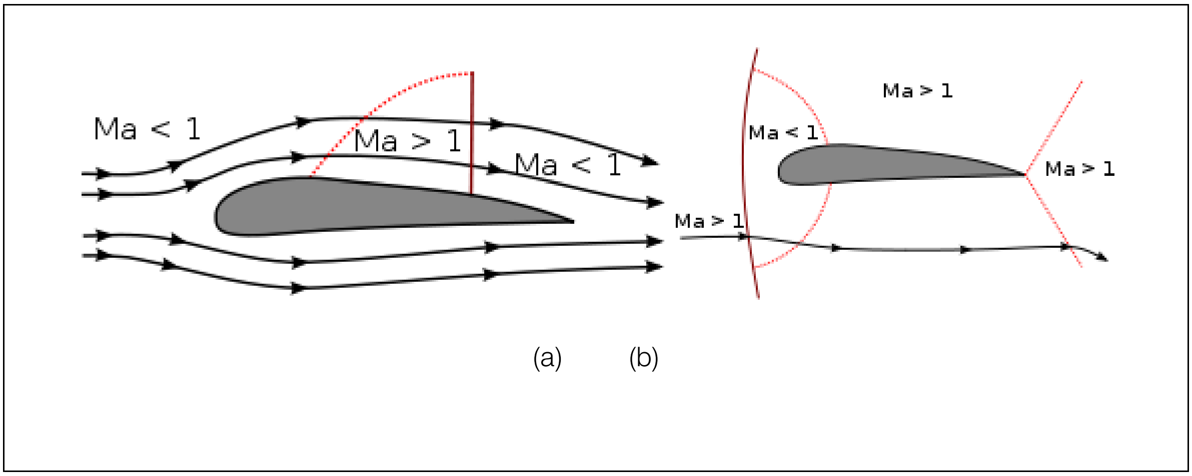


Fig. 8 : Mach number in transonic airflow around an airfoil; M < 1 (a) and M > 1 (b)

g) Thus from Figure 5, 6 & 7

- One can compare the velocity distribution for any angle of attack without and with ground in effect.

h) Flowfeild

Here in (Figure 9) the flow can be seen around the airfoil considering the angle of attack as 10º and with the boundary layer around an airfoil, it also incudes the friction to show the boundary layer to result the exact behaviour of an airfoil as in practical. Where the rectangular grid is showing the local velocity points. And these calculation uses the vorticity distribution on the surface and neglects friction which leads to no seperation flow or a wake behind the airfoil. And the streamlines are calculated from the software with the help of Runge Kutta method and Streamlines around the submersed airfoil can be seen through the blue continuity lines, while the black tuffs are the black discontinued dashes.

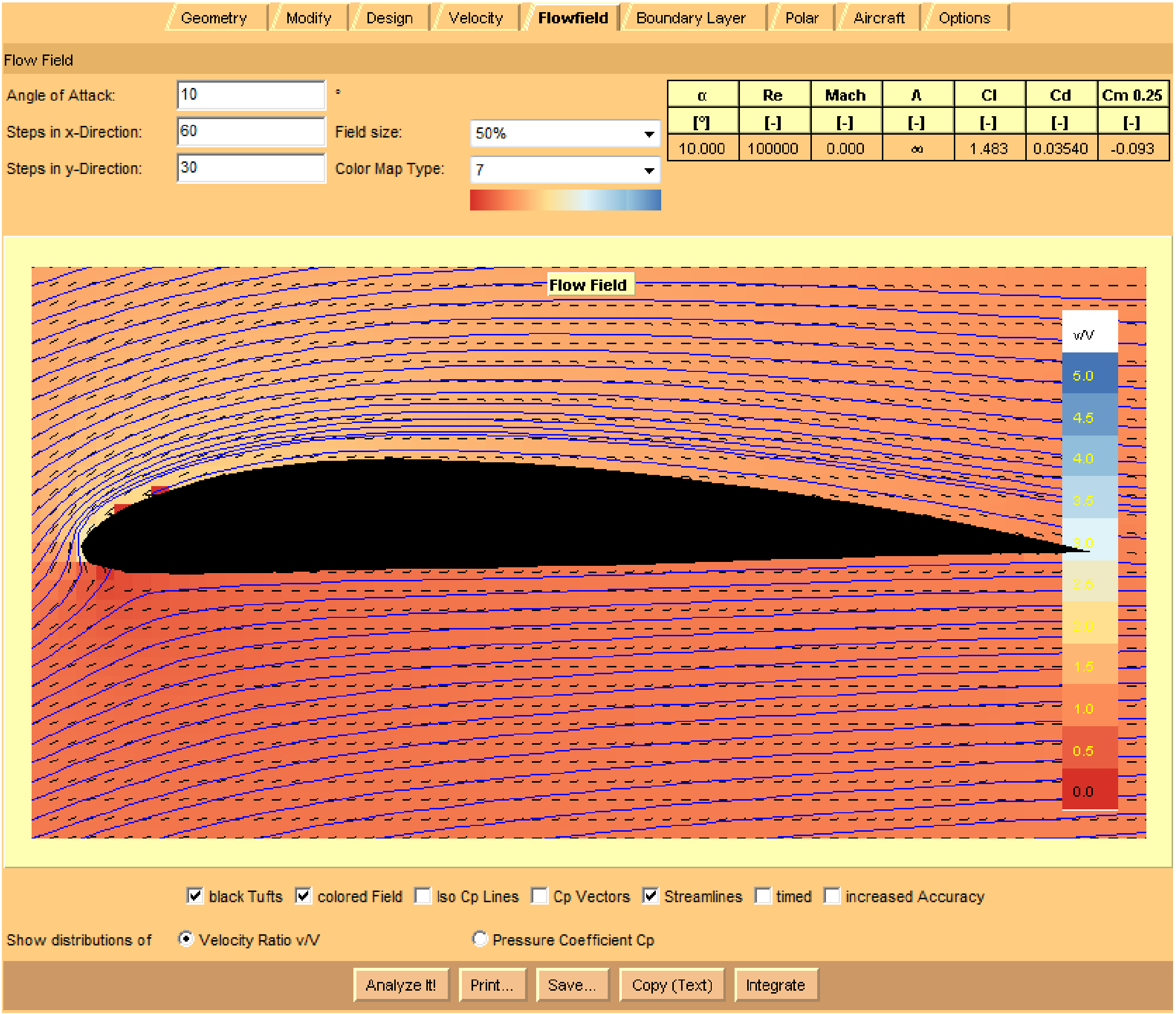


Fig. 9 : Streamlines around the submersed hydrofoil (note that image is clipped at y=0) but the generated surface wave are extending above this border

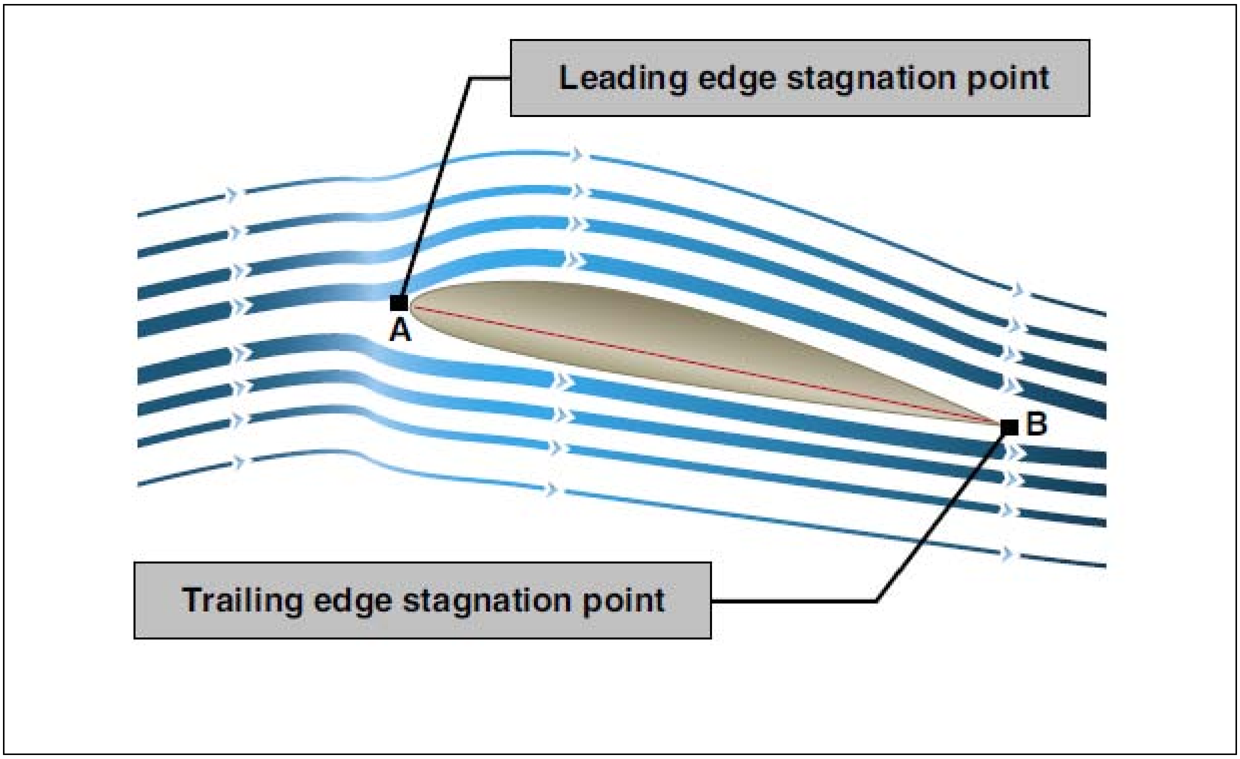


Fig. 10 : (stagnation points)

i) Stagnation Point

A *stagnation point* is a point in a flow field where the local velocity of the fluid is zero.

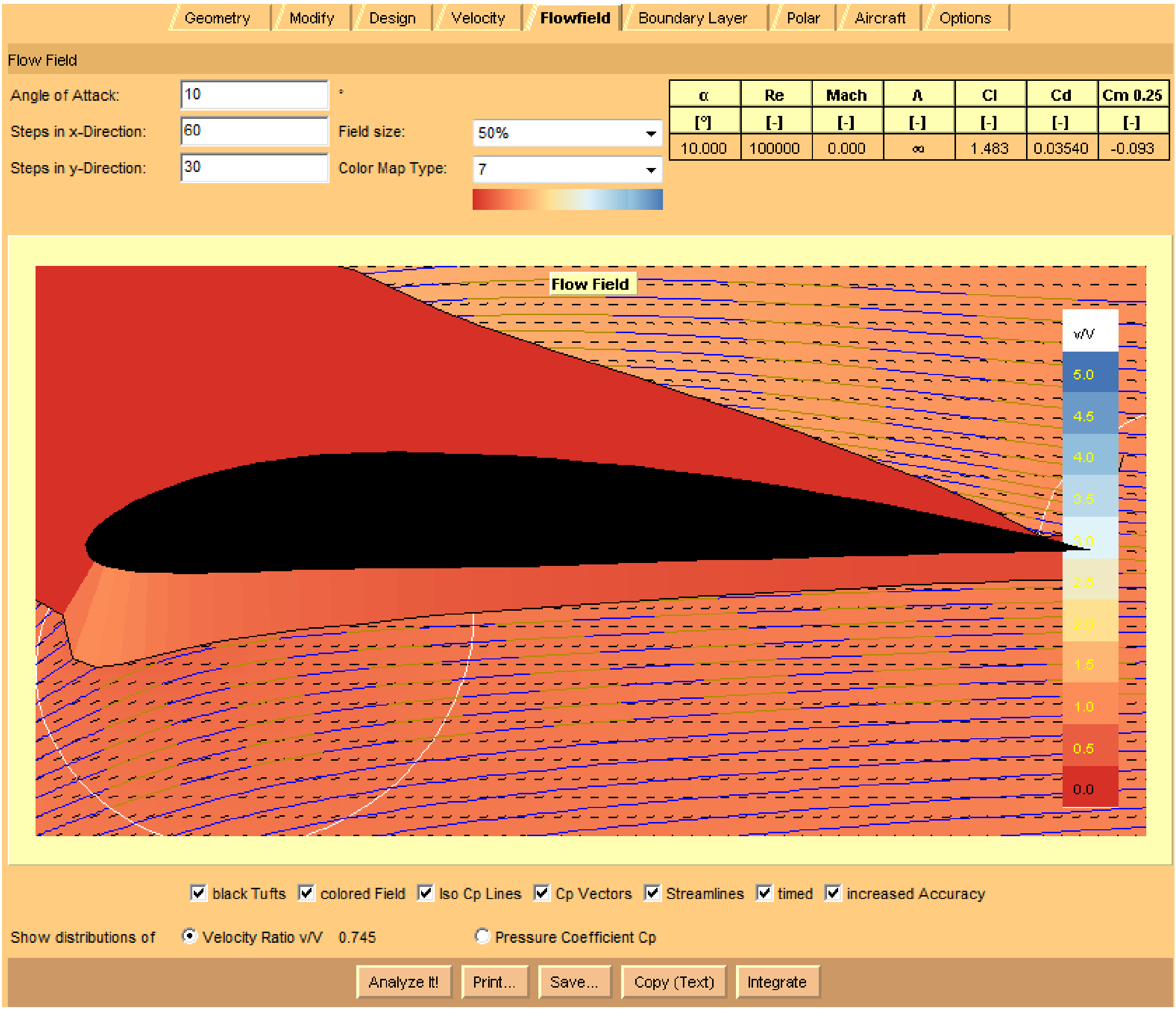


Fig. 11 : (The velocity ratio is zero at the Red location for which the v/V is given as 0.0 at the stagnation point)

j) Pressure Distribution

It has been determined that as air flows along the surface of a wing at different angles of attack there are regions along the surface where the pressure is negative, or less than atmospheric, and regions where the pressure is positive, or greater than atmospheric. This negative pressure on the upper surface creates a relatively larger force on the wing than is caused by the positive pressure resulting from the air striking the lower wing surface.

