Design and Development of a Grass Hopper Linkage for a Heavy Duty Diesel Engine

FINAL YEAR PROJECT REPORT

Supervisor: **Dr. Riaz Ahmed Mufti**

Co – Supervisor: **Dr. Samiur Rahman Shah**

Submitted by: **Shahvaiz Masood**

Syed Zubair ul Islam

<u>NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY</u>

BE Mechanical Project Report

We hereby recommend that the report prepared under our supervision by:

Student Name: **SHAHVAIZ MASOOD** Regn No. **2009-NUST-BE-ME-26**

Student Name: **SYED ZUBAIR UL ISLAM** Regn No. **2009-NUST-BE-ME-23**

Titled: **<u>Design and Development of a Grass Hopper Linkage for a Heavy Duty Diesel Engine</u>** be accepted in partial fulfillment of the requirements for the award of BE degree.

<u>Examination Committee Members</u>

1. Name: Dr. Samiur Rahman Shah Signature: ________________
2. Name: Dr. Hussain Imran Signature: ________________
3. Name: Dr. Mushtaq Khan Signature: ________________

Supervisor's Name: Dr. Riaz Ahmed Mufti Signature: ________________

Dated: ____________________

____________________ Dated: ______________________

Dr. Shahid Ikramullah
(**Head of Department**)

<u>COUNTERSIGNED</u>

______________________________ Dated: ____________________

Dr. Abdul Ghafoor
(Dean)

Dedication

We would like to dedicate this report to our parents and teachers who have always been there for us and have supported us throughout our academic careers.

Acknowledgements

First of all we would like to thank Almighty Allah for giving us the strength and courage to complete our project.

We would like to thank Mr. Fazal Badshah whose efforts in the disassembling/assembling of the engine have been valuable to us.

We would also like to thank Dr. Mushtaq Khan and Mr. Rehan Zahid for their help in Pro-E.

Last but not the least, we would like to thank our supervisors Dr. Riaz Ahmed Mufti and Dr. Samiur Rehman who have always been there to guide us.

Table of Contents

List of Tables & Figures

Abstract

Engine and lubricant technologies are driven by fuel economy and emissions. One of the preferred ways of improving fuel economy and thus reduction in emissions is to reduce engine component friction. Out of the three main tribological components, piston assembly contributes the most towards engine friction. To study the piston assembly friction, IMEP method will be used for which a custom made grasshopper linkage will be designed.

Introduction

One of the majors concerns of the today's world is to improve and economize the fuel consumption in order to improve the overall performance of engines in automobiles. This is becoming increasingly necessary by the days as the prices of the raw oil rises and as the environmental standards for emission gets stringent. The main hindrance in the way of improving the fuel economy is the mechanical friction, which plays a vital role in the engine's performance and is the primary reason for reduction in the efficiency of the engine. So in order to improve the engine's performance, the first step is to identify and quantify the main friction sources. Experiments tell us that the piston assembly contributes the largest in the mechanical losses. So the lubrication between the piston assembly and the cylindrical walls becomes of prime importance in reducing the mechanical friction.

There are two main methods for measuring the piston assembly friction:

1) Floating liner method:

In this method, the liner is isolated from its surroundings and is axially supported on a series of load cells. The frictional force moves the liner axially and thus the force is measured directly.

But for this method extensive engine modification is required as the cylinder liner needs to be isolated from the engine block. It is because of this modification of the engine that this method may not give us the true piston assembly friction.

2) IMEP (Indicated Mean Effective Pressure) Method:

In this method, the piston assembly friction is determined indirectly by measuring the forces acting on the piston assembly and on the connecting rod. Since this method requires no modification of the engine at all, it gives us the true value for piston assembly friction.

Forbes and the Taylor [1] were the first ones who used the floating liner method. Uras and Patterson [2] at the University of Michigan implemented the IMEP method for the piston assembly friction measurement for the first time without the major modification in the engine.

As IMEP method requires very little modification, it gives us the true measurement of the piston assembly friction. Hence it is preferred

.

Literature Review

The IMEP method requires a special type of mechanism called a Grasshopper Linkage which will be used to direct the wires from the sensors on the connecting rod to the side of the crankcase. The linkage is usually made of Aluminum.

