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VIBRATION AND CAVITATION EFFECTS ON THE COOLING SYSTEM IN ICE DUE TO PISTON-CYLINDER DESIGN

The problem of possible pitting and cavitation in internal combustion engines is receiving considerable attention. Both theoretical and simulation studies are carried out in order to understand the noise and vibration sources, using a force equation. A foundation is also laid to study cavitation and find possible ways of increasing the life of the engine components. Some important results have been shown with negative pressures leading to the fact that the developed models predict the presence of cavitation in the cylinder liner surface, stressing the importance of improving the piston and cylinder liner design.

Keywords: cavitations, vibrations, cooling system, cooling fluid, internal combustion engine.

Introduction

Periodic loads on structures may results in severe vibratory motion. Letting the structure interact with a fluid affects the characteristics of the system behaviour. This coupled problem is of interest when designing for example cylinder liners in combustion engines. Neglecting this effect may result in unexpected occurrence of severe pitting and failure due to cavitation. This presentation explores modeling and simulation of the occurrence of cavitation on a liquid cooled cylinder liner surface.

In the world today, there are more vehicles as compared to other machines. Of the two internal combustion engines, IC Diesel Engines are now replacing the more expensive petrol engines. They are mostly being used as commercial vehicles due to its fuel economy. Diesel Engines do not always have the good news, for beneath its fuel economy, comes the noise factor. They are known to generate a lot of noise as a result of piston slap. They operate at high peak pressure giving rise to greater noise and vibration.

The noise generates a lot of vibration in the cylinder chamber which causes cylinder liners to vibrate, there is also the effect of the piston slap which is the result of the piston side thrust on the cylinder liner as it moves to and fro from TDC to BDC, the net effect of which makes the cooling fluid in the cooling chamber to undergo vibration and then the production of the unwanted cavitation in the cooling chamber. The forces causing the cavities to form and collapse are due to a continuous series of high frequency pressure pulsation in the liquid.

It has been a fact that the effects of cavitation are very worrying. Some of these effects are so damaging that they can even destroy the whole cylinder liner and thus a new one needs to be purchased. Theoretical aspect of this work deals with various types of cavitation, how they affect the cylinder liner, the dynamics of the piston-crankshaft assembly, the piston slap and the vibration forces that comes with it [1–4].

The purpose of this work is to model a coupled fluid-structure interaction featuring cavitation at the interfacing domain boundary, applied on the cylinder liner and cooling liquid in an internal combustion diesel engine. Focus is put on representing the varying pressure distribution along the cylinder liner, assuming negative pressure values imply presence of cavitation.

Materials and methods

An overview of the cavitation phenomenon and its physics based on a literature survey is given here as a support to the modelling approach in the present work.

It is difficult to give a precise definition of cavitation. Cavitation is the formation and activity of bubbles or cavities in a liquid. Formation of bubbles refers to creation and change in existing cavities. These bubbles may be suspended in a liquid or may be trapped in tiny cracks either in the liquid's boundary surface or in solid particles suspended in the liquid.

The expansion of the minute bubbles may be affected by reducing the ambient pressure by static or dynamic means. The bubbles then become large enough to be visible to naked eye. These bubbles may contain a gas or vapour or a mixture of both. If these bubbles contain gas, then the expansion may be due to diffusion of dissolved gases from the liquid to the bubble, or by pressure reduction, or by temperature rise. However the bubbles chiefly contain vapour, reducing the ambient pressure sufficiently at essentially at constant temperature causes an explosive vapourization into the cavities which is the phenomenon that is called cavitation, where as rising the temperature sufficiently causes mainly the vapour bubbles to grow continuously producing boiling. This gives an interesting observation that explosive vapourization or boiling does not occur until a threshold is reached. F. Ronald Young [1].

The start of cavitation is observed with the formation of a bubble. The growth and collapse of a bubble play an important role in the determining the type of cavitation to follow. Following are the ways in which a bubble may grow.

1 For a gas filled bubble, it could be by pressure reduction or increase in temperature. This is called gaseous cavitation.

2 For vapour filled bubble, by pressure reduction. This is called vapourous cavitation.

3 For a gas filled bubble, by diffusion. This is called degassing as gas comes out the liquid.

4 For a vapour filled bubble, by sufficient temperature rise. This is called boiling.

A critical examination of cavitation reveals the following facts.

1 Cavitation is a liquid phenomenon and does not occur in solid and gases.

2 Cavitation is the result of pressure reduction in the liquid and thus presumably, controlling the amount of the minimum absolute pressure can control it. If the pressure is reduced and maintained for sufficiently long duration of time, it will produce cavitation.

3 Cavitation is a dynamic phenomenon and it is concerned with the growth and collapse of cavities.

Some significant observations from previous experiments show some interesting characteristics of cavitation, which are listed below.