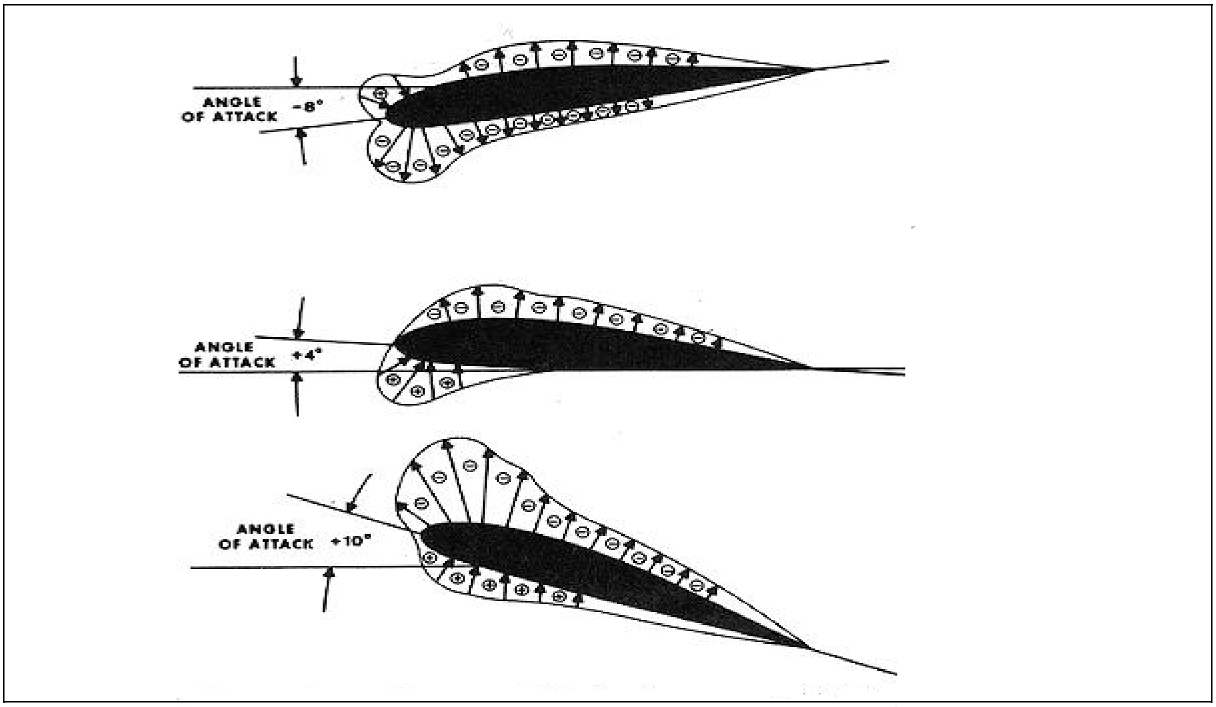


Figure 12 : Pressure distribution on an airfoil

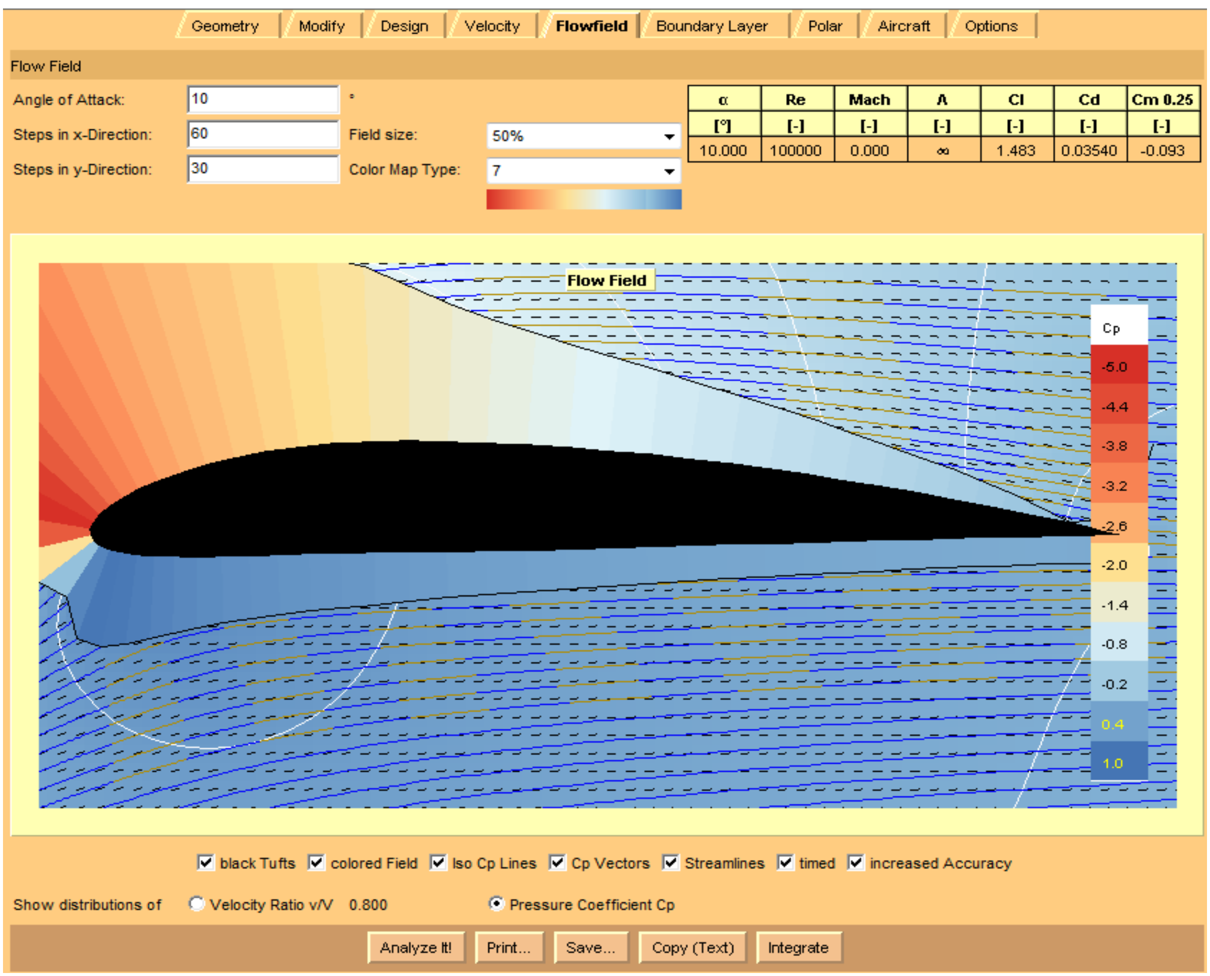


Fig. 13 : (Pressure distribution around airfoil)

While the pressure distribution is described in terms of Pressure coefficient and from the figure we can see the positive pressure and negative pressure along the length of an airfoil. Because the velocity of the flow over the top of the airfoil is greater than the free-stream velocity, the pressure over the top is negative.

Therefore here (from figure 13), we have the centre of pressure at the yellow point/region and we can read the pressure as Coefficient of pressure as (-2.0), similarly we can read the positive pressure which is responsible for the lift of an airfoil as Cp= 1.0 indicated in blue color while the negative pressure can be read which is around the upper surface of an airfoil.

k) Boundary Layer

The boundary layer analysis describes the behaviour of an airfoil around it with the flow of air. The boundary layer module works best in the Reynolds number regime between 500'000 and 20'000'000. During the way towards the trailing edge, the method checks, whether transition from laminar to turbulent or separation occurs.

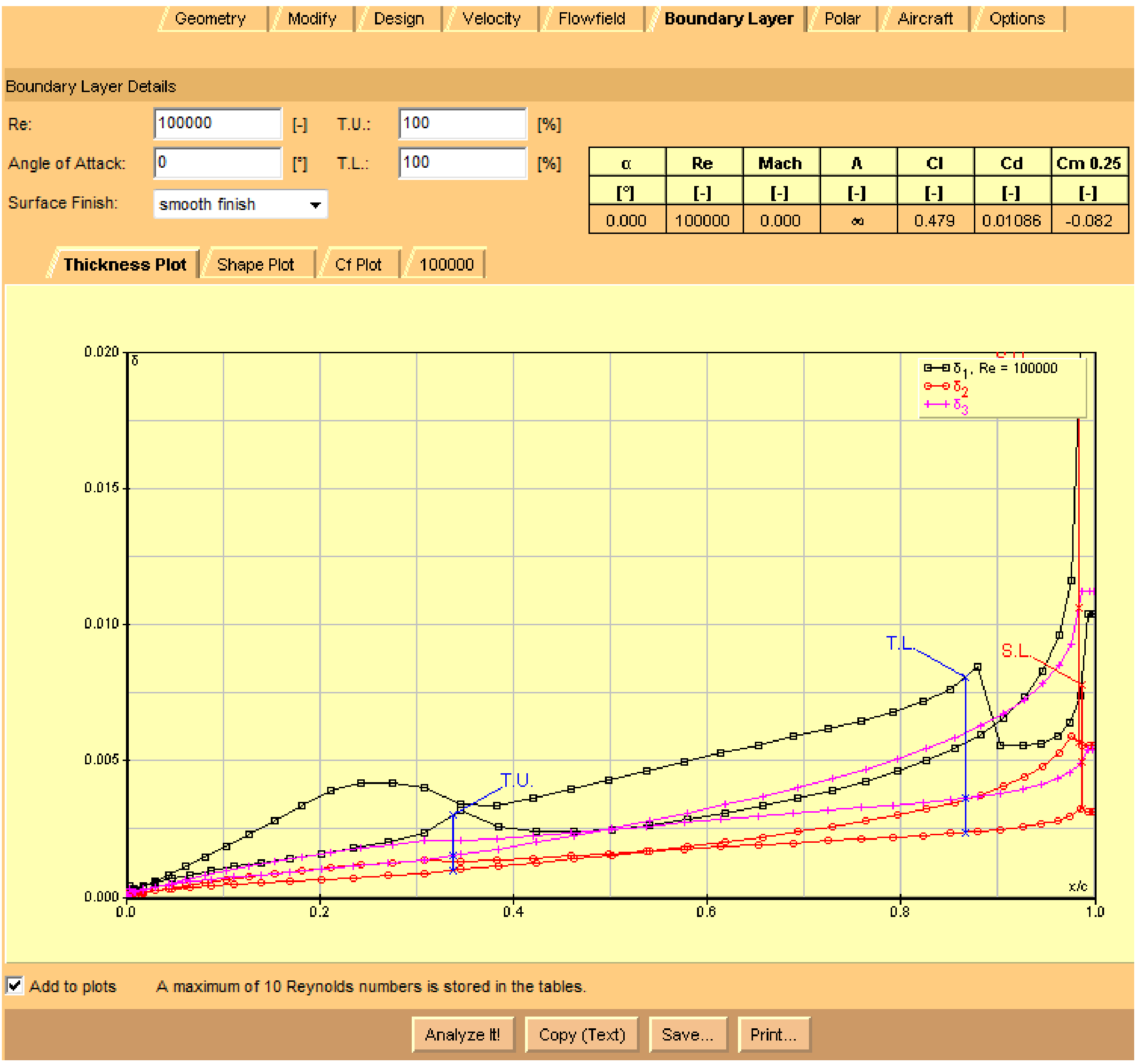


Fig. 14 : Analyzed boundary layer of NACA 4311

Therefore (from figure 14), we see that for δ_1, δ_2 $and\ \delta_3$ the blue line is indicating transition of flow from laminar to turbulent on the upper layer of the airfoil surface (TU) and transition of flow from laminar to turbulent on the lower layer of the airfoil surface (TL) while (SL) is indicating the turbulent separation of the flow near the end of the trailing edge.

Where,

- δ_1 *(m) is the* displacement thickness of boundary layer is the distance by which a surface would have to be moved in the direction perpendicular to its normal vector away from the reference plane in an inviscid fluid stream of velocity u_0 to give the same flow rate as occurs between the surface and the reference plane in a real fluid.

- δ_2 (m) is momentum thickness of boundary layer is the distance by which a surface would have to be moved parallel to itself towards the reference plane in an inviscid fluid stream of velocity u_0 to give the same total momentum as exists between the surface and the reference plane in a real fluid.
- δ_3 (m) is energy thickness of boundary layer
- T is transition laminar-turbulent
- S is turbulent separation
- U is upper surface
- L is Lower surface
- A *shape factor* is used in boundary layer flow to determine the nature of the flow.

$$H = \frac{\delta^*}{\theta}$$, Note $\delta^* = \delta_1/\delta_3$ and $\theta = \delta_2$

Where, H is the shape factor, δ^* is the displacement thickness and θ is the momentum thickness. The higher the value of *H*, the stronger the adverse pressure gradient. A high adverse pressure gradient can greatly reduce the Reynolds number at which transition into turbulence may occur.

- $H_{12} = \delta_1/\delta_2$ is the shape factor of boundary layer and $H_{32} = \delta_3/\delta_2$ is the shape factor of boundary layer, C_f is the local skin friction coefficient.

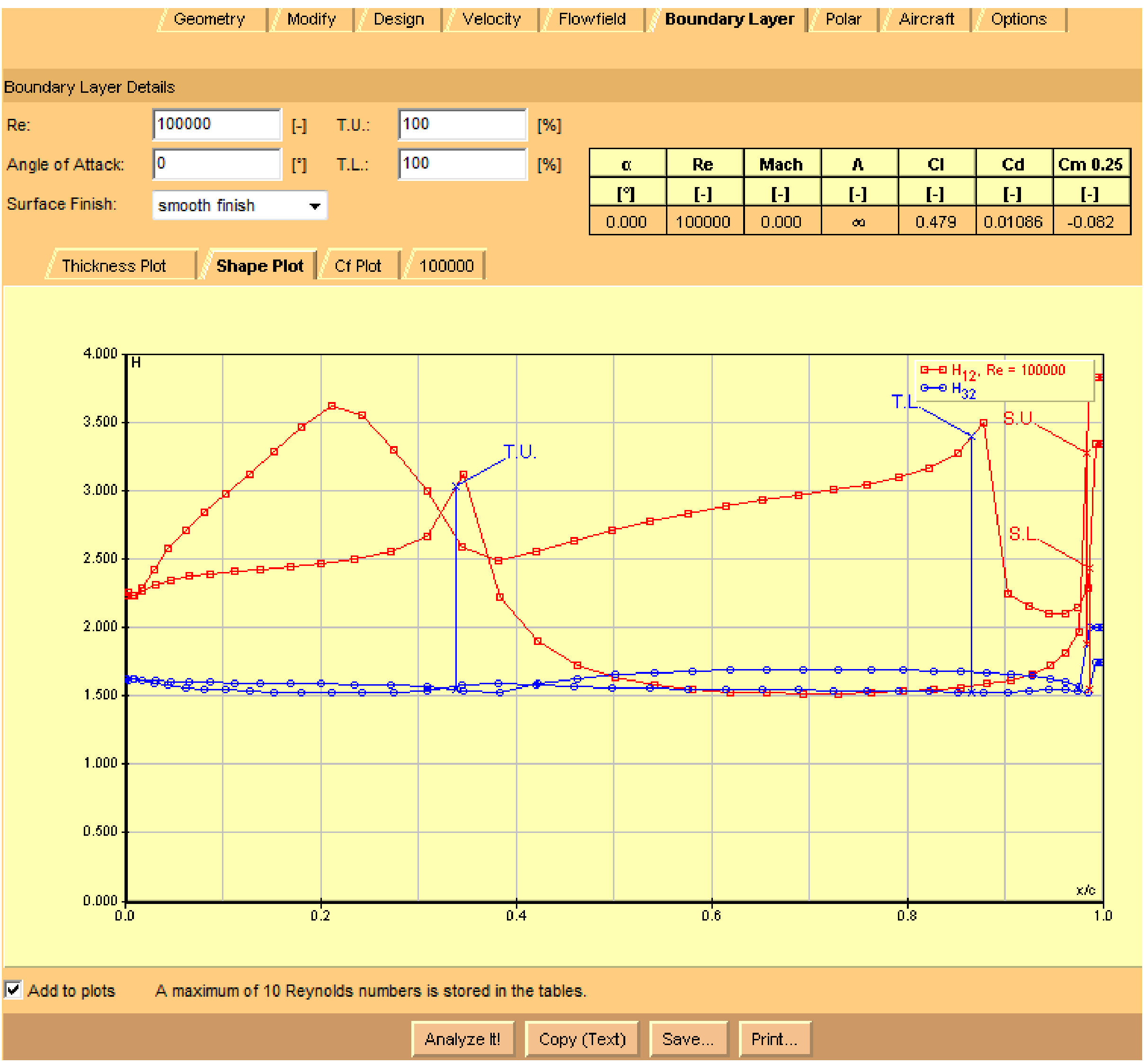


Fig. 15 : Flow state graph on airfoil NACA 4311

Pressure gradient is high (red line at point $H_{12} > 3.5$ for the Reynolds no. Here (from figure 18) it can be observed that for the maximum thickness of the airfoil, number (Re) $=$100000. Also we can see the for the H_{32}

Where,

$H_{32<1.51509}$ will have the laminar flow and $H_{12} <$ 1.46 will have the turbulent flow, which can be observed from the figure 18, at TU,TL and SU,SL. The blue line is indicating transition of flow from laminar to turbulent on the upper layer of the airfoil surface (TU) and transition of flow from laminar to turbulent on the lower layer of the airfoil surface (TL) while (SL) and (SU) is indicating the turbulent seperation of the flow near the end of the trailing edge in the lower and upper surface of NACA 4311 in the both cases of H_{12} and H_{32}.

