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## REDUCTION AND MAINTENANCE OF TURBOCHARGERS BY APPLYING VALID TRIBOLOGICAL CONSTRUCTING

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**Abstract:** Condition recordings and turbochargers test results indicate that during the long driving at higher speeds may cause turbochargers overheat. Lubricate termination after shutting generator can cause damage to the sliding surface bearings. As a result, eventually comes to unbalance of rotating parts, turbine rotor and the compressor impeller. One of the solutions is application of sensor which would not allow shutting generator down until the temperature is lowered to an acceptable value.

**Keywords:** turbocharger, internal combustion engines, overheat, valid tribological constructing.

### 1. INTRODUCTION

Tribology is not a science “for the sake of science” [1]. Tribology is scientific approach by extending and solving problems of parts which are exposed to wear. The aim is to reduce costs and losses of tribological nature [2].

In one type of famous car brand, with 1.9 l diesel engine with power range from 66 to 77 kW, which was manufactured from 2004 to 2008, condition recording have found frequent damage of turbocharger's axle. One authorized distributor and servicer in Croatia sold in this period a total of 101 vehicles of this type. Vehicles in that group at that time had a guarantee of two years from the date of taking-buying. Based on data on activation of the guarantee and service has led to information that in 2010 21 turbochargers were replaced. Also, a similar appearance is observed on vehicles from another manufacturer, only turbocharger had different constructional design.

If the turbocharger is broken engine does not have sufficient supply of air required for combustion in the cylinder, the stoichiometric ratio of the mixture of air and fuel is disrupted. Due to larger damage, decomposition of rotating bodies in the turbocharger, fragments are entering the cooler and air supply which causes higher repair price. Turbochargers price is not insignificant; range is from 10,000 HRK to 12,000 HRK, for replacing turbocharger takes approximately four hours.

Given that this is a relatively frequent case there was a need for analysis of turbochargers tribosystem. Recording conditions include operating parameters and parts of turbochargers. Examination carried out dimensional control, analysis of the chemical composition, metallographic examination and hardness measurements of damaged parts. The aim is to find the causes of damages, reduce costs and indirect losses.

The collected results of the analysis and mutual comparison should serve as the basis

for the approach to solving problems by applying measures known as tribological properly construction [3,4].

