Failure analysis of broken turbo wheel flange

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Failure analysis, welding, fatigue, wheel flange

1. Introduction

In our days failure analysis is a must for every product or process. Each of them has different modes of failure.

An analysis of potential failures helps the designers to focus on and understand the impact of potential process or product risks and failures [1]. In some cases this has to be performed after the product is in s ervice in order to correct production errors [2]. The case persented in this paper refers to such an example. A turbo wheel with a broken flange was delivered for analysis by a customer. According to the customer the wheel was used in 3-axle trailer. The failure was reported in the company Service Report and leaded to production stop. The request was to perform failure analysis of the turbo wheel flange.

2. Inspection phases performed

2.1. Visual inspection

The wheel with the broken off crown of the flange is shown in Fig. 1. The central part of the flange is shown in Fig. 2. The flange crown consists of 10 lugs with the holes for fastening the flange to the wheel. All lugs broke off at their base.

Figure 1. View of the wheel with broken off flange crown.

The typical fracture surface of the lug is shown in Fig. 3. It is characteristic of fatigue fracture initiated at one of the sides and propagated till about a half of the lug thickness up to the final fracture.

2.2. Chemical analysis

The chemical composition of the broken part was investigated using a Spectro Lab S type spectroscope. Special specimen for the analysis was prepared by melting. The analysis results are presented in Table 1.

Figure 2. View of the failed flange – the crown is broken off.

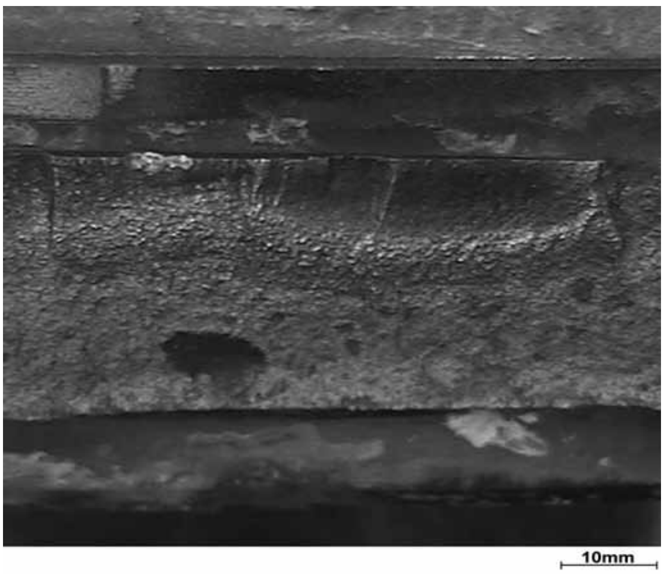

Figure 3. Close-up of the fracture surface of the flange.

The analysis results indicate that the chemical composition of the flange corresponds to ductile (nodular) cast iron SAE J434.

2.3. Metallographic analysis

The microstructure of the flange material was investigated in a metallographic section prepared close to the fracture surface. After grinding and polishing the section was investigated using an optical microscope. The spheroidal graphite of type I according to SAE J434 was found (Fig. 4). After etching in Nital 2% the microstructure metallic matrix consisting of ferrite and pearlite was revealed (Fig. 5a, 5b). As can be seen from these photographs the pearlite content varies from about 10 to 40%. The graphite form and the microstructure of the metallic matrix correspond to the ductile cast iron SAE J434 Grade 4512 to Grade 5506.

Table 1. Chemical analysis results.

Elements, [%]	Analysis	SAE J434 Grade D5506
C	3.18	3.20÷ 4.10
Si	2.59	1.80÷ 3.00
Mn	0.33	0.10÷ 1.00
P	0.019	–
S	0.014	0.005÷0.033
Fe	balance	balance

