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ANALYSIS OF HYDRODYNAMIC BEARINGS IN LIGHTWEIGHT CRANKSHAFTS

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Abstract. *The crankshaft and connecting rods are some of the most important components of an internal combustion engine. They are responsible for transforming the linear motion of the pistons into rotational motion. To allow such a rotary movement and prevent wear, the crankshaft is mounted on hydrodynamic bearings, which sustain the weight of the crankshaft and the dynamic loads. Due to the relative movement between them a film of oil is generated in the connection surface of the crankshaft and main bearings and it is responsible to sustain those loads.*

Due to the requirement for reducing emissions and fuel consumption, weight reduction of the engine components and compression ratio increasing have been considered. However, these changes have great influence on the hydrodynamic bearings that support the crankshaft and may lead to premature wear.

This work aims to study the influence of weight reduction of crankshafts on the load carrying capacity of hydrodynamic bearings. Under this goal, the ALV Excite software was used to perform dynamic simulations and assess the bearing support loads.

Keywords: *Lightweight crankshaft, Bearings, Internal combustion engines*

1 INTRODUCTION

Nowadays there has been better efficiency is a requirement in all fields of engineering and this includes internal combustion engines. For the automotive industry the goal is even more critical because they must attend environmental legislation such as Euro 6, which is very restrict on maximum exhaust emission standards. The emission standards have been hardly driven down, that the automotive engine makers are struggling to achieve the environmental goals.

These requirements have changed the premises for developing ICE (Internal Combustion Engines), such as the downsizing of engines to achieve high specific power. For that reason, the main parts of the powertrain must also become lighter without losing the capacity of transmitting power. They need also to support larger dynamic loads due to the increase of the combustion pressures.

One of the alternatives to reduce emission is to improve the thermal efficiency. However, the side effect is the larger strains and stresses on the engine components which may result in reduced component life, as well as significant increase in friction and wear between components. The main hydrodynamic bearings may not sustain the larger dynamic loads and the respective stresses. Such situation would ultimately lead to excessive wear and may cause fatigue failure.

Hydrodynamic bearings are strongly affected by parameters such as the applied load, the geometry, the relative velocity of the surfaces, fluid viscosity and temperature. The dependence on the applied load variations may alter the functioning of the main bearings. Reducing the weight of the crankshaft may contribute the operation of the main bearings .

This study will evaluate the response of the main bearings for lightweight crankshafts to better understand the effects inherent to downsizing. For the study the AVL Excite software, commonly used for dynamics simulation of internal combustion engines, was used.

2 AVL EXCITE DESIGNER

AVL Excite Designer software determines the kinematic quantities of the piston-conrod-crankshaft mechanism using the geometrical description. Then displacements, velocity and acceleration are expanded in Fourier series.

The dynamic analysis starts from the force generated on the piston by the combustion, calculated from the cylinder pressure curve multiplied by the piston area. The forces acting on the bodies are calculated considering the forces applied by the previous body plus the body's inertial forces of oscillation.

The pre-calculation of the loads on the bearings is done by considering the system as statically determined.

3 CRANKSHAFT WEIGHT REDUCTION

For the simulation we used a mono cylinder crankshaft which was built based on data from the example I4_demo crankshaft that comes with the AVL software. The new crankshaft is designed with a CAD system to obtain data such as the estimated weight and moments of inertia.

The change from the four cylinder scheme to the single cylinder was made to reduce the computational cost and facilitate the reconstruction of the crankshaft to obtain the mass and moments of inertia for the lightweight crankshaft.

The mass reduction process was performed by removing material from the center of the main bearing of the crankshaft and the center of counter weight. The bearing surface has an outside diameter of 60 mm and a hole of 10 mm was considered. The mass was reduced by 124 g on each counter-weight and 5 g of each bearing support. Figure 1 shows the final geometry of the crankshaft.

