

DESIGN OF A TEST BENCH FOR MEASURING FRICTION FORCE IN A PISTON-CYLINDER SYSTEM

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ABSTRACT

In the present work, design of a first approach of a test bench prototype for measuring friction in a piston-cylinder system is presented. The bench consists of a motor, belt and pulley transmission, crank mechanism, a piston, a cylinder and a lubrication system. Friction will be determined by means of strain gages placed on the connecting rod of the mechanism. The bench also includes a phonic wheel for acquiring angular speed and angular position signals of the crank. In future research, friction will be studied for different surface finishes obtained by means of honing and plateau honing. Honing processes provide a crosshatch pattern that holds oil and helps lubrication of piston and rings. Honing conditions will be selected with the goal of minimizing friction. Friction is directly related to energy consumption of an engine and, thus, to its environmental impact.

Keywords: test bench, friction, piston-cylinder system, honing, roughness

1. INTRODUCTION

The manufacturing process of combustion engines usually includes honing processes on internal cylinder surfaces. In order to perform honing operations, a honing head with abrasive stones is employed. Stones are made of an abrasive material, with a certain grain size and density, as well as a bond material. The honing head is provided with a mechanism that expands abrasives in the radial direction, leading to a certain pressure value on the workpiece's surface. Honing stones combine a linear alternate movement with a rotation movement.

Honing processes improve both shape and surface finish of parts. In addition, honing provides a specific crosshatch pattern in which valleys are necessary for circulation and retention of lubrication oil film. In combustion engine cylinders it is necessary to partially remove ridges so as to smoothen the cylinder surface in a way that the piston rings can work properly from the beginning of the engine life. This leads to higher engine efficiency. The plateau honing process removes ridges and consists of a finish honing operation with lower grain size that partially removes previous roughness peaks obtained with higher grain size.

Some authors have developed test benches for measuring friction in piston-cylinder systems [1, 2]. However, only some of them tested different honing finishes. For example, Yousfi et al. tested two different plateau honed surfaces, for finish honing and final honing [3]. Sabeur et al. took into account three different cutting conditions for rough, finish and plateau honing respectively [4].

The main objective of the present paper is to present the preliminary design of a test bench that is being built in order to measure friction in a piston-cylinder system. In the future, different surfaces

will be tested in order to determine which honing parameters lead to lowest friction. In internal combustion engines, friction losses correspond to more than 50 % of total losses in the cylinders. They are caused by hydrodynamic cushion that is formed between rings, piston and cylinder, in which surface roughness plays a fundamental role. Reduction of such losses will contribute significantly to oil consumption reduction, as well as to decrease of pollutant gas (CO₂, NO_x, HC, CO and particles). Thus, environmental impact of the process will be reduced.

2. REQUIREMENTS OF THE TEST BENCH

Main requirements of the test bench are as follows:

- The test bench must guarantee the system rigidity and should be flexible enough to be able to adapt future modifications.
- The design must permit changing the cylinder samples in the test bench, and guaranteeing safety in the fastening operation of cylinders.
- It is required to lubricate the cylinder-piston interface.
- It is required to measure forces on the connecting rod for each angular position of the crank mechanism.
- Economic costs must be as limited as possible.

3. DESIGN PROPOSAL FOR THE TEST BENCH

The starting point for the proposed design of the elements of the test bench was the use of steel cylinders St-52 of 80 mm diameter and 100 mm length that were available. In future tests, internal surface of cylinders will be subjected to honing operations, with similar conditions to those used in the manufacturing process of internal combustion engines for reducing friction and providing lubricant adherence on the cylinder wall. Dimensions of said cylinders allow the use of a standard piston of 79.93 mm diameter.