Figure 1: Grasshopper Linkage

Problems faced previously by researchers

Although the design of a grasshopper linkage seems like the perfect answer to measuring the piston assembly friction, it is not so simple a task. Designing the linkage requires extensive amounts of very precise calculations and later, fabrication needs to be accurate as well. Or else, the end results may not be precise. Also since the linkage is a rigid mechanism which would be installed in a running engine and if there were to be some errors in designing or the fabrication process, it might lead to possible chances of the grasshopper linkage failing and breaking. In the worst scenario, it may even lead to engine failure. This would force the repetition of the whole process from the start, costing valuable time any money. Thus durability issues are a problem with the Grasshopper Linkage and these problems were also stated by Ron Matthews [4].

Since the development of the grasshopper linkage requires precise calculations of the piston-cylinder assembly, the engine needs to be disassembled completely so that accurate measurements of diameter of the piston head, length of the connecting rod etc. may be made. Unfortunately, this option is not available at the moment as there are currently other projects under progress on the Hino Ec-100, the engine that will be used in this project, and disassembling it will not be feasible at the moment. Hence, an alternative method needs to be developed.

How we intend to overcome these problems

As durability is a problem with the grasshopper linkage accompanied by the fact that the engine is currently being used in multiple projects, a new method/mechanism is required which would effectively transmit the wires from the sensors on the connecting rod to outside the engine.

Now since a new mechanism is to be developed, it should not only overcome these problems, it should also, if possible, be better than the existing mechanism i.e. the grasshopper linkage.

Doing some more literature review by finding research papers online and skimming through them, there popped up a method which seemed to be the perfect solution to the problem at hand. The method made use of a Ribbon cable [4] to transmit sensor signals out of the engine. The ribbon cable would start from the sensor attached on the connecting rod and move along the boundaries of the connecting rod and out of the engine into a data acquisition system.

The next page shows a comparison between the two methods; Grasshopper Linkage and the Ribbon Cable Method.

Grasshopper Linkage	Ribbon Method
- Relatively less accurate - Solid linkage so occupies more space	- More accurate - Flexible - Can be adjusted in small spaces
- Once manufactured ,cannot be changed -Hard to replace -Manufacturing is costly and difficult	- Can easily be replaced -Breaks easily, so replacing again and again is hectic - Minimum manufacturing costs

Table 1: Comparison between Grasshopper Linkage & Ribbon Method

Here is a schematic diagram showing how the ribbon will attach to the sensors on the connecting rod.

