RAILWAY PARTS FATIGUE BEHAVIOUR UNDER INFLUENCE OF THE INNER IMPERFECTIONS

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Contribution is devoted to the study of cracking of cast railway frog. In contribution are summarized of findings that were found during investigation of source of cracking. Material properties were investigated by mechanical properties of materials. Fracture area was study by macro and microstructure (fractography) and microstructure and structure defects of bulk material was study by optic and SEM microscopy. Initialization of crack was found in synergic incidence of initial heat cracks and stress concentration in sizable change of cross-section of cast. Main source of failure was found in technology of heat treatment of cast and/or not very proper design of cast.

Key words: fractography, cast steel, high strength steels, microstructure

1 Introduction

In a polycrystalline material, there are only two types of fracture, either transgranular or intergranular. Under tensile loading, the transgranular mode can be subdivided into brittle and ductile types of failure. Failures that occur under cyclic loading are usually transgranular, whereas long-term creep failures occur in an intergranular mode. Other types of failure, such as stress corrosion cracking, can take place in either a transgranular mode or an intergranular mode [1].

Aim of our research was study of railway frog fracture during operation time. The frog was cast from steel Lo8CrniMo. We tested fracture with aim of find degradation mechanism and detect influence of steel quality to initialization and/or propagation of cracking.

For metallographic testing was railway frog cut for samples. Samples for testing of mechanic properties of material were cut off from massive part of material near rupture.

2 Methodology of testing

Quality of material was tested by spectral analysis of steel composition, changing of composition in different parts of component part. Structure characterization of material was study with purpose to find correlation between structure defects and fracture behaviour (appearance of fracture) of material. There were tested mechanic properties (tensile test, hardness measurement) of material.

Results and Discussion

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Mechanic properties of steel were evaluated from selected places of sample, near of fracture. Results of mechanic properties (strength and plasticity) show good correlation between real material and standardized properties. There was not found any significant difference from among samples located in different places of material. In real service is material shock loading, that appreciation of material response in real condition was evaluate from fractographic analysis.

Hardness testing was take using Brinell hardness $HBW_{2.5/187.5}$. The hardness was measure on tensile test rod and near fracture location with aim to find difference of mechanic properties near fracture location.

Results of hardness measurement did show that hardness was in range of 330 to 400 HB. From this result is possible estimate similar mechanic properties in all volume of sample including zone of initialization and cracking growth.

Chemical analysis was made at all parts of sample in localization of mechanic properties measurements. Aim if this analysis was finding some correlation between chemical composition and mechanic properties and find real amount of alloying elements in relation to fracture behaviour. Chemical analysis of samples shows that composition of tested material is in range of standardized composition.

Structure characteristic was focuses to evaluation of differences in internal structure of material in correlation to initialization and/or growth of fracture. Samples for structure characterization were cut off from places adjacent to fracture area. For comparison of structure was cut metallographic samples from distant places of materials.

Metallographic analyses do not show any correlation between type of fracture and structure of steel – the structure was uniform in all localization of sample. Typical structures of steel are show in fig. 1, and fig. 2. Structure is mixed high and low bainite with relatively fine carbide dispersion.