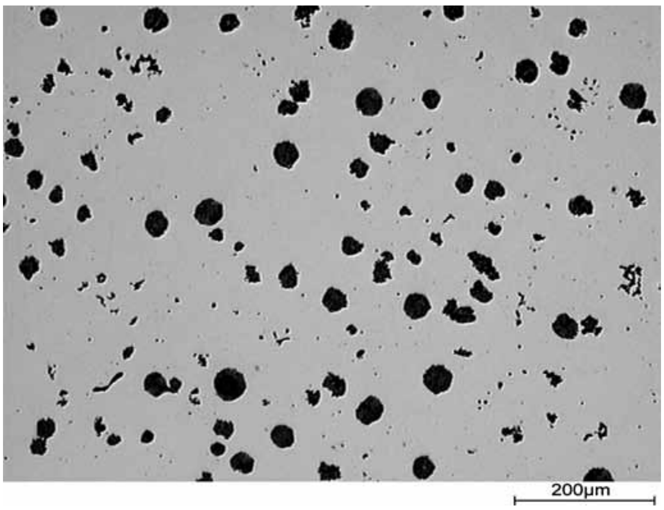

Figure 4. Nodular graphite form of the flange material.

2.4. Brinell hardness test

The hardness of the flange material was measured with the 3000 kg test load and the indenter of 10 mm diameter.

The measured hardness was in the range: 177÷179 HB. This hardness corresponds to the hardness of the ductile cast iron SAE J434 Grade 4512 (156÷217 HB). It does not correspond to the Grade 5506 (187÷255 HB).

2.5. Tensile test

Tensile test was performed on a specimen made from the flange material. The test was performed using an Instron 4400R testing machine. The test results are presented in Table 2.

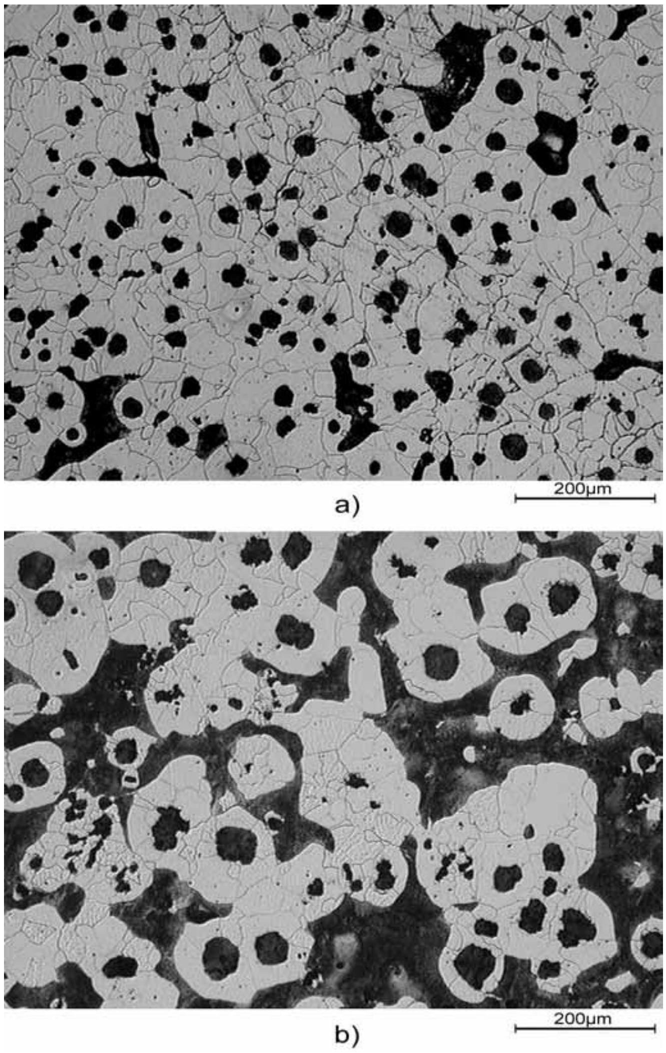

Figure 5. Ferritic-pearlitic microstructure of the metallic matrix: a – 10% pearlite content, b – 40% pearlite content.

The test results indicate that the mechanical properties of the of the flange material are between the typical values of the ductile cast iron of the Grades D5506 and Grade 4512.

2.6. Fractographic analysis of the fracture surface by SEM

The morphology of the fracture surface was examined using a Philips XL30 scanning electron microscope (SEM). The fatigue striations found in the fatigue zone of the fracture surface are shown in Fig. 6. The morphology of the fracture surface in the final fracture zone consists of large shallow

Table 2. Tensile test results.