Table 5 : Shape factor boundary layer condition

Flow State	Separation assumed when
Laminar	$H_{32} < 1.51509$
Turbulent	$H_{12 < 1.46}$

Also shape factor displacement thickness/ momentum thickness has the relation as

$$H_{12} = \frac{\delta 1}{\delta 2}$$

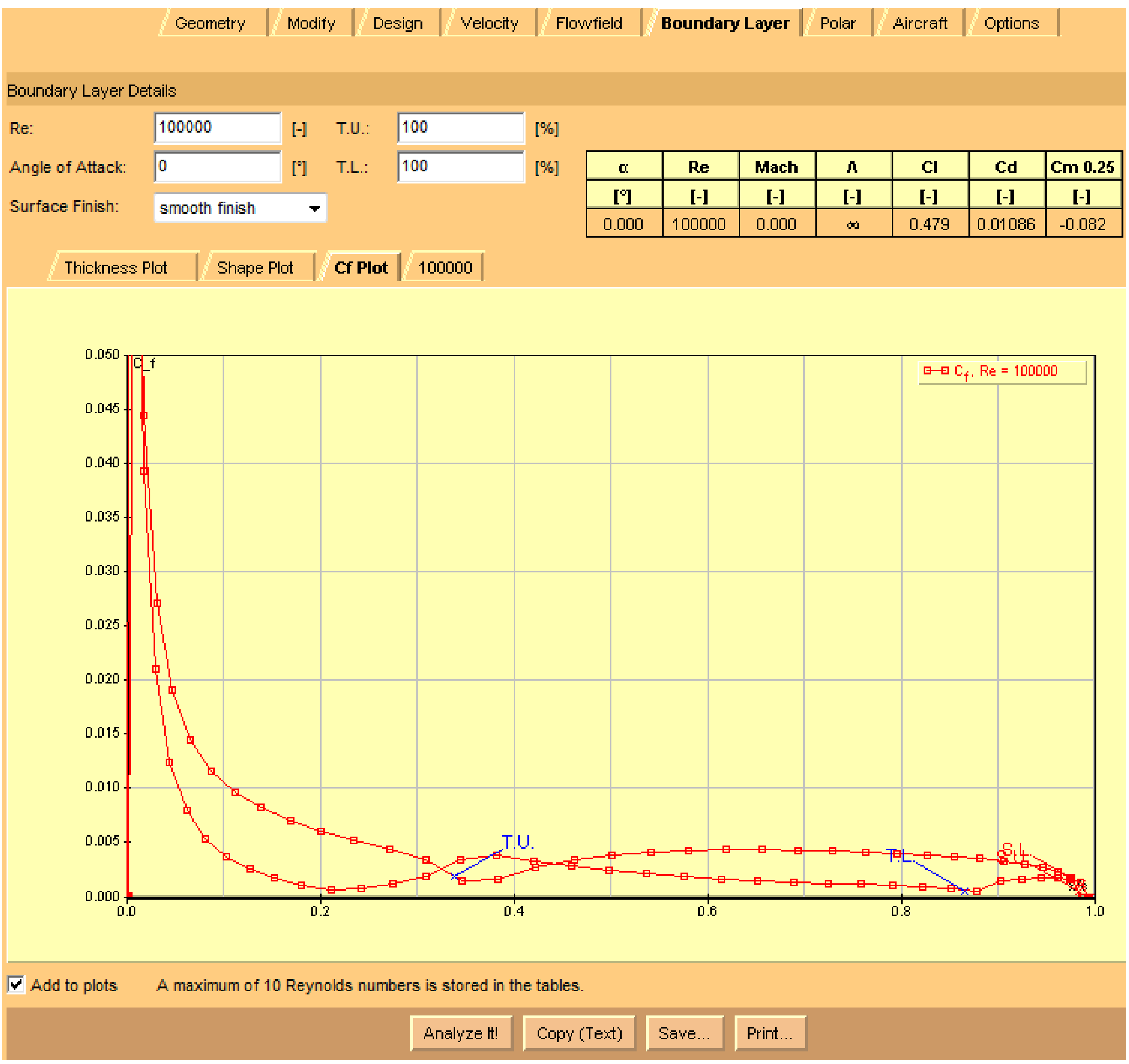
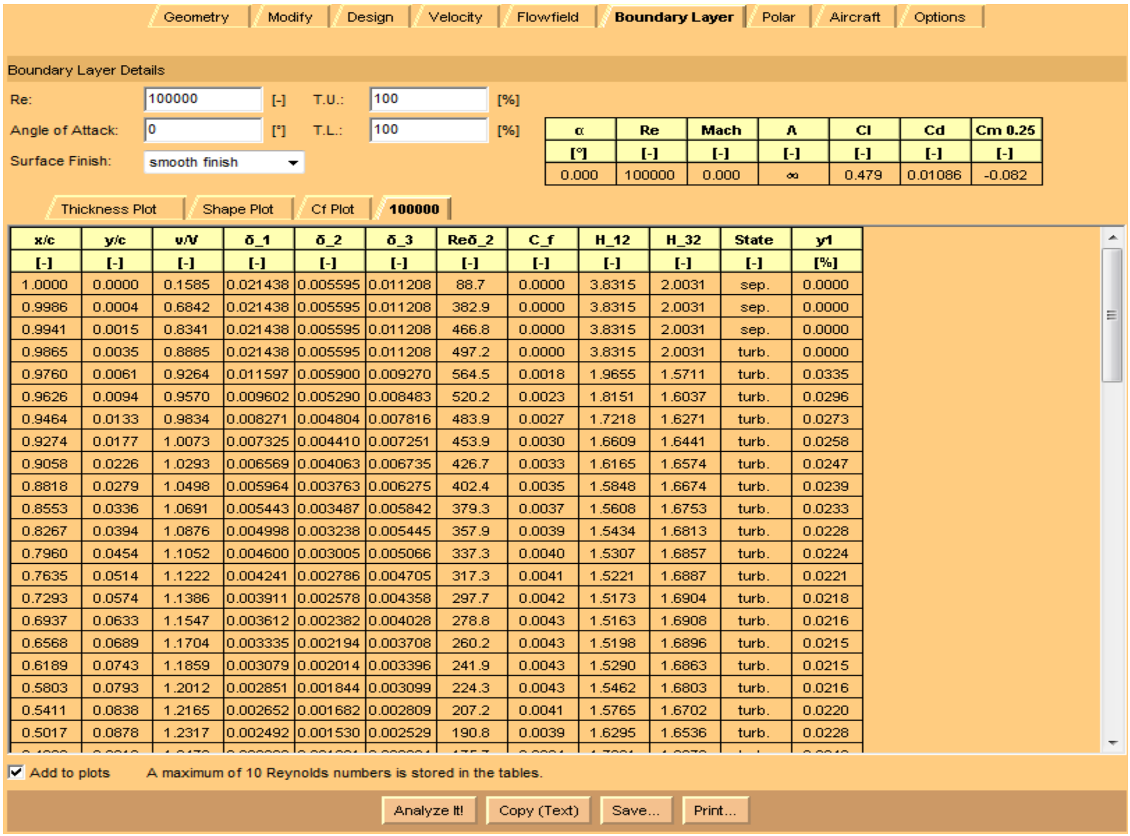


Fig. 16 : (local skin friction coefficient)



x/c	y/c	v/V	δ_1	δ_2	δ_3	Reδ_2	C_f	H_12	H_32	State	y1
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[%]
1.0000	0.0000	0.1585	0.021438	0.005595	0.011208	88.7	0.0000	3.8315	2.0031	sep.	0.0000
0.9986	0.0004	0.6842	0.021438	0.005595	0.011208	382.9	0.0000	3.8315	2.0031	sep.	0.0000
0.9941	0.0015	0.8341	0.021438	0.005595	0.011208	466.8	0.0000	3.8315	2.0031	sep.	0.0000
0.9865	0.0035	0.8885	0.021438	0.005595	0.011208	497.2	0.0000	3.8315	2.0031	turb.	0.0000
0.9760	0.0061	0.9264	0.011597	0.005900	0.009270	564.5	0.0018	1.9655	1.5711	turb.	0.0335
0.9626	0.0094	0.9570	0.009602	0.005290	0.008483	520.2	0.0023	1.8151	1.6037	turb.	0.0296
0.9464	0.0133	0.9834	0.008271	0.004804	0.007816	483.9	0.0027	1.7218	1.6271	turb.	0.0273
0.9274	0.0177	1.0073	0.007325	0.004410	0.007251	453.9	0.0030	1.6609	1.6441	turb.	0.0258
0.9058	0.0226	1.0293	0.006569	0.004063	0.006735	426.7	0.0033	1.6165	1.6574	turb.	0.0247
0.8818	0.0279	1.0498	0.005964	0.003763	0.006275	402.4	0.0035	1.5848	1.6674	turb.	0.0239
0.8553	0.0336	1.0691	0.005443	0.003487	0.005842	379.3	0.0037	1.5608	1.6753	turb.	0.0233
0.8267	0.0394	1.0876	0.004998	0.003238	0.005445	357.9	0.0039	1.5434	1.6813	turb.	0.0228
0.7960	0.0454	1.1052	0.004600	0.003005	0.005066	337.3	0.0040	1.5307	1.6857	turb.	0.0224
0.7635	0.0514	1.1222	0.004241	0.002786	0.004705	317.3	0.0041	1.5221	1.6887	turb.	0.0221
0.7293	0.0574	1.1386	0.003911	0.002578	0.004358	297.7	0.0042	1.5173	1.6904	turb.	0.0218
0.6937	0.0633	1.1547	0.003612	0.002382	0.004028	278.8	0.0043	1.5163	1.6908	turb.	0.0216
0.6568	0.0689	1.1704	0.003335	0.002194	0.003708	260.2	0.0043	1.5198	1.6896	turb.	0.0215
0.6189	0.0743	1.1859	0.003079	0.002014	0.003396	241.9	0.0043	1.5290	1.6863	turb.	0.0215
0.5803	0.0793	1.2012	0.002851	0.001844	0.003099	224.3	0.0043	1.5462	1.6803	turb.	0.0216
0.5411	0.0838	1.2165	0.002652	0.001682	0.002809	207.2	0.0041	1.5765	1.6702	turb.	0.0220
0.5017	0.0878	1.2317	0.002492	0.001530	0.002529	190.8	0.0039	1.6295	1.6536	turb.	0.0228

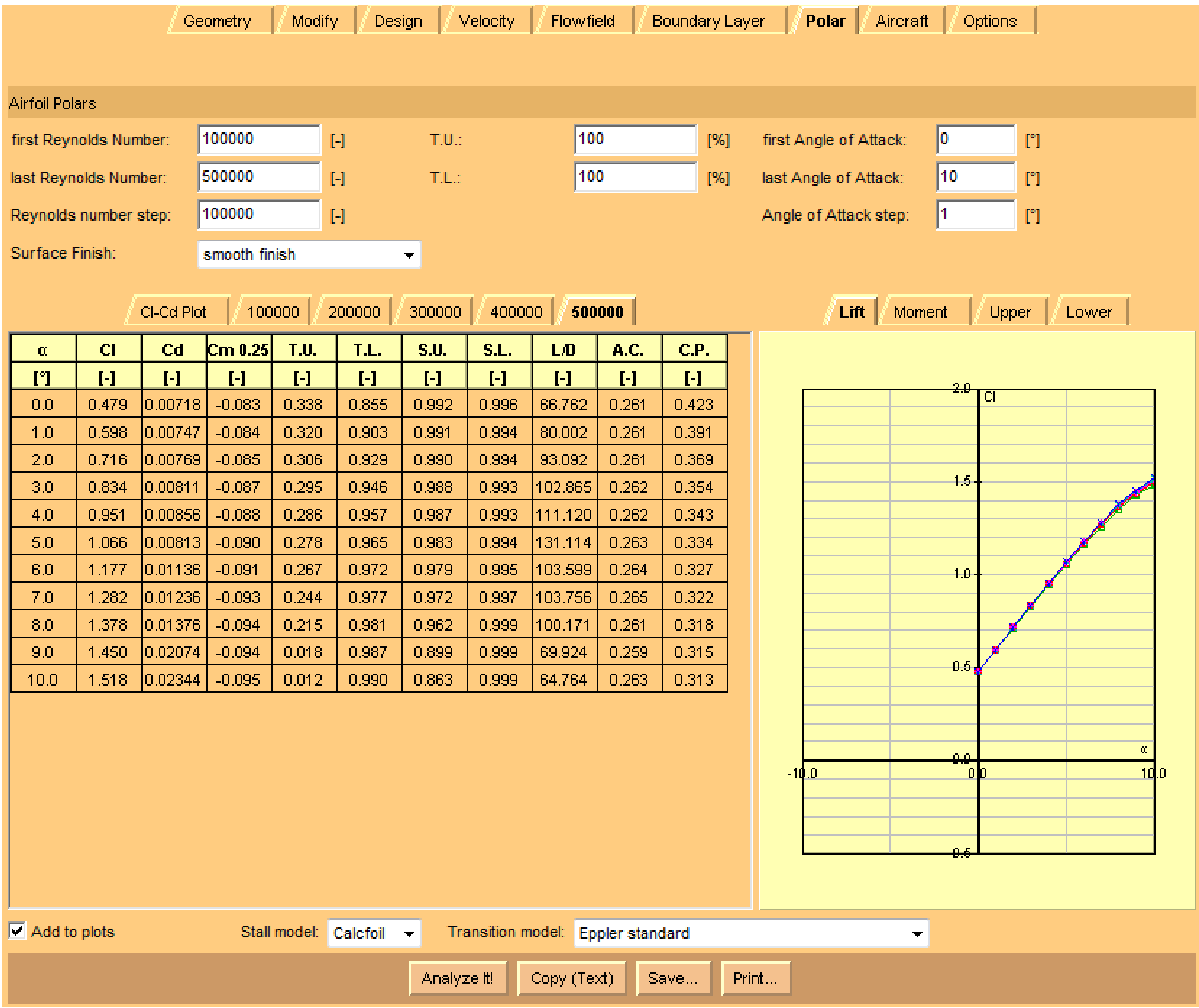
Fig. 17 : (different value of calculated properties for the boundary layer)

Fig. 18 : (Lift versus drag coefficient polars for a NACA 4311 airfoil and wings of different aspect ratio)

The graph above shows the effect of lift over drag coefficient. Starting with infinite aspect ratio (aspect ratio = 0 on the Options card). It can be clearly seen, that for five Reynolds number (Re) the lift is increasing for larger value of (Re). As the lift will be maximum if the flow of air around the airfoil will be maximum.

l) Polars for Constant Wing Loading

The lift coefficient of any body depends on the speed because the wing loading is usually fixed during flight – flying at low lift coefficients results in high speeds (and high Reynolds numbers) and vice versa. Therefore the operating points during flight would slice through a set of polars having constant Reynolds numbers. It is possible to create polars more closely related to the conditions during flight. This would require adjusting the wind speed to each lift coefficient, which is cumbersome and expensive in a wind tunnel, but feasible in a numerical tool like J AVAFOIL. And here we use the Aircraft card to calculate polars for a given wing loading.

