

Simulation Investigation of Effect of Bio-Lubricant between Tribological System of Piston Ring and Cylinder Liner

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ABSTRACT: In an Engineering situation, a particular machine is selected on the basis of its reliability and life span. The life span and reliability are in turn governed by the frictional wear characteristics of individual component of machine. The life of any machine is determined by the life of its most sensitive part that is susceptible to wear. In tribological system “piston -ring-liner” observed 40-50% of mechanical frictional losses. To reduce such losses Lubricants perform as anti-friction media. They maintain reliable machine functions, provide smooth operations, and lower the risks of frequent failures. To manufacture lubricant important source is Crude oil. But in today’s scenario, crude oil increasing prices as well as depletion of crude oil reserves in the world, and global concerning protecting the environment from pollution have renewed interesting developing and using environment-friendly lubricants derived from alternative sources. A bio lubricant is renewable lubricants that is non-hazardous, biodegradable and emits approximately zero greenhouse gas. The objective is to presents the potential of a bio lubricant based on vegetable oil as an alternative lubricant. The mechanical properties as well as advantages and disadvantages of the different piston ring material are discussed in the first section. The second part describes the potential of vegetable oil-based bio lubricants as alternative lubricants. The final part describes the simulation effect of bio-lubricants on piston ring liner system.

KEYWORDS: Bio-Lubricant, Piston-Ring-Liner Assembly, Neem oil, Jatrophaoil, Karanja oil.

I. INTRODUCTION

The depletion of the world’s crude oil reserve increasing crude oil prices and other issues related to conservation have brought about renewed interest in the use of bio-based materials. Emphases on the development of renewable, biodegradable and environmentally friendly industrial fluids, such as bio-lubricant and bio-diesel have resulted in the widespread use of vegetable oils for non-edible purposes. The desirability of developing alternative fuels and bio-lubricant & decreasing the dependency on petroleum based fuels has been discussed by many over the last few decades. The reduction of wear and friction between “piston-ring-liner” is a largely function of lubrication. Better quality lubricants are now being formulated to reduce the wear and friction of the tribological components of the engine. The development of modern lubricants and their proper use are of great importance for the national economy, individual and environment. Lubricants, optimally adjusted to a given task, can save billions of dollars in the case of an industrialized nation, reduce wear; reduce maintenance requirements and the problem of air pollution [1]Continued growing environmental concerns are providing the impetus for increased demand and usage of vegetable oil utilization in lubricants for many applications. Bio lubricant is a product, other than food or feed, substantially composed of certain biological products agricultural materials or forestry materials. The Product is used in place of a petroleum based lubricant. [2]

The piston ring is the most complex tribological component in any engine/compressor etc. Power, fuel consumption, hydrocarbon emission, oil consumption, wear, noise and cooling are affected by the design of the ring-liner interface. Studies of the mechanism of piston ring lubrication and related friction phenomena have found that piston rings

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contribute significantly to the total engine mechanical friction losses [3]. The formation of a hydrodynamic lubrication film at the interface between the piston rings and cylinder liner is expected while the engine is in operation. However, the lubrication regime of the mating surface affects the efficiency, durability and emission output of the engine. In general, most friction occurs at, or near, top dead center where piston velocity means that hydrodynamic film thickness is low and where the temperature is higher, due to the proximity of the combustion chamber. The Experimental tribological behavior of advanced material pairs of piston ring/cylinder liner has been studied using a reciprocating tribo tester by various researchers [4] have investigated that the wear rate, including scuffing resistance, was strongly dependent on material properties and the combination of the ring/liner pair. [5, 6] has conducted lubricated wear experiments using blended diesel lubricating oil with sunflower oil fuel. A review study of [7] showed that use of all bio-based fats, oils and their derivatives had better lubricates than diesel fuel. [8] has performed experiments using palm oil methyl ester (POME) blended lubricant in a two-stroke engine and found that POME acts as a lubricating oil additive. Choi, et al. [9] has explained the effect of antiwear additives in vegetable oils and their tribological performance. Furthermore systematic efforts were undertaken by many researchers to determine the suitability of vegetable oil and its derivatives as fuel or blended into diesel. The objective is to provide CFD analysis behaviour of cylinder liner-piston ring combination under different bio lubricant.

