UDK 669.13:621.827:620.18
Professional article/Strokovni članek

ISSN 1580-2949
MTAEC9, 42(2)93(2008)

A METALLOGRAPHIC EXAMINATION OF A FRACTURED CONNECTING ROD

METALOGRAFSKA PREISKAVA PRELOMA OJNICE

Roman Celin, Boris Arzenšek, Dimitrij Kmetič

Institute of Metals and Technology, Lepi pot 11, 1000 Ljubljana
roman.celin@imt.si

Prejem rokopisa – received: 2007-10-08; sprejem za objavo – accepted for publication: 2007-12-17

The connecting rod converts the piston's reciprocating motion into the rotary motion of the crankshaft. During service, connecting rods are subjected to a various loads. In the case of the connecting rod investigated here, the failure occurred after just 20,000 km on the car's odometer (approximately 2 years of service). The paper describes the results of an analysis of the fractured connecting rod's shank.

Keywords: connecting rod, nodular cast iron, failure, metallographic examination

Ojnica motorja z notranjim zgorevanjem pretvarja recipročno gibanje bata v krožno gibanje ročične gredi. Med obratovanjem so ojnice izpostavljena raznim obremenitvam. V primeru preiskovane ojnice se je prelom zgodil po le 20 000 prevoženih kilometrih (po približno dveh letih uporabe avtomobila). V članku so opisani razultati preiskave prelomljenega stebla ojnice.

Ključne besede: ojnica, nodularna litina, prelom, metalografska preiskava

1 INTRODUCTION

Connecting rods are generally manufactured using casting or forging, and in use support a variety of loads, such as [1]:

- compressive loading in the longitudinal direction, as a result of the gas pressure on the piston crown,
- alternate tensile and compressive loads, as a result of the changing piston velocity,
- bending loads in the connecting rod's shank, as a result of the oscillating motion about the gudgeon-pin axis,
- buckling stress, as a result of large compressive loads.

The frequency of alternating loading increases rapidly with an increase in the engine's rpm. In many cases a catastrophic engine failure is caused by a connecting-rod failure and sometimes the broken connecting rod's shank may even be pushed through the side of the crank-case, thereby rendering the engine irreparable. There are many reasons for such a failure, e.g., the overheating of the engine, cracking, deficiency of the bearing lubrication, poor maintenance, etc. A catastrophic failure occurred for one of the four connecting rods of a 1.8-litre 16-valve internal combustion car engine while travelling at 100 km/h on a motorway. The side of the crank-case was ruptured and the corresponding piston was very deformed. Both parts of the fractured connecting rod are shown in **Figure 1**.

Figure 1: Connecting rod's fractured shank
Slika 1: Prelomljeno steblo ojnice

2 EXAMINATION

The analysis of the fracture consisted of a visual examination, hardness measurements and a metallographic examination. The specimens for the metallographic and scanning electron microscope (SEM) examinations were cut from the connecting rod's shank

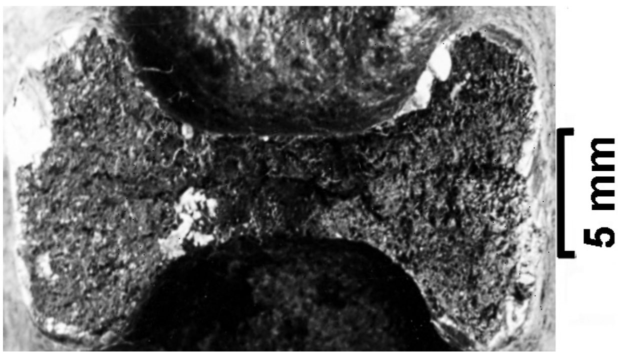

Figure 2: Fractured surface near the small end of the connecting rod's shank
Slika 2: Površina preloma na strani glave ojnice

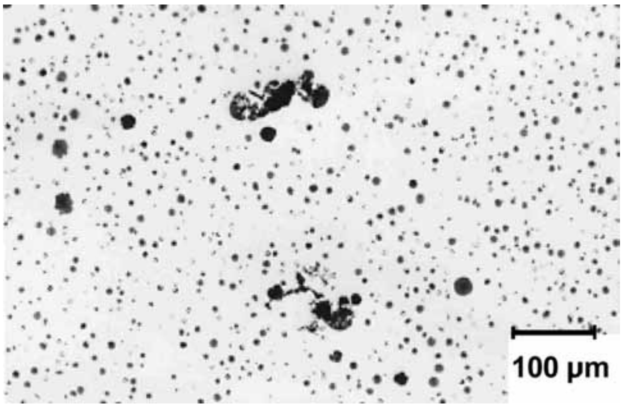

Figure 3: Specimen's microstructure (unetched)
Slika 3: Mikrostruktura vzorca ojnice (nejedkana)