1 Cavitation occurs in a liquid, which is moving, or at rest.

2 There is no indication that the occurrence of cavitation is either restricted to or excluded from solid boundaries. This goes to show that cavitation may occur either in the body of the liquid or on a solid boundary.

3 The description is concerned with dynamics of cavity behaviour. A distinction is implied between the hydrodynamic phenomenon of cavity behaviour and its effects such a cavitation erosion.

Cavitation can be classified in to two types based on its occurrence.

Due to tension in the liquid. The engine, in generating mechanical power also generates waste heat energy because they are not perfectly efficient. Cooling is therefore prevalent in order to prevent the engine from cooking in its own heat.

Even though some waste heat goes out with the exhaust in most IC engines, further cooling is required to prevent the engine from material and lubricant failure. For this work we concentrate on liquid coolants.

Most liquid coolants contain a greater amount of water and approximately 30 percent of ethylene glycol. The cooling process starts at the radiator where there is a store of the liquid. The liquid is pumped into the cooling chamber going round the wet side of the cylinder liners. The heat transfer is such that the liner gets cooled and the liquid gets hot. The hot liquid is then returned to the radiator where a fan blows around it to cool it for the process to begin again. For an effective running of the engine the cooling liquid is kept at a temperature between 70° and 75° Centigrade. A low temperature cooling liquid also slows down the efficiency of the engine.

The above diagram shows the cold liquid in the lower hose the hot liquid in the upper hose. The rest of the parts are labeled in the diagram in figure.1 above.

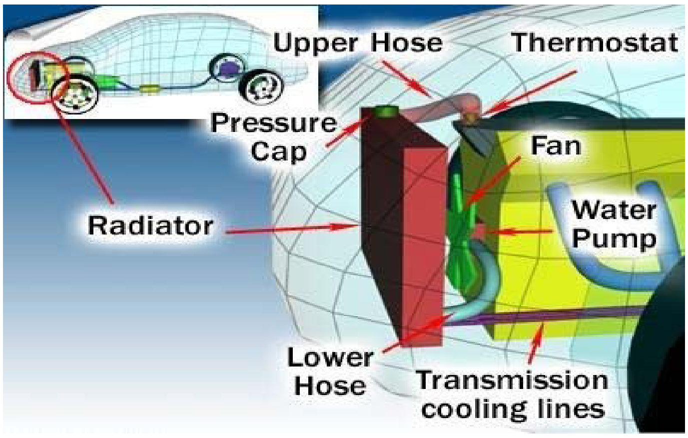

Figure 1 – Layout of a typical cooling system of IC Diesel Engine

The geometry of the parts in the studied system was created using the Autodesk Inventor CAD software. The figures 2 and 3 below show the piston cylinder liner geometry and assembly. Shigley and Uicker [5, 6].

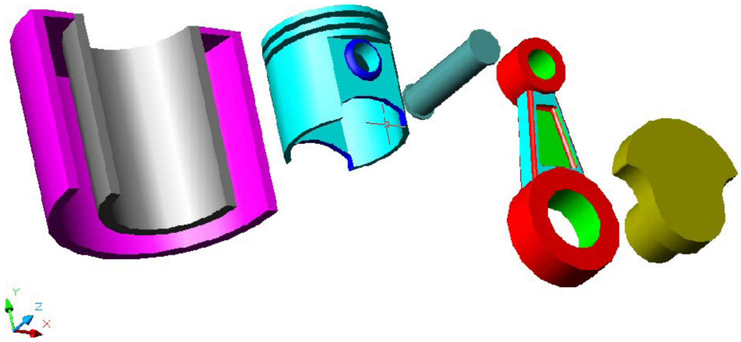

Figure 2 – The parts in the studied system

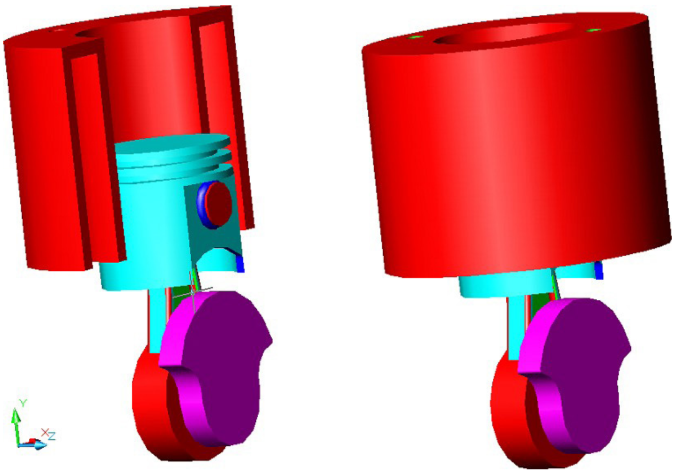

Figure 3 – Total Assembly

Results and discussion

The presence of cavitation in IC Diesel engines is real and cannot be overlooked. Its damaging effect leads to economic and material constrain on its owners.