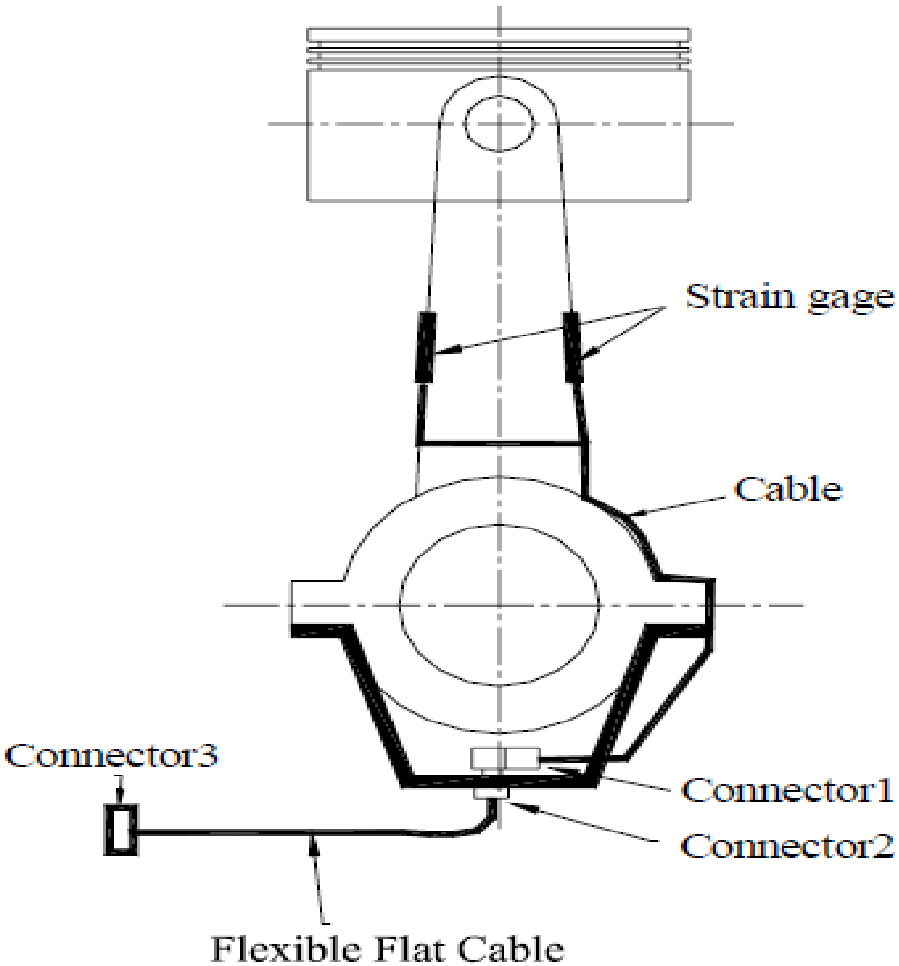

Figure 2: Ribbon Cable Method

Now although the ribbon cable will break quite frequently, it will be far easier to replace the ribbon cable than the Grasshopper Linkage. Also the Ribbon Cable method will be more accurate that the Grasshopper Linkage mechanism because of a few reasons:

- Grasshopper Linkage is made of Aluminum. It will heat up as the temperature in the crank case will rise. This heat will affect the accuracy of the wires within the linkage and data may be corrupted to a little extent.
- Ribbon Cable is made up of plastic and can withstand the crankcase temperatures. Hence the data is accurate.

In addition to all the above stated advantages of the Ribbon Cable Method over the Grasshopper Linkage, the Ribbon Cable is also a lot more economical as compared to the Grasshopper Linkage.

Methodology

Old vs. New Aim

The discovery of an even better and economical method has somehow changed the approach of this project. Whereas previously it was to use a **“grass hopper linkage”** to transmit data from the connecting rod to outside the engine, it is now to **“effectively employ the Ribbon Cable Method”** to transmit data from the connecting rod to outside the engine.

Pro – Engineer Modelling

It was necessary to model different parts of the engine in Pro Engineer before the actual testing could be done. Modelling the engine and running simulations would help us understand the internal dynamics of the running engine including the exact BDC position, the distance between the big end bearing of the connecting rod and the external wall of the sump. These details would give us a good assumption of the motion of the piston assembly and thus the motion of the Ribbon Cable when it is installed.

Hence different parts of the engine were first accurately measured and then modeled on ProE. The following pages show screenshot images of different parts.