II. RELATED WORK

I. Piston Ring and Its Properties

Piston ring is one of the most important parts of the Diesel/Petrol engines. It is an open-ended ring that fits into a groove on the outer diameter of a piston in a reciprocating engine such as an internal combustion engine or steam engine. The principal function of the piston rings is to form a seal between the combustion chamber and the crankcase of the engine. The goal is to prevent combustion gases from passing into the crankcase and oil from passing into the combustion chamber the three main functions of piston rings in reciprocating engines are:

- Sealing the combustion/expansion chamber.
- Supporting heat transfer from the piston to the cylinder wall.
- Regulating engine oil consumption

II. Ring Material

The materials used to make Piston Rings are one of the most critical factors in its performance. Thus we have selected Cast Iron bronze and nylon material to make piston ring.

- **Cast Iron:** Cast iron is an iron carbon alloys with a carbon content great then 2%.As the most common ring material, cast iron has a low – friction , wear-resistance, characteristics used in a broad range of high temperature and high speed engine application. It produces Consistence presence against the bore. Cast iron retains the integrity of its original shape under heat, Load and other dynamic forces.
- **Bronze:** Bronze it is an alloy primarily of copper, about 12% of tin and often with addition of other metal and non –metal. These additions leads to useful property such as stiffness, machinability, ductility .Bronze also has a tendency to expand faster than cast iron which is beneficial during period of momentary losses of lubrication. The other advantages reduce ring breakage and as well as reduce cylindrical wear because of its low co-efficient of friction and high co-efficient of thermal conductivity characteristics.
- **Polyamide (Nylon6):** Polyamide exhibit property of low friction and no lubrication property. Nylon is quiet in operation, resists abrasion, wears at low rate, and easily molded cast, or machined to close tolerance. Nylon is very inexpensive. Nylon is a suitable replacement for a cast iron ring in

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some hydraulic cylindrical application. This material produces a positive seal and able to absorbed particulates in the hydraulic fluids.

The Table 1 summarizes the values that has been used for the simulation analysis in ANSYS for different piston ring material i.e. cast iron, Bronze (3-10% Al), Polyamide (Nylon 6).

Parameters	Cast Iron	Bronze (3-10% Al)	Polyamide(Nylon 6)
Density	7200 kg/m ³	8890kg/m ³	1150kg/m ³
Young's Modulus	120GPa	100GPa	2.5GPa
Poisson's Ratio	0.211	0.34	0.39
Bulk Modulus	69.20GPa	104.2GPa	3.788GPa
Shear Modulus	49.55GPa	37.31GPa	0.8993GPa
Tensile Yield Strength	-	0.551GPa	0.231GPa

Table 1: Properties of different material to make piston ring

III. Lubricant and its Properties

The main purposes of lubrication are (1) to reduce wear and heat loss that result from the contact of surfaces in motion, that is, to reduce the coefficient of friction between two contacting surfaces; (2) to prevent rust and reduce oxidation;(3) to act as an insulator in transformer applications; & (4) to act as a seal against dirt, dust, and water. A lubricant is a substance that reduces friction and wear by providing protective film between two moving surfaces .Lubrication occurs when two surfaces are separated by a lubricant film. Lubricants are available in liquid, solid, and gaseous forms. A good lubricant exhibits the following characteristics: high VI, high boiling point, thermal stability, low freezing point, corrosion prevention capability, and high resistance to oxidation.

Here three different kinds of bio-lubricants are being used to reduce the frictional loss of piston ring liner assembly. Table 2 describes the fuel property in which cylinder liner in being tested.