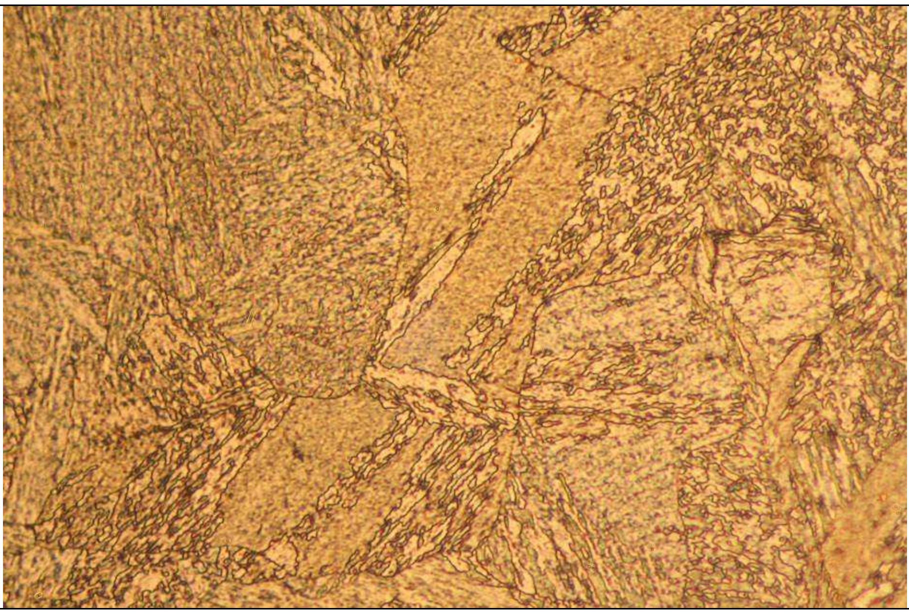

Fig. 1. Typical structure of material – bainite, mag. 250x

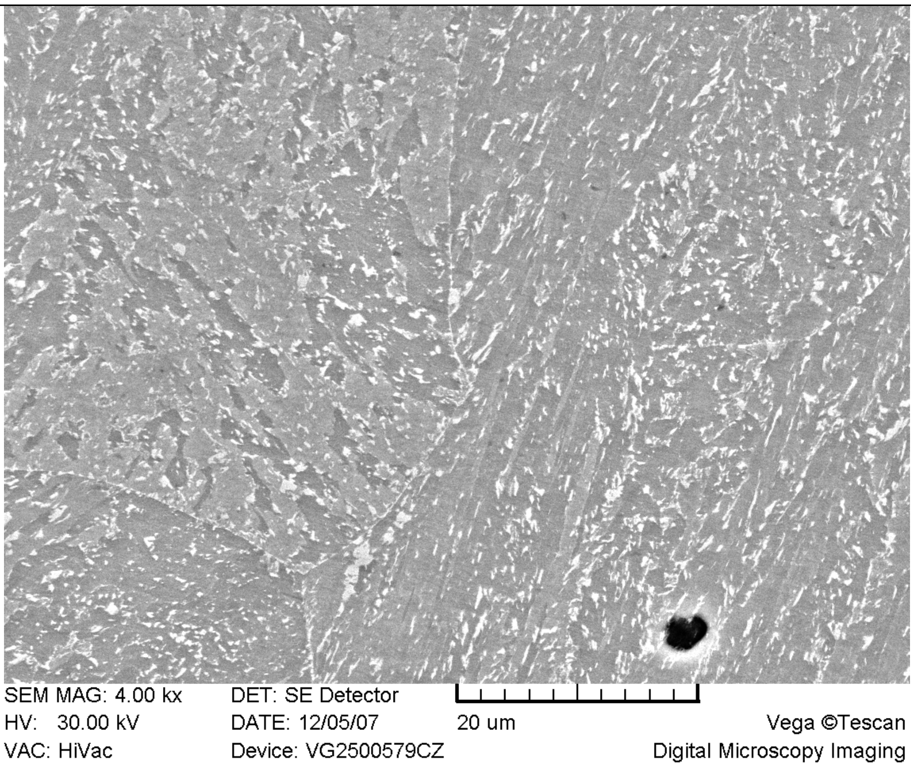

Fig. 2. Morphology of bainite

Presence of casting defects was evaluated in correlation to potential structure differences near fracture area and in basic material. Structure corresponds to typical cast steel with micro shrinkage porosity.

As typical impurity was found presence of complex oxidic inclusions and nitrides (or carbonitrides). In any case of evaluated zones was not observe presence inclusion with abhorrent morphology or distribution, i.e. was not found bands structure or interdendritic structures.

For evaluation of possibility of cracking initialization under cast rim was study steel structure near surface. Presences of surface cracks correspond to typical cast material. Cracks rise from surface conduce to local flaking of cast rim, but without growth to basic material, see fig. 3.

