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Research Article

Design and Development of Experimental setup for Direct Acting Overhead Camshaft (DOHC) Valve System

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Abstract

The reduction in the frictional losses in the valve system has been the focus of many studies in the past. The complexity of the interaction between the various tribological interfaces of the valve system requires its accurate evaluation. Since the interacting cam and follower tribo pair passes through boundary, mixed and elastohydrodynamic lubrication regimes in a single cycle, therefore analytical estimation of its performance, measured in terms of the frictional torque, is complex. Therefore the performance evaluation of the cam and follower mechanism is generally carried out experimentally. This paper presents the design and development of an experimental test setup for Direct Acting Overhead Camshaft (DOHC) valve system for the study of effect of spring stiffness, preload and cam operating speed on friction between the cam and follower. The experiments were performed using radial offset cam and roller follower and the results are reported.

Keywords: *Tribology, engine valve, frictional torque, cam and follower.*

1. Introduction

The cam and follower mechanisms are required for the control of motion in a mechanical system with very high precision and repeatability. The cam and follower mechanisms are used in variety of machines and devices. Almost all automated production machinery utilizes cam and follower mechanism for obtaining automation. Their use in automotive engines is indispensible. Proper design of cam and follower would facilitate in achieving the targets of high reliability & productivity and better product quality. A poorly designed cam and follower mechanism would increase the frictional loss; induce unwanted vibrations & noise in the system leading to premature failure.

The design of a cam and follower mechanism requires a suitable design of its primary and most critical tribo pair: the cam and follower interface. Since this tribo pair passes through boundary, mixed and elastohydrodynamic lubrication regimes in a single cycle, therefore analytical estimation of its performance, measured in terms of the frictional torque, is complex. Therefore the performance evaluation of the cam and follower mechanism is generally carried out experimentally.

The paper presents the experimental determination of the frictional torque of a radial eccentric cam and roller follower. The next section describes the design and development of the test setup.

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2. Experimental setup

The friction between cam and follower depends on various parameters such as spring stiffness, cam profile, spring preload etc. An experimental setup is designed and developed to study the effect of these parameters on the friction between cam and follower. Figure 1 depicts the cam and follower experimental setup.

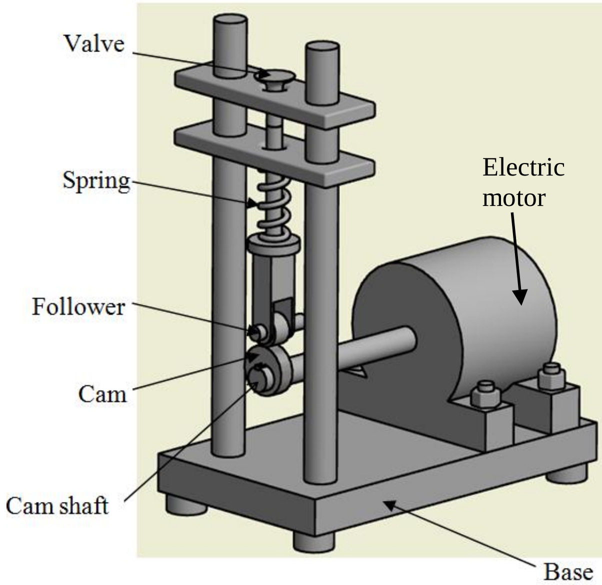

Figure 1 Cam and follower experimental setup

The experimental setup consists of spring loaded direct acting valve train driven by DC motor. All the components are mounted on steel channel which is firmly bolted to the table to avoid vibrations. Main components of the setup are motor, cam, roller follower, spring, valve and valve seat. The shaft of the cam is connected to the shaft of the DC motor using coupling. Camshaft is also supported by roller bearing. Cam and follower of the valve train has proved to be the most difficult component of IC engine to lubricate, so dry friction condition is taken. Follower used is roller follower to replace sliding contact of tappet follower by rolling contact. Valve and valve seat used in the setup are prepared to the dimensions proportional to the ones used in engine. Mechanism is operated at different speeds by varying the speed of motor. Speed of the motor is varied by using thyrister, which changes the speed of motor by varying the voltage supplied. Display unit shows input voltage and current consumed by motor.