	Specimen's diameter [mm]	Yield stress [MPa]	Ultimate stress [MPa]	Elongation, L = 25 mm [%]
Test ASTM E8 / E8M - 13a	6.02	346	531	8.3
SAE J434 Grade D5506	6.02	379	552	6.0
SAE J434 Grade D4512	6.02	310	448	12.0

dimples formed from graphite spheroids (Fig. 7). At higher magnification small dimples were also found (Fig. 8). This morphology is characteristic of final fracture of the ductile material [3].

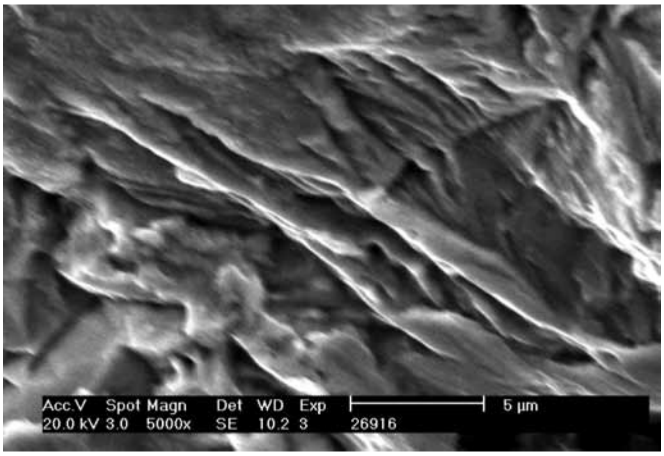

Figure 6. Fatigue striations found in the fatigue zone of the flange fracture surface.

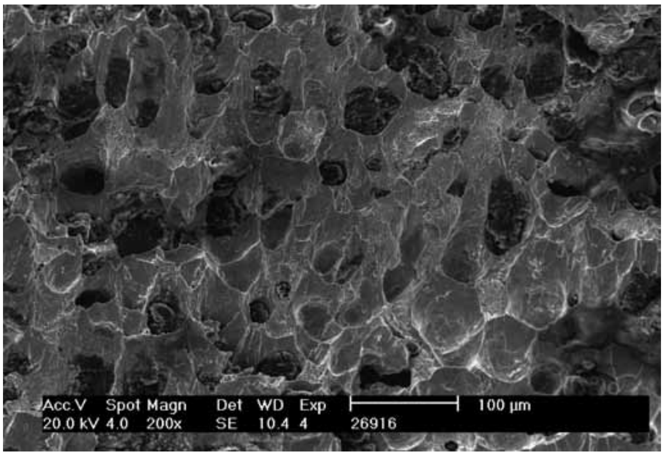

Figure 7. Final fracture zone at low magnification.

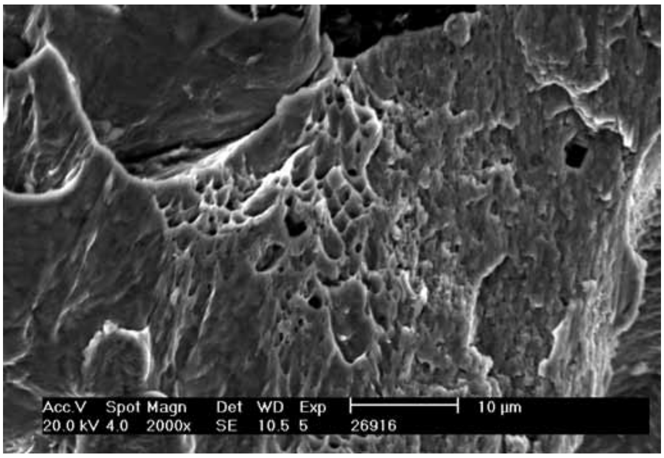

Figure 8. Final fracture zone at high magnification.

3. Conclusion

- The failed turbo wheel flange was manufactured of ductile cast iron corresponding to SAE J434.
- According to microstructure and hardness the material corresponds to Grade 4512, but has a decreased elongation. According to tensile mechanical properties the material can be qualified as Grade 5506.
- The microstructure of the metallic matrix is not uniform: the pearlite content varies from 10% to 40%. The areas with decreased pearlite content have decreased local strength, which manifest itself in decreased fatigue strength.
- The failure of turbo wheel flange is a result of fatigue crack initiation and propagation. The lifetime of the product was reached.

References

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