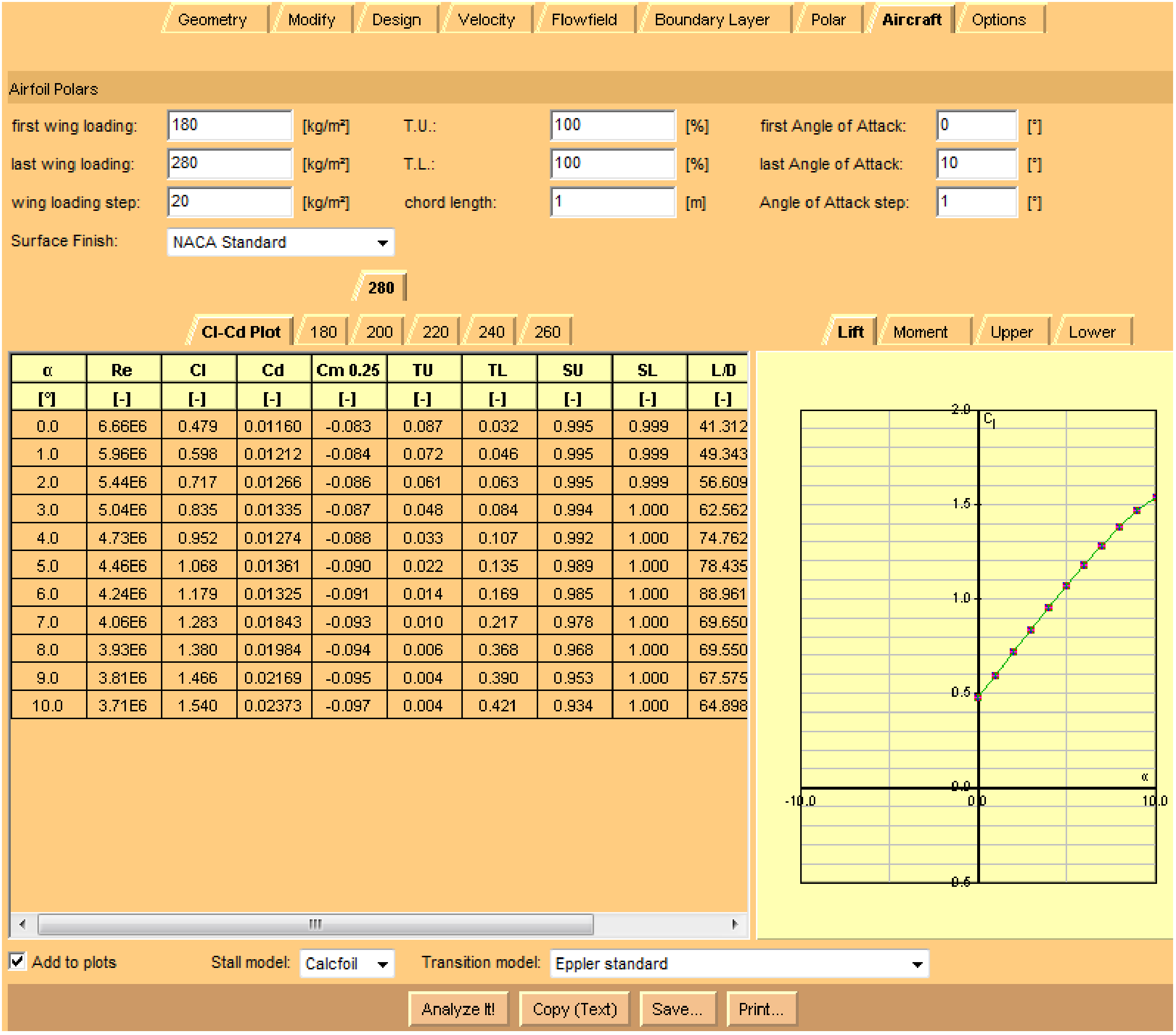


α	Cl	Cd	Cm 0.25	T.U.	T.L.	S.U.	S.L.	L/D	A.C.	C.P.
[°]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
0.0	0.479	0.00718	-0.083	0.338	0.855	0.992	0.996	66.762	0.261	0.423
1.0	0.598	0.00747	-0.084	0.320	0.903	0.991	0.994	80.002	0.261	0.391
2.0	0.716	0.00769	-0.085	0.306	0.929	0.990	0.994	93.092	0.261	0.369
3.0	0.834	0.00811	-0.087	0.295	0.946	0.988	0.993	102.865	0.262	0.354
4.0	0.951	0.00856	-0.088	0.286	0.957	0.987	0.993	111.120	0.262	0.343
5.0	1.066	0.00813	-0.090	0.278	0.965	0.983	0.994	131.114	0.263	0.334
6.0	1.177	0.01136	-0.091	0.267	0.972	0.979	0.995	103.599	0.264	0.327
7.0	1.282	0.01236	-0.093	0.244	0.977	0.972	0.997	103.756	0.265	0.322
8.0	1.378	0.01376	-0.094	0.215	0.981	0.962	0.999	100.171	0.261	0.318
9.0	1.450	0.02074	-0.094	0.018	0.987	0.899	0.999	69.924	0.259	0.315
10.0	1.518	0.02344	-0.095	0.012	0.990	0.863	0.999	64.764	0.263	0.313

Fig. 19 : (polar condition of flight for differnt Reynolds number (Re))

m) Aircraft

The Polars card analyzes the airfoil for constant Reynolds numbers. For an aircraft in flight the lift coefficient depends on the flight speed and hence on the Reynolds number.



α [°]	Re [-]	Cl [-]	Cd [-]	Cm 0.25 [-]	TU [-]	TL [-]	SU [-]	SL [-]	L/D [-]
0.0	6.66E6	0.479	0.01160	-0.083	0.087	0.032	0.995	0.999	41.312
1.0	5.96E6	0.598	0.01212	-0.084	0.072	0.046	0.995	0.999	49.343
2.0	5.44E6	0.717	0.01266	-0.086	0.061	0.063	0.995	0.999	56.609
3.0	5.04E6	0.835	0.01335	-0.087	0.048	0.084	0.994	1.000	62.562
4.0	4.73E6	0.952	0.01274	-0.088	0.033	0.107	0.992	1.000	74.762
5.0	4.46E6	1.068	0.01361	-0.090	0.022	0.135	0.989	1.000	78.435
6.0	4.24E6	1.179	0.01325	-0.091	0.014	0.169	0.985	1.000	88.961
7.0	4.06E6	1.283	0.01843	-0.093	0.010	0.217	0.978	1.000	69.650
8.0	3.93E6	1.380	0.01984	-0.094	0.006	0.368	0.968	1.000	69.550
9.0	3.81E6	1.466	0.02169	-0.095	0.004	0.390	0.953	1.000	67.575
10.0	3.71E6	1.540	0.02373	-0.097	0.004	0.421	0.934	1.000	64.898

Fig. 20 : (Wing loading condition for maximum weight and result for different angle of attack)

Notes

- To check the airfoil for different angles of attack, one can analyze complete polar for different angles of attack and Reynolds numbers. The angle of attack is changed by rotating the airfoil around the point (0.25/0), which will change the height of the airfoils 25% chord point above ground somewhat.

n) Option

The aspect ratio is used for an approximate correction of the results on the Polar and Aircraft cards for a finite wing.

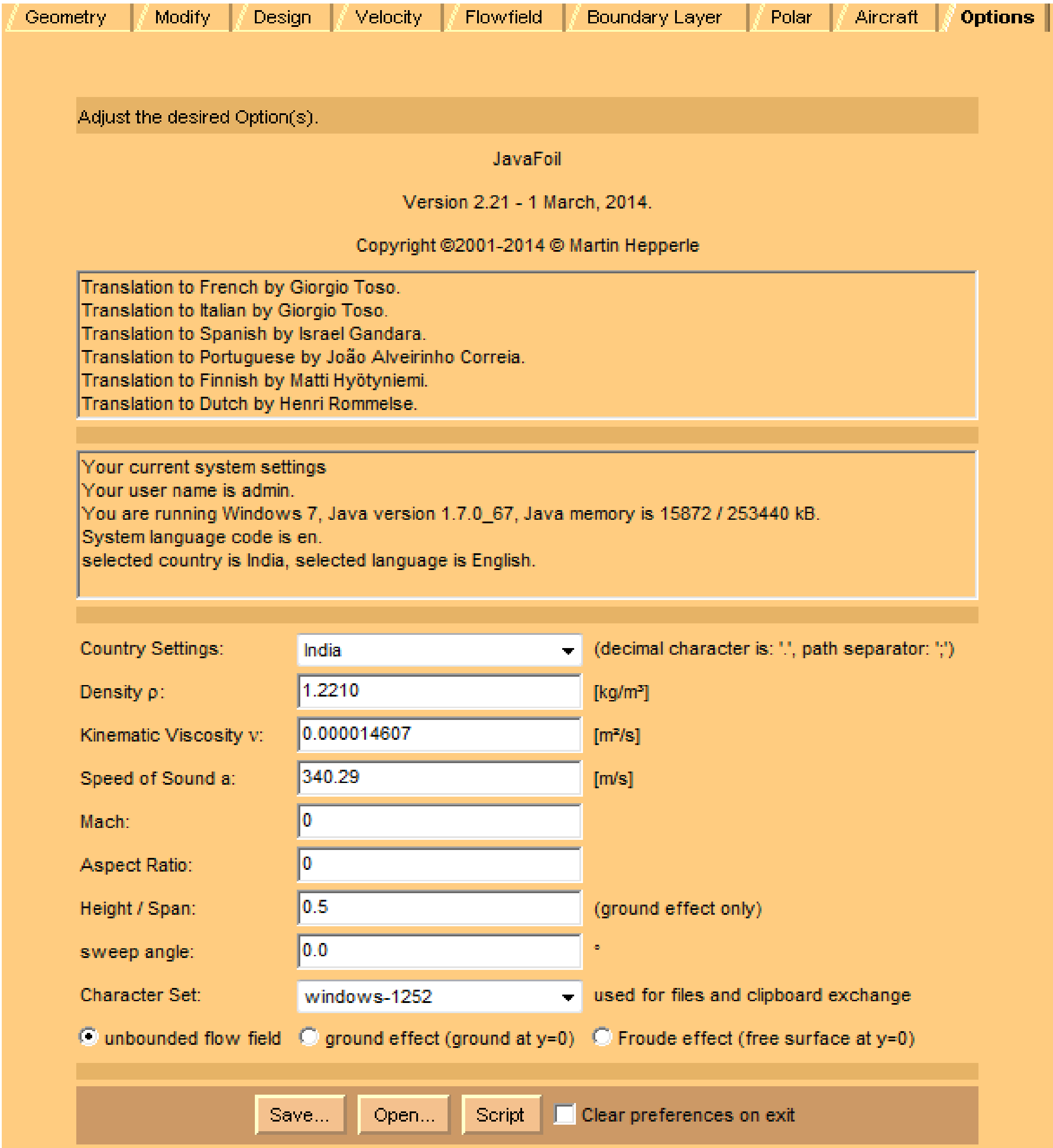


Fig. 21 : (Setup values for the analysis of Airfoil data)

III. Conclusion

From the analysis program in Java Foil for an NACA 4311 it is observed that on the final loading of both front and rear wings, the result is positive and there is no drop in coefficient of lift for angle of attack considered ($\propto=10^{0}$) with the consideration of ground effect with a air density of 1.2210 kg/m³ and kinematic viscosity (v) of which results for the unbounded flow for the swipe angle of 0.0 because the wing considered is uniform in cross section (rectangular) behaving under speed of sound (a=340.29 m/s) as it result the mach number.

References Références Referencias

1. Amit Singh Dhakad, and Pramod Singh. "Flying bike concept." International Research Journal of Mechanical Engineering, Vol 1, PP. 001-011. March 2014.
2. Amit & Arun Singh. "Power Requirement for Flying Bike." *International Journal of Innovative Research and Development* [Online], 3.5 (2014): n. pag. Web. 17 Jun. 2014.
3. Mehrdad Ghods. "Theory of wings and wind tunnel test of a NACA 2415 airfoil" Technical

Communications for Engineers, The University of British Columbia, pp-1-13, July 23, 2001.
4. Christopher A Lyon, Andy P Broren, Philippe Gigu'ere, Ashok Gopalarathnam, Michael S Selig (1997). Summary of low speed airfoil data, soar Tech publications, Virginia.
5. Dava Newman, Pete Young (2004). Introduction to aerospace and Design-Chapter 4, Massachuetts Institute of Technology, pp.1-17.
6. Jonathan Densie, Model Aircraft Design, Defence Science and Technology organisation-Researching Aircraft Flight Mechanics, Melbourne http://www.-concept2creation.com.au/xstd_files/Jon%20Dansie %20Model%20Aircraft%20Design.pdf.
7. Mustafa Cavcar, e-material (2005): The International Standard Atmosphere (ISA), Anadolu University, 26470 Eskisehir, Turkey. pp. 1-7
8. Wikipedia on aircrafts (lift, thrust, propellers and theory of flight) http://en.wikipedia.org/wiki/Aircraft
9. Wing Design e-Book (2010). National Aeronautic and Space Administration, Museum in a box series - Aeronautics Research Mission Directorate.
10. Fan wing manned aircraft project (http://www.-fanwing.com/fanwing%20manned%20aircraft%20project%202013.pdf)
11. B. L Singhal, Fluid Machinery, Tech-Max Publications, ISBN 978-81-8492-805-1,First edition, (2011).
12. Airfoil generator (software), www.airfoil.com/-airfoil/naca4digit
13. Air properties, M= http://www.engineeringtoolbox.-com/dynamic-absolute-kinematic-viscosity-d_412.-htmlM=v http://www.engineeringtoolbox.com/air-absolute-kinematic-viscosity-d_601.html
14. Textbook Investigation of Different Airfoils on Outer Sections of Large Rotor Blades, Torstein Hiorth Soland and Sebastian Thuné 2012, Report code: MDH.IDT.FLYG.0254.2012.GN300.15HP.Ae
15. Scott Richards, Keith Martin, and John M. Cimbala, *ANSYS Workbench Tutorial – Flow Over an Airfoil,* Penn State University Latest revision: (17 January 2011), pp1.
16. A. Firooz and M. Gadam, Turbulence Flow for NACA 4412 in Unbounded Flow and Ground Effect with Different Turbulence Models and Two Ground Conditions: Fixed and Fixed moving ground conditions, Int. Conference on Boundary And Interior Layers BAIL 2006 (Eds), University of Gottingen, 2006.
17. Charles D, NASA Technical Paper 2969, NASA Supercritical Airfoils: A Matrix of Family -Related Airfoils, Harris Langley Research Center, Hampton, Virginia, 1990.
18. Richard L. Fearn, Airfoil Aerodynamics Using Panel Methods, Mathematica Journal 10:4, Wolfram Media, Inc (2008).
19. E.M Sparrow and J. L. Gress, Technical note 4311, Prandtl number effects on unsteady forced convection heat transfer, National Advisory committee for Aeronautics, Clevelan, ohio, Washington, june 1958.
20. IRA H. ABBOTT, ALBERT E. VON DOENHOFF and LOUIS S. STIVERS, SUMMARY OF AIRFOIL DATA NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS REPORT No. 824, Langley Memorial Aeronautical, Laboratory Langley Field, Va.1945.
21. Hamidreza Abedi, CFD with Open Source software, A course at Chalmers University of Technology Taught by H° akan Nilsson, Project work, (Nov-10-2011).
22. *Java Foil,* Martin Hepperle, 1996-2008 Source (http://www.mh-aerotools.de/aerfoils/jf_applet.htm)
23. Rama Krishna N Parasaram and and T N Charyulu, AIRFOIL PROFILE DESIGN BY REVERSE ENGINEERING BEZIER CURVE, ISSN 2278 – 0149. www.ijmerr.com Vol. 1, No. 3, October 2012.
24. Helmut Sobieczky and DFVLR Gottingen, RELATED ANALYTICAL, ANALOG AND NUMERICAL METHODS IN TRANSONIC AIRFOIL DESIGN, Reprint: AIAA 79-1566 (1979).
25. Dr. Richard Eppler, Eppler Airfoil Design and Analysis Code, Petersburg, USA.
26. Clark y Wikipedia.
27. J. F. Marchman and Todd D Werme , Clark y airfoil performance at low Reynolds Number, Virginia polytechnic institute and state university, Blackburg, Virginia 1-7, jan 9-12, 1984/reno, Nevada, Publisher: American institute of Aeronautics and Astronauts.
28. Timur Dogan, Michael Conger, Maysam Mousaviraad, Tao Xing and Fred Stern, Verification and Validation of Turbulent Flow around a Clark-Y Airfoil 58:160 Intermediate Mechanics of Fluids, CFD LAB 2, Hydroscience & Engineering The University of Iowa, IA 52242-1585, p 1-54.
29. Prof. E.G. Tulapurkara, Flight dynamics-I: Chapter-3
30. Tanveer Chandok, Analysis of an airfoil using Computational Fluid Dynamics, Independent research thesis at the Georgia Institute of Technology, 12/17/2010, P 1- 21.
31. Dr. Asiminia Kazakidi, Fluids dynamics software lab, second summer school on embodied intelligence," simulation and modelling within embodied intelligence. Heraklion 70013, Crete, Greece, 27 june- 1 july 2011.
32. Robert D. Quinn and Leslie Gong, Measurement on a Hollow Cylinder at a Mach Number of 3.0 in flight boundary layer, NASA technical paper 1764, Dryden flight Research centre, Edwards, California Nov 1980, p 1-52.
33. Christian J. Kähler, Sven Scharnowski, Christian Cierpka, High resolution velocity profile measurements in turbulent boundary layers,16th Int

