ON BEARING DEFORMATION AND TEMPERATURE DISTRIBUTION IN DYNAMICALLY-LOADED ENGINE BEARINGS

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ABSTRACT. Two recurring questions relating to the performance of dynamically-loaded engine bearings are:

1) How reliable are the calculated oil-film thicknesses, considering the fairly high bearing deformations? In practical engine bearings the ideal circular shape deforms appreciably under the working loads. In calculating the oil-film thicknesses, however, the ideal circular form is almost invariably assumed. Should it not be concluded that such calculations give misleading results?

2) The most important property of a lubricant is its viscosity, which is heavily dependent on temperature. Do the temperature differences which exist around the circumference of an engine bearing demand an improvement on conventional isothermal theory for dynamically-loaded engine bearings?

This lecture gives some answers to these questions, provided by research work carried out on an automotive petrol engine and on a marine diesel engine.

1. Introduction

The crankshaft of a reciprocating engine plays an important role in the propagation of combustion noise and piston slap, and in exciting vibration across clearances in the main bearings. Basically the crankshaft represents a dynamically-loaded and vibrating component, which runs in deformable and vibrating bearing housings. Coupling is achieved through the lubricant films in the hydrodynamic main bearings, which are highly non-linear, and temperature dependent.

This noise and vibration generation by the crankshaft is of special importance in engines with weak burning and hence relatively low burning noise as, for example, in I.C. engines. Experiments have shown for example that by minimising bearing play, the sound energy at the engine exterior can be reduced by up to 70%.

2. Bearing Loads

The loads applied to a large end bearing are relatively easy to determine, consisting principally of an inertia force which can be readily calculated plus a gas force which can be measured with reasonable accuracy by a pressure transducer inserted in the cylinder head.

The determination of main bearing loads is quite a different problem however. Only in an engine with a two main-bearing crankshaft is the system statically determinate, and this situation is generally limited to single cylinder and vee twin engines. For a normal multicylinder engine, with more than two main bearings, the calculation of bearing loads is a structural dynamics problem with the added complication of a non-linear spring and damper to represent each main bearing oil film.

Gross and Hussman [1] addressed the problem by considering three different approximations. They predicted main bearing loads for a particular engine by using these approximations and tested the results by strain gauging a bearing in the actual engine for comparison with the predictions. The first approximation was the "pin-jointed" or statically determinate approximation, where each span of the crankshaft was considered to be pin-jointed to the next at the main bearing centre. Each large end load was therefore shared only by the two main bearings adjacent to it, and each main bearing load was taken as the sum of the large end load components applied from the bays on either side. The second method was based on the assumption that the crankshaft was a continuous beam on rigid supports. The third method used a continuous beam loaded at the crankpins but assumed flexible supports; this method was perhaps most like the real case. The bearing oil film and its elastic support were considered as linear springs in series, no account being taken of non-linear hydrodynamic effects. Gross and Hussman's conclusions indicated that the second method was particularly poor, while the statically determinate approximation was much better. The third method worked best of all, but required assumptions to be made about the stiffness of the crankcase acting as a bearing support. This might be difficult to assess in practice.

Von Schnurbein [2] described yet another approximation, considering the crankshaft again as a continuous beam, but carried on plain bearings,