## 2. RECORDING CONDITION

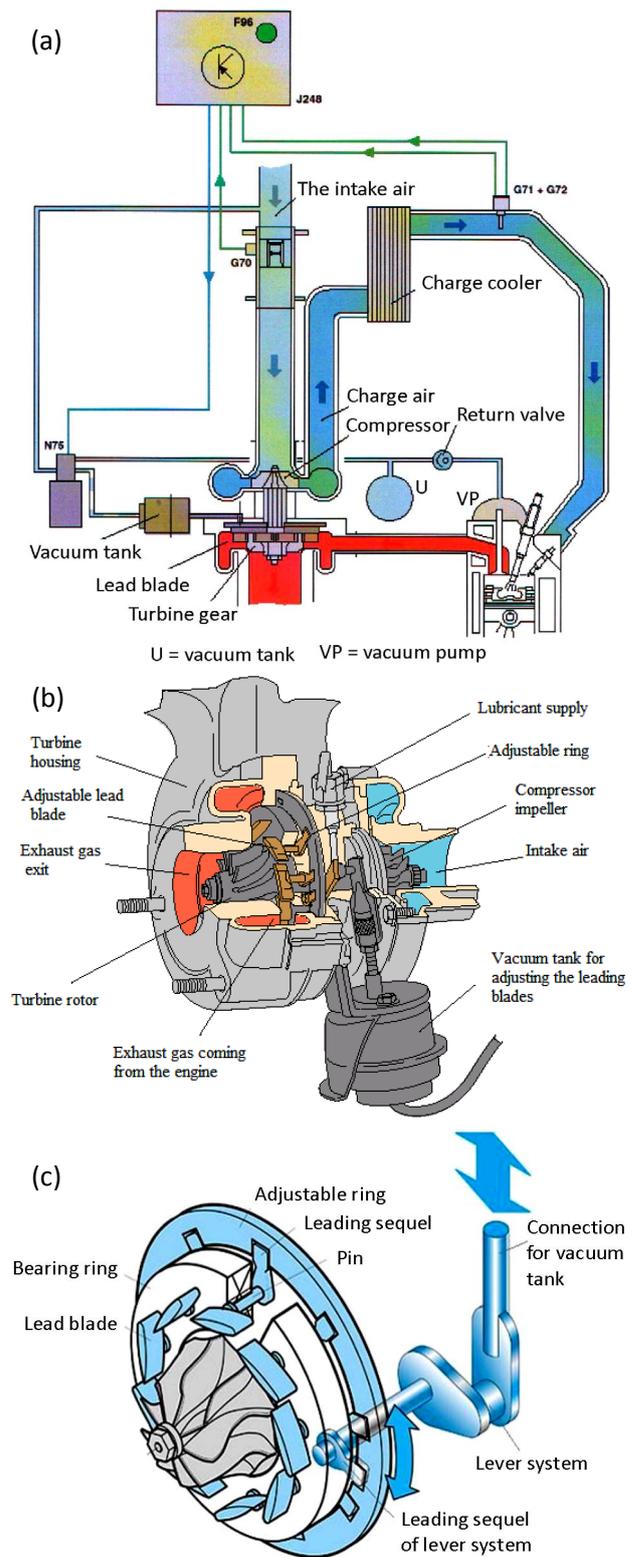
### 2.1 Basic construction features

Turbocharger consists of a compressor and exhaust part which are connected by the same axle. Figure 1 shows main parts of turbochargers.

Impellers are made by technique of vacuum casting and they are connected with the axle by blunt welding. Since the operation temperature of the blades is higher than the temperature of rounds, different materials can be used, for instance, disc is made from steel alloy with 13 % Cr, or CrNi steel 1613, and the blades are made from In-713C. The choice of material depends on the expected exhaust temperature of the engine. Temperature of exhaust gas in the diesel engine is max.  $450 \div 500$  °C, while the temperature of exhaust gas in the Otto engine is to 1000 °C. Following materials for compressor impellers can be used: silumin gamma (cast or wrought), aluforit 47 (cast), perunal B (wrought), steel G-x22 CrMoV 121 (cast), steel DMU83 (wrought – softened by releasing), titan 1,33 (wrought) and titan alloy 6AL4V [5,6].

For smaller turbochargers are used indoor slide bearings which are connected to the oil circuit of the engine. They have reduced wear in properly constructed bearings with full hydromechanics lubrication on low stress and high speeds. They have a longer life and they are less sensitive on shock and vibration. Their disadvantage is a need for greater flow and higher pressure for oil to be brought to the heat produced by friction. It is necessary to perform lubrication before starting the engine as well as continuous lubrication after the engine is stopped at high load. The reason is that the heat that enters the bearing through the axle may overheat and cause oil “coking”.

The main advantage of this system is that the pressure can be varied by rotating blades by changing their effective sliding surface. In