Symp on Applications of Laser Techniques to Fluid Mechanics Lisbon, Portugal, 09-12 July, 2012, P 1-8.
34. Lelanie Smith, An interactive boundary layer modelling methodology for Aerodynamic flows, Submitted in partial fulfilment of the degree *Masters of Engineering* Department of Mechanical and Aeronautical Engineering University of Pretoria November 2011, p 1-75.
35. D.G. Mabet and W. G. Sawer, Experimental studies of the boundary layer on a flat Plate at mach no. 2.5 to 4.5, Procurement Executive Ministry of Defence Aeronautical Research Council, Reports and Memoranda by Aerodynamic Department, R.A.E., Bedford, London her majesty's stationary office.1976, p 1-101.
36. Y. B. Suzen, P. G. Huang, Lennart S. Hultgren and David E. Ashpis, Predictions of Separated and Transitional Boundary Layers Under Low-Pressure Turbine Airfoil Conditions Using an Intermittency Transport Equation, Journal of Turbo machinery National Aeronautics and Space Administration, Glenn Research Centre at Lewis Field, Cleveland, OH 44135, JULY 2003, Vol. 125 / 455 (p1-10) 455-464.
37. D. W. Holder and R. F. Cash, Experiments with a two dimensional aerofoil designed to be free from turbulent boundary layer separation at small angles of incidence for all mach numbers, reports and memoranda number 3100, Ministry of supply, N.P.L, London her majesty stationary office, august, 1957 .p.1-52.
38. T. A. Cook, Measurement of boundary layer and wake of two aerofoil sections at high Reynolds numbers and high-subsonic mach numbers Aeronautical Research Council Reports and Memoranda, Aerodynamic Department., R.A.E., FARNBOROUGH, LONDON: Her majesty's stationary office, 1973, Reports and Memoranda number. 3722, june 1971, R.A.E. TECHNICAL REPORT 71127-A.R.C. 33 660, P 1-91.
39. J. Hogendoorn and C Proefschrift Heat Transfer Measurements in Subsonic Transition boundary layer, (Textbook) ISBN 90-386-0550-1 NUGI831, 1997, P. 1-135.
40. Jens M and Arne v. Johnson, MEASUREMENT IN A FLAT PLATE TURBULENT BOUNDARY LAYER, Department of Mechanics, Royal Institute of Technology. 100 44 Stockholm, Sweden. P 1-6.
41. Dr. R. Rajappan and V. Pugazhenthi, Finite Element Analysis of Aircraft Wing Using Composite Structure, IJES, ISSN: 2319 – 1813 ISBN: 2319 – 1805, Vol2, Issue: 2, 2013, p-74-80.
42. Tim Meyers, Ian Clark and Aurelien Borgoltz, Aerodynamic Measurement On a Wind Turbine Airfoil, *Virginia Tech, Blacksburg, VA 24061, U.S.A.*, William J. Devenport, *Virginia Tech, Blacksburg, VA 24061, U.S.A. Virginia Tech, Blacksburg, VA 24061, U.S.A.,* P 1-21.
43. Galal Bahgat Salem and Mohammed Khalil Ibrahim, Measurement of Pressure Distribution over a Cambered Airfoil, Aerospace Engineering Department, Aerodynamics Laboratory – Experiment #1, Cairo University, Faculty of Engineering, April 2004, Page 1-8.
44. Dr. Peyman Taheri NUMERICAL CALCULATION OF LIFT AND DRAG COEFFICIENTS FOR AN ELLIPSE AIRFOIL, ENSC 283 INTRODUCTION TO FLUID MECHANICS, ENSC 283 (Spring 2013), Simon fraser university.p1-5.
45. MEHMET MERSINLIGIL, AIRFOIL BOUNDARY LAYER CALCULATIONS USING INTERACTIVE METHOD AND TRANSITION PREDICTION TECHNIQUE (Thesis), AEROSPACE ENGINEERING, SEPTEMBER 2006, p1- 113.
46. Saso Knez, Airfoil Boundary layer, University of Ljubljana, 25 may 2005, p 1-15.
47. NASA STI PROGRAM, NASA SP-7037 (303), April 1994.
48. M. E. Lores, K. P. Burdges and *G.* D. Shrewsbury, Analysis of a Theoretically Optimized Transonic Airfoil, NASA Contractor Report 306s, Prepared for Ames Research Centre under Contract NAS2-8697, *Lockheed Georgia Company Marietta, Georgia,* NOVEMBER 1978, P 1-104.
49. *Dan M and Somers,* EXPERIMENTAL AND THEORETICAL LOW-SPEED AERODYNAMIC CHARACTERISTICS OF A WORTMANN AIRFOIL AS MANUFACTURED ON A FIBERGLASS SAILPLANE, NASA TECHNICAL NOTE, *Langley Research Centre*, *Hampton, Va. 23665,* FEBRUARY 1977.
50. P. Migliore AND S. Oerlemans, Wind Tunnel Aeroacoustic Tests of Six Airfoils for Use on Small Wind Turbines, conference paper, *AIAA Wind Energy Symposium Reno,* Contract No. DE-AC36-99-GO10337, *Nevada January 5–8, 2003-2004,* P 1-18.
51. Philip N. Johnson-Laird, Flying bicycles: How the Wright brothers invented the Airplane, Mind & Society (2005) 4: 27–48 DOI 10.1007/s11299-005-0005-Received: 31 May 2004 / Accepted: 28 June 2004, Fondazione Rosselli 2005.p1-22.

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Design Customization and Development of Split Hopkinson Pressure Bar for Light and Soft Armour Materials

By Shishay Amare Gebremeskel, Neelanchali Asija, Aryan Priyanshu, Hemant Chouhan & Naresh Bhatnagar
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GJRE-A Classification : FOR Code: 091399p

DESIGNCUSTOMIZATIONANDDEVELOPMENTOFSPLITHOPKINSONPRESSUREBARFORLIGHTANDSOFTARMOURMATERIALS

Strictly as per the compliance and regulations of:

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Highlights

- Particular SHPB is developed for impact characterization of soft and light materials.
- FEM simulation is done for the critical parts of the setup.
- Hydraulic momentum arrest is provided to avoid repeated loading of specimens.
- Isolation of launching unit vibration is provided to eliminate noise signals.
- Velocity-pressure calibration is performed.

Abbreviations

CAE	Computer Aided Engineering
DAQ	Data Acquisition
FBD	Free Body Diagram
FEM	Finite Element Method
FOS	Factor of Safety
FRP	Fibber Reinforced Polymers
HPB	Hopkinson Pressure Bar
PLC	Programmable Logic Control
SHPB	Split Hopkinson Pressure Bar
STF	Shear Thickening Fluids

Author α σ ρ Ѡ ¥: Department of Mechanical Engineering, Indian Institute of Technology Delhi, Hauzkhas, New Delhi, India. e-mail: nareshb@mech.iitd.ac.in

I. Introduction

An increasing demand of high strength, lightweight and soft armour material systems, especially for military applications, resulted in interesting research challenge to characterize possible materials at ballistic impacts. Nowadays FRPs and STFs are the main materials of emphasis as a solution for the mentioned challenge. Thus, their high strain rate impact behaviours need to be studied, since their properties at static loadings could not be employed for dynamic designs. For this reason, having an appropriate test setup is significant and SHPB is a potential set up to be used, Jadhav [1]. Since available SHPB setups are designed for particular challenges in terms of capacity, material type and other requirements, design customization and development of own setup for soft materials is found to be necessary.

Thus, studying the historical background in advancements of SHPB set up starting from its first innovation up to the latest customizations is important for this particular design. According to studies in [2-5] Bertram Hopkinson primarily developed a set up called HPB in 1914 using a single bar and its modification was made in 1948 in which electrical equipment was incorporated to record the stress waves. Following this modification, Herbert Kolsky split the HPB in to incident and transmission bars in 1949 and hence the name SHPB. It is this Split Hopkinson Pressure Bar set up that has been widely used in many research studies to characterize materials at dynamic loadings. Articles [6-13] addressed a common design theory for any customization of SHPB design that could result in acceptable calibration curves and stress wave shapes. T he customization made by Robertson et al. [14] is one of the advancements that enabled the setup to test materials at strain rates ranging 50 to 104 s-1. In a more suitable approach, Haines et al. [9] followed two design phases as mechanical system and DAQ system. The mechanical system includes the launching unit which has the high pressure cylinder as a main part, the pressure bars (striker bar, incident bar and transmission bar) and the momentum arrest. The DAQ system includes the strain gauges, oscilloscope and computer as per Guedes et al. [15].

To design the pressure bars, more emphasis should be given to the extent of stress waves to be propagated through and the following governing equations for strain rate ($\dot{\varepsilon}$), strain (ε) and stress (σ) on specimen to be tested on the setup are used, Akil [2] and Song &Chen [16]:

$$\dot{\varepsilon}(t) = -\frac{2C_b}{L_s}\varepsilon_r(t),\ \varepsilon(t) = -\frac{2C_b}{L_s}\int_0^t \varepsilon_r(t)dt, \text{ and } \sigma(t) = \frac{E_b A_b}{A_s}\varepsilon_t(t)$$

Where, C_b is the elastic wave velocity in the bar, L_s is the sample length and A_s and A_b are the specimen and bar cross-sectional areas respectively. ε_i, ε_r and ε_t are incident, reflected and transmitted strains measured from strain gages on the bar, respectively. The pressure bars are of the same material having elastic modulus E, density ρ, same cross sectional area Ab, and hence same elastic wave velocity $C_b = \sqrt{E/\rho}$.

Since the conventional SHPB setup has been designed for testing hard and metallic materials it is not suitable for softer materials like polymers and STFs. Thus, newly customized SHPB setup has to be designed depending on the nature of the planned test specimen and expected maximum impact velocity. As part of the customization process, selection of material for the pressure bars is very important as the stress wave transmission is highly dependent on it. Even though polymeric and aluminium bars are found to be suitable for the stated softer materials in terms of impedance matching as per Meng & Li [17] and Butt & Xue [18], the viscoelastic behaviour causing wave dispersion and plastic deformation of both these bar materials made them unfit for higher velocity impacts. To overcome the stated drawbacks of polymer and aluminum bars, titanium bars are employed in this particular design as it has higher yield strength with high elastic deformation behavior at impacts of extreme speeds. This study presents the mechanical design analysis of main parts of customized SHPB, where the critical ones are supported and validated by FEM simulation using Abaqus CAE.

The current design has the following specifications that made it suitable to test softer materials at higher strain rates; (a) Pressure cylinder designed to accommodate extreme pressure up to 300 bar of nitrogen gas. (b) Automated control of gas filling, firing and instantaneous striker bar velocity recording. (c) Separate foundation and construction of the pressure cylinder to isolate the vibration in order not to get transmitted to the bars which otherwise would create more noise signals. (d) Complete arrest of momentum using hydraulic momentum trapping system. (e) Slender titanium alloy (ASTM Grade-5) bars with diameter of 12 mm having reasonably lower acoustic impedance suitable for high strain rate impact testing of softer materials. (f) Negligible friction between bars and bearings, by using custom designed adjustable three-point miniature ball bearings. (g) Simplified axis alignment provisions. The overall work is presented in the following chapters.

II. Materials and Methods

a) Design of launching unit, the bars and momentum trapping

i. Design of high pressure gas cylinder

Using the design procedures of pressure vessel:

From theory of elasticity according to Budynas & Nisbett [19], a pressure vessel experiences three simultaneous principal stresses as shown in Fig. 1. The stresses over the pressure vessel wall are function of radius.

Principal stresses; $\sigma_1 = \sigma_t$ (tangential stress or hoop stress), $\sigma_2 = \sigma_r$ (radial stress), $\sigma_3 = \sigma_l$ (longitudinal stress).

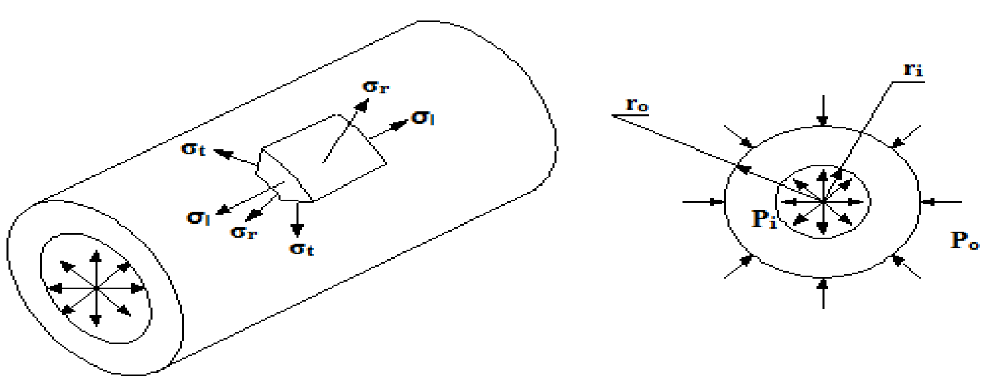

Fig. 1 : Schematic drawing of cylinder under pressure and its principal stresses

Thick-wall theory is considered, as it is used for any wall thickness-to-radius ratio. Cylinder geometry includes r_i, r_o and L (internal radius, outer radius and length respectively). Cylindrical stresses representing the principal stresses, σ_t, σ_r and σ_l, can be calculated at any radius 'r' in the range of wall thickness between r_i and r_o.

