Chapter 1

Introduction

Since the 1973 Arab oil embargo, reduction in fuel consumption has become an important issue. Other reasons for improving fuel economy are: pollution, running cost (fuel is now more than 80 pence/litre), and conservation. Emission control and fuel economy have had a great influence on recent engine designs. The general trend in engine design has been towards the improvement of combustion. The adoption of double intake and exhaust valves (16 valves for a four-cylinder engine) is one of the alternatives. With a carefully designed intake manifold, the two intake valves create two separate streams of inlet air swirling in opposite directions to improve the breathing and the combustion of the engine.

On the other hand, in order to improve the breathing of the engine, cam opening rates can be increased. This requires valve train stiffness of a higher order than can be achieved by a pushrod valve train. Thus the overhead cam valve train came into favour. This comes in many forms; 'bucket follower', 'rocker follower', and 'finger follower' being the main categories. The bucket follower is a relatively low-friction system, which also has low rates of wear. For a four-cylinder engine with 16 valves, two camshafts are needed if bucket followers are to be used. This means the power loss arising from the valve train will be doubled.

The Institute of Tribology at the University of Leeds has for some time collaborated with the Ford Motor Company Limited on studies of automobile valve trains and wider aspects of engine friction. The valve train studies have covered all forms of automotive cam and follower mechanisms and entailed experimental and analytical research. A wide-ranging development of design software for the prediction of the tribological performance of all valve train forms has been undertaken by the Institute and has been installed on Ford computers. In addition to the analytical studies comprehensive experimental programmes have been conducted to investigate the tribological performance of a cam and flat-faced (bucket) follower. Several important factors including the friction torque, power loss, electrical resistivity across the contact of the cam and follower, and temperatures at the cam nose and in the valve guide were monitored in each test.

At the present time there is a strong trend towards the use of roller followers and bucket followers. With the drive for quieter engines and longer service intervals the hydraulic lash adjuster is also becoming more and more common. While much of the information presented by the Institute has related to cam and flat-faced follower with nominal line contact, there remain many challenging problems in more practical arrangements. An analysis to understand the tribological implications of the arrangement having an offset taper cam and a domed rotating follower incorporated with an hydraulic lash adjuster is complex and challenging.

As a research project supported by the Ford Motor Company, the work presented in this book has been concerned with both theoretical and experimental studies of the tribological performances of an automobile valve train having an offset taper cam and a domed rotating follower incorporated with an hydraulic lash adjuster with particular reference to the ZETEC engine valve train. The arrangement of the valve train is shown in Fig. 1.1. The work has included three main parts: (a) the theoretical formulation; (b) the experimental investigation and validation; and (c) the correlation of theory and experiments.

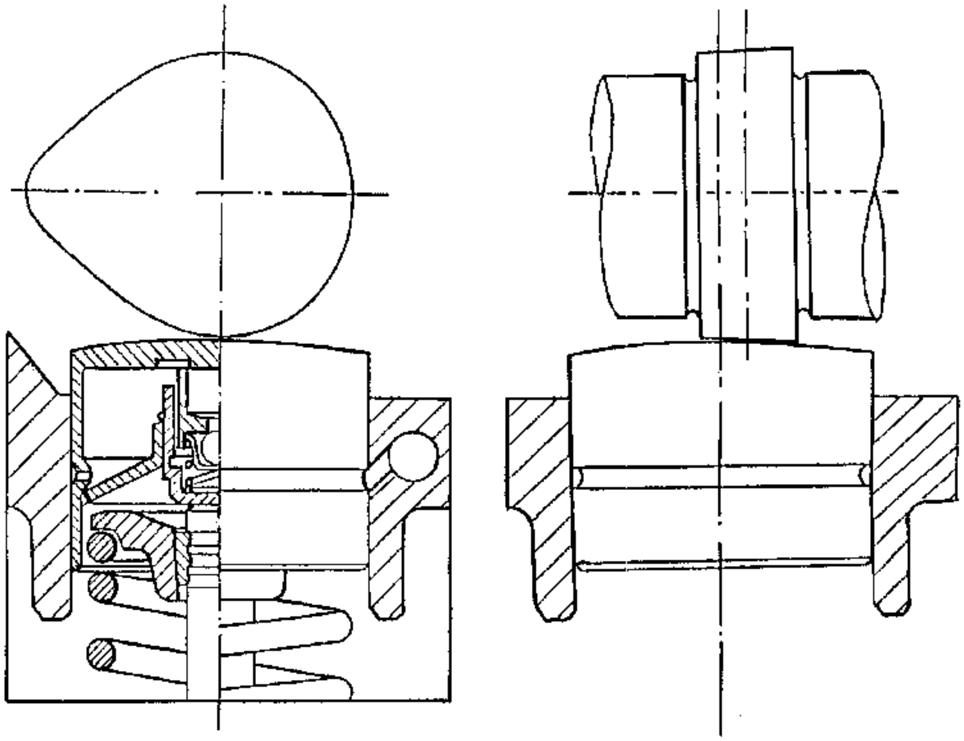

Fig 1.1 Domed tappet incorporating hydraulic lash adjuster

First, a sophisticated theoretical model has been developed to predict the tribological performance of the valve train. The development of the model is to provide a useful tool for the tribological design of the engine valve train. Several important tribological characteristics of the valve train, such as the maximum Hertzian stress, the central and minimum lubricant thickness, and the friction and power loss arising from the interfaces of the valve train including cam/follower, tappet/bore, and valve stem/guide interfaces, can be predicted by this model. In addition to this, the model can estimate the instantaneous and the average rotational frequency of the follower. Furthermore, the performance of the hydraulic lash adjuster can be predicted by the current theoretical model.

Second, a careful and comprehensive experimental programme consisting of a series of tests at different camshaft rotational frequencies and different bulk temperatures has been undertaken. This is to investigate the tribological performance of the valve train and also to validate the theoretical model. Several important variables including the friction torque, the power loss, the follower rotational frequency, and the temperatures of the lubricant supply, inside the test cell and in the valve guide, have been monitored in each test. Some sophisticated techniques for data acquisition and data processing, including a PC-based data acquisition system and a follower rotational frequency monitoring system have been developed. The accomplishment of the comprehensive experimental programme has provided a vast amount of reliable data. This enables the validity of the theoretical model to be examined.

Finally, in order to validate the theoretical model, the experimental measurements have been correlated with the theoretical predictions that simulate the test conditions of the valve train. The agreement between the experimental measurements and the theoretical predictions is excellent.