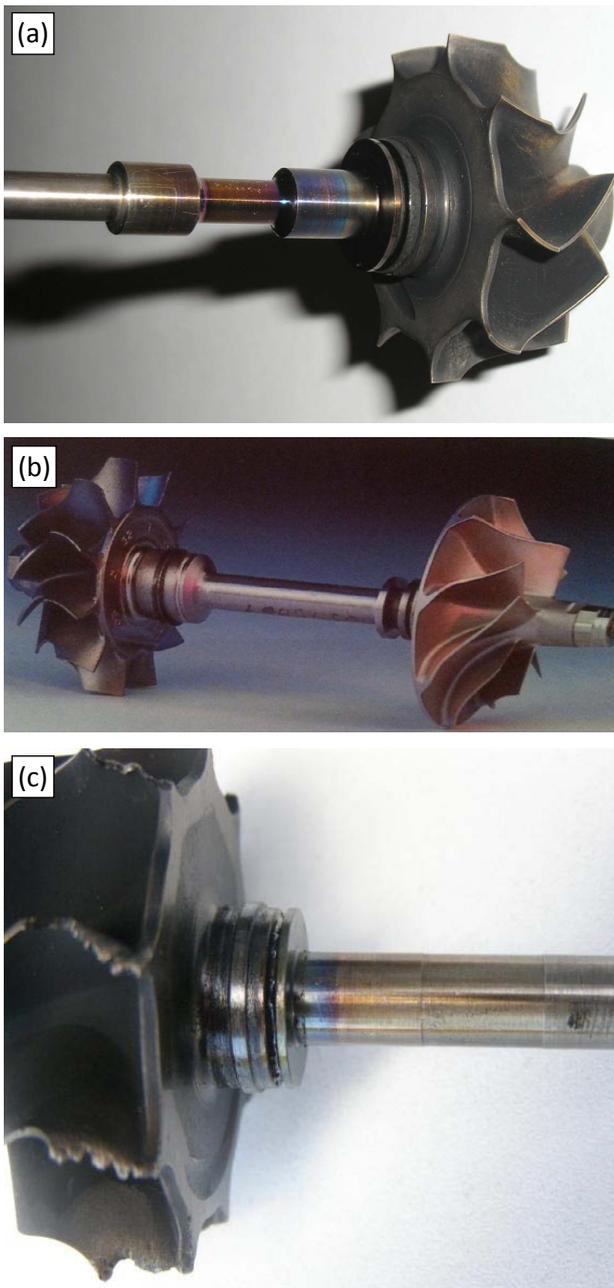
**Figure 1.** The layout and basic parts of turbochargers [6]: (a) turbocharger system, (b) basic parts and (c) radial inlet turbine with variable geometry of nozzle

this way, given the extent of the expansion, turbine flow may range from 1 to 4. The turbine characteristics adapt to the needs of the engine without bypass of mass flow directly into the exhaust with valve

roundabout. This mode optimizes pressure and boost pressure of the exhaust gas, increases engine power at a given pressure and boost output temperature at high speed is reduced by about 50 °C.

## 2.2 Damage examination of selected samples

From 21 damage turbochargers of first type of car 5 were randomly selected. From other type of car one turbocharger is selected. The layout is shown in Figure 2.



**Figure 2.** The characteristic appearance of damaged parts of turbochargers

Detailed overview is done on turbochargers.

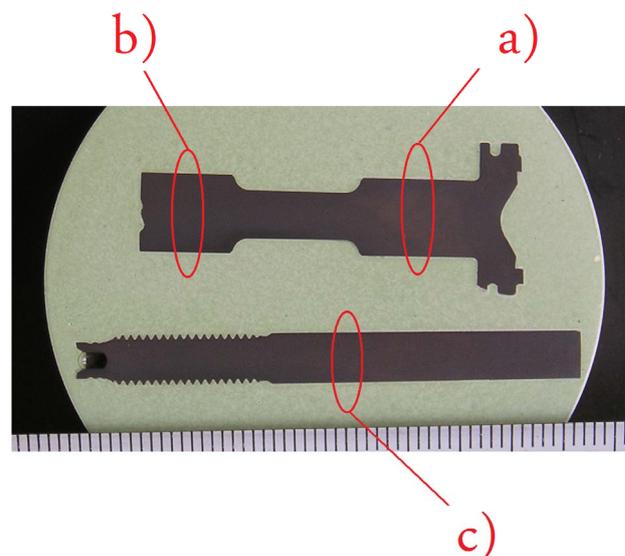
Overview shows:

- there is no visible damage on the housing of turbochargers,
- there is no visible damage on the compressor impeller,
- there is no visible damage on the turbine rotor,
- axle backlash is not increased, and
- visually it was found that the axle changed colour; colour of the axle towards the rotor blades of the impeller is from purple to dark red, Fig. 2c.

After the change of colour it is clear that there has been overheating, cause of overheating is insufficient cooling, axle is cooled with oil. Cause of damage is bad termination or termination of lubrication. Interruption of lubrication causes an increase of temperature in the bearings and increase of material wear, it occurs as a result of imbalance of rotating bodies: damage of the rotor and impeller.

