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FINAL DESIGN AND CONSTRUCTION OF A TEST BENCH FOR MEASURING FRICTION FORCES IN COMBUSTION ENGINES

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ABSTRACT
In this paper the final design and the construction of a test bench for measuring friction forces in a piston-cylinder system is presented. Requirements of the bench and conceptual design were exposed in a previous paper. The bench consists of five modules: power module, engine module, block module, lubrication module and data acquisition module. Power module contains electric motor and mechanical transmission. Engine module has a crank, a connecting rod and a piston. Block module comprises block and cylinder. Lubrication module will be included in future works. It will consist of a piezoelectric device and a high frequency feeding system. Finally, data acquisition module consists of a phonic wheel, an inductive sensor and strain gages. The bench allows interchange of cylinders with different surface finish, obtained by means of honing processes.
Keywords: final design, test bench, friction forces, cylinder-piston system

1. INTRODUCTION
In a previous paper, conceptual design of a test bench for measuring friction forces in a piston-cylinder system was proposed. There, the design requirements of the bench were established [1]. The proposed design consists of five modules: power module, engine module, block module, lubrication module (not included) and data acquisition module. In the present paper, the detail design of each module, as well as the virtual design and the construction of a prototype of the bench, is presented.
From the study of the state of the art, it was found that test benches can be classified into two groups. First one is dedicated to testing of internal combustion engines (performance of the engine or friction –global friction, piston-cylinder friction and friction with cylinder exchange). Second one corresponds to tribological benches (with rotation or translation movement). The bench proposed in the present paper refers to the a.m. first group. Within internal combustion engine test benches, three subgroups can be defined: global friction, piston-cylinder friction and friction with interchange of cylinders (Figure 1) [2-8]. As a novelty, the present designed bench combines measurement of piston-cylinder friction with cylinder exchange. The reason for this is that it required to measure friction between one piston and some cylinders with different surface finish that have been machined by means of honing processes.
The designed and manufactured bench uses a standard piston corresponding to a monocylindrical engine of a standard motorcycle with cylinder displacement of 250 cm^3. Cylinders have 80 mm internal diameter and 100 mm length. As a first approach, the system works with no internal combustion gas pressure. The Indicated Mean Effective Pressure (IMEP) method requires measuring deformation of the connecting rod by means of strain gages. The method is based on the balance of forces on the piston (weight of the piston, inertial forces, friction force, force exerted by the connecting rod).

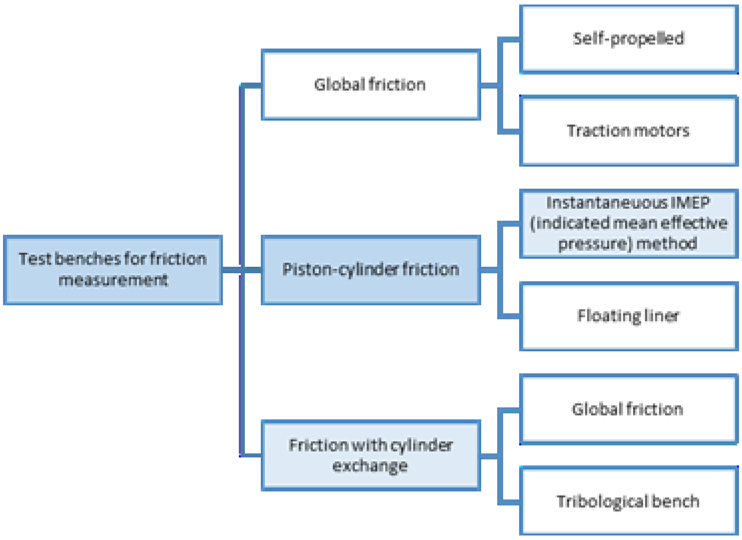


Figure 1. Classification of test benches for friction measurement.

In the next section, the detail design of the different modules of the test bench is exposed. The paper presents, in a summarized way, some aspects of the selection process of the different commercial components (electrical motor selection, pulley transmission, etc.) and of the calculation of non-commercial components, for example the inertial wheel.