Properties	Unit	Jatropha	Karanja	Neem
Density@15°C	gm/cc	.918	.935	.946
Density@40°C	cm ² /s	35.4	38.8	65.04
Flash Point	°C	186	212	204
Pour Point	°C	-6	-4	-9
Water Content	%	-5	<0.05	8
Ash Content	%	0.7	0.05	0.07

Table 2: Bio-Oil property of Jatropha, Karanja and Neem oil [1]

IV. Advantages and disadvantages of bio lubricants

Vegetable oils can be used as lubricants in their natural form. They have several advantages and disadvantages when considered for industrial and machinery lubrication. On the Advantage side: 1) Vegetable oils have

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excellent lubricity, which is far superior compared with that of mineral oils.2) Vegetable oils also have a high VI.3) they have higher flash Point. 4) More importantly, vegetable oils are biodegradable, generally less toxic, renewable, and reduce dependency on imported petroleum oils.

On the disadvantage side: 1) vegetable oils in their natural form lack sufficient oxidative stability for lubricant application.2) Low oxidative stability indicates that oil will oxidize rapidly during use if untreated, becoming thick and polymerizing to a plastic-like consistency,3) Vegetable oil also have low-temperature limitations, unpleasant smell, poor compatibility with paints and sealants.

III. MODELLING PISTON –RING- CYLINDER LINER

Modified Piston Ring Assembly Design:

A piston need to be designed in such a manner that it can withstand the damage caused by the extreme heat and pressure of combustion process, the gas forces and inertia forces. In addition, the piston should design in such a way that it rigid enough to prevent mechanical and thermal distortion and it should have sufficient bearing area to prevent under wear. The piston is designed based on both strength and thermal considerations. Preliminary dimensions of piston have been determined using the strength and thermal based design approach [16]. Below Fig1 (a) and (b) shows the design of two piston ring assembly. By using PRO-E software piston ring, piston and cylinder is being designed. The boundary condition and specification for further analysis is length in X axis is 89.48mm, Length in Y-axis is 125mm and Length in Z axis is 89.48. volume of the model is 3.7282e+005mm³, Mass is 3.092 kg.

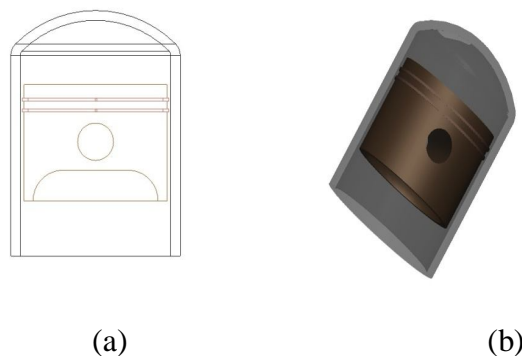


Fig.1. (a) Piston-ring-Liner assembly (b) Model Piston-Ring-Liner Assembly

IV. EXPERIMENTAL RESULTS

I. Static Structural Analysis of Piston-Ring-Liner Assembly

Piston and Piston ring plays a very important role in an engine. Let us take an example to explain the Piston phenomenon i.e. working of piston inside an engine. During combustion process, Force gets transmitted to piston through the gudgeon pin. During combustion process piston also experience the shock. The piston is designed in such a manner that it stand and perform during the shock and withstand with the repeated cycles or transient loading, it should not get into fatigue failure. At the time of combustion process, the piston is subjected to distortion and the energy stored inside the piston serves as a determining factor to know the yield and failure conditions of a piston when subjected to static loading. Von misses yield criterion can be formulated in terms of the von Misses stress or equivalent tensile stress, σ_v , a scalar stress value that can be computed from the stress tensor as shown in eq. 1 [17]. In this case, a material is said to start yielding when its von Mises stress reaches a critical value known as the yield strength, σ_y . As shown in eq – (1)

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$$\sigma_v^2 = \frac{1}{2} [(σ_{11} - σ_{22})^2 + (σ_{22} - σ_{33})^2 + (σ_{11} - σ_{33})^2 + 6(σ_{23}^2 + σ_{31}^2 + σ_{12}^2)] \dots\dots (1)$$

In this analysis, an attempt has been made to calculate the contact analysis with respect with the different piston ring assembly with specific values, and thereby simulating the working condition. Although this analysis isn't accurate, the obtained results are comparable to the actual stress and deformation values.

