Study of some Tribological Aspects of the Charging System of an IC Engine

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Abstract. The objectives of this paper were focused on the study of wear of the turbocharger, and providing a solution to ascertain friction losses in this equipment, because the value of this parameter contributes to pollutant emissions level of the engine.

Friction loss in the turbocharger assessed by the driving power losses was considered a parameter to appreciate tribological efficiency of turbochargers.
Theoretical studies conducted within the project required a practical validation through the determination of performance parameters, functional parameters and the influencing factors of these parameters. In the first phase it was designed a model of the equipment which allows the study of tribological factors on the functional parameters of the turbocharger, the key element being a GT1544 turbocharger coupled to an electric high speed motor.
The results show how speed and friction losses change when the outlet pressure of the lubricating system is modified.

Keywords: friction; turbocharger; test bench

1 Introduction

During the life cycle of a turbocharger, its components are subject to different types of stress, internal and external influences. These have adverse effect on the functional parameters of turbochargers and duration of use. The results of these negative effects are:

- part geometry damage (turbine covers, blower impeller, shaft);
- superficial damage of the material structure or mass;
- damage to work surfaces of the parts;
- breakage of parts [1].

To avoid these adverse effects and to withstand stress conditions, parts are required operational conditions and mechanical resistance that minimizes the influence factors, the right choice of the material having dominant share [2].

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One of the major goals pursued by turbocharger design is to separate the friction surfaces in a manner so that the friction and thus wear, to be kept at the lowest possible level, with direct consequences on its efficiency and reliability [3], [7].
During the operation of the turbocharger one can encounter the four main types of friction [2]:

- dry friction occurs between two surfaces with no lubricant in the contact area;
- boundary friction appears in areas covered by a very thin layer (molecular layer) of lubricant;
- mixed friction occurs between surfaces which have a layer of lubricant, but this is not continuous because small, rough areas are in direct contact;
- fluid friction is friction between two surfaces with a continuous lubricant layer between them.

Each type of friction generates types of wear. During the preliminary stage of the project, special attention was accorded to observe the most common types of wear that can occur during the lifetime of a turbocharger, as seen in the images that follow.

Asperities of uneven surfaces during high rotational speeds of the shaft are welded and break, producing a metal transfer from one surface to another. As seen in figure 1 and figure 2, scoring can completely destroy the friction surfaces, leading to extreme clearances between shaft and bearing, thus leading to turbine or compressor wheel damage, as shown in figure 2 [4,5].

Seizure is the result of solid particles in the lubricant or solid deposits on one of the friction surfaces as the result of extreme turbine housing temperatures.

Welding of surface roughness occurs on large areas, blocking the relative movement of the components.

The abrasive micro particles reaching the lubricant layer between the journal bearing and the shaft have a high hardness and a greater diameter than the thickness of the lubricant layer. These hard particles will be embedded in the soft surface of the bearing, and will act on the shaft as a cutting tool. The result will be the fast bearing and shaft clearance change, loss of pressure in the lubricant layer and finally seizure [4],[6].

Fig. 1. Turbocharger shaft scoring

Fig. 2. Compressor wheel damage due to extreme journal-shaft clearance

Fig. 3. Turbocharger shaft seizure

The objectives of this work were focused on the study of friction in the turbocharger, and to provide a solution to ascertain friction losses in this equipment, because the value of this parameter contributes to pollutant emissions level of the engine.

2 Material and methods

The starting idea was to basically determine friction losses, ie the power lost through friction in the turbocharger, being a tribological factor influencing the mechanical efficiency of it. In the first phase it was designed and developed a variant of the test bench which allows the study of the factors that influence the functional parameters of the turbocharger (figure 4).

The main element of the test bench (fig.5) is a GT1544 turbocharger (5) coupled to a high speed electric motor (2). To ascertain the power loss through friction in the turbocharger bearing, the latter was driven by the electric motor at different speeds in different conditions.

In order to ensure good working order of the turbocharger at high rotational speeds for a long period of time, a lubricating system (6) had to be attached, to carry out the hydrodynamic lubrication of the journal bearing, present on this type of turbocharger.