Tangential or hoop stress can be given as;

$$\sigma_t = \frac{P_i r_i^2 - P_o r_o^2 - r_i^2 r_o^2 (P_o - P_i)/r^2}{r_o^2 - r_i^2}; r_i \leq r \leq r_o \qquad (1)$$

and similarly the radial stress can be given;

$$\sigma_r = \frac{P_i r_i^2 - P_o r_o^2 + r_i^2 r_o^2 (P_o - P_i)/r^2}{r_o^2 - r_i^2}; r_i \leq r \leq r_o \qquad (2)$$

However, the *longitudinal stress* is applicable to cases where the cylinder carries longitudinal load, such as in capped ends and in boiler vessels, valid where bending, nonlinearity and stress concentrations are not significant and can be estimated as;

$$\sigma_l = \frac{P_i r_i^2 - P_o r_o^2}{r_o^2 - r_i^2}; r_i \leq r \leq r_o \qquad (3)$$

Two mechanical design cases can be considered as;

Case-1: internal pressure only (P_o=0)

Case-2: external pressure only (P_i=0)

This particular design of high pressure gas container corresponds to the first case, where P_o=0; therefore, the critical section exists at r = r_i, for which the hoop stress can be evaluated as;

$$\sigma_t(r = r_i) = \sigma_{t,max} = P_i \frac{r_o^2 + r_i^2}{r_o^2 - r_i^2} = P_i \frac{\zeta^2 + 1}{\zeta^2 - 1} = P_i C_{ti} \qquad (4)$$

Where,

$$\zeta = \frac{r_o}{r_i} \qquad (5)$$

$$C_{ti} = \frac{\zeta^2 + 1}{\zeta^2 - 1} \qquad (6)$$

are function of cylinder geometry only.

And the radial stress will become;

$$\sigma_r(r = r_i) = \sigma_{r,max} = -P_i (\text{which is a natural boundary condition}) \qquad (7)$$

The longitudinal stress depends on end conditions:

$$\sigma_l = \begin{cases} P_i C_{li}, \text{capped ends} \\ 0, \text{uncapped ends} \end{cases} \qquad (8)$$

Where,

$$C_{li} = \frac{1}{\zeta^2 - 1} \qquad (9)$$

For calculating the thickness 't' of the cylindrical shell [20], the following equation can be used.

$$t = \frac{P_i r_i}{SE - 0.6P_i} \qquad (10)$$

Where,

$$S(\text{allowable design stress}) = \frac{\sigma_{yt}}{FOS} \qquad (11)$$

The dimensions of the designed pressure cylinder are given in Fig. 2.

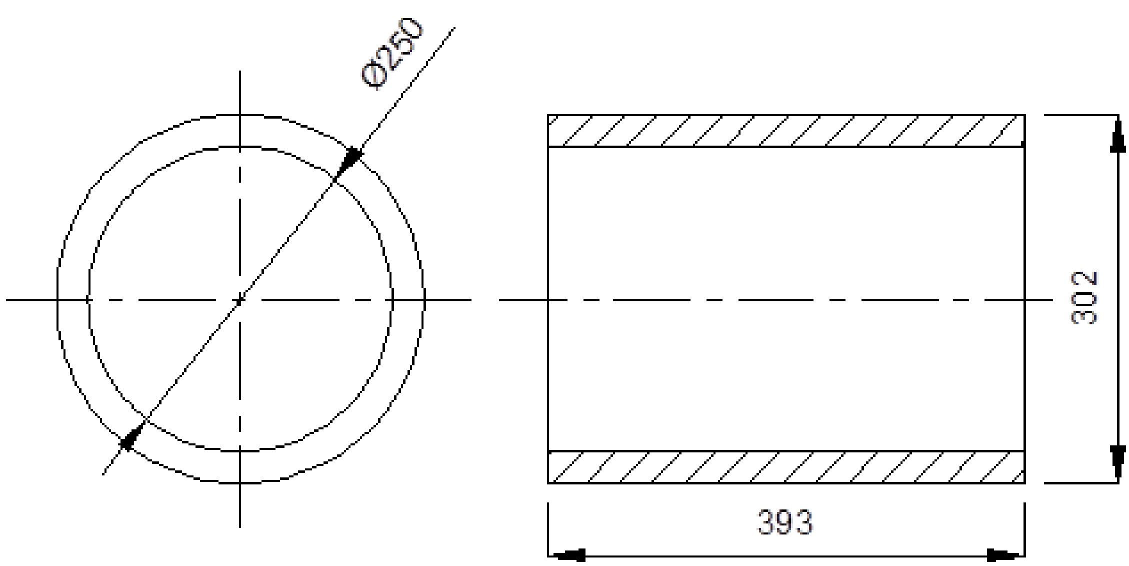

Fig. 2 : High pressure gas cylinder (all dimensions in mm)

ii. *Design of column for the pressure cylinder*

The high pressure gas cylinder is subjected to thrust force generated after each firing process. This thrust force will be transmitted to its column. Fig. 3 shows the dimensions of the column and point of application of the transmitted thrust force.

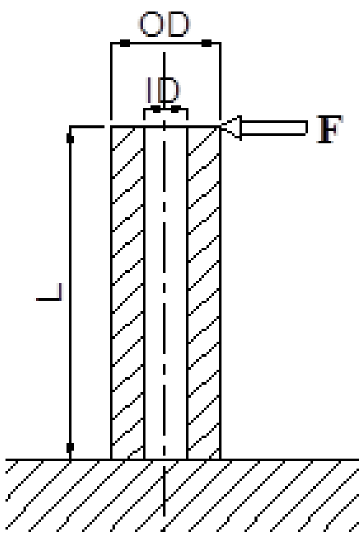

Fig. 3 : FBD of pressure cylinder column

The maximum thrust force F_t that this part can face is dependent on the net drop of the cylinder pressure after single firing.

$$F_t = P_{net} * A_{bore} \quad (12)$$

Where, P_{net} is the net drop of the pressure at single firing

A_{bore} is cross sectional area of the cylinder bore

Using the formula for design or allowable bending stress σ_b:

$$\sigma_b = \frac{M}{Z} \quad (13)$$

Where, M= bending moment and Z= section modulus

$M = F_t * L$, length L of the column is fixed by the axis height of the set up to be 800 mm.

Internal diameter ID of the column is fixed by the swivel of the thrust bearing seat to be 75 mm and the outer diameter OD to be calculated.

iii. *Design of bars and barrel*

Titanium alloy is considered to design the bars as it reasonably satisfies the following criteria:

- Bars must remain elastic after impacts (higher modulus of elasticity E)
- Bars should neither breakdown nor plastically deform (higher yield strength σ_y)
- Bars should have less density to reduce mismatch of acoustic impedance Z with soft specimens like Polymers. $Z = \rho C$

b) Striker Bar

From conservation of energy:

Potential energy of the striker bar = kinetic energy of the striker bar

$$PE_s = KE_s \quad (14)$$

$$P_i A_s l_b = \frac{1}{2} m_s V_s^2 \quad (15)$$

Where, A_s = cross sectional area of the striker bar, l_b = length of the barrel, m_s = mass of the sriker bar.

The dimensions of the striker bar as a result of the above assumption are given in Fig. 4.

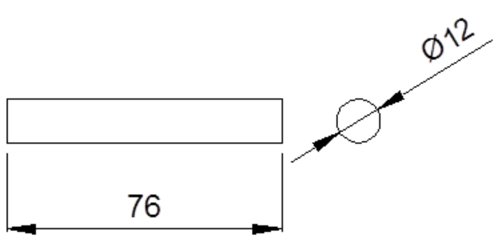

Fig. 4 : Striker bar (all dimensions in mm)

c) Design of incident and transmission bars

To avoid buckling of the bars in between the supports, most literatures recommend that their aspect ratio (L/D ratio) should be limited to 100, however with three-point contact miniature ball bearings (floater bearings) having low coefficient of friction can be used to increase the L/D ratio. As shown in Fig. 5, the length L of the barsis maintained to be 1200 mm while their diameter is fixed by striker bar to be 12mm.

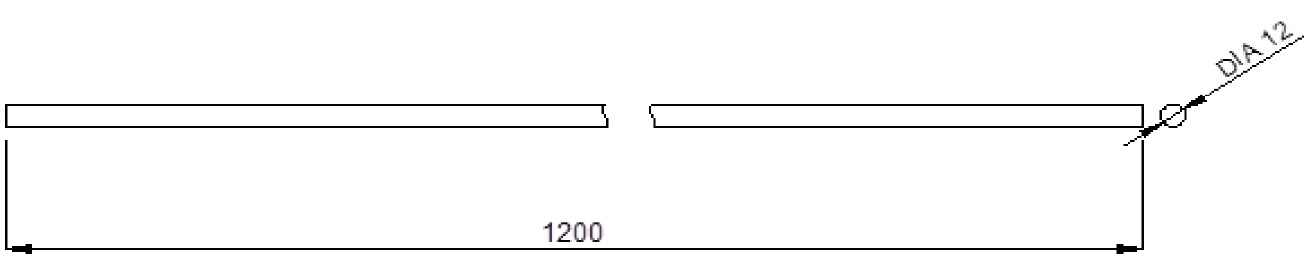

Fig. 5 : Incident and Transmission bars (all dimensions in mm)

To predict the *Stress capability of incident and transmission bars* the following equations are used;

$$KE = \frac{1}{2} m_s V_s^2 \quad (16)$$

Where,

$$m_s = \rho A_s l_s \quad (17)$$

Then the maximum stress on the bars will be the maximum dynamic force divided by the cross sectional area A of the bars.

$$\sigma_{max} = \frac{F_d}{A} \quad (18)$$

Where,

$$F_d\,(\text{Maximum dynamic force on the bars}) = \frac{KE}{l_s} \quad (19)$$

Position of bearing supports of Incident and Transmission bars

The number of bearing supports 'n' is fixed to be two for each bar and their position is calculated by using Airy's formula[21].

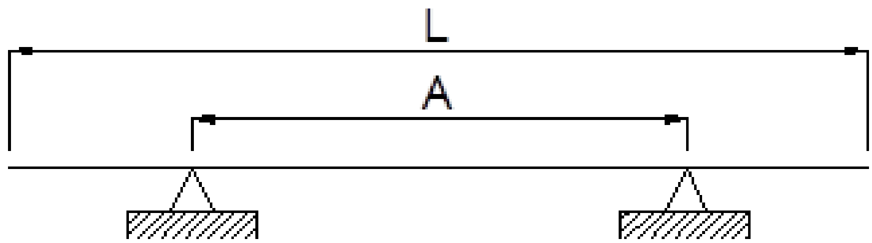

Fig. 6 : FBD of position of bearing supports of incident and transmission bars

As shown in Fig. 6, the distance between centers of the bearings 'A' has been calculated as follows;

$$A = \frac{L}{\sqrt{n^2-1}} \quad (20)$$

Where, L= 1200mm, n=2; $A = \frac{1200}{\sqrt{2^2-1}} = 693 \text{ mm}$

Therefore, the bearing supports are placed at 253.5 mm distance from both ends of the bar.

d) Design of the barrel (launching tube)

Considering the barrel as a short time pressure vessel with no welded joints; corresponding joint efficiency, *E*, is given as 1 and FOS is fixed to be 2.Its thickness 't' is calculated using the formula in equation (10) above as the internal radius of the barrel 'r_{ib}' is fixed by the radius of the striker bar to be 6mm.

The necessary dimensions are accordingly calculated and given in Fig. 7.

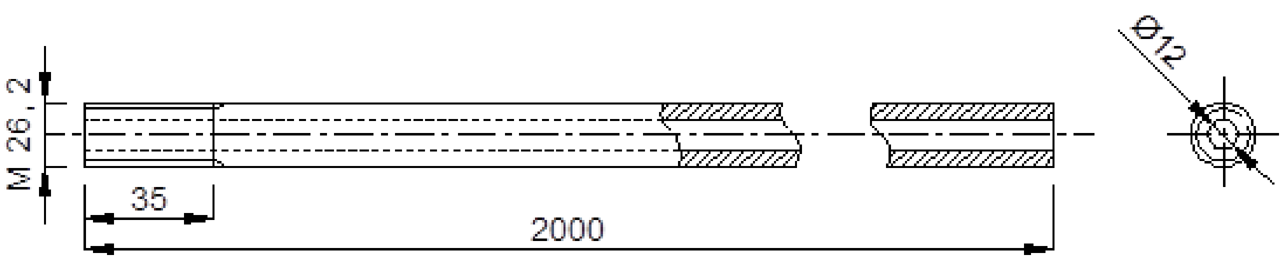

Fig. 7 : Barrel or launching tube (all dimensions in mm)

e) Momentum Trapping

i. *Selection of hydraulic oil*

Selection of the right hydraulic oil should be made based on its bulk modulus or compressibility. For complete absorption of the kinetic energy KE generated at 300 bars of reservoir pressure and safe design, we assume that the total KE of the striker bar at its maximum velocity of 600m/s will be transferred to the momentum trap.

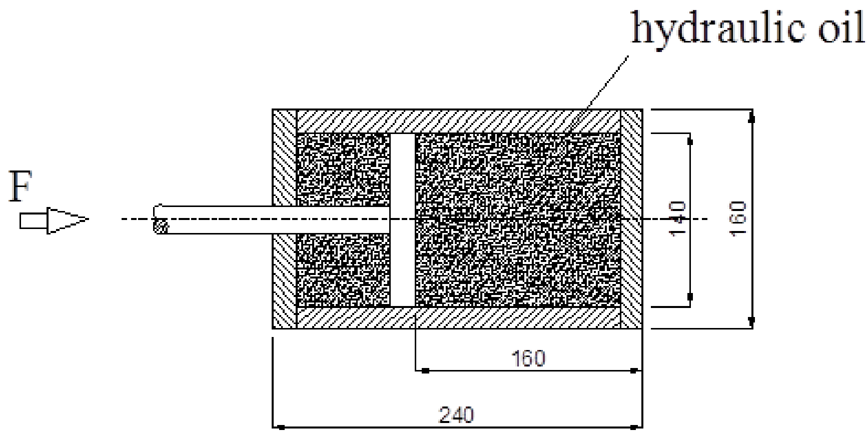

Fig. 8 : schematic drawing of momentum trap hydraulic cylinder (all dimensions in mm)

From Fig.8 it is observed that the level H of oil responsible to absorb the momentum is made 160mm and an initial volume V_o is calculated as;

$$V_o = \pi * \frac{d_i^2}{4} * H \tag{21}$$

Allowing 0.2 % change in volume ΔVof the oil, bulk modulus E of the hydraulic oil will be calculated as;

$$E = \frac{KE}{\Delta V} \tag{22}$$

According to the technical data in [22] the possible oil at 300 bar pressure is the petroleum based hydraulic oil with corresponding bulk modulus E of 1.6 GPa is therefore selected.

Considering the momentum trap as a mass attached with a spring and damper as shown in Fig.9, it is modeled and the stiffness and damping coefficient are predicted as follows;

$$F_d + Kx + Cv = 0 \tag{23}$$

Where, F_d is the maximum dynamic force to be trapped, K is the stiffness of the momentum trap, x is the maximum axial displacement of the piston, C is the damping coefficient of the momentum trap and v is velocity of the striker bar.

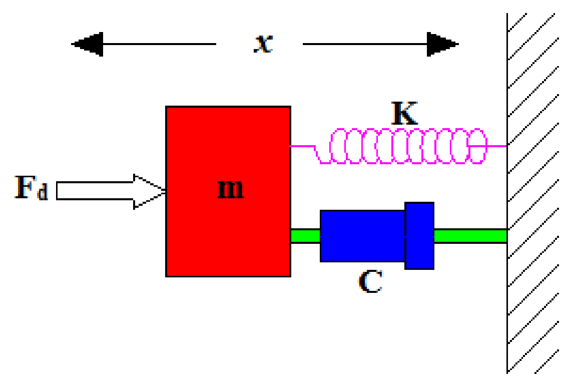

Fig. 9 : FBD of mass attached to a spring and damper representing the momentum trap

The stiffness K is calculated using the following formula;

$$K = m * \omega_n^2 \tag{24}$$

Where, m is mass of the movable parts in the momentum trap (head+rod+piston), and ω_n is the natural frequency.

$$\omega_n = \frac{C_{st}}{2 * L_t} \tag{25}$$

where C_{st} is speed of sound in the bars given as $5073 \frac{m}{s}$ and L_t is length of the transmission bar.