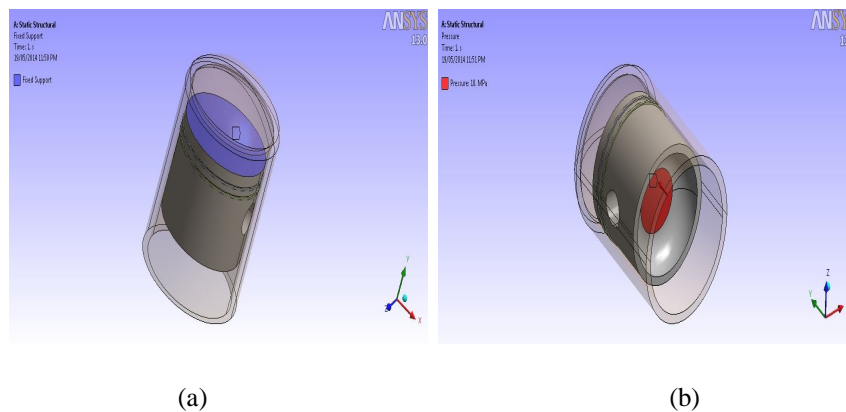


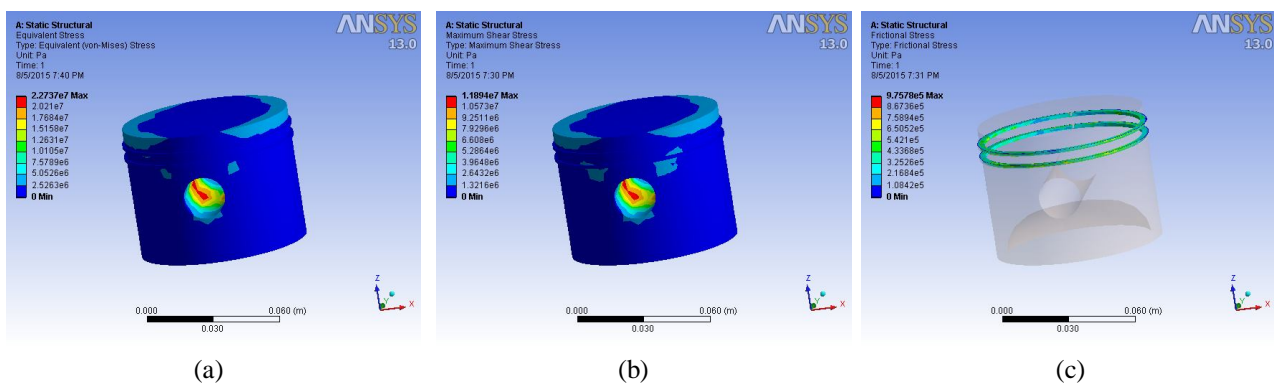
Fig.2. Piston-Ring-Liner Assembly (a) Fixed Support applied over piston (b) Pressure applied over piston.

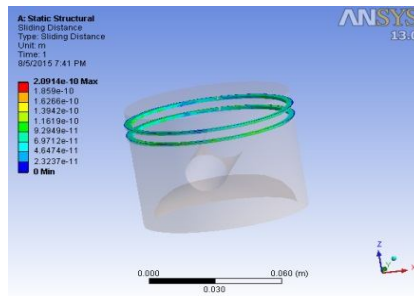
Firstly Piston is being fixed and then a specified pressure is being applied and then the further result is being calculated

II. Contact Analysis' of Piston Ring made by different material

Cast –Iron Piston ring

As we see below are the few result which obtain after the conatct analysis between the cylinder liner and the piston ring. In this we are using Piston ring material as Bronze. As we know bronze is one of the best material available in the market for the piston ring. In the above figure von-misses stress and maximum shear stress is distributed on different area and these area indicated by different colors The maximum von-misses stress obtained as 11.89Mpa. The above von-misses stress obtained is coming under the design stress consideration so the above design is safe for the intial condition with pressure applied as 10MPa.As we keep on increasing the pressure we will get different von-misses stress for different Pressure.Also we will get shrear stress,frictional stress and the sliding distance result.