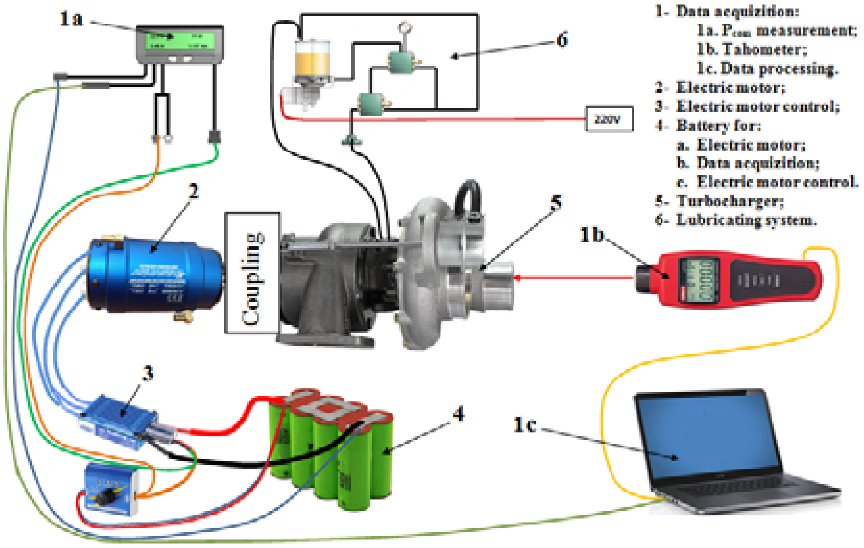

Fig. 4. Friction loss measurement principle

Power supply for the electric motor was provided through an electric motor control system (3), which made possible speed and torque control as well, so that the turbocharger could be driven at different rotational speeds. Data acquisition system (1c) was connected to the electric motor control system to directly measure the power consumption of the electric motor and a digital tachometer (1b) connected to a computer (1c) was used to determine as precisely as possible the speed of turbocharger-electric motor assembly. Figure 5 shows the complete test bench during measurements.

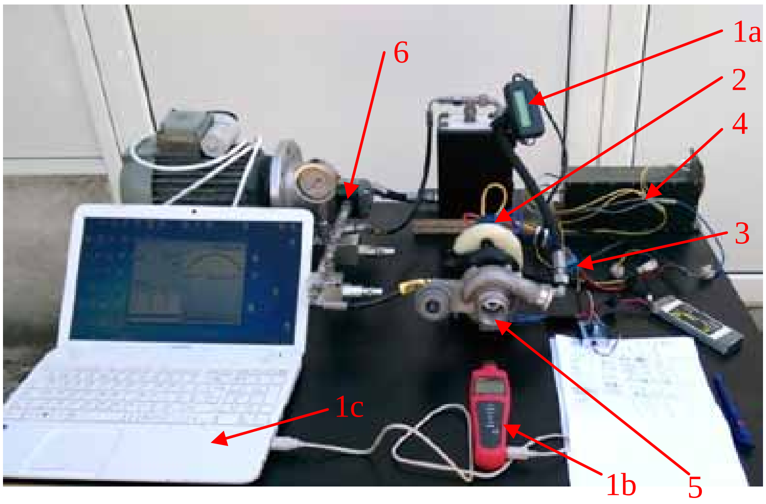

Fig. 5. Experimental test bench

3 Results and discussions

Measurements were made in three phases:

a. Test bench operating principle validation. In this phase the turbocharger was driven for a few seconds without pressure in the lubricating system (p = 0), turbine speed was within 5000-25000 rev/min.

b. The turbocharger operation was carried out in the range of speeds from 5000 to 25000 rev/min at an oil pressure p = 1.5 bar

c. Pressure in the lubricating system was set to p = 3 bar at the same speeds, ranging from 5000 to 25000 rev/min.

Results measured in these phases are shown in table 1.

Table 1. Measured results

Nr	1st experiment		2nd experiment		3rd experiment	
	Lubricating system pressure [bar]	**0**	**Lubricating system pressure [bar]**	**1.5**	**Lubricating system pressure [bar]**	**3**
	Speed [rpm]	**P_{abs} [W]**	**Speed [rpm]**	**P_{abs} [W]**	**Speed [rpm]**	**P_{abs} [W]**
1	5933	77	6400	74	6810	74
2	9018	125	9960	120	10291	119
3					11927	158
4	16354	238	15036	225	15394	227
5					18204	298
6	19703	298	20900	323	20133	351
7					23196	451
8	25510	470	25143	481	25017	515

Results measured in the first phase show a rising power loss especially from 20000 rpm.

