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Failure Analysis of a Damaged Turbocharger

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Abstract

Failure analysis, carried out in order to explore the causes of the failure of equipment, is one of the most complex types of material testing work. It is not only necessary to know a wide range of material testing procedures, but also to have sufficient experience in performing a significant part of them and evaluating the test results. As an example of this, the article describes the investigation of the cause of failure of a car engine component that became damaged during normal service. The examinations include various methods of optical microscopy, scanning electron microscopy, EDS analysis and fractography. From the results of the failure analysis, it can be concluded that the root cause of the failure was, most probably, abnormal wear of some components, wear that can be traced back to small manufacturing inaccuracies.

Keywords: *failure analysis, optical microscopy, scanning electron microscopy, wear.*

1. The damaged equipment

The internal components of the turbocharger tested for damage are shown in **Figure 1.** The assembly drawing of the assemblies is shown in **Figure 2**, with the names of the components. The purpose of the study was to determine the forms of damage and possible causes. According to the rules of damage analysis [1, 2, 3], the components were examined with optical and scanning electron microscopes, and the composition was also analysed with EDS analysis.

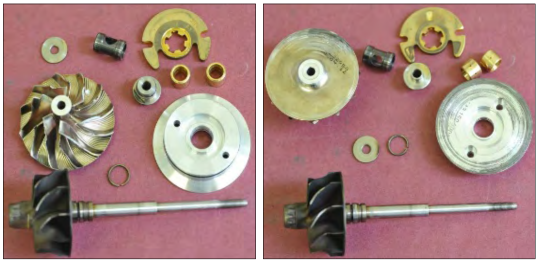

Figure 1. *Parts of the internal assembly of the failed turbocharger; the total length of the turbine + shaft assembly is 120 mm.*

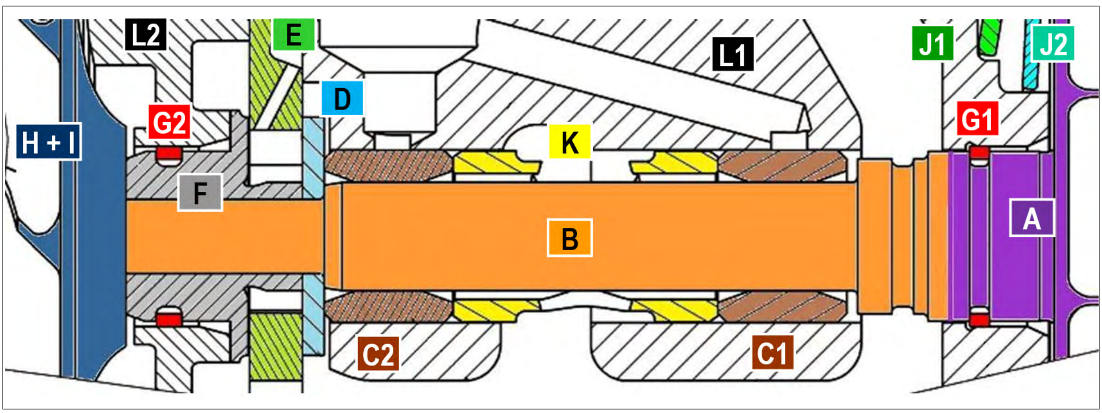

Figure 2. *Internal assemblies the turbocharger: A = turbine wheel, B = shaft, C = bearing, D = thrust ring, E = axial bearing, F = sealing bush, G = labyrinth ring, H = back plate, I = compressor wheel, J = heat shield plate (belleville spring), K = journal bearing spacer, L = housing.*

Based on Figure 2 it is easy to see that it is an extremely complex device consisting of many components, the operating stress of which should be known as it can operate at tens of thousands of revolutions per minute. Figure 3 shows the assembled internal assembly; the damage locations and modes detected by visual inspection are marked in the figure.