(d)

Fig.3. Piston-Ring Assembly (a) Equivalent Stresses (von-misses) (b) Result Maximum shear stress (c) frictional Stress Acting on Bronze Piston Ring (d) Sliding distance occur during the operation.

Cast –Iron Piston ring

As we see below are the few result which obtain after the conatct analysis between the cylinder liner and the piston ring. In this we are using Piston ring material as grey cast iron . As we know grey cast iron is one of the oldest material available in the market for the piston ring. In the above figure von-misses stress and maximum shear stress is distributed on different area and these area indicated by different colors The maximum von-missess stress obtained as 23.74Mpa. The above von-misses stress obtained is coming under the design stress consideration so the above design is safe for the intial condition with pressure applied as 10MPa.As we keep on increasing the pressure we will get different von-misses stress for different Pressure.Also we will get shrear stress,frictional stress and the sliding distance result.

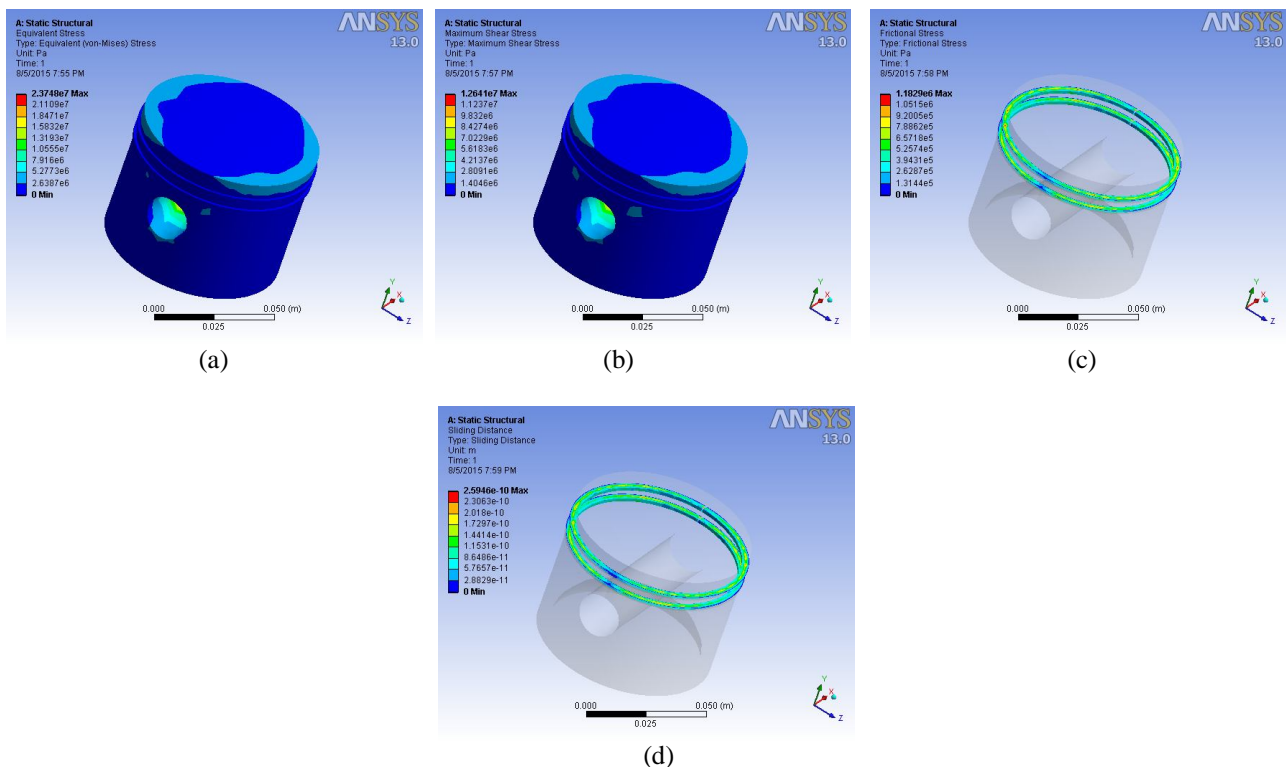


Fig.4. Piston-Ring Assembly (a) Equivalent Stresses (von-misses) (b) Result Maximum shear stress (c) frictional Stress Acting on Grey Cast Iron Piston Ring (d) Sliding distance occur during the operation.

Polyamide Piston Ring

As we see below are the few result which obtain after the conatct analysis between the cylinder liner and the piston ring. In this we are using Piston ring material as Polyamide(Nylone) . As Polyamide(Nylone6) is the lightest, cheap piston ring available in the. In the above figure von-misses stress and maximum shear stress is distributed on different area and these area indicated by different colors The maximum von-missess stress obtained as 22.73Mpa. The below von-misses stress obtained is coming under the design stress consideration so the above design is safe for the intial condition with pressure applied as 10MPa.As we keep on increasing the pressure we will get different von-misses stress for different Pressure.Also we will get shrear stress,frictional stress and the sliding distance result.

