Design of Self-Adjusting Strainer Assembly for Off-road Conditions used in Diesel Engine

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Abstract: The main function of lubrication oil system in IC Engine is to lubricate the engine parts for reducing friction, removing products of wear, preventing rust and partially cooling individual assemblies of the engine. Oil flows from oil-sump to oil pump through the strainer. The oil level in oil-sump is kept in such a way that continuous flow of oil is maintained through the strainer. During the off-road condition, oil in oil pan is displaced to the rear or to the front of oil-sump. This causes the air to suck instead of oil. Thus insufficient pressurized supply of air to various engine components is occurred when oil level inside the oil-sump falls below strainer during this condition. This results into friction of engine components, thus reducing the engine efficiency. The objective of proposed work is to design oil-sump strainer assembly which will get self-adjusted during the off-road condition. The design consists of sliding mechanism which gets slide in the tilted direction. Thus it is possible for the strainer to suck the oil which is at lower level. This allows lowering down the oil-sump height, increase in engine compactness and ground clearances.

Keywords: Lubrication oil system, off-road condition, oil pan strainer assembly, sliding mechanism and tilt condition.

1. INTRODUCTION

In an IC engine, lubrication system is used to reduce friction and wear between contact surfaces and thereby reduce friction loss and increase life of an engine. Oil pump, oil filters, pressure relief valve, oil cooler, piston cooling jet, oil level dipstick, oil-sump, strainer, oil are the main components of lubrication system. An oil pump is used to source pressurized oil to lubricate various type of lubrication system. Generally, conventional oil suppling system consists of feed pipe through which oil gets supplied from oil-sump to oil pump. The inlet of feed pipe consists of strainer which is used to prevent dirt and positioned normally at the center of oil-sump. The level of oil in the oil-sump is maintained below the crankshaft and above the strainer.

When the vehicle travels along a flat surface or normal highway condition, it is convenient for oil pump to suck the oil as it is below the strainer. But during off-road condition, vehicle undergoes acceleration or deceleration and tilts forward or backward. In these cases, oil in the oil-sump is displaced to the front or to the rear of the oil-sump. This results into insufficient supply of oil to desired parts of the vehicle engine, as air gets sucked through the strainer instead of oil. This results into friction of engine components, thus reducing engine efficiency and life of an engine. Hence large amount of oil is required in the oil-sump thus increasing the oil-sump size.

Analysis of various oil-pick mechanism and engine components was performed to optimize the design of lubrication system for maintaining desired oil flow rate. One of the patents discussed an oil pick-up system for an engine which allowed continuous flow of oil through engine components (Kampichler and Madl, 2001). Another patent with oil feeding system was described which effectively supply oil to an oil pump at all operating conditions (Moren and Mats, 2008). It is irrespective of whether the vehicle is deaccelerating, accelerating, tilting or turning. During the tilting condition one of feed pipe gets slide in the direction of tilted oil. Simultaneously other end of feed pipe gets blocked by flow control valve present in the system, thus ensuring continuous flow of oil.

One of the patents proposed oil pick-up system for dry sump lubrication system of an engine (Woolson, 1932). It consists of ball valve which slides in either direction due to effect of gravity. During the inclined condition, it blocked the passage through which air comes, thus maintaining continuous supply of oil.

Computational flow dynamics (CFD) analysis of plastic oil-sump was performed in comparison with sheet metal oil pans (Kolekar *et al*, 2009). To obtain sloshing result for developed thermoplastic oil-sump, experiment was carried out. CFD and experimental results predicted that uncovering time for pick-up inlet was more for plastic sump as compare to steel sump. Also from an analysis which was done at different speed verses pressure and velocity, it was seen that plastic oil-sump modules have similar performances as that of steel oil-sump. A math based analysis was performed to increase the efficiency of Gerotor pump (Natchimuthu *et al*, 2010). Simulation of flow through the Gerotor oil-pump was performed using CFD. Simulation results show that mass flow rate was similar to experiment flow rate. This validation predicts that CFD have provision of predicting oil flow rate of an oil pump.

2. Problem statement

During off-road conditions, oil in the oil-sump is displaced to the front or to the rear of the oil-sump. Thus it is not possible for existing strainer to supply sufficient pressurized supply of air as it is not fully dipped in engine oil and partially or fully exposed to air. Hence instead of oil, air gets sucked through the strainer. This results in oil starvation of engine components. In order to prevent this situation; the level of oil in oil-sump is kept high enough, thus preventing the air to get sucked through the strainer. A drawback with this solution is that a large quantity of oil is required to be maintained in the oil-sump, which increases overall cost. Also oil-sump is required to make larger in size to hold such large quantity of oil which increases manufacturing cost and design constraints. The fuel efficiency of vehicle also decreases due to increase in weight of oil pan and sump.