The eccentric circular cam is used in the experimental test setup. To find out the effect of spring stiffness on friction two type of springs are used. The stiffness of each spring is determined experimentally.

A DC electric motor of 0.5 Horse Power (Volt-230V, Current-2.3A) with operating speed of 1500 rpm is used in the test setup. The Speed control is obtained by using thyrister. Fig. 2 shows the circuit diagram. A 230V AC is supplied to the thyrister which gives DC output. By rotating the knob of thyrister its firing angle is changed and DC output voltage is varied, which is supplied to motor armature. Change voltage gives rise to change in speed. Display unit consists of ammeter and voltmeter which shows current and voltage readings, is connected in circuit as shown in figure 2.

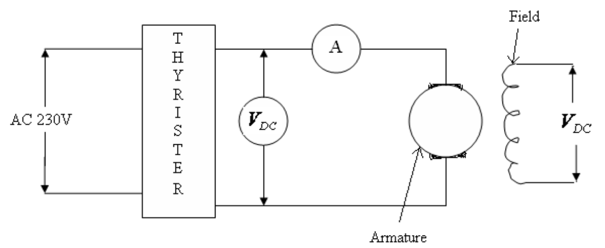

Fig.2 Speed control circuit

An eccentric circular arc cam with the following details is used in the test setup:

Maximum cam lift, L = 12 mm
Base circle radius, R = 15 mm
Follower roller radius, r = 16 mm
Follower mass, m = 0.75 Kg
Eccentricity, E = 6 mm
Coefficient of friction between follower and its guide, μ= 0 .1

Two springs with Spring 1 stiffness, K1 = 6.3 N/mm and Spring 2 stiffness, K2 = 26.7 N/mm are used. The valve and its seat used in the test setup are shown in figure 3 and 4.

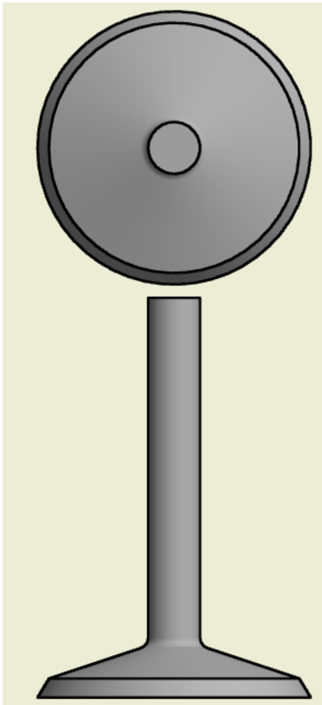

Fig.3 Valve

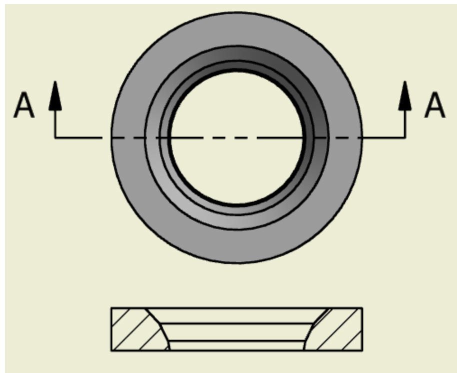

Fig.4 Valve Seat

3. Experimental Procedure

The total torque required to run the mechanism is known as Drive Torque. It is composed of friction torque and geometric torque. Friction torque is function of tribological performance. Geometric torque arises from the force required to open the valve against resistance of the valve spring, the energy from which is stored in the valve spring and returned to the camshaft as torque in the opposite rotational direction as the valve closes. Taking the mean of drive torque over the cam event effectively removes the geometric torque contribution which ideally has equal positive and negative parts. This assumes that there is no energy loss in geometric torque during complete cycle of valve opening and closing. Thus torque required given by the motor over the complete cycle of operation is friction torque. This torque can be measured by using input voltage and current taken by the motor.

