REAL CASES OF OCCURRENCE OF UNTYPICAL BRITTLE RUPTURE OF STEEL COMPONENTS DUE TO BENDING STRESS

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Abstract
Companies carry out wide range of activities, whose quality, range and form significantly affect its performance, success on the market and overall competitiveness. Marketing activities are part of company management process and affect the philosophy of the development of the company, its overall position on the market and competitiveness. Marketing contribution in the company depends on economic and technical conditions as well as the size of the company. Content of marketing is different in small and medium enterprises and large companies. In terms of increasing competitiveness, small and medium enterprises create development strategies, which include strategic marketing.

Keywords: embrittlement of steels, thin-walled components, retained austenite, martensite

1 Introduction

The contents of this paper is closely connected with description of real cases and conditions of real situations under which arises cracking of steel components due to external loading in operation. Fractographic analysis of these components showed occurrence of untypical brittle intergranular rupture. Initiation and mechanism of fracture distribution for given fracture is not characteristic for any of described cases of brittle fracture till now. Some features which are described in this paper are similar to features relating to step by step fracture which is caused by hydrogenization of material. We suppose, that mechanism occurrence for this brittle rupture is caused by disintegration of retained austenite to martensite due to externals bending forces.

1.1 Pressure plate

The pressure plate is the component, which was made of a material 16270. This material is characterized as high-alloy steel with high hardenability, high hardness and simultaneously high toughness in hardened and tempered state. Tendency of given material not to be brittle in relation to tempering process is not known [1].

Pressure plate (Fig. 1) has a thickness of 1 mm, inner hole and outer removing which is determined for a safety pin. This component has been hardened and tempered to a hardness of 61-64 HRc [1, 3].

Fig. 1 *Pressure plate [1]*

After seizing the hydrostatic converter, there was the destruction of the component. The subsequent analysis of the accident showed that plate was not installed horizontally. Due to dimensional inaccuracies in assembly, the given plate was installed under an unspecified small slope. Component was not only exposed to pressure loading, as it was determined by designer, but there was also the bending loading [1, 3].

Component was broken through the whole diameter. Inter circumference was ruptured in one area. Surface of both front functional areas of the pressure plate showed traces of thermal and mechanical influence circa 5 mm and it was from the outer circumference up to inner circumference [1, 3].

Microstructure of the outer and inner perimeter was composed of fine acicular low-tempered martensite and retained austenite. The structure was gradually changed to the sorbitol towards the middle between the inner and outer circumference [1, 3].

Micromorphology of the original fracture surface was mostly formed by intergranular fissile (IGF) rupture in a thermally and mechanically uninfluenced area. According to this finding, laboratory fractures were prepared and it was carried out by impact bending breaking of unnotched samples from these areas. In the case of these samples, there was observed band in sub-surface area (in the area of pressure loading) and this band was only with IGF facettes and it was along the whole width of sample (Fig. 2, 3). Towards to core, the mechanism of fracture was changed suddenly and it was the break moment where the mechanism of fracture was transgranular pit fracture (TGH) and it was towards to opposite side of surface (Fig. 2) [1, 3].

X-ray analysis was used for determination of content of retained austenite to 13.0 ± 1.5%, while the usually accepted content of retained austenite for this steel is up to 5% [1, 3].