From the wear shown in Figure 3 it can be concluded that the axis of rotation of the moving parts of the turbine has tilted, and because of this, the moving parts have come into contact with the fixed or stationary parts. In the case of possible wear, the possibility of contact with opposite surfaces of the housing casting must be mentioned. The customer of the damage analysis did not hand over this component for testing, so there is no data on it. Nevertheless, it is not at all excluded that the parts that are clearly visible in Figure 2 close to some of the surfaces of the housing have experienced friction and wear.

2. Examination of turbine and shaft

The material of the turbine wheel is heat-resisting nickel alloy: Ni-12.5Cr-6Al-4.5Mo-2Nb-Fe-Ti, and the material of the shaft is 1.5Cr-0.5Mo alloyed heat-resistant steel. The friction-welded turbine + shaft assembly can be seen in Figures 4, 5 and 6 which show signs of wear on the faceplate and shaft of the turbine

The damage to the turbine wheel shown in Figure 5 on the blade holder base plate is conspicuous. The wear is only around the circumference of the circular base plate. it extends to a third, but it is strong there. Since the surface is almost completely clean, it can be assumed that the turbocharger was not in operation or only for a very short time after the breakdown leading to wear. Another element of the wear process was presumably the opposite surface of the heat shield and/or the turbine housing.

Shaft wear is indicated by the polishing of the surface under the bearing bushings. Diameter reduction cannot be measured with a measuring device with micrometre accuracy, but surface wear can be easily detected.

3. Inspection of bearing bushings

A burr can be seen on the front of the cylindrical ring of the bearing bushings (Figure 7).

The formation of grey spots on the brass material is noticeable both on the outer and inner surface (Figure 8). According to the EDS analysis, the spots are material smears, the material of which is mainly Fe, Cr, Ni, in some places Sn and Pb. A change of shape indicating a strong heating of

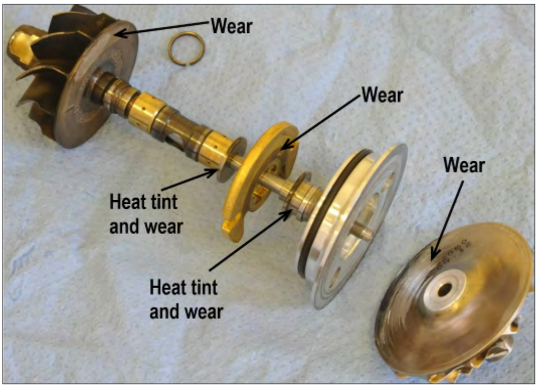

Figure 3. *The internal fittings of the turbocharger are loosely assembled.*

Figure 5. *Wear traces on the turbine wheel.*

Figure 4. *The welded turbine and shaft.*

Figure 6. *Wear marks on the shaft.*

the edge can be seen in the holes, and in some cases partial blockage.

The piece of material shown in Figure 9 was attached to the inner surface of one bearing. Based on the EDS analysis, it could be identified as austenitic steel: Fe-1.7Al-2.7Si-1.9Mo-16.9Cr-2.5Mn-9.4Ni.