III. Fem Simulation of Critical Parts using Abaqus CAE 6.10

a) Pressure Cylinder

The following input data are provided to simulate the stress condition of the cylinder under maximum nitrogen gas pressure and observation of the maximum stress is taken, as shown in Fig. 10, to compare with the yield strength of the selected material.

Material = AISI4130, steel

Load type = 300 bar uniformly distributed internal pressure

Element type = tetrahedral

Number of elements = 8908

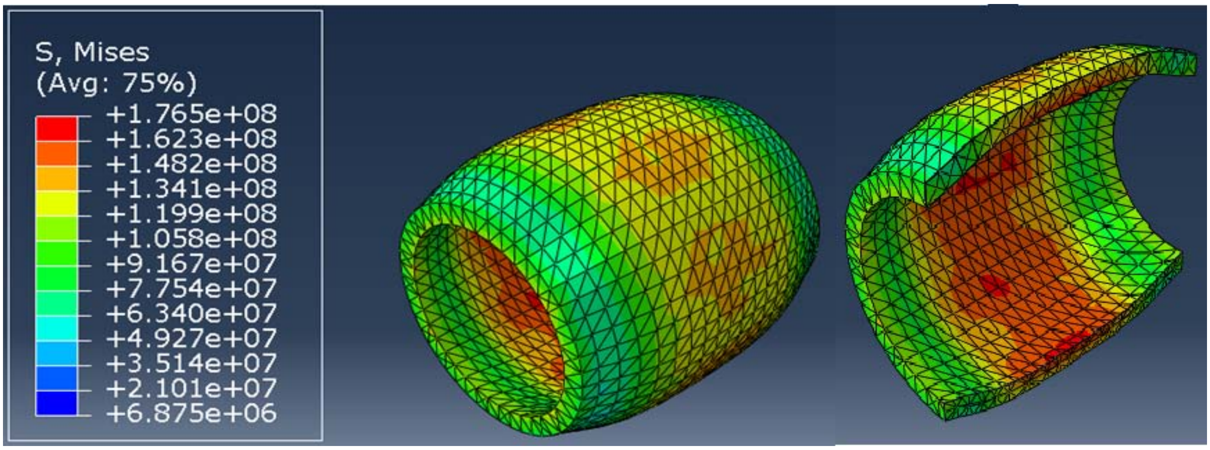

Fig.10 : Visualization of FEM simulation results of pressurized SHPB cylinder

b) Column of the pressure cylinder

The following input data are provided to simulate the stress condition of the column under dynamic loading and observation of the maximum stress is taken, as shown in Fig. 11, to compare with the yield strength of construction material.

Material = AISI4130, steel

Load type = dynamic/explicit, due to the maximum net pressure drop of gas cylinder after single firing (20 bar of uniformly distributed pressure)

Element type = tetrahedral

Number of elements = 56091

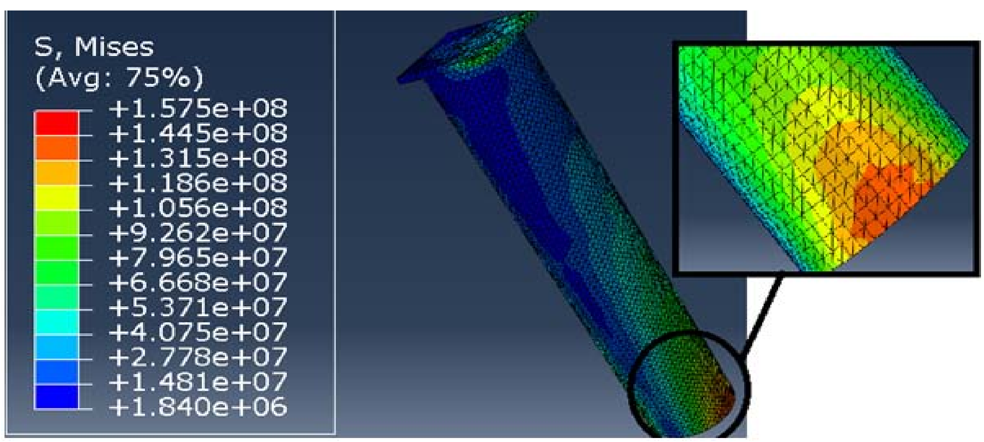

Fig. 11 : Visualization of FEM simulation results of the column

c) Pressure Bars

The following input data is provided to simulate the one dimensional stress propagation in the pressure bars during firing and observation of the maximum compressive stress is taken, as shown in Fig. 12, to compare with the yield strength of the Titanium bar material.

Material = Ti6Al4V, Titanium (ASTM Grade-5)

Load type = dynamic/explicit, due to the maximum net pressure drop of gas cylinder after single firing (20 bar of uniformly distributed pressure)

Element type = tetrahedral

Number of elements = 103306

Loading Duration = 60 μs (set to be two times period of the wave to check for higher stress)

Since each bar of the assembly could not be visually identified in a window at a time, the zoomed images of the interaction areas are displayed in Fig. 12. The first one is the interaction between striker bar and incident bar while the second one is between incident bar, specimen and transmission bar. The results of which are discussed later in the Results and Discussion section.

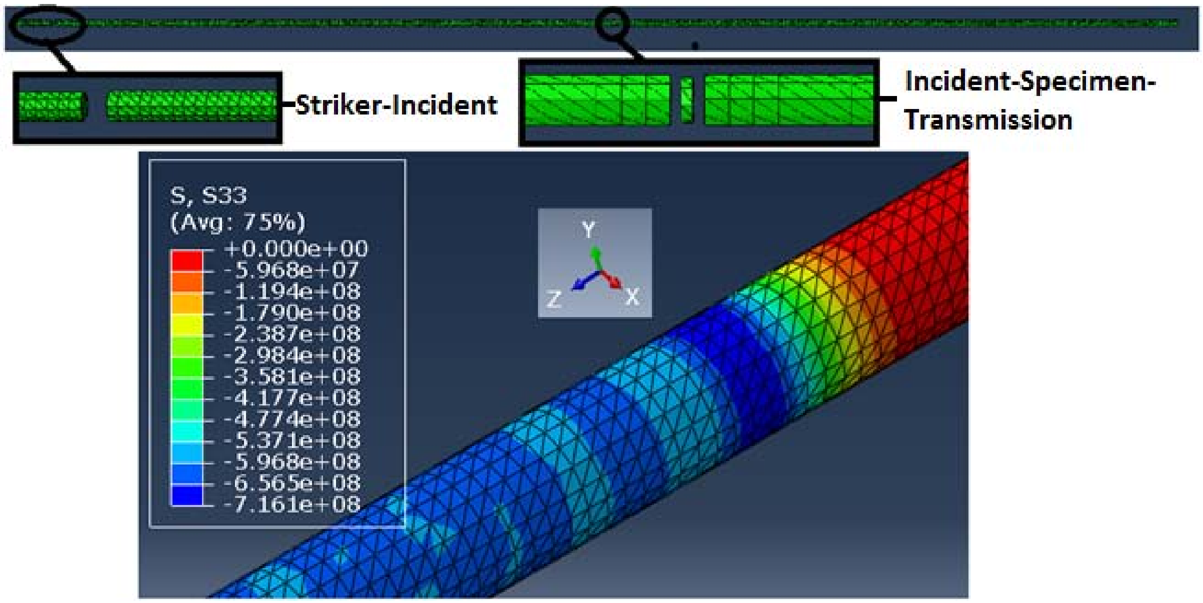

Fig. 12 : Visualization of FEM simulation results of 1-D stress wave propagation through pressure bars under impact

d) Data Acquisition System (DAQ)

The instrumentation of the SHPB set-up typically comprises a velocity measurement system, strain gauges, high speed strain gage input module with built-in signal conditioner and amplifier as well as voltage excitation source for powering the wheat stone bridge circuit, and oscilloscope for the display of acquired strain signals in both the incident and transmission bars. The following section discusses each of the above components of DAQ system in detail.

i. *Velocity Measurement System*

The main purpose of the velocity measurement system is to determine the impact velocity of the striker bar. It comprises of two IR (Infra-red) sensors, KOYO PLC and high speed counter module (HO-CTRIO-2). As soon as the striker bar is triggered, it passes in front of the IR sensors within a fraction of second. Consequently, pulse state and stop is registered in the PLC. The function of the high speed counter module is to determine the time duration between the consecutive pulse start and stop. By knowing the distance between the speed sensors, the impact velocity of the striker bar is calculated. The schematic of the velocity-measurement system is illustrated in Fig.13.

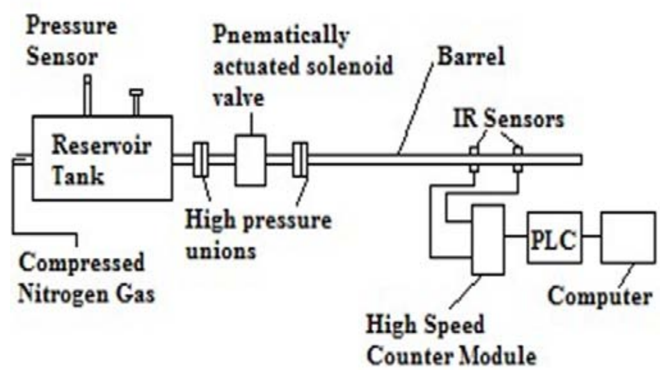

Fig. 13 : Schematic diagram of Velocity Measurement System

ii. *Stress-Strain Measurement System*

This system comprises of the strain gages, signal conditioner cum amplifier and data acquisition (DAQ) system. The selection of appropriate DAQ system is solely based upon the required sampling frequency (f_s) i.e. number of samples taken per second. The sampling rate of the DAQ system must satisfy the Nyquist criterion [23], which states that the signal must be sampled at a frequency which is greater than twice the highest frequency component of interest in the signal, otherwise, the high frequency content will alias at a frequency inside the spectrum of pass-band. The specific DAQ system used in this setup is based on NI PXIe supported by Lab view software. Fig.14 shows the photograph of the DAQ and analysis system including the strain input card and the monitor.

Sampling rate f_s *of the* DAQ *system*

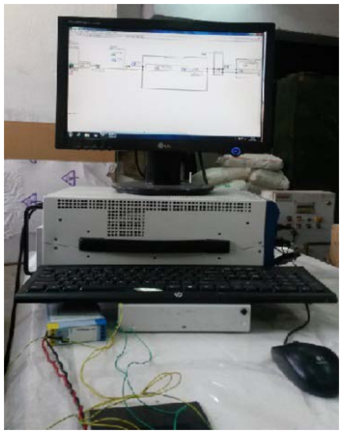

Fig. 14 : Photograph of the DAQ and analysis system

Calculation of loading duration T of pressure bars is essential to fix the minimum sampling rate required by the DAQ system.

$$T = \lambda/C \tag{26}$$

Where, λ is the wave length and C is the wave speed with in the pressure bars. The wave length λ is two times the length of the striker bar which comes out to be 0.152m (2*0.076m). Period T is calculated to be 30 μs and the subsequent maximum wave frequency f_{max} will be 1/T, which is nearly 34 KHZ. Thus, sampling rate of DAQ system, according to Nyquist criteria; $f_s > 2f_{max}$, should at least be 70 Kilo samples per second (>2*34 KS/sec).

Wheatstone Bridge Configuration

Two active strain gages were mounted diametrically opposite on the bars, thus constituting Half Bridge Type II configuration.

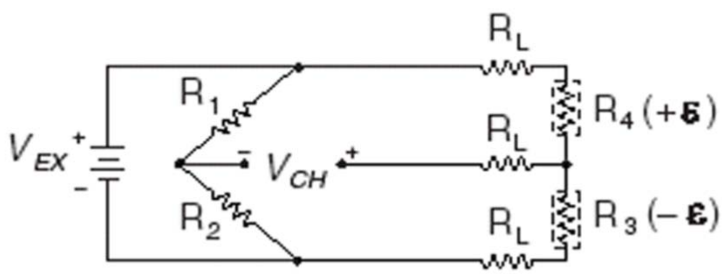

Fig. 15 : Half Bridge Type II Circuit Diagram

In Fig. 15, R_1 and R_2 are the half bridge completion resistors, R_3 is the active strain gage element measuring the compressive strain (-ε) and R_4 is the active strain gage element measuring the tensile strain (+ε). This bridge configuration measures purely axial strain while rejecting the bending strain. The strain gage output voltage was converted to corresponding strain units by using the following equation.

$$\text{Strain } (\varepsilon) = \left(\frac{-2Vr}{GF}\right) * \left(1 + \frac{R_L}{R_g}\right) \tag{27}$$

$$\text{Where, } V_r \text{ (the voltage ratio)} = \frac{V_{CH}(strained) - V_{CH}(unstrained)}{V_{EX}} \tag{28}$$

V_{EX} is the excitation voltage, V_{CH} is the measured signal voltage, GF is Gage factor of the strain gages and R_L & R_g are lead resistance andnominal strain gage resistance, respectively.

e) Fabrication and Installation

Fabrication of the designed SHPB parts, their assembly and the total installation is thereby accomplished. The total setup assembly contains different mechanical, electrical and electromechanical parts as tabulated in Table 1 below.

Table 1 : List of SHPB parts

List of Split Hopkinson Pressure Bar Parts

Mechanical parts

- Base tables
- High pressure gas reservoir (300 bar capacity)
- Reservoir vent needle valve (250 bar capacity)
- Reservoir column
- Swivel
- Nitrogen gas supply pressure cylinder (accumulator)
- High pressure nipples (400 bar capacity)
- High pressure Union pipe joints (250 bar capacity)
- Barrel support block-1 (large)
- Barrel support block-2 (small)
- Barrel clamps (2)
- Cross channels (2)
- Bearing supports (4)
- Floater bearings (4)
- C-clamps (18)
- Hydraulic momentum trap
- Momentum trap backing mechanism
- Momentum trap sit bracket and supports
- Barrel (launching tube)
- Striker bar
- Incident bar (weigh bar)
- Transmission bar (anvil bar)

Electrical and Electromechanical Parts

- Pneumatically actuated high pressure solenoid valves (2) (300 bar capacity)
- Pressure transmitter (250 bar capacity)
- Control panel
- Digital pressure indicator (0.1 bar resolution)
- High speed counter module
- E32-TC200-2M fiber optic velocity sensor
- IR velocity sensors with individual amplifier unit
- NI PXIe-10620 DAQ (Data Acquisition) system supported by Lab view software
- Strain gauges
- Strain gauge wires

The solid model and photograph of the developed setup are shown in Fig. 16 and Fig.17 respectively, which is in effect developed from scratch and will give an idea to others to create it from a junk yard.