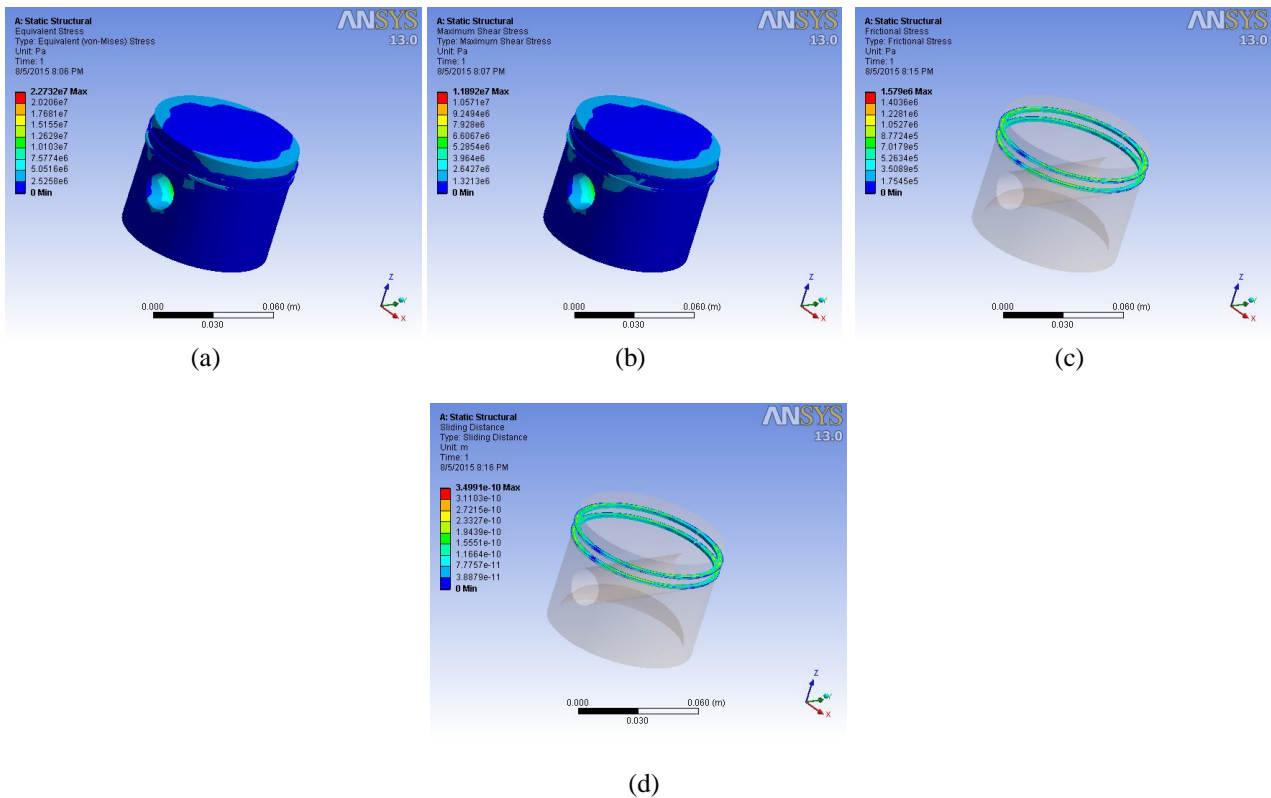


Fig.5. Piston-Ring Assembly (a) Equivalent Stresses (von-misses) (b) Result Maximum shear stress (c) frictional Stress Acting on polyamide Piston Ring (d) Sliding distance occur during the operation.

III. CFD Result for Polyamide (Nylone6) Piston Ring

The above analysis focuses only on the contact analysis between the Piston-ring-liner. But now in this first part an attempt of bio-oil used as lubricant on one of the piston ring instead of any synthetic lubricant because synthetic lubricant