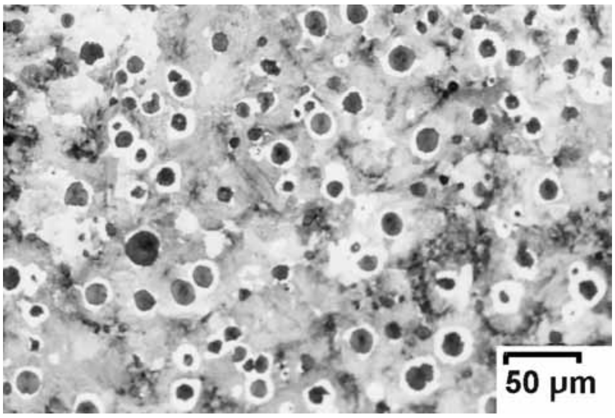

Figure 4: Specimen's microstructure (nital etched)
Slika 4: Mikrostruktura jedkanega vzorca (nital)

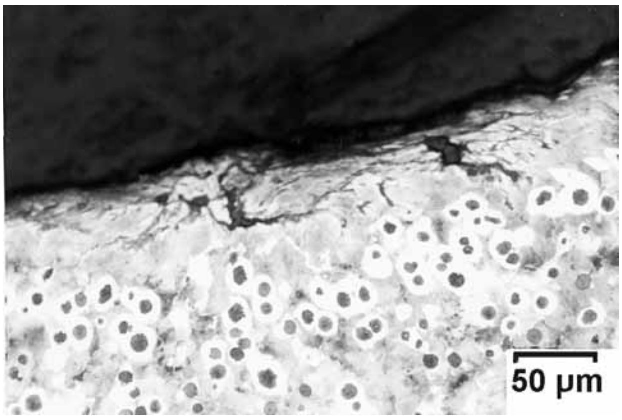

Figure 5: Casting defect on the surface of the connecting rod
Slika 5: Livarska napaka na površini ojnice

near the fracture surface. The double-T cross-section of the shank's fractured surface is shown in **Figure 2**, and the rod's microstructure is shown in **Figure 3**.

The microstructure in **Figure 3** is typical for ductile iron (nodular graphite iron), with a fine lamellar pearlite matrix and small inserts of ferrite (approximately 5 %) around the graphite nodules (**Figure 4**).

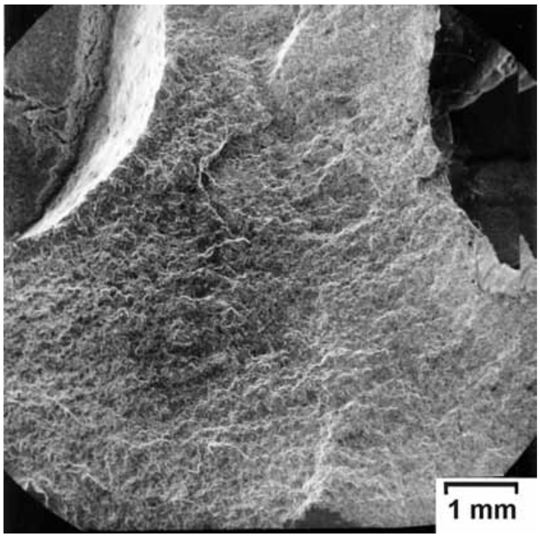

Figure 6: SEM image of the small-end fracture surface
Slika 6: SEM-posnetek preloma na strani glave ojnice

The whole surface of the connecting rod's two halves was examined carefully and numerous surface-casting defects were found. One of which is shown in **Figure 5**.

The fracture surface of the connecting rod was examined in the SEM, and the small-end fracture surface is shown in **Figure 6**.

3 RESULTS AND DISCUSSION

The connecting rod is made of pearlite ductile iron (nodular graphite cast iron), which is frequently used to substitute wrought or cast steel components. Examples of such a substitution include callipers and cylinders, turbochargers, connecting rods, etc. The benefits of using ductile iron in these applications are lower manufacturing costs [2].