The conceptual design of the test bench consists of using five basic modules. These are (Figure 1):

- a). Power module** (its function is to introduce power and motion in the mechanical system),
- b). Engine module** (its function is to convert rotation of the crank into translation of the piston),
- c). Block module** (its function is to hold and fix cylinders)
- d). Lubrication module** (its function is to supply lubricant to the piston-cylinder interface, and
- e). Instrumentation and acquisition module** (its function is to perform measurement of forces and to record the piston position with time).

The five modules mentioned above will be mounted on a frame, which should ensure the system rigidity and flexibility to adapt future modifications of the bench. Most parts of the bench modules will be added to the frame with removable screw connections, in order to facilitate modifications or changes of such parts in the future if required.

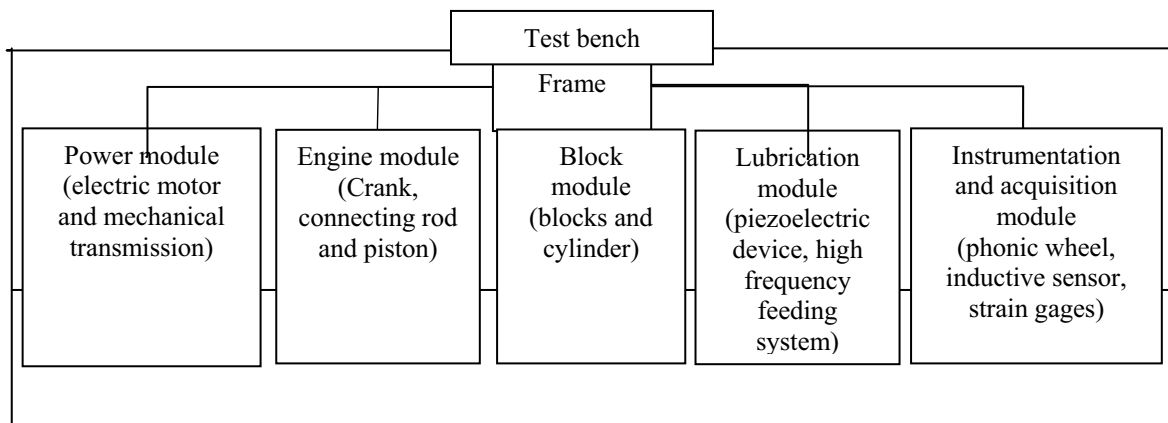


Figure 1. Modules of the test bench

From the conceptual design analysis above exposed, the possibility of using some material resources available in the laboratory is analyzed. Thus, following resources were selected: a single-phase electric motor and an assembly module that consists of two bearings fixed on a shaft and a pulley with two trapezoidal grooves. Therefore, the design of the rest of the mechanical elements of the test bench had to be adapted to the restrictions of the available parts. Hence, a test bench sketch is proposed, as shown in Figure 2. Each part of the test bench will be explained below.