Fig.16 : Solid model of the entire SHPB setup

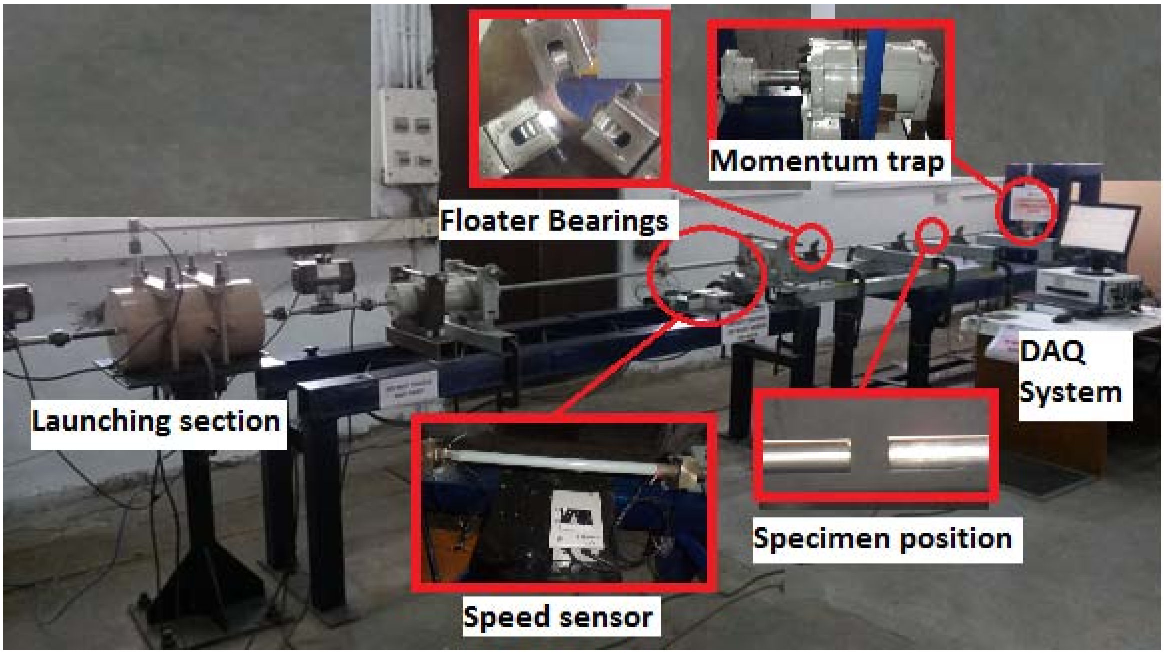

Fig.17 : Photograph showing the entire SHPB setup assembly and zoomed details of speed sensors, specimen position, momentum trap and the floater bearings

IV. Results and Discussion

From the start of the design, assumptions of perfect gas law and adiabatic expansion were considered to make use of maximum pressure energy for safe design of the parts of the setup. The maximum pressure of nitrogen gas with in the cylinder which is 300 bar is considered throughout the entire design of each component part. Accordingly, every part of the setup is shown to be safe against the maximum applied stress. The main parts are summarized and listed in Table 2 for comparison of their strength with the maximum possible stresses obtained in FEM simulation as well as analytically.

Table 2 : Comparison of stresses and strength of SHPB main parts

Strength and Stresses	Pressure Cylinder (AISI4130, steel)	Column of Cylinder (AISI4130, steel)	Pressure Bars (Ti6Al4V)
Yield Strength(σ_y)	460 MPa	460 MPa	830 MPa
Max. Stress (by design)	160.5 MPa	230 MPa	796.2 MPa
Max. Stress (bysimulation)	176.5 MPa	157.5 MPa	716 MPa

As presented in Table 2 above, the maximum possible stresses in each part as a result of design and simulation are reasonably close to each other and less than the corresponding yield strengths, which shows a safe design, however, the stress in pressure barsis quite close to the yield strength and may require continuous observation of their ends for any plastic deformation.

The one dimensional stress S-33 propagation along the axial direction (Z-axis) of the pressure bars is shown by post process in Fig. 18. For visualization purpose, around half the length of the incident bar is taken and the graph is displayed in five even and successive step time frames namely S33_T1, S33_T2, S33_T3, S33_T4 and S33_T5. Since the time period is set to be 100μs, each step frame occurs at every 20 μs. It can be observed that the maximum stress on the pressure bars during such a very short loading duration is a compressive stress just exceeding 700 MPa in all the time frames. The exact value of this maximum stress can be seen in Fig.12and Table 2 as 716MPa (compressive).

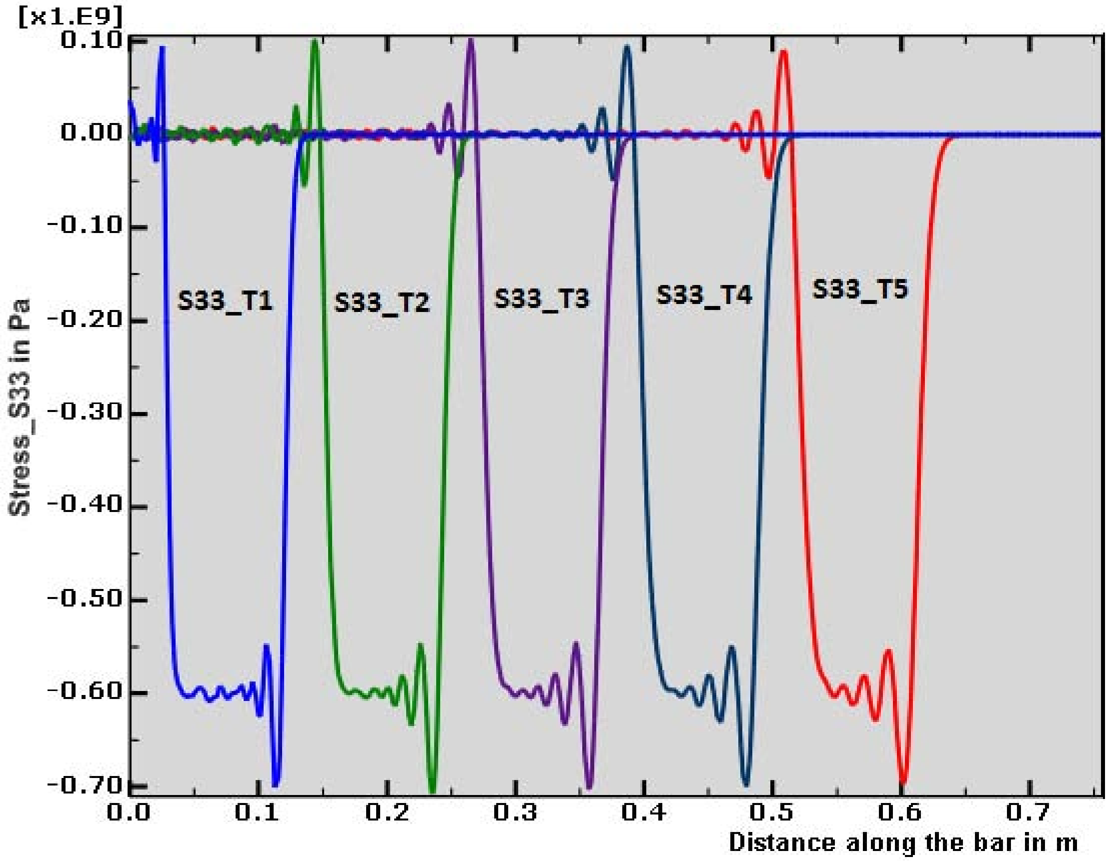

Fig. 18 : Postprocess visualization of 'FEM simulation' results of 1-D stress wave propagation through pressure bars under impact

For the velocity-pressure calibration, the striker bar was fired with compressed nitrogen gas. The pressure was varied from 60 bar to 0.1 bar in decreasing order, to avoid frequent filling of the pressure cylinder, and subsequently the velocity of the striker bar was computed by measuring the time duration between the consecutive IR sensors. The graph obtained from the velocity-pressure calibration is shown in Fig.19 as under.

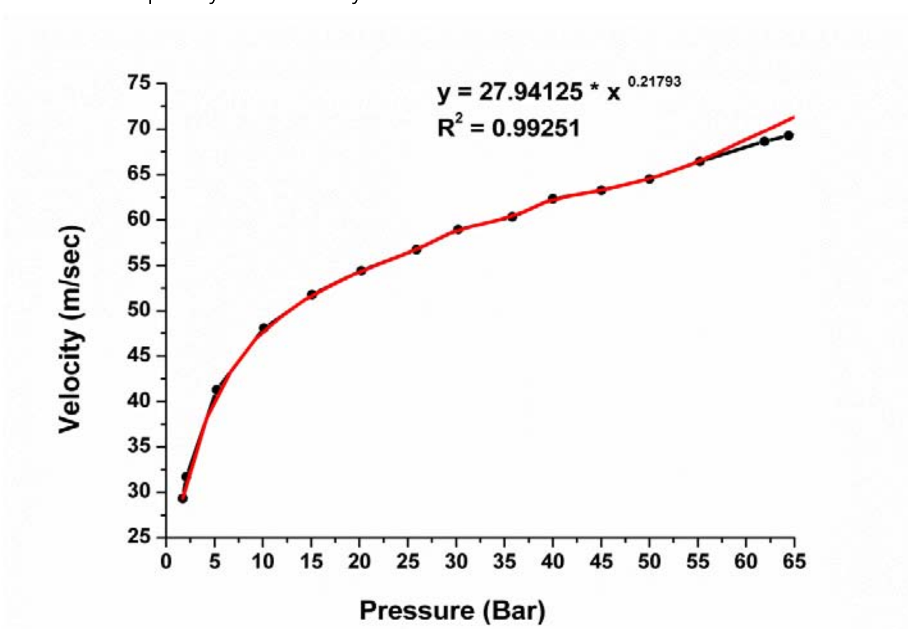

Fig. 19 : Velocity-Pressure calibration of Split Hopkinson Pressure Bar

Only one available paper by Haines *et al.* [9] presented the velocity-pressure curve of SHPB having curve fitting equation of $y = 7.9507x^{0.2387}$. In this work the curve fitting equation shown in the above graph is about 3.5X steeper. That means the velocity of the striker bar of this design is 3.5 times more at the same firing pressure. Moreover, the regression parameter R^2 is close to one which indicates consistency of the nitrogen gas expansion, negligible gas leakage through the joints, proper propelling barrel length and size of striker bar.

V. Conclusion

Development of particular SHPB set up of length 6.5m, height 1.2m and width of 0.56m is done after necessary design analysis and overall customization in house. This set up mainly focuses for high strain rate impact characterization of soft and light armor material systems like polymers and FRPs. Parts of the setup are designed for the maximum firing pressure of 300 bar with slender titanium bars of 12 mm diameter to help the assumption of one dimensional stress wave propagation theory. The launching unit is made separated by foundation from the bars table to protect the vibration noise signals not to be transmitted to the pressure bars. Mechanism for floater bearings is also developed to reduce the coefficient of friction which could happen between the bearing-bar interactions. A hydraulic momentum trap is provided to avoid repeated loading of test specimens so that the specimen could further be examined by subsequent tests like scanning electron microscopy. The maximum stresses on the critical mechanical parts of the setup; the cylinder, column and bars were cross checked with the FEM simulation results and compared with its corresponding yield strengths, hence safe design of the setup is observed. The velocity-pressure calibration graph achieved in this design shows that the velocity of the striker bar at a particular pressure is about 3.5 times more than the one presented in previous works. Testing of polymers and composites is in progress using this newly developed setup.

VI. Acknowledgement

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References Références Referencias

1. Jadhav (2003) High strain rate properties of polymer matrix composites. M. S. thesis, Univ. of Pune.
2. O. Akil (2004) Quasi-Static and High Strain-Rate Mechanical Behavior of FP™ (α-alumina) Long Fiber Reinforced Magnesium and Aluminum Metal Matrix Composites. M.S. thesis, Dept. Materials Science & Eng., Izmir Inst. of Tech., Turkey.
3. U.S. Lindholm, L. M. Yeakley (2006) Split Hopkinson Pressure Bar Apparatus. ASME, Southwest Research Institute, San Antonio, Texas.
4. B.A. Gama, S.L. Lopatnikov, J.W. Gillespie (2004) Hopkinson Bar Experimental Technique: A critical Review. ASME Appl. Mech. Rev., vol. 57, no. 4.
5. K.T. Ramesh (2008) High Strain Rate and Impact Experiments. Experimental Solid Mechanics, Springer.
6. F. Gallina, R.S. Birch, M. Alves, "Design of a Split Hopkinson Pressure Bar", Univ. of Sao Paulo, Brazil, Unpublished results.
7. S.M. Lang (2012) Design of a Split Hopkinson Bar Apparatus for use with Fiber Reinforced Composite Materials. M.S. thesis, Dept. Mech. Eng., Utah State Univ., Logan, Utah.
8. A.T. Owens (2007) Development of a Split Hopkinson Tension Bar for testing stress-strain response of particulate composites under high rates of loading. M.S. thesis, Auburn Univ., Alabama.
9. J. Haines, C. Knight, R. Glaser (2007) Design and Characteristics of a Split Hopkinson Pressure Bar apparatus. Dept. Mech. Eng., Univ. of Maine.
10. T. Yokoyama, "Prediction of Maximum Strain and Strain Rate in SHPB Specimens Based on Energy Analysis", Okayama Univ. of Science, Japan, Unpublished results.
11. N. Tasneem (2002) Study of wave shaping techniques of Split Hopkinson Pressure Bar using Finite Element Analysis. M.S. thesis, Dept. Mech. Eng., Osmania Univ., Osmania.
12. S. Huang (2009) Dynamic testing of soft and ultra-soft materials. M.S. thesis, Dept. Civ. Eng., Univ. of Toronto.
13. W. Chen, F. Lu, D.J. Frew, M.J. Forrestal (2002) Dynamic Compression Testing of Soft Materials. ASME Journal of Appl. Mech., vol. 69, pp. 214- 223.
14. K.D. Robertson, S.C. Chou, J.H. Rainey (1971) Design and operating characteristics of a Split Hopkinson Pressure Bar Apparatus. Army materials and mechanics research center, Mechanics of materia1s division, W. Massachusetts, Rep. AMMRC TR/1-49.
15. R.M. Guedes, M.A. Vaz, F.J. Ferreira, J.L. Morais, "Response of CFRP Laminates under High Strain Rate Compression until Failure", Portugal, Unpublished results.
16. B. Song, W. Chen (2005) Split Hopkinson Pressure Bar Techniques for Characterizing Soft Materials. LAJSS, vol. 2, pp. 113-152.
17. H. Meng, Q.M. Li (2003) An SHPB setup with reduced time-shift and pressure bar length. IJIE, vol. 28, pp. 677- 696
18. H.S.U. Butt, P. Xue (2013) Determination of the wave propagation coefficient of viscoelastic SHPB:

Significance for characterization of cellular materials. IJIE.
19. R.G. Budynas, J.K. Nisbett (2011) Stress in pressurized cylinders. in Shigley's Mechanical Engineering Design, 9th ed. McGraw-Hill, New York, ch. 3, sec. 3-14, pp. 113-115.
20. Manual, "Stress in pressure vessels", Unpublished results.
21. Airy Points (2013) The Engineer's Notebook .
22. Sauer-Danfoss (2010) Hydraulic fluids and lubricants technical information. 520L0463. REV HC.
23. W. Kester (2009) What the Nyquist criterion means to your sampled data system design. Analog devices, MT-002 tutorial.

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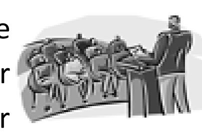

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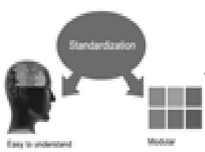

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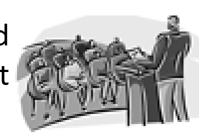

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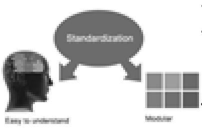

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Note :

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2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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- Please note the criterion for grading the final paper by peer-reviewers.

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- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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