Connecting Rod

Figure 3: Connecting Rod

Piston

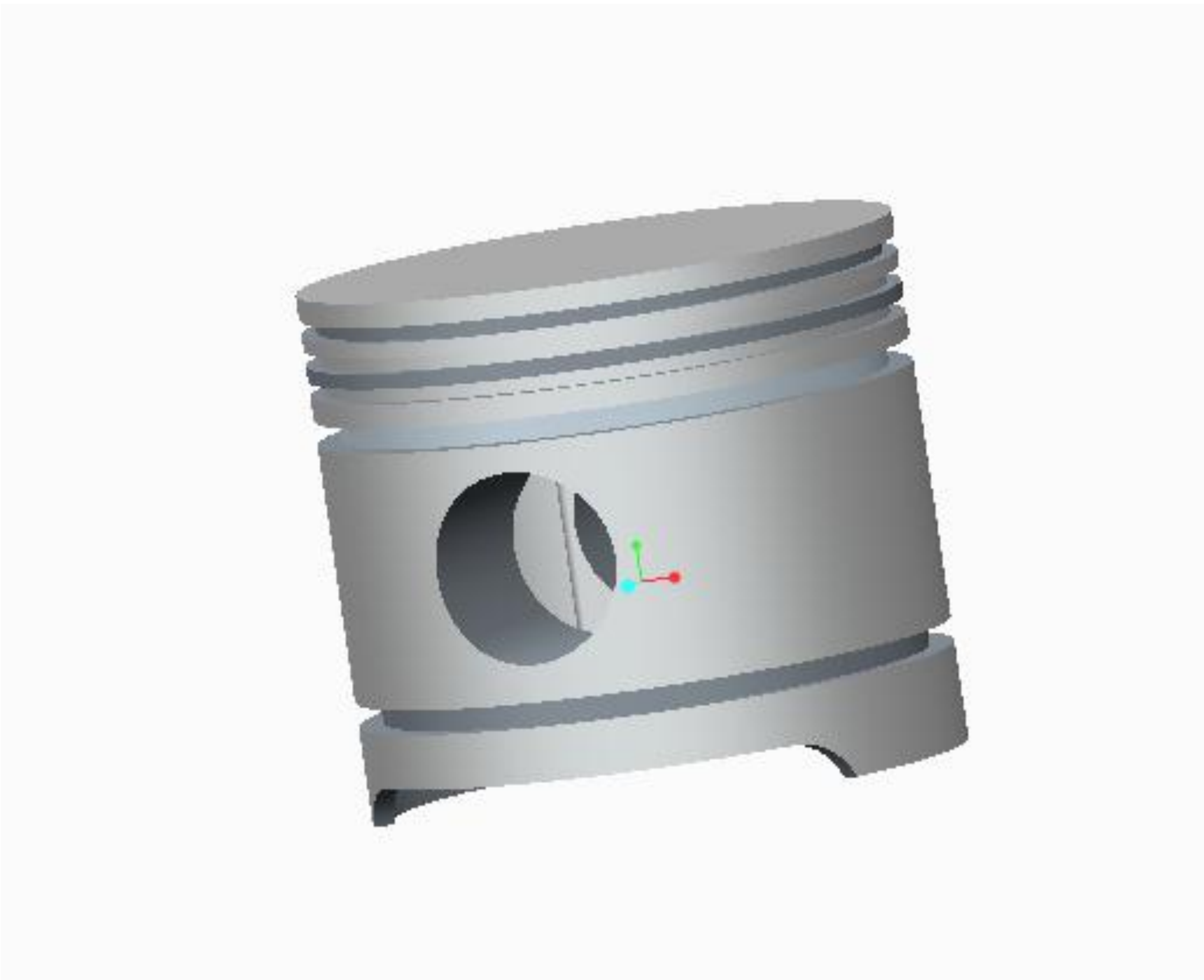

Figure 4: Piston

<u>Crank Shaft</u>

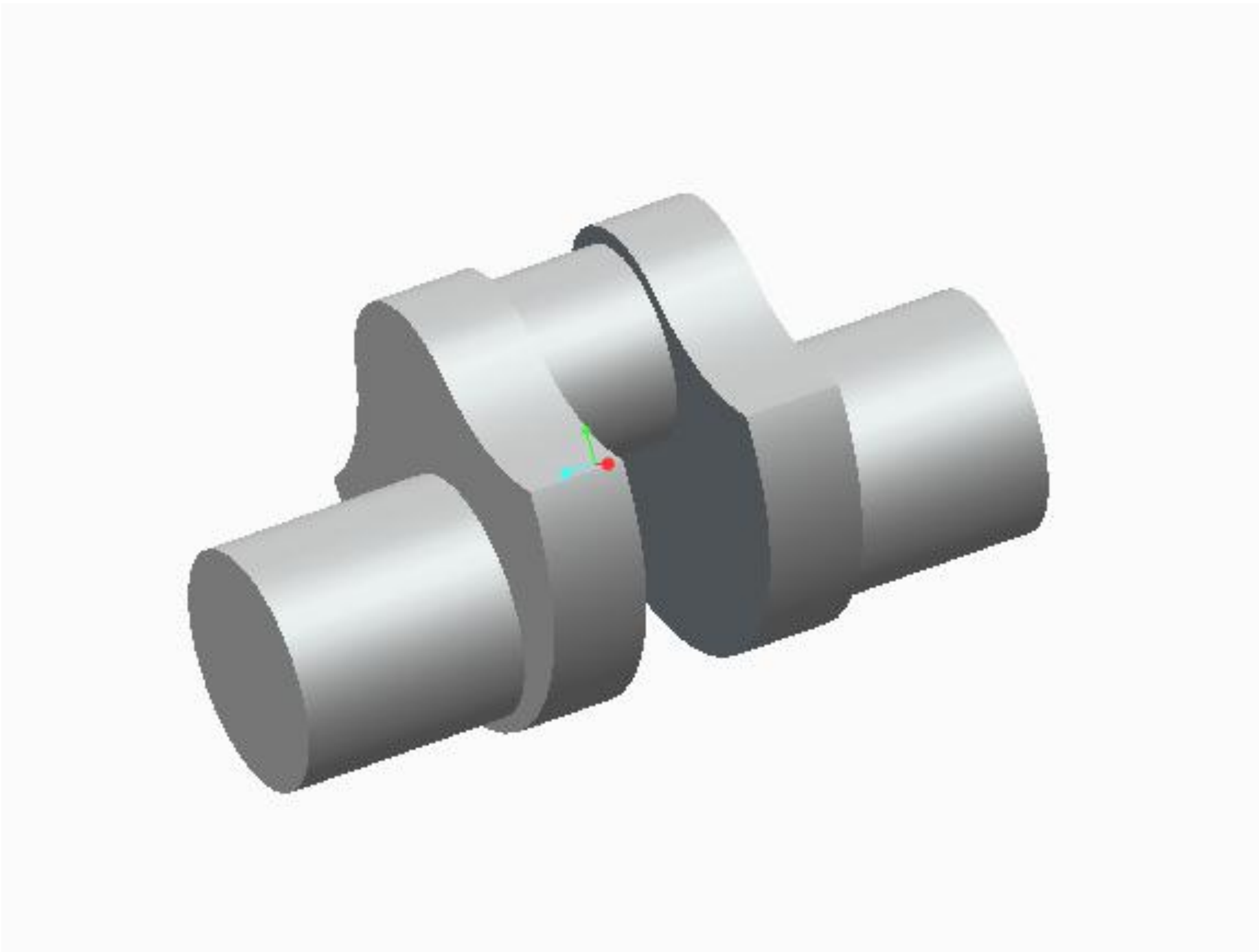

Figure 5: Crank Shaft

Sump

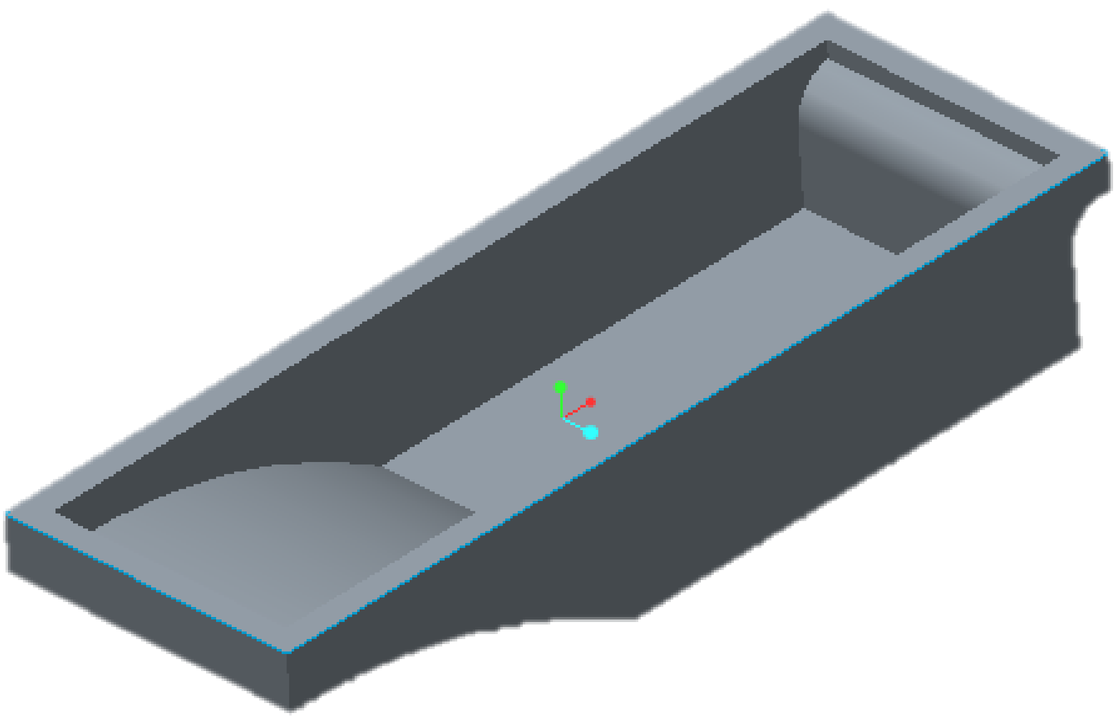

Figure 6: Sump

Complete Assembly

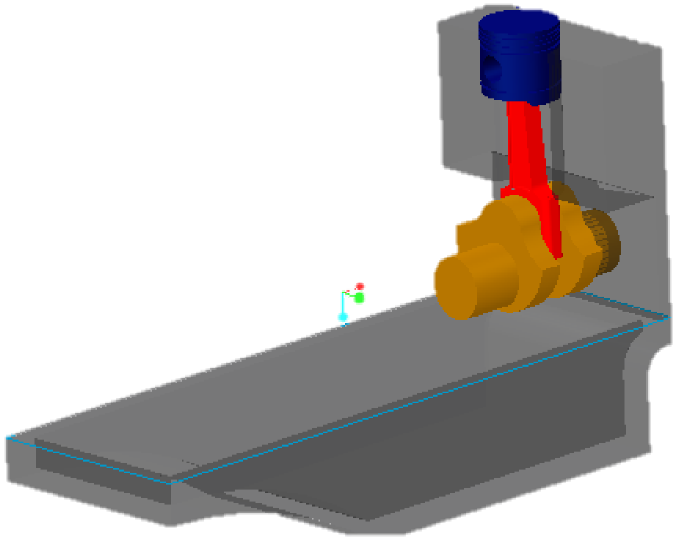

Figure 7:

Complete

Assembly

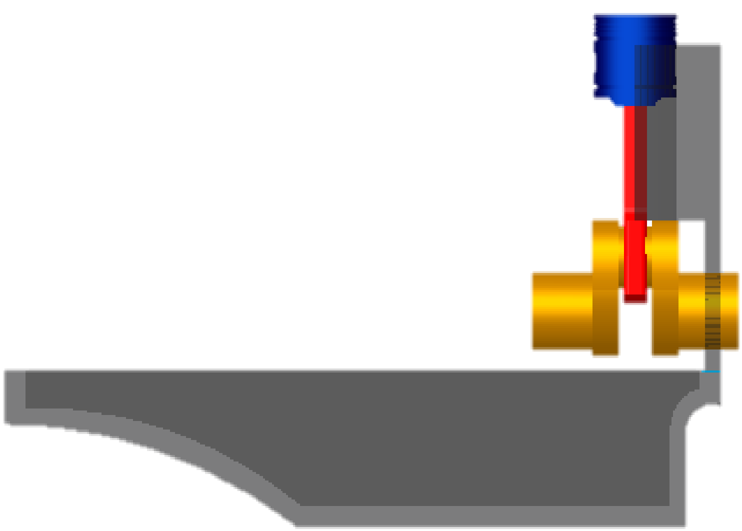

Figure 8:

Complete

Assembly

Curve Tracing

Once done with the modeling of the engine, the exact point on the big end bearing where the ribbon cable would be attached was to be figured out. This was of extreme importance and the point chosen had to be the best possible choice or else the Ribbon Cable would snap.

The main objective of choosing a point of attachment was that it would help produce the least amount of bend in the Ribbon Cable as the piston-connecting rod assembly would move from one extreme to the other. Thus ProE was used to trace curves of 3 different points of attachments. These curves showed us the path each point followed during a complete cycle. Also the distance of these points from the side boundaries of the sump would be important as the minimum distance between the point and the boundary would also mean minimum bend (Ribbon Cable will be drawn out of the engine through the side boundary of the sump).

The image on the next page shows us the points taken under consideration and the final chosen point of attachment.