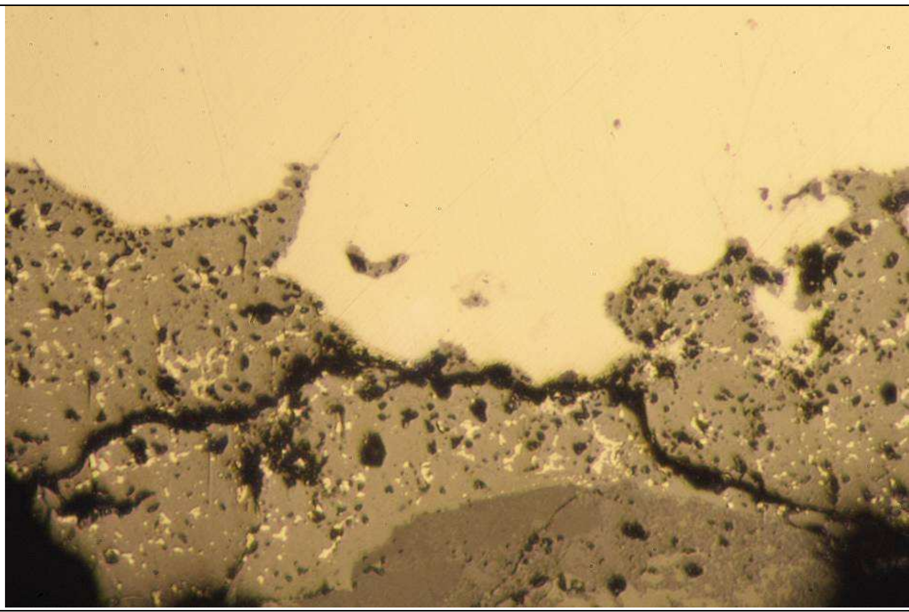

Fig. 3. Cracks in cast rim.

Surface of fracture area was hard corroded that was impossible provide direct fractography analyze. Fracture mode of this surface was evaluated after chemical cleaning of surface. Results of this study are introduced in next part of this study. In experimentally create part of fracture was identified brittle transcrystalline failure, cleavage facets corresponds to bainitic structure of steel. There was only minimal presence of ductile fracture. Ductile fracture was observed only on microsurfaces that connect detached step of brittle fracture. This fracture mode corresponds to previous analysis of this bainitic steel.

Macroscopic analysis did not show any relationship between structure of steel (including imperfections) and fracture characteristic. Fractograph watched different mode of fracture (fatigue and laboratory break) did not show different structure of steel in both locations. Subsurface layers of steel in area localized in operation fracture show specific cracks with serrated character. Near these cracking was observed only finer structure of steel; there were not identified other material defects.

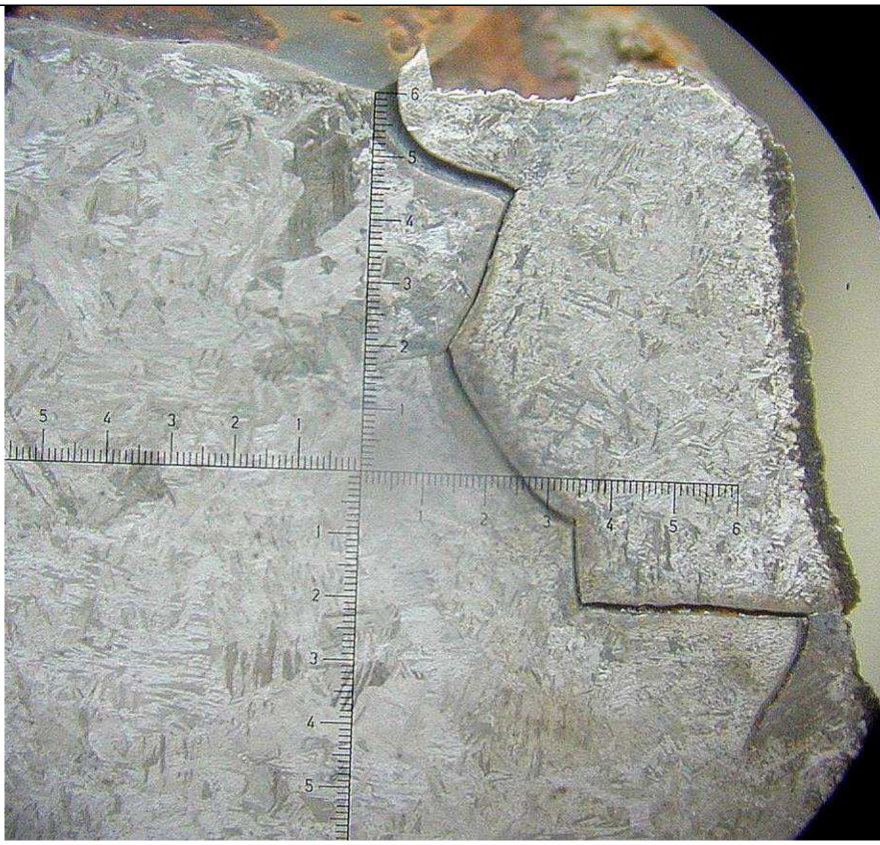

Fig 4. Crack starting at fatigue crack surface, mag. 20x

Possible reason of crack initialization was found in microstructure of subsurface region near fracture initialization. Change of structure in this region is show in fig 5. In figure is show change structure around the crack perpendicular to operational crack. This defect is not creating during steel solidification nor initialize on structure imperfection. Crack is propagating in solid steel by different structure. This change of structure was due to different decarburization of steel, probably during heat treat of material. Change of structure of austenitic grain was in correlation to the amount of decarburization. Decarburization and change of structure has direct influence to next phase transformation. This “heat treating induced” crack were initialization of fatigue crack of material [2].