are not eco-friendly and economy wise very costly whereas if we go for bio-oil as one of the alternative lubricant replacement of current lubricant it will help environment as well as it is economically cheap as compared to the other lubricant. The figure below shows three different Bio-Lubricant Sample over Nylon piston Ring.

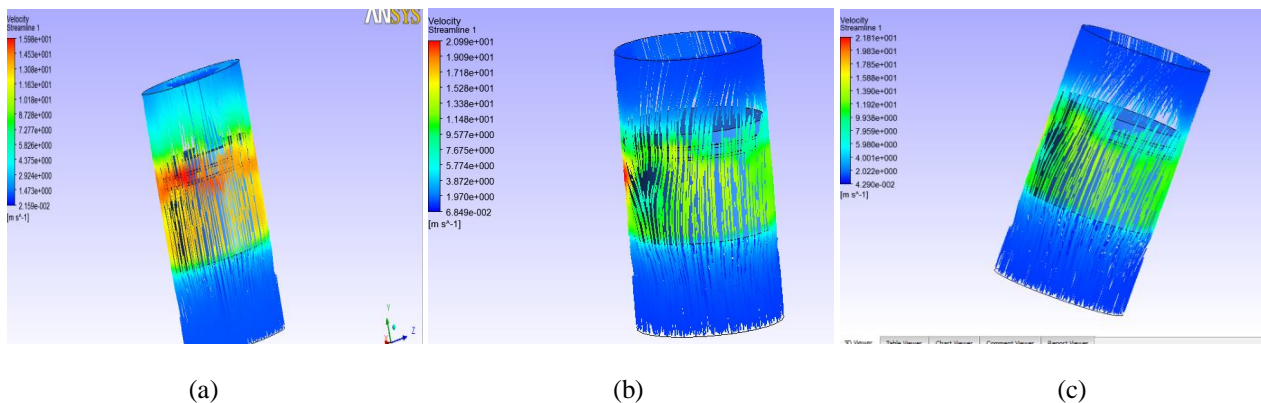


Fig.5. Fluent Analysis (a) Jatropha oil in Polyamide Piston ring (b) Karanja Oil with Polyamide Piston Ring (c) Effect of Neem oil on Polyamide Piston ring.