These difficulties are overcome by developing self-adjusting strainer assembly which supplies continuous flow of oil during off-road conditions (Malode, *et al*). The proposed design of self-adjusting strainer assembly consists of plunger which slides inside the barrel. Plunger comprises of inlet port through which oil gets sucked from oil-sump. During the off-road condition plunger gets slide in the tilted direction and thus maintain continuous flow of oil through engine lubrication system. In this paper, with reference to proposed design, simulation analysis is carried out at extreme tilt condition. The results show that, it is possible for the strainer to suck the oil which is at lower level. This allows lowering down the oil-sump height, increase in engine compactness and ground clearances.

3. Design of Proposed Strainer

The inlet and outlet dimensions of strainer depend upon the volumetric flow rate of oil through the oil-pump. The dimension of inlet and outlet port of strainer is determined in such a way that desired oil flow rate is obtained through the pump.

Table 1 shows the engine specifications for which the proposed strainer is designed

Table 1 Diesel engine specifications

S. No	Parameters	Values
1	Rated power at rated speed	50KW
2	Rated speed	2200 rpm
3	Mass flow rate of fuel	11.25 kg/h
4	Brake specific fuel consumption	225 gm /KW-hr
5	Calorific value of fuel	44799 KJ/kg

Circulation rate of oil i.e volumetric flow rate of oil pump is given by

$$Vc = \frac{Q_0^1}{\rho_0 \times C_0 \times \Delta T}$$

Where,

Vc = Volumetric flow rate of oil pump

Q_0^1 = Engine heat dissipated by oil ρ_0

= Density of oil

C_0 = Thermal capacity of oil ΔT

= Rise in temperature of oil

The value of engine heat dissipated by oil is calculated by heat analysis.

The inlet diameter of an oil-pump is calculated from the below equation which is required to maintained required flow through oil-pump.

$$Vc = \frac{\pi}{4} \times d^2 \times v$$

Where,

Vc = Volumetric flow rate of oil pump

d = Inlet diameter of an oil-pump

v = Velocity of engine oil through strainer

The outlet diameter of feed pipe attached to strainer is equal to calculated diameter of pump

4. Generation of CAD model

CAD modelling of existing oil-sump strainer and proposed oil-sump strainer assembly is done by using Unigraphics (NX 9.0) software.

Figure 1 shows the isometric view of self-adjusting strainer assembly. It consists of plunger having arms attached to its end. The upper surface of plunger is having elliptical hole where the filter plate is fitted. The plunger is hollow in structure and is closed at the outer ends of plunger arm. A small hole is provided to the arm for the removal of air inside the plunger.

First the model of plunger is constructed having elliptical hole at the middle of its upper surface. Then during the assembly of the model, the outer arms are attached to plunger by taking distance and concentric constraints. The plunger is enclosed inside the barrel by using touch align and distance constraints. The upper surface of barrel is having circular port to which feed pipe is connected. The oil feed pipe is attached to barrel by using concentric constraints during the part assembly of the model. When the assembly is in the static position or parallel to the horizontal plane, the inlet holes/ports of the pipes gets half closed by the barrel as shown in figure.

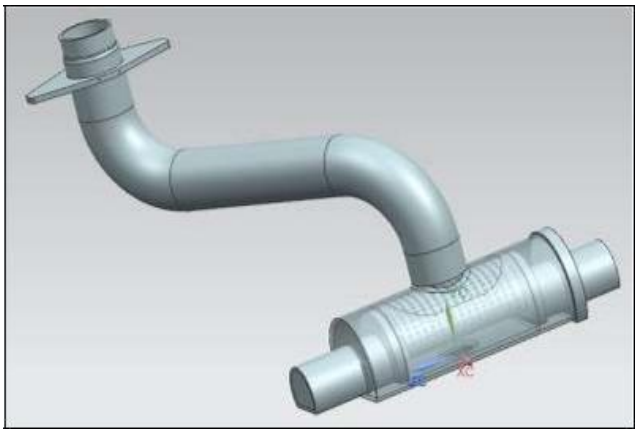

Fig.1 Isometric view of self-adjusting strainer assembly

Figure 2 shows sectional view of self-adjusting strainer assembly. Both plunger and its arm have inlet ports at its lower surface. The lower surface of barrel is having circular hole concentric to upper circular port of barrel and lower inlet port of plunger. During the off-road condition, one of the inlet ports of plunger gets slide in the direction of tilted oil, thus blocking the other inlet port as it gets slide inside the barrel. This prevents the suction of air from the other blocked inlet port.