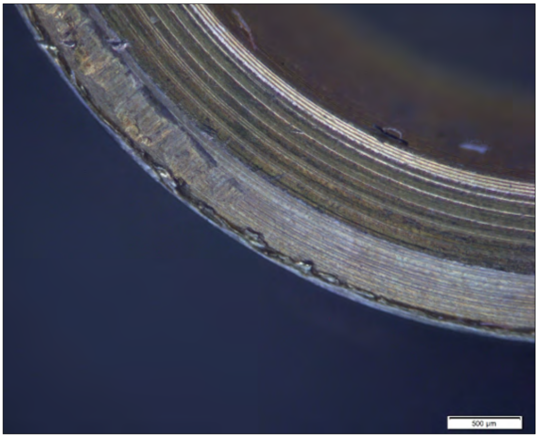

Figure 7. *Traces of burr formation on the bearing.*

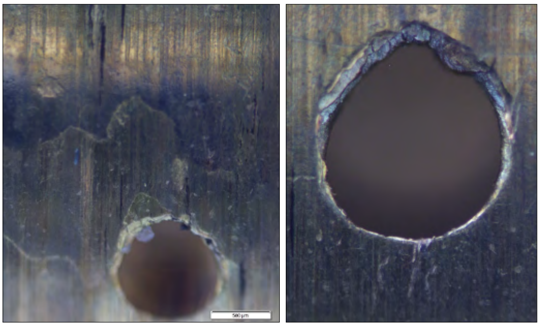

Figure 8. *Wear of the bore rim on the bearing.*

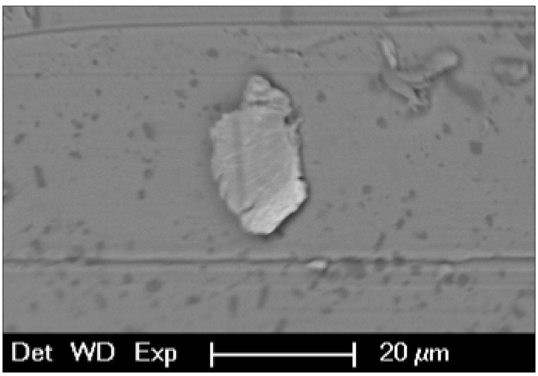

Figure 9. *A chip stuck to the bearing surface.*

Figure 10. *Wear marks on the axial bearing.*

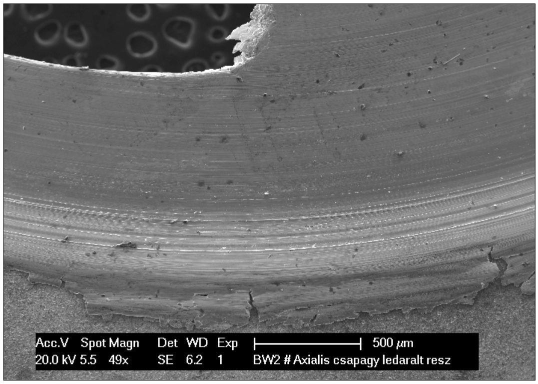

Figure 11. *Wear marks on the support bearing.*

4. Examination of the axial bearing

The wear marks on the support bearing (Figure 10) can be seen in Figure 11. Rough wear grooves formed on the surface, squeezing the upper material layer out of the contact surface as a burr.

5. Inspection of the compressor wheel

The material of the compression wheel shown in Figure 12: Al-2Mg-2Ag-1Fe-2Ni-3Cu-0.1Zn-0.2Ti-0.35Si-0.1Mn; coating material: nickel alloy with ~10% phosphorous. The most typical mechanism for the wear process is the cracking and flaking of the brittle coating

6. Assessment of damage analysis

The main findings of the evaluation of the nature of the damage to the turbocharger are as follows:

Figure 12. *Wear marks on the compressor wheel.*

Foreign substances have been placed on the surface of the components; they are the product of organic contamination and wear of other components. No material connection between foreign materials and the wear of any of the parts can be demonstrated.

There is such an amount of material missing from the various components due to wear and tear that this alone makes general and heavy wear the essence of the damage process.

We could not determine the amount of material missing from the various parts, as we do not know the exact weight of the parts before installation. It would be advisable to pay attention to this in the analysis of damage processes.

Damage to the turbine-side labyrinth ring groove and labyrinth ring (G1 and G2 in **Figure 2**) is usually key, but in this case the wear on the parts in question was not significant.

On the large-diameter components – turbine wheel, compressor wheel – the wear occurred on their surfaces far from the axis of rotation, namely not circularly.

Consequently, the wear-causing displacement spread to the entire axle assembly. The responsibility of the tested components for this development could not be established. For this reason, the only hypothesis that seems to be correct is that the surfaces of the cast housing began to wear intensively, and these surfaces are meant to ensure the uniaxiality of the shaft assembly. Additionally, the crumbs we identified on some of the filter inserts indicate the wear of the housing.

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