Chemical analysis of materials is performed with spectrometer and shows that the axle is made of 50CrMo4 (Č4733) CrMo steels for quenching.

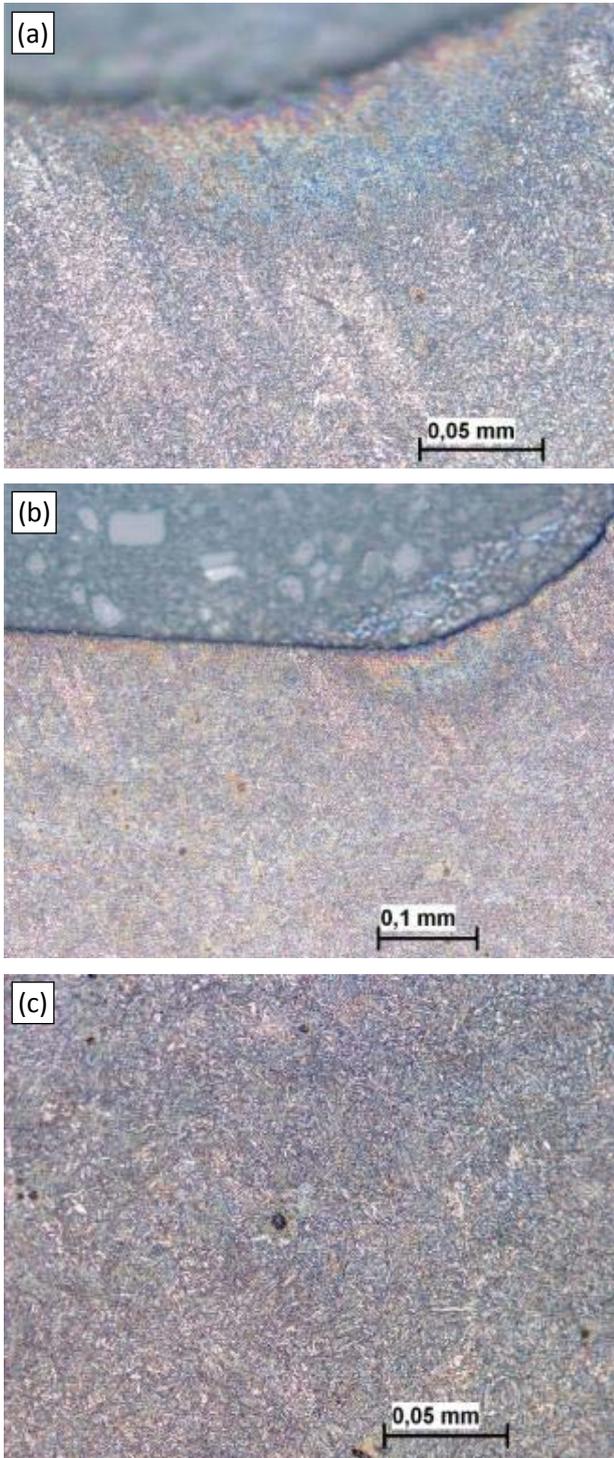
Metallographic examination and measurement of microhardness were performed on the three sections shown in Figure 3. Results of metallographic tests on the axle of turbochargers have shown that in the heat affected zone has been a change of material structure. Additional measurements



**Figure 3.** Positions of recording structure and microhardness measurements

of hardness in the impact zone of elevated temperature are indications that there has been a significant local change in hardness of the surface layer.

On the parts of section “b” and “c” hardness is between 330 and 350 HV0.1. On section “a” (part of axle where you can see purple colour) hardness is from 420 to 430 HV0.1.