2. DETAIL DESIGN OF THE BENCH

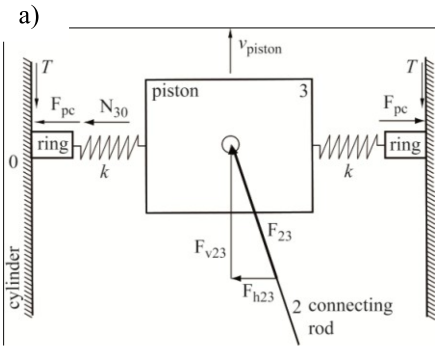
Taking into account the conceptual design of the bench [1], five different modules were designed: power module, engine module, block module, lubrication module and instrumentation and acquisition module. Lubrication module will be included in further works.

In order to select the components of the bench modules among different design options, selection matrices were employed [9]. In the next subsections, the different modules will be explained in a summarized way.

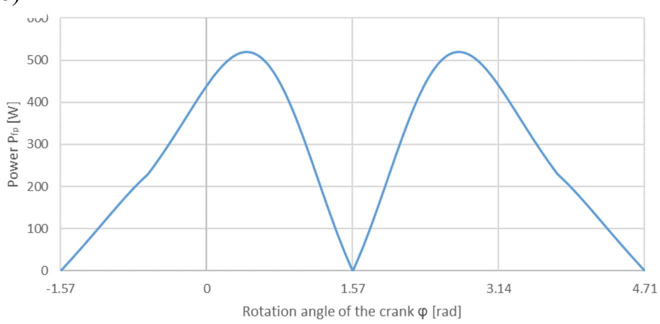
2.1. Power module

The power module comprises an electric motor with speed control, transmission pulleys and a V-belt. In this case, there is not compression phase in the combustion engine, so, in order to determine the resistive torque in the conducted shaft of the belt transmission, a model for estimating a value of the power of the passive resistance P_{rp} due to the friction piston-cylinder was proposed (Figure 3a). Estimated value was 520.3 W (Figure 3 b). By adding to this value a small percentage of the friction losses due to the belt (8 %), an adequate value of resistive power was found of 551.5 W. Using this value, the calculation for the selection of the transmission belt and for the electric motor was carried out.

a)



b)



a) *b)*

Figure 3. a) Model for estimating the power of the passive resistance due to the friction piston-cylinder, b) Power of the passive resistance vs rotation angle of the crank.

From the above model, and assuming a steel-steel friction coefficient $\mu_{steel-steel} = 0.57$ [10] the following expression was obtained (Equation 1).

$$T = \mu_{steel-steel} \cdot \left(N_{30} + F_{pc}\right) \qquad (1)$$

Where T is the estimated tangential force (N), N_{30} is the normal force between piston and cylinder (N) determinate by using the PAM software, and F_{pc} is the force exerted by the rings (N) measured with a dynamometer.

From the tangential force T, and using the speed of the piston v_p also was obtained by means of the PAM software, the power of the passive resistances P_{fp} is calculated (Equation 2).

$$P_{fp} = T \cdot v_p \qquad (2)$$

From the values above, and using the corresponding procedure of belt and motor selection, an SPZ profile V-belt and an AC motor was selected.

2.2. Engine module, block module and data acquisition module

In order to determine the geometry and inertial characteristics of the elements of the engine module, a kinematic and dynamic analysis of the slider-crank mechanism was made using the PAM software [11]. A dynamic forces analysis, very important in a single piston engines, was performed, determining the value of the forces applied by the piston N_{30} and the crank F_{10} to the frame. In order to reduce the magnitude of such forces, making a balance of such mechanism and accomplishing with an adequate range of a coefficient of fluctuation of speed ($\delta = 0.0125 - 0.006$). Thus, the dimension and the mass moment of inertia, as well as the location of the gravity center of an inertial flywheel was determined. Figures 4 a) and 4 b) depict the forces in the mechanism and the graphic of the force F_{10} and its components during a rotation cycle of the crank. The connecting rod has a weak section in order to permit measuring its deformation by means of strain gages.