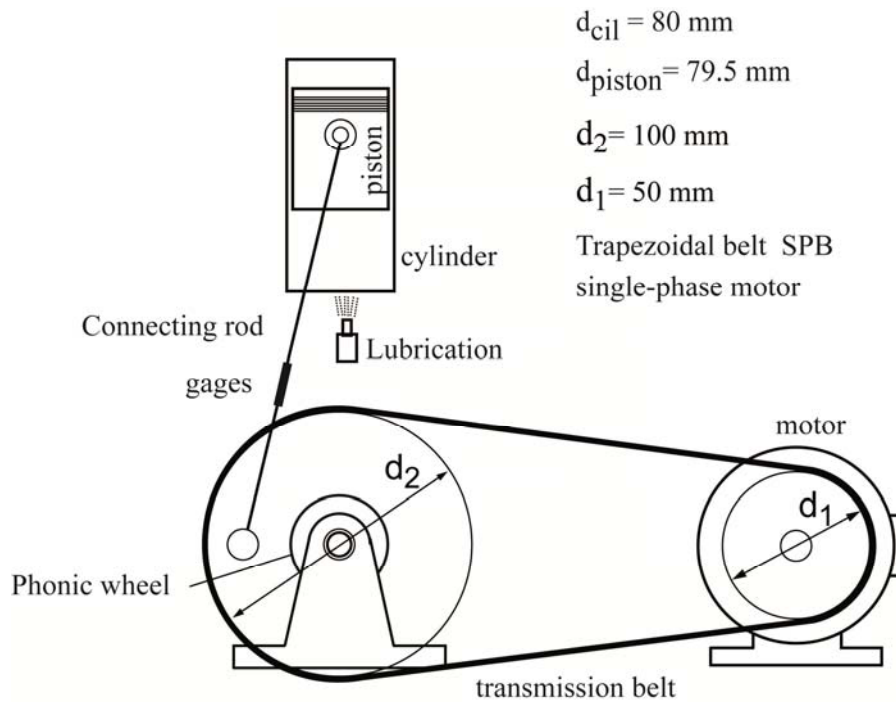


Figure 2. Schematic drawing of the test bench

2.1 Power module.

It introduces power and motion into the mechanical system (engine module). The power module consists of a single phase electric motor with speed control and transmission pulleys and V-belts. Diameters of the pulley wheels are: $d_1 = 50$ mm –driver pulley wheel– and $d_2 = 100$ mm –driven pulley wheel. Thus, transmission ratio is $\tau = 2$, to guarantee an appropriate torque on the crank axis.

2.2 Engine module

It converts crank rotation into reciprocating motion of the cylinder (Figure 2). The engine module will consist of a crank mechanism (that must be designed taking into consideration the geometrical characteristics of the available parts like the phonic wheel, the diameter of the crank axis and the connecting rod head), a connecting rod and a standard piston of 79.93 mm diameter.

2.3 Cylinder block module

Its function is to hold and fix cylinders. The cylinder block module will be composed of two half-blocks and a cylinder. The first one will be fastened to the vertical wall of the frame and the second one will fit with it to hold the cylinder in the right position. The second half-block needs to be removed in order to allowing changing cylinders. The top of the cylinder block module will have two security segments to prevent that the cylinder come loose out of its position by the action of the frictional force between cylinder and piston.

2.4. Lubrication module

Lubrication module consists of a piezoelectric device that generates vibration acting on oil and an alternating current generator that allows varying frequency and voltage level.

2.5 Instrumentation and acquisition module

In order to determine friction force it is necessary to measure and acquire analogical signal of axial efforts in the connecting rod. From measured axial force, force components such as piston weight and inertial component of the signal will be subtracted. Instrumentation module consists of strain gages connected to a Wheatstone bridge to compensate variations. Gages will be placed on a flat surface of the connecting rod near its head, so as to avoid possible contact with the engine block module. Measured signal will be sent to an amplifier and brought to a data acquisition card. The amplifier supplies voltage to the bridge too. The test bench design also requires an auxiliary system with additional mechanical elements – it may be a four bars mechanism– that allows protecting the cable of the signal recorded by the Wheatstone bridge between the head of the connecting rod and the amplifier device.

A phonic wheel of 60 pulses per revolution will be used for analogical acquisition of angular speed of the crank, with a precision of 6°. Angular speed will be related to the position of the cylinder. The rotation sensor generates a representative signal for the crank position. It is an induction type sensor, and is made up of a permanent magnet and an iron core surrounded by a coil. It is assembled in front of the phonic wheel, which is a gear that rotates at the same time as the crank. The gear has 58 teeth plus a void corresponding to two teeth. A period of the signal contains 58 oscillations plus a time of continuous signal corresponding to a void in the wheel. This allows detecting the moment when the crank has turned around completely. This void also defines the top dead center (TDC) of the piston.

4. CONCLUSIONS

A preliminary design of a test bench for measuring the friction in a piston-cylinder system is exposed in the present paper. The bench will allow measuring friction force for different honing and plateau honing finishes and for different lubrication parameters, with the aim of minimizing friction, thus reducing oil consumption and emissions.

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