**Figure 4.** The characteristic microstructure of turbochargers damaged axle: (a) and (b) zones of overheating and (c) the core

**Table 1.** Hardness measuring results in the zone “a”

Hardness values measured on diameter of 8 mm		
Position of measurement	Distance from the edge [mm]	Hardness, HV0.1
1	0.05	425
2	0.1	413
3	0.15	276
4	0.2	311
5	0.3	333
6	0.5	336
7	1	345
8	1.5	339
9	2	336
10	3	339
11	4	342

**Table 2.** Hardness measuring results in the zone “b”

Hardness values measured on diameter of 8 mm		
Position of measurement	Distance from the edge [mm]	Hardness, HV0.1
1	0.05	360
2	0.1	360
3	0.15	366
4	0.2	363
5	0.3	354
6	0.5	363
7	1	354
8	1.5	360
9	2	357
10	3	363
11	4	366

**Table 3.** Hardness measuring results in the zone “c”

Hardness values measured on diameter of 5 mm		
Position of measurement	Distance from the edge [mm]	Hardness, HV0.1
1	0.05	351
2	0.1	342
3	0.2	345
4	0.3	336
5	0.5	333
6	1	336
7	1.5	336
8	2	339
9	2.5	336

The measurement results confirm that in the heat affected zone has been a change of the material structure which is manifested by increasing hardness, in a layer located below the hardened layer has been a noticeable decline of decarburization and hardness. According to the change in the structure we know that the material was exposed to a temperature higher than the temperature of the austenitising.

### 2.3 Testing the turbocharger on the work desk

Testing of the working conditions at the temperature of normal load showed that the temperature does not exceed the extreme limits. Testing is performed on the work table, Fig. 5, at heavy load of turbocharger, 3440 rpm, Fig. 6.



Figure 5. Testing the turbocharger

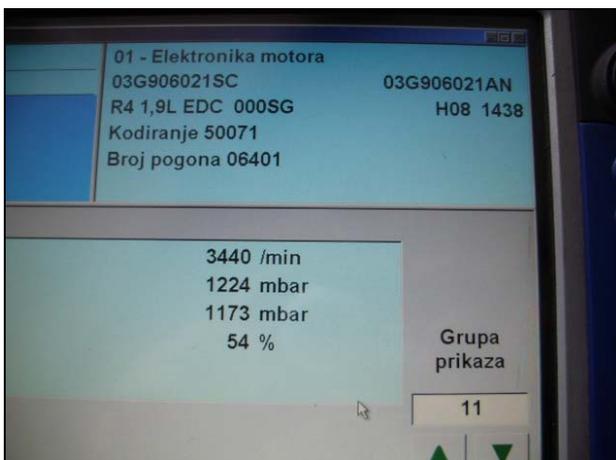


Figure 6. The pressure and temperature at 3440 rpm

The temperature of the engine coolant has reached 90 °C, and temperature on the housing slide bearing was 219.2 °C. For safety

reasons, rpm of the engine was no longer supported, but the test shows that the temperature rapidly increases depending on rpm. The maximum is 6000 rpm.

The lubricant recommended by the manufacturer for lubricating the slide bearing is used for lubricating the engine.

The critical temperature at which the oil begins to fall apart at the lighter components and coke is quite low and only 360 °C, which does not satisfy. The results of the tests indicate that in extreme temperature conditions turbochargers may exceed the permissible temperature of the oil of 360 °C.

### 3. POSSIBLE STRUCTURAL SOLUTION

To avoid the influence of temperature changes on the turbocharger, some of these design solutions are possible:

1. Sensor for temperature of turbochargers which would not allow shutdown of the power aggregate until the temperature is lower and acceptable.
2. Separate lubrication system of the sliding bearing that is not connected to the lubrication system of the drive unit, with custom lubrication and with a separate cooling and drive pump that continues to work after stopping the drive unit.
3. Cooling housing of turbochargers with liquid which cools drive unit. In this solution, the problem is that the engine coolant temperature is 90 °C, and the temperature of the exhaust gas of the turbochargers is much higher and would require adjustment cooling system with larger refrigerators and plenty of coolant.

### 4. CONCLUSION

Condition recordings and turbochargers test results indicate that during the long driving at higher speeds may cause turbochargers overheat and the disconnect of the lubrication leads to damages of the sliding surfaces of bearings.

Over time, they can cause unbalance of rotating parts, and damage of the turbine rotor and the compressor impeller.

To avoid the influence of temperature changes on the turbocharger, there is a solution with a sensor which would not allow shut down of a drive unit until the temperature is not lowered on the acceptable value.

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