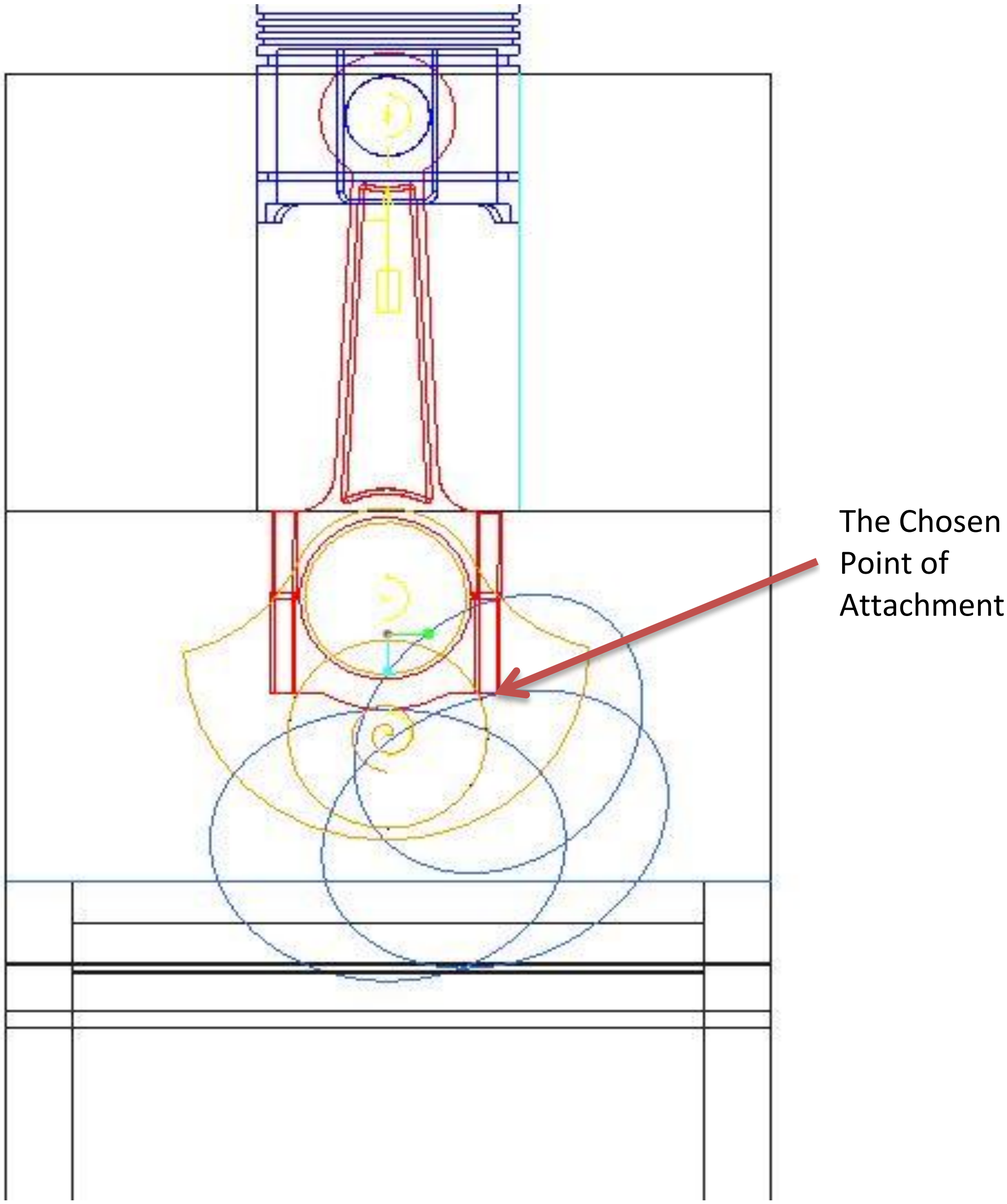

Figure 9: Curve Tracing

Testing (a)

Now that all the modeling had been done, it was time for the real test. The ribbon cable was attached to the big end bearing using an aluminum plate of dimension 2x4.2 cm and a small piece of rubber. The purpose of the rubber was to provide support to the ribbon cable. The aluminum plate was permanently fixed using two screws. The picture below shows the whole setup.