In this study much was done on the literature review of cavitation, force equations on the piston cylinder/assembly of an IC diesel engine and geometrical model of the piston and the cylinder.

The data gathered were used as boundary conditions to generate a model using the software ANSYS.

A steady state analysis and a harmonic analysis were considered for both a 2D and a 3D model. Use was also made of a thermal and acoustic properties pertaining to grey cast iron and fluid, the materials in question. The effect of thermal properties led to results of higher values of pressure variations in magnitude.

From the results gathered it was shown that there were areas along the fluid/solid boundary that experienced negative pressures, the purpose of the work, negative pressure predicts that cavitation can occur.

This work was done using ANSYS. In furtherance to this work can be done using other software like IDEAS to get the mode shapes and other quantise that were not done here.

An effort has been made to analyse the sources and types of cavitation. Piston slap is a source of Vibratory cavitation and Acoustic cavitation as well.

So to reduce the cavitation the piston motion has to be studied and the following are some of the ways of reducing the vibrations and noise coming from the piston-slap [7–11].

1 Reducing the clearance between piston and cylinder liner, this is based on the assumption that the impacting energy increases with increasing the lateral travel distance of the piston. Although this technique is simple and easy to understand, there are a few drawbacks, it is difficult to achieve such a small clearance on the production line and maintain it during the whole operating life of the engine. If the clearance is too small then it's a source of a wear and tear in the engine.

2 Wrapping the piston skirt with leather, this is an attempt to add a cushioning or a compliant material on the piston side. This method is not directly applicable due to its durability. But a similar technique has been developed with Teflon pad on the thrust side.

Conclusions

Following are some of the modern developments in the piston design in reducing the vibrations and noise:

1 Thermal strut piston.

2 Articulated piston.

3 Piston pin offset.

Thermal strut piston contains a steel strut inside the piston skirt. This strut controls the clearance between the piston and the cylinder wall during all operating conditions by controlling thermal expansion.

Articulated piston is a combination of two pistons which perform the two main functions of a piston separately, that of a slider and vertical load carrier. The piston is divided into two parts connected to each other by a piston pin. The upper part (mainly ring land) carries the combustion force and can rock back and forth. The lower part (skirt) slides up and down in the cylinder. With this design it is easier to control the oil film thickness than when using a solid piston.

Piston pin offset is commonly used and the idea is to shift the impact timing by setting the piston off the centre line of the piston and thus centre in the cylinder. The amount of offset might differ from cylinder to cylinder.

Studies of the performance of the above mentioned and other designs are left as suggestions for future work.

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ПОРШЕНЬ-ЦИЛИНДР ҚҰРЫЛЫСЫНА БАЙЛАНЫСТЫ ІЖМ-ДАҒЫ САЛҚЫНДАТУ ЖҮЙЕСІНЕ ДІРІЛ МЕН КАВИТАЦИЯНЫҢ ӘСЕРІ

Ішкі жану моторларында коррозия мен кавитацияның пайда болу проблемасына көп көңіл бөлінеді. Теориялық және имитациялық зерттеулер күш теңдеуін қолдана отырып, шу мен діріл көздерін түсіну үшін жүргізіледі. Сондай-ақ, кавитацияны зерттеу және қозғалтқыш компоненттерінің қызмет ету мерзімін ұзартудың мүмкін жолдарын іздеу үшін негіз қаланды. Кейбір маңызды нәтижелер теріс қысым кезінде көрсетілді, нәтижесінде жасалган модельдер цилиндр гильзасының бетінде кавитацияның болуын болжайды, бұл поршень мен цилиндр гильзасының қрылысын жақсартудың маңыздылыгын көрсетеді.

Кілтті сөздер: кавитация, діріл, салқындату жүйесі, салқындатқыш, ІЖМ.

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ВИБРАЦИОННОЕ И КАВИТАЦИОННОЕ ВОЗДЕЙСТВИЕ НА СИСТЕМУ ОХЛАЖДЕНИЯ В ДВС ИЗ-ЗА КОНСТРУКЦИИ ПОРШЕНЬ-ЦИЛИНДР

Проблеме возможного образования точечных коррозии и кавитации в двигателях внутреннего сгорания уделяется значительное внимание. Как теоретические, так и имитационные исследования проводятся для того, чтобы понять источники шума и вибрации, используя уравнение силы. Также заложен фундамент для изучения кавитации и поиска возможных путей увеличения срока службы компонентов двигателя. Некоторые важные результаты были показаны при отрицательных давлениях, что привело к тому, что разработанные модели предсказывают наличие кавитации на поверхности гильзы цилиндра, подчеркивая важность улучшения конструкции поршня и гильзы цилиндра.

Ключевые слова: кавитация, вибрация, система охлаждения, охлаждающая жидкость, ДВС.

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