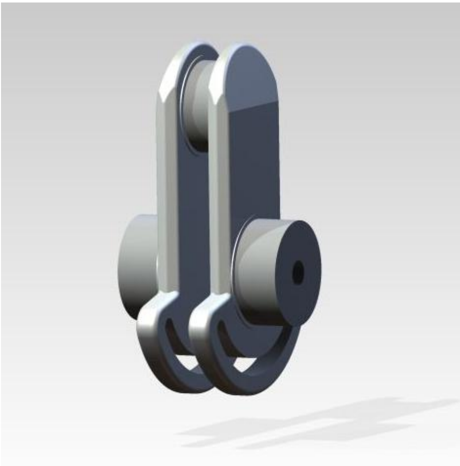

Figure 1. Crankshaft throw for one cylinder engine

4 SIMULATION

The simulation was performed in the AVL Excite Designer software and the bearing are considered rigid under dynamic loads. A pre-calculation of loads on the bearings was considered based on a statically determined system. Three cylinder pressure curves for speeds of 1000 rpm, 2000rpm and 3000rpm were adopted and are shown in Figure 2.

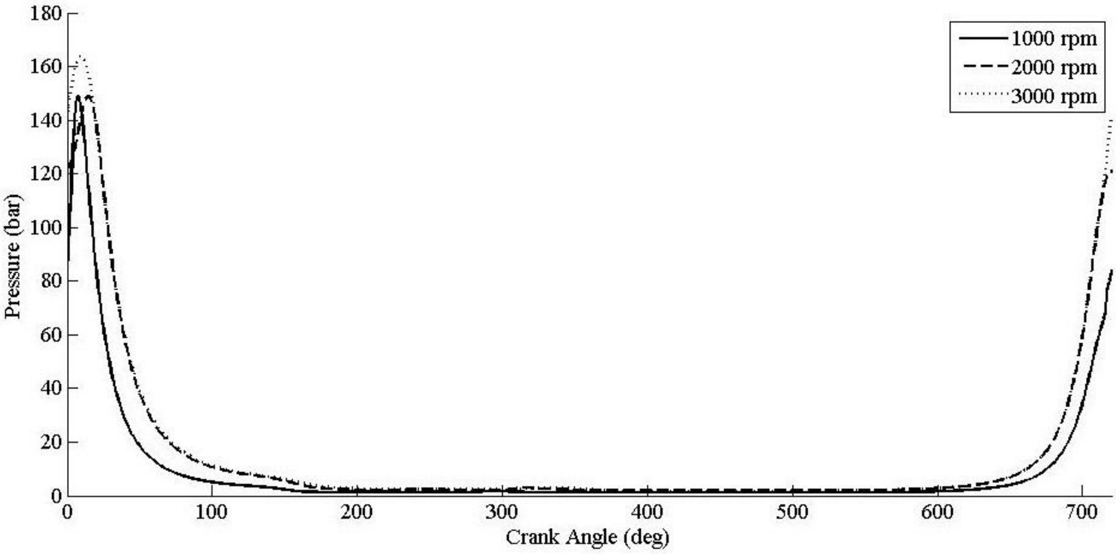

Figure 2. Cylinder pressure curves versus crank angle

The forces on the bearings were analyzed for engine speeds of 1500rpm, 2500rpm, and 3500rpm. It was possible to analyze how the increased rotation for the lightweight crankshafts affected the loads on the bearings. To perform the simulation we considered the lubricant oil SAE 5W30, commonly used engines.

5 RESULTS

Figure 3 shows the reaction loads on the main bearing versus the crank angle. The mono cylinder crankshaft configuration was subjected to the same loads. The bearing reaction loads are shown in Figure 3. The behavior for the speed range of 0-50 rpm are illustrated in Figure 4.