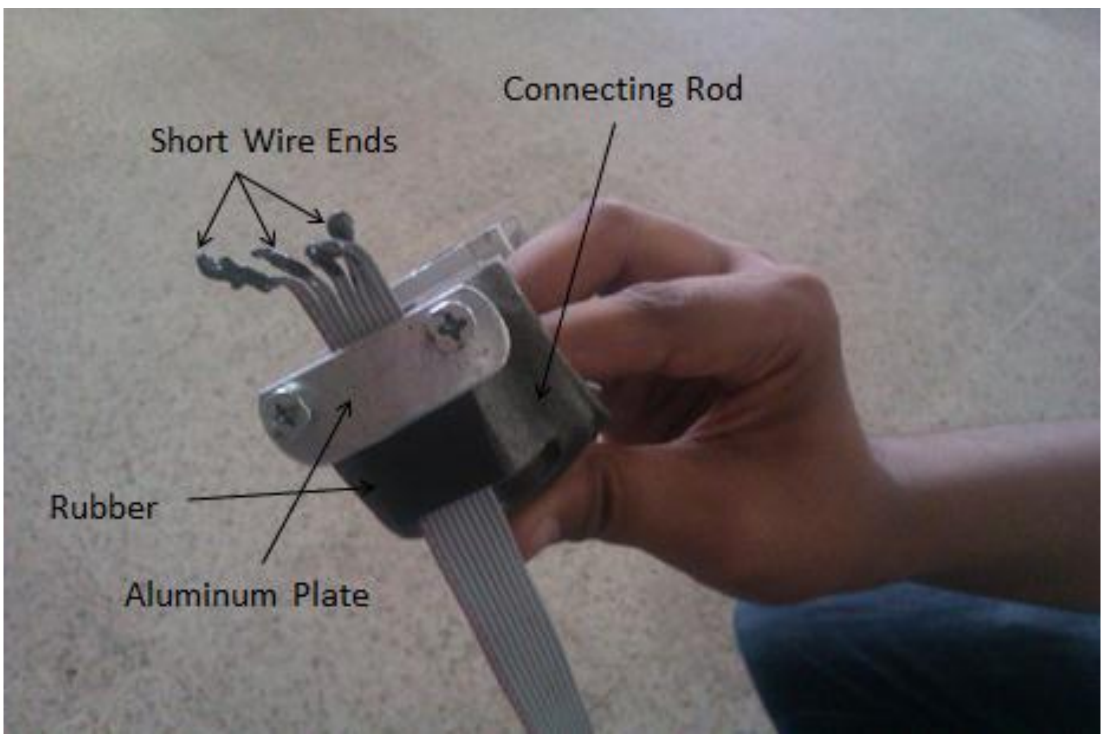

Figure 10: Assembled Hardware

The ribbon cable, at the end attached to the bearing, was cut into pairs of two and was shorted. This would later, using a multi meter to check for continuity, help us find out whether the wire was intact or it had broken.

Here is another picture of the hardware setup.

Figure 11: Assembled Hardware

And this is how it looked like when the big end bearing was reinstalled into the engine.

Figure 12: Assembled Hardware

Testing (b)

The results, which will be discussed later, did not turn out to be as positive as hoped. So a different method to connect the ribbon cable was employed. This time the ribbon cable was deployed with the help of a piece of elastic such that the elastic would stretch/relax and hence bear all the stress.

Here are a few pictures showing how this configuration was achieved.

Figure 13: Elastic Configuration

Figure 14: Elastic Configuration

Results

Initially a ribbon cable of length 21cm was used. The cable, as mentioned before, was attached to the big end bearing using an aluminum plate and a small piece of rubber. After installing the setup into the engine, the engine was turned on. The engine was operated for a total of 90 minutes during which 4 pairs of wire snapped while 1 remained intact (checked by continuity test). The reason behind 4 pairs snapping and 1 staying intact was not known. It was expected that the wire would completely snap if it did.

Non satisfying results prompted us to deploy the ribbon cable in another manner i.e. using a piece of elastic. The thought here was that the ribbon cable had snapped because all the stress was focused on it. So the piece of elastic was supposed to stretch and relax and hence would decrease the stresses acting on the ribbon cable. And it worked a lot better than the first configuration.

Initially the engine was run at 690 rpm for 20 minutes and all the 5 pairs were intact. Then the rpm was stepped up to 790 rpm for another 20 minutes, the whole ribbon cable was still intact. However when the rpm was further increased to 890 rpm, the whole cable snapped.

Hence, for an rpm of up to 790, the ribbon cable worked perfectly.

Conclusion & Future Recommendations

Further Research can be done using the Ribbon Cable Mechanism we have installed to study the internal friction and temperatures and these studies can ultimately help to reduce this friction and increase fuel economy

However we would recommend that the quality of ribbon cable used needs more research. A new ribbon cable needs to be searched which can with stand even higher temperatures and rpms and is flexible and strong as well so that one does not need to install and reinstall the cable after every few hours of the engine running.

If such a cable is available in the market (which we doubt as we searched a lot) then using that cable can prove very helpful in this research. Otherwise a custom made cable can be ordered because a good cable is the difference between this apparatus running for a few minutes or hours to several weeks or months.

References

[1] Forbes, J.E. and Taylor, E.S., 1943, “A Method of studying piston friction”, NACA Wartime report, March 1943.

[2] Uras, H.M. and Patterson, D.J., 1983, “Measurement of piston and ring assembly friction by instantaneous IMEP method”, SAE Paper 830416.

[3] Picture of grasshopper linkage courtesy of Dr. Riaz Ahmed Mufti, Prof. of School of Mechanical & Manufacturing Engineering, National University of Sciences & Technology.

[4] Ron Matthews, PI, 2005 “Reduced Engine Friction and Wear”, Prof. of Mech. Engineering, the University of Texas