According to the graphite classification, the microstructure in **Figure 3** corresponds to graphite form VI and graphite size 8 [3]. The graphite nodules are small

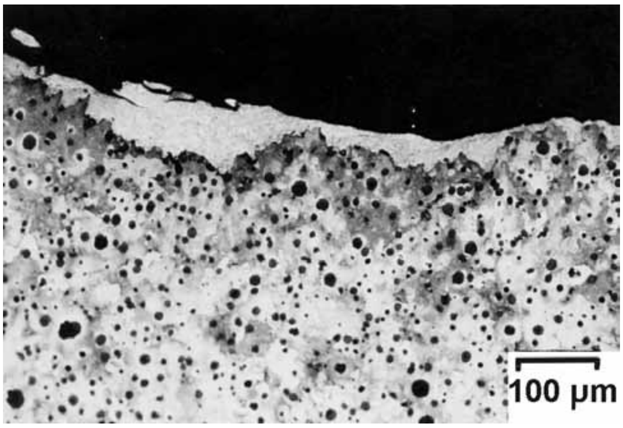

Figure 7: Residue of aluminium on the big-end fracture surface
Slika 7: Ostanki aluminija na površini preloma na strani noge ojnice

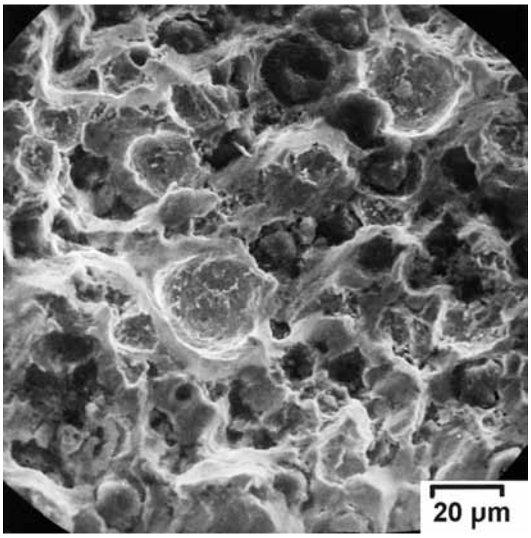

Figure 8: SEM image of small-end fracture surface
Slika 8: SEM-posnetek površine preloma pri glavi ojnice

(**Figure 3**), and this is evidence of an efficient process of nodulation with the probable addition of magnesium or cerium to the melt [4].

Figure 7 shows the microstructure of the big-end fracture surface. Residues of aluminium were found; a result of the connecting rod being pushed through the aluminium crank-case. The aluminium can be seen in **Figure 7** as structure on the edge of the fractured surface.

The surface of the connecting rod was sandblasted to increase the strength with strain hardening and to close the casting defects (**Figure 5**). The connecting rod supports a complex fatigue load, with repeated loading during every crankshaft revolution, and because of this loading, every casting defect has the potential to became the initial point for fatigue-crack initiation, where the local stress in the defect tip is increased because of the "notch effect". After an initial propagation, with each crack opening the crack advances by one striation, at a critical crack size the rupture occurs. On the investigated fracture surface the striations were not sufficiently clear to reliably determine the initiation point. The final fracture surface has marks of plastic straining and from their microscopic appearance it is concluded that the final fracture occurred with a very small plastic deformation preceding the opening of the crack. The final rupture was, thus, very severe. At a low rate of separation the loose graphite nodules would be crushed and deposited on the fracture surface's dark-grey region [5]. Such regions were not detected on the examined sample.

The small end of the connecting rod's fracture surface was examined with the SEM. On the fracture surface there are numerous dimples with embedded graphite nodules or where the nodules had fallen out (**Figure 8**).

The HB hardness was measured on the connecting rod's shank. The measured value of 280 HB corresponds to pearlite ductile iron.

4 CONCLUSION

The fractured connecting rod had a microstructure of pearlite ferrite ductile iron with a normal size and shape of graphite nodules as well as a normal hardness of 280 HB. The share of ferrite is approximately of 5 %. The morphology of the fracture surface indicates that the fracture occurred instantaneously. Near the fracture surface several casting defects with a shape partially changed by sandblasting were found on the connecting rod's shank. It is concluded that one of these casting defects was probably the initiation point for the connecting-rod shank's fracture. Connecting rods made of ductile cast iron must have proper mechanical properties and microstructural characteristics, and should be without any manufacturing defects, because ductile iron is a notch-sensitive material. The rapid in-service failure of the examined connecting rod with surface defects is clear evidence that the foundry's and/or the engine manufacturer's quality control were in this case insufficient to detect the surface defects and prevent the use of the connecting rod in the car's engine.

5 REFERENCES

[1] Fisher R. et al. Modern Automotive Technology. Haan-Gruiten: Europa Lehrmittel; 2006

[2] ASM handbook, vol. 15, Casting. ASM International, Materials Park, OH 1998, p. 1454

[3] Designation of microstructure of cast irons ISO/DIS 945-1, 2006

[4] Brandes E. A., Brook G. B. Smithells, Metals Reference Book. Oxford: Butterworth Heinemann; 1999, 26–81

[5] Jen K., Scardina J. T., Smith D. G. Fractographic analysis of an ASTM as-cast pearlitic nodular iron. Metallography (**1986**) 3, 359–370