Detailed experimental procedure is as follows:

(i). Firstly motor is disconnected from camshaft and it is run at different speeds by varying voltage using thyrister. For each speed voltage and current readings are noted down. Product of voltage and current is taken as no load power loss.
(ii). One of the three cams is then mounted on the camshaft. Motor also connected to camshaft using coupling.
(iii). Then first spring is loaded to the mechanism. Preload is set by using adjustment screw.
(iv). For each preload mechanism is run at different speeds. Corresponding voltage and current readings are noted down. Product of theses voltage and current readings is taken as power loss at load.
(v). To account for the motor losses, frictional power loss is taken as difference between load and no load power. Torque is then calculated as ratio of power to angular speed.
(vi). Thus frictional torque is determined for each set preload corresponding to different speeds.

4. Experimental Results and discussion

The experimental values of average friction torque determined from voltage and current readings are given in tables 1 and 2. The average friction torque is determined for two types of springs with three different spring-preloads at different operating speeds.

Table 1 Values of average friction torque for spring 1

Spring 1: Stiffness K1 = 6.275 N/mm			
Cam rotational Speed (rpm)	Torque (Nm)		
	Spring preload		
	S = 13 N	S = 55 N	S = 80 N
250	0.075	0.115	0.276
350	0.071	0.114	0.274
400	0.068	0.104	0.263
500	0.066	0.102	0.256
600	0.059	0.094	0.251

Table 2 Values of average friction torque for spring 2

Spring 2: Stiffness K2 = 26.66 N/mm		
Cam rotational Speed (rpm)	Torque (Nm)	
	Spring preload	
	S = 80 N	S = 105 N
250	0.453	0.62
350	0.422	0.607
400	0.401	0.592
500	0.39	0.581
600	0.38	0.573

The variation of the average frictional torque for spring 1 and spring 2 are plotted against the cam rotational speed and depicted in figure 5 and 6 respectively.

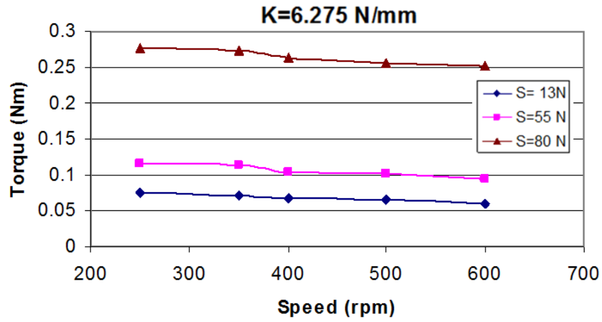

Figure 5 Average frictional torque Vs cam operating speed for spring 1 for three spring preloads

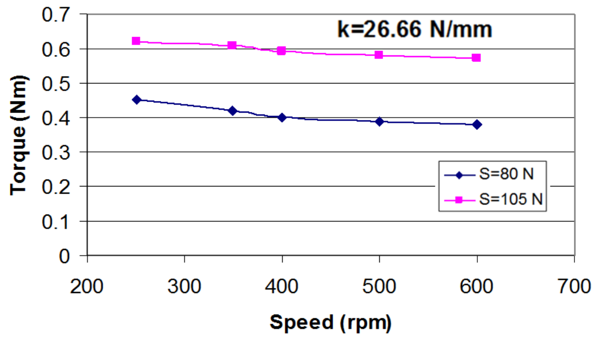

Figure 6 Average frictional torque Vs cam operating speed for spring 2 for three spring preloads

It is observed from figures 5 and 6 that the average friction torque reduces slightly with the increase in the cam rotational speed. However there is a significant increase in the average friction torque with the increase in the spring preload. The average friction torque also increases with the increase in stiffness of spring.

Conclusions

An experimental test setup has been designed and developed for the determination of frictional torque of the cam and follower mechanism. The experiments were conducted on radial cam with roller follower using two springs with different spring preloads at different cam rotational speeds.

The experimental results indicates that for direct acting valve train, increasing preload and spring stiffness increases the average frictional torque resulting in increased losses. The variation of frictional torque with speed is dependent on inertia force.

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