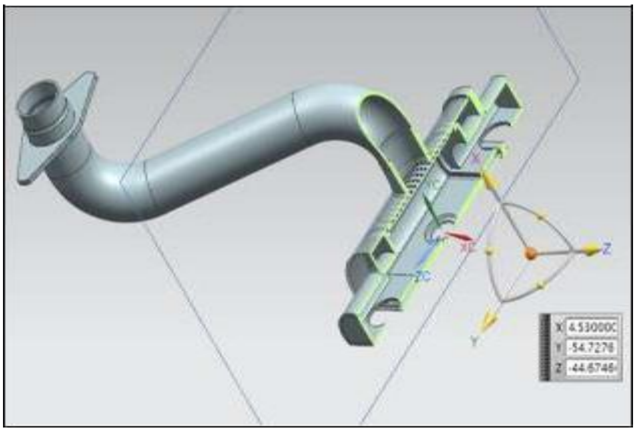

Fig.2 Sectional view of self-adjusting strainer assembly

Figure 3 shows existing oil-sump strainer assembly. The strainer is placed at the middle of an oil-sump with the help of touch align constraint. 'Infer Center Orientation' is used for this purpose. During the assembly, fixed constraint is given while positioning the existing strainer in order to restrict its degree of freedom in all direction.

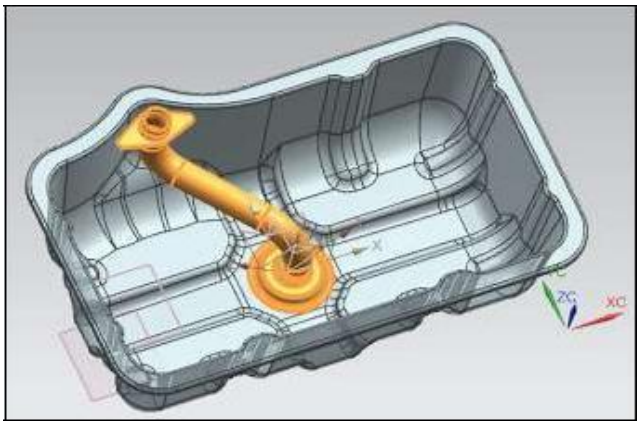

Fig.3 Existing oil-sump strainer assembly

Figure 4 shows the proposed oil-sump strainer assembly. Similar oil -sump is used for both existing and proposed model. The sliding strainer is placed at the middle of an oil-sump with the help of touch align constraint through 'Infer Center Orientation'. During the assembly, fixed constraint is given to the barrel and oil-feed pipe in order to restrict its motion in all direction. Whereas, plunger is allow to move in horizontal direction. During the tilting condition, the plunger moves in the tilted direction of oil, thus maintaining a continuous flow of oil through the strainer.

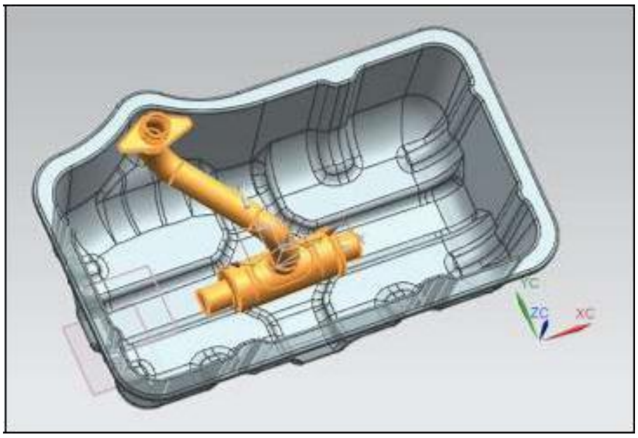

Fig.4 Proposed oil-sump strainer assembly

5. Results and discussions

Simulation of both existing and proposed oil-sump strainer assembly is carried out by using Unigraphics (NX 9.0) software. This includes the determination of minimum oil requirement in the oil-sump at which oil gets sucked by oil -sump during tilt condition of vehicle for both models. A tilting angle of 45^0 is taken as extreme tilted situation for the vehicle during off-road condition. Simulation results are obtained at such extreme tilting condition for both existing and proposed oil-sump strainer assembly. 'Space Finder' is a tool which is used to calculate volume enclosed by

assembly part during the simulation. It helps to determine the parameters like volume-height relation of the oil in the gearbox assembly.
Figure 5 shows minimum oil requirement for existing oil- sump strainer assembly at 45^0 tilt condition. From the simulation results, it is seen that minimum 8.0 litre oil is required in the oil-sump to maintain continuous flow of oil through the engine.