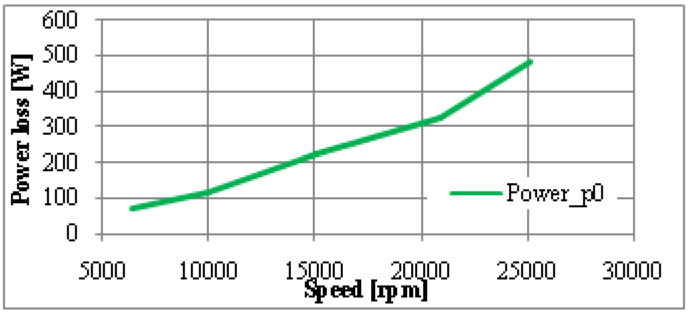

Fig. 6. Power loss when relative pressure in the lubricating system was 0 bar

When applying 1.5 bar relative pressure in the lubricating system, no major changes can be observed (see figure 7).

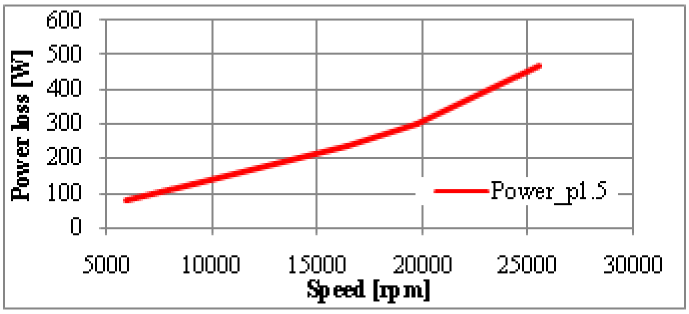

Fig. 7. Power loss when relative pressure in the lubricating system was set to 1.5 bar

As lubricating pressure rises, power loss is seen to rise at higher revs (figure 8).

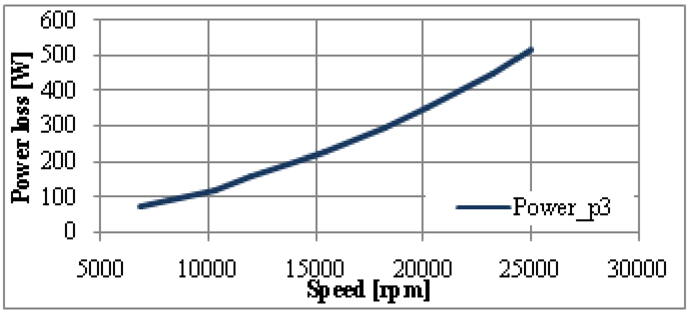

Fig. 8. Power loss when relative pressure in the lubricating system was set to 3 bar

As it becomes obvious from figure 9, in the very low speed region power losses can be somewhat lowered with an intermediate lubricating pressure, but from 20k rpm and above power losses generated by friction become greater with higher lubricating pressure.

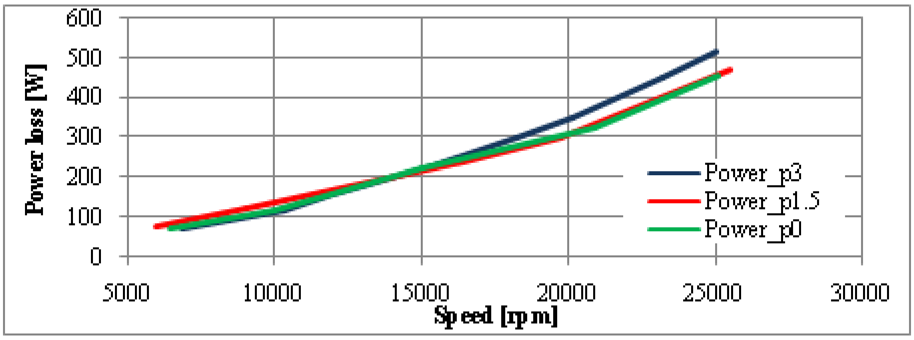

Fig. 9. Power loss change versus lubricating pressure change

4 Conclusions

The experimental results obtained validate the operating principle of the test bench.

The measured values for frictional losses arising from the wear of the friction surfaces, give the possibility to find ways to reduce these losses even in the design stage of the turbochargers.

The test bench design gives us the possibility to extend our studies of the tribological factors by studying how the system behaves with several lubricant types, extended rotational speeds, different bearing types, different shaft materials and different journal bearing materials.

The study of the influence of tribological factors on the efficiency and reliability of turbochargers is truly important in the design and maintenance of these equipment.

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