V. CONCLUSION

In the above paper simulation analysis between the piston –ring-liners is being examined with the different type of piston ring. When the pressure is low we got the maximum stress for the all the piston ring under the allowable stress. So the design is safe. If the pressure is keep on the increasing. Von-misses stress will also be increase. In the above analysis we saw that when 10Mpa pressure is applied to the bronze ring von-misses stress obtained as 22.73Mpa. Similarly same pressure is applied to the grey cast iron and Polyamide (Nylone6) we got von-misses stress obtained as 23.74 and 22.758.As we see bronze, grey cast iron and Polyamide is having almost nearby von-misses stress but as we know by economy wise nylon6 is cheap and light in weight which give almost as much as result of grey cast iron and Bronze.

This is first part of contact analysis is done without any lubricant. If further lubrication is provided between the piston-ring-liner the performance of the piston ring will increase. If bio-lubricant is provided in between the piston and cylinder liner they work as a lubricant between two and also these lubricant are bio-friendly. With Polyamide Piston ring (Nylone6) different bio-oil i.e. Karanja oil, Jatropha oil and Neem oil is applied and a CFD analysis is performed. The result is satisfactory and they can be used with certain modification as adding additive to change their viscosity and viscosity index.

REFERENCES

- [1] U. Todsén, H. Kruse., “Hydrodynamic Optimization of the Tribological System Piston-Ring-Liner”(1982). International compressor Engineering Conference. Paper 413.
- [2] A.K.Singh, Monoesters of high viscosity from vegetable oils 10th lubricating grease conference, Jan 2008 Aurangabad.
- [3] Hosni, M, Reduction friction losses in automobile engines, (1984) Tribol. Int. 17:185-189.
- [4] Albert, Z. and S. Herbert, Tribological behavior of advanced material pairs of piston ring/cylinder-liner, year 1996 Trans. SAE, 105: 900-908.
- [5] Fernando, S., M. Hanna and S. Adhikari, Lubricity, characteristics of selected vegetable oils, animal fats and their derivatives, year 2007, Appl. Engg. Agri., 23: 5-11.
- [6] Sutaria B.M, Bhatt D.V., Mistry K.N., Simulation and Modelling of friction force and oil film thickness in piston ring – Cylinder liner assembly of I.C. Engine, Proceeding of the world congress on engineering 2009 vol-II, WCE 2009, July1-3, 2009, London, UK
- [7] Masjuki, H.H. and M.A. Maleque, Wear, performance and emissions of a two-stroke engine running on palm oil methyl ester (POME) blended lubricant, year 1996, Proc. Inst. Mech. Eng., 210: 213-219.
- [8] Choi, U.S., B.G. Ahn, O.K. Kwon and Y.J. Chun, Tribological behavior of some antiwear additives in vegetable oils, Tribol. Year 1997. Int., 30: 677-683.
- [9] Serddari, A. and K. Fragioudakis, Impact of using bio diesels of different origin on the performance of a stationary diesel engine, Trans. Of ASME, year 2000, 122: 624-630.
- [10] Deepak Agarwal, Lokesh Kumar and Avinash Kumar Agarwal. Performance evaluation of a vegetable oil fuelled compression ignition engine, Renewable Energy, year , 2008 , 33(6): 1147-1156
- [11] Ramdhas, A.S., C. Muraleedharan and C. Jayaraj, Performance and emission evaluation of diesel engine fueled with methyl ester of rubber seed oil, year 2005, Renewable Energy, 30: 1789-1800.



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- [12] Hossain, A.K. and P.A. Davies, Plant oils as fuels for compression ignition engines-A technical review and life cycle analysis, Renewable Energy, 35: 1-13.
- [13] McCormick, Robert. L. Graboski and S. Michael, Impact of Biodiesel source material and chemical structure on emission of criteria pollutants from a heavy duty engine, year 2001, Environmental Science and Technology, 35: 1472-1477.
- [14] Augustusa, G.D.P.S. and M. Jayabalan, Evaluation and bio induction of energy components of Jatropha curcas, Biomass and Bioenergy, year 2002, 23: 161-164.