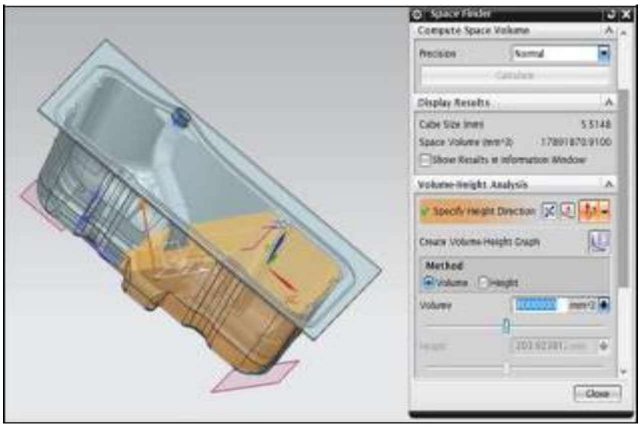

Fig.5 Minimum oil requirement for existing oil-sump strainer assembly at 45^0 tilt condition

Figure 5 shows minimum oil requirement for proposed oil-sump strainer assembly at 45^0 tilt condition. From the simulation result, it is seen that minimum 5.5 litre of oil is required in the oil-sump to maintain continuous flow of oil through the engine at such extreme slope condition.

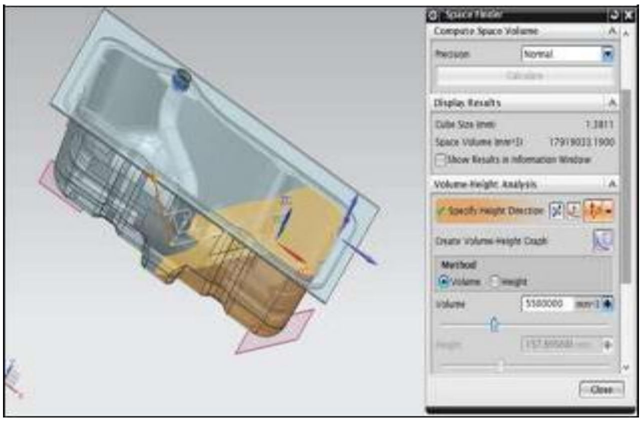

Fig.5 Minimum oil requirement for proposed oil-sump strainer assembly at 45^0 tilt condition

From the table 1, it is seen that the difference between minimum oil requirements for both assembly is 2.5 litre. This allows reducing oil-sump height, thus making the engine more compactible.
Thus minimum volume requirement of oil in oil-sump is found out for both model and based on that volume parameter; result analysis is performed.

Table 1 Minimum oil requirement for both proposed and existing assembly model at 45^0 tilt condition

Sr. No	Type of Assembly	Minimum oil requirement at 45^0 tilt condition (litre)
1	Existing oil-sump strainer assembly	8.0
2	Proposed oil-sump strainer assembly	5.5

Conclusions

The amount of oil required at 45^0 slope condition is always large as compare to other slope conditions having slope angle less than 45^0. Also it is the maximum slope, the vehicle can travel during off-road condition. Hence the simulation was carried out for 45^0 slope condition, which is treated as most worst off-road condition.

From the simulation results, following conclusions are drawn.

1) The minimum oil requirement for proposed oil-sump strainer assembly is reduced by 2.5 litre as compare to existing assembly. Thus the total volume of oil in the oil-sump can be reduced by 2.5 litre for the proposed strainer.
2) Decrease in quantity oil in oil-sump results into reduction of oil-sump height of an engine, thus reducing manufacturing cost
3) Due to low oil-sump height, engine compactness increases, thus decreases the vehicle manufacturer's design constraints.
4) This also results into increase in ground clearance which decreases vehicle's center of gravity and thus improves its directional stability
5) Also weight of an oil-sump gets decreased which results into increase in fuel efficiency of an engine.

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