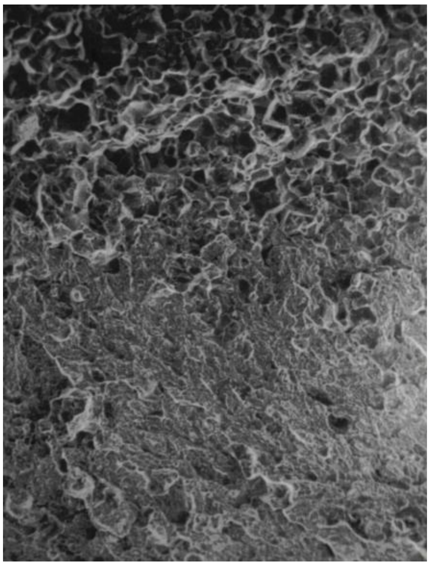

Fig. 2 *IGF + TGH fracture, zoom: 105x [1]*

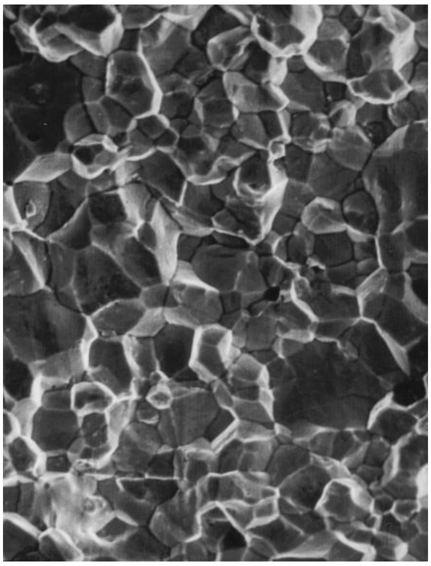

Fig. 3 *detail of Fig. 2, zoom: 350x [1]*

For an explanation of the mentioned untypical problem, the following conclusion was created. Because the given material contains a very high content of retained austenite, this austenite could be transformed to martensite because of loading of pressure plate by bending loading and it could be caused by incorrect mounting during installation. Mentioned mistake during the installation caused that there was the occurrence of intergranular fissile fracture. On the base of obtained results and from the diagram of dependence of hardening temperature as well as content of retained austenite for materials sheet of material 16 270 on parameters hardening, listed in the standards, we concluded that the pressure plate was incorrectly hardened [1, 3].

1.2 Rib

Other component, at which we observed mentioned rupture, is component called rib (Fig. 5). This component is part of assembly for harvesting and it was made of a material DOMEX 044 alloyed by boron. It consists of two semi- products of thin sheets of which the mutual seam was made up by pressing in [2, 3].

After determining of crack occurrence in this component, weld joint was designed. The variant of seam scoring was used because these cracks were still detected and it was caused either by exploitation or after a prolonged storage period. The cracking has not been already occurred after this change, which had minimized internal stresses in the material,. Simultaneously, the evaluation of microstructure and fracture helped to propose the modification changes of heat treatment [2, 3].

The several samples were prepared with original cracks of defective ribs and of suitable ribs. Samples with the original cracks had significantly heterogeneous, granular, acicular microstructure which was comprised by tempered martensite or bainite. Grain size was evaluated by degree 5 - 6 according to standard STN 42 0426. In the case of the defective ribs, the microstructure was mild heterogeneous, fine with significant needles and grain size was of 8 to 9. For samples of suitable ribs, the microstructure was fine, grained, homogeneous and it was composed of low-tempered martensite and grain size was 10 [2, 3].

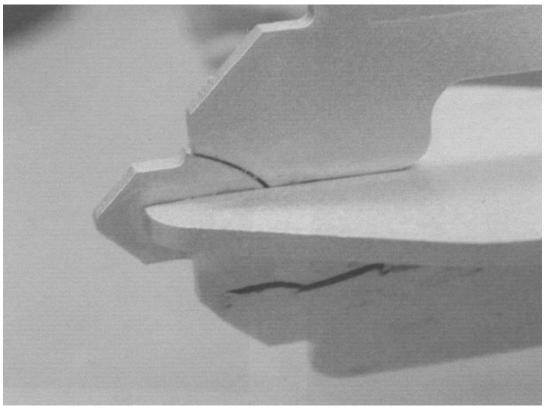

***Fig. 5** Cracked rib [2]*

Micromorphology of fracture surfaces of the original crack was formed by IGF rupture. The laboratory fracture of defective rib showed occurrence coarse intergranular facettes in the undersurface areas, where they worked in the breaking of pressure stress (Fig. 6). The remaining part of fracture was formed predominantly by transgranular quasi-fissile (TGQ) rupture (Fig. 7). In relation to suitable of ribs, only TGH fracture was observed (Fig. 8) [2, 3].

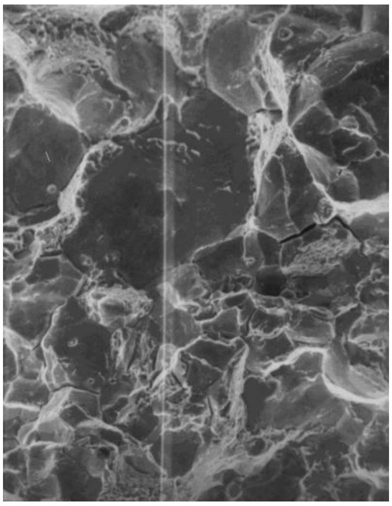

***Fig. 6** IGF frac. zoom.: 320x [2]*