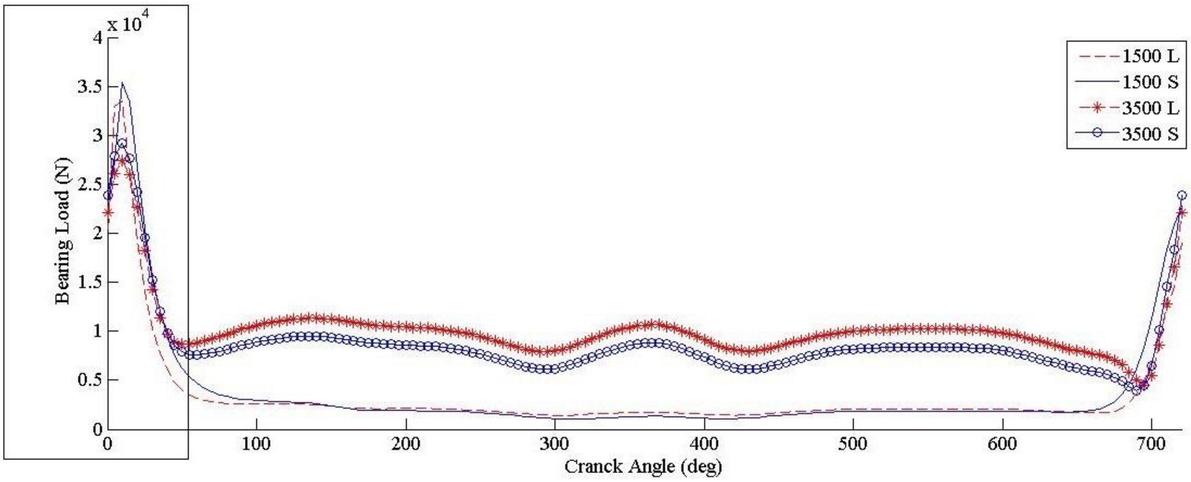

Figure 3. Bearing load versus crank angle

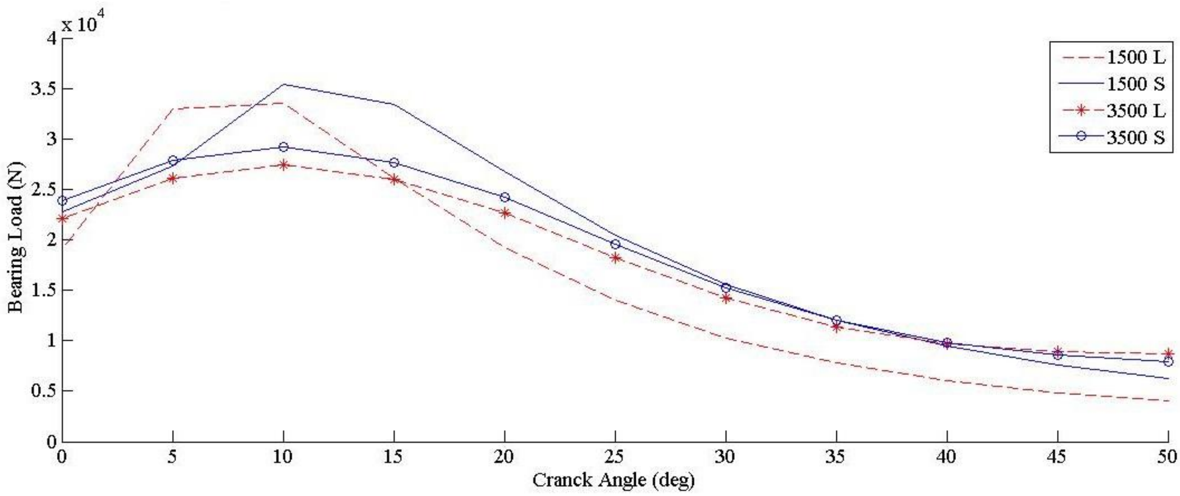

Figure 4. Detail for speed interval of 0 - 50 rpm

We can see that the lightweight crankshaft had smaller reaction loads on the main bearings. At low speeds the inertia forces are less dominant. With the increasing speed, the main bearing loads increased due to the inertial forces.

6 CONCLUSIONS

The simulations allowed us to evaluate that the lightweight crankshaft reduces the load on main bearings in the lower ranges of speed. However, at higher speeds, the main bearing loads increased because of the inertia forces.

By reducing the weight, we raised the influence of each mass on the balancing of the crankshaft and this fact also changed the overall balance. At higher speeds unbalancing becomes more apparent and increases the loads on the bearings.

From the results presented it can be concluded that the weight reduction decreased the loads on the bearings at lower speeds. However the lightweight crankshaft should be re-balanced to meet the balancing standards.

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