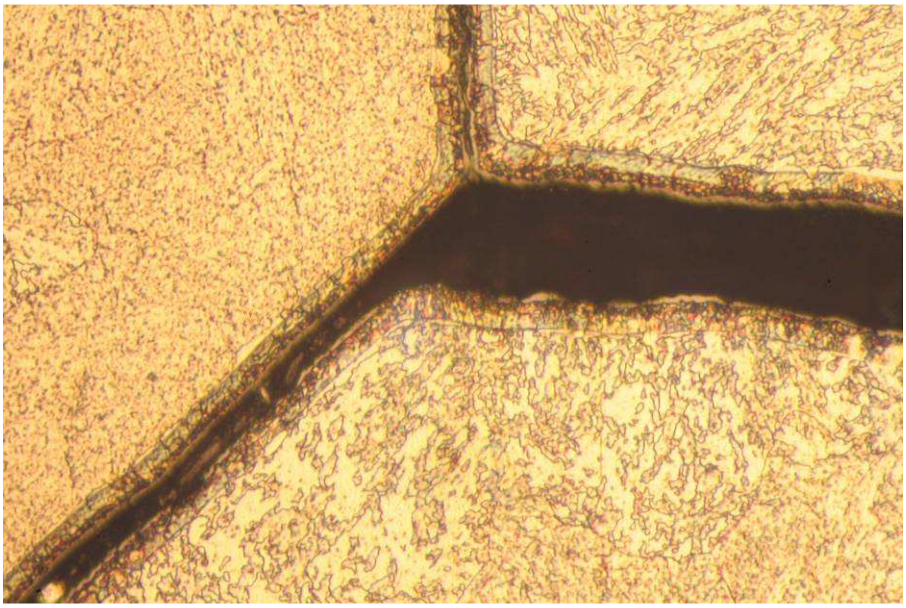

Fig. 5. Change structure in neighborhood of subsurface cracks, mag. 250x

From results mentioned above is possible to evolve circumstances that leads to creation and development of damage. Initialization of cracks was creating before operational loading, during austenitization of steel. There was crate wide discreteness that in some directions initialize fatigue crack growth.

Near fracture initialization was not found any structure imperfections. There was not found any significant structure changes against other material volume. Near fracture area was found two pattern of crack:

i) Typical secondary cracks that locally increase broken relief. In this type of cracks is possible to suppose absorption of energy during growth that is probably positive influence to fracture toughness of steel. Branching of these cracks is result of presence microheterogeneity of structure (brittle inclusions).

ii) Cracks originate before operational loading during heat treating (austenitisation).

3 Conclusion

Measuring of mechanical properties of steel does not show any difference between tested materials and data sheet. Mechanical properties (hardness, strength) of cast were comparable from all parts of article. Chemical composition of material corresponded to technical manual too. Macro and micro purity of steel was good in all tested parts of cast. Fractography analysis din not show any relation between structure defect and fracture initialization. Structure defects on slightly modified propagation of fracture.

From metallographic and fractographic analysis near initialization of fracture was found presence of material degradation and their influence to fracture initialization. Near initialization of fracture location was found presence of cracks, the cracks was localized near fracture initialization that was identify by fractography method. These cracks were probably initialized during heat tread cycle. Stress relaxation (heat and structural stresses) is connecting to shear on grain boundary with hardening inside of grain (in consequence of increasing of dislocation concentration). Due to these effects was initialize intercrystalline cracking. Effect of stress a structure change was probably amplify by considerable change of cross-section of cast (strengthen arris).

Morphology and propagation of identified crack clearly show that these discontinuities were present in cast before dynamic loading. These cracks work as concentrator of strain during dynamic loading; this crack growth was clearly identified in sample near fracture initialization area. Presence of these defects conduces to probability lead to early initialization of early process.

From above mentioned results was possible conclude substantially degradation of fatigue life due to presence basic discontinuity of material. Basic discontinuity of material was found in various orientations to fracture area. Initialization was created in synergic incidence of initial heat cracks and stress concentration in sizable change of cross-section of cast (near strengthen arris).

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