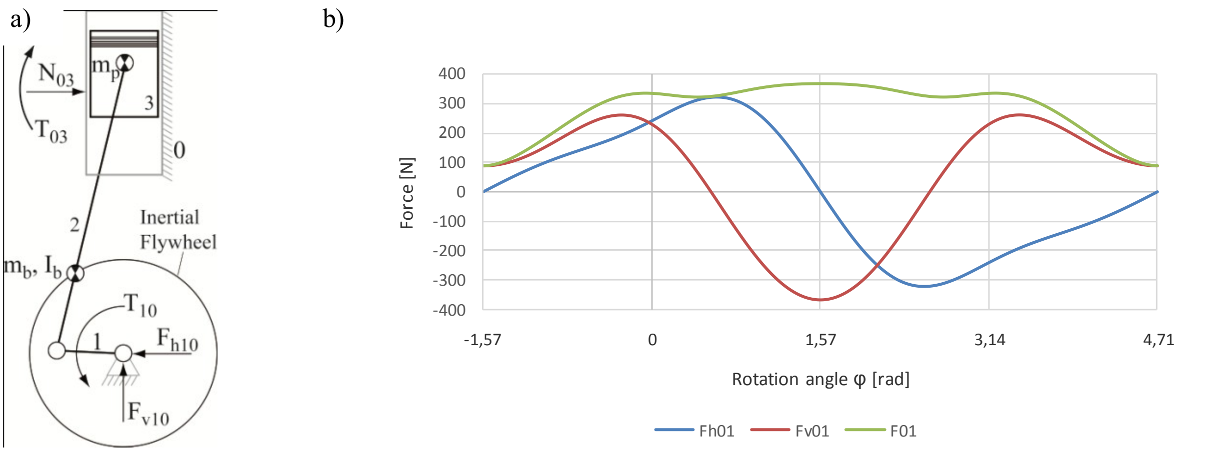


Figure 4. a) Forces scheme (including the flywheel), b) Graphic of the fluctuation of the force F_{10} once the mechanism has been balanced

The block module was designed and manufactured with a cylinder support that has a groove acting as a clamp, in a way that it allows fixing the cylinder and also the cylinder exchange (Figure 5 a).
The data acquisition module consists of a phonic wheel with an inductive sensor, strain gages and a signal amplifier.
In Figure 5 b) a picture of the assembled test bench is shown. The main parts of the bench are indicated.

a) b)

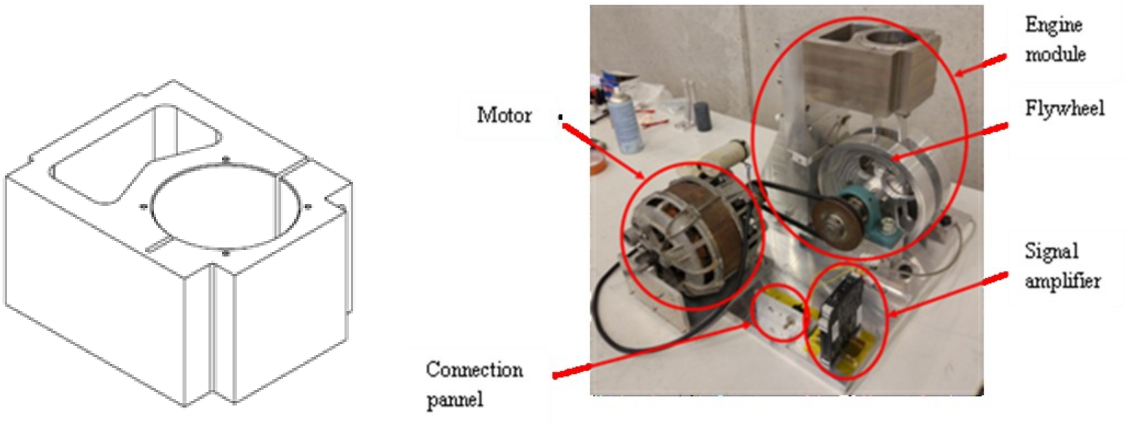


Figure 5. a) Cylinder support, b) Main components of the test bench

3. CONCLUSIONS

A test bench for measuring friction between piston and cylinder was designed and manufactured. It allows cylinder exchange and is open to future modifications. A flywheel is included in the bench, which guarantees the force balance in the slider-crank mechanism and the accomplishment of an appropriate coefficient of fluctuation of speed. The bench will allows to measure friction force for different surface finishes of the cylinder, obtained by means of honing processes.

4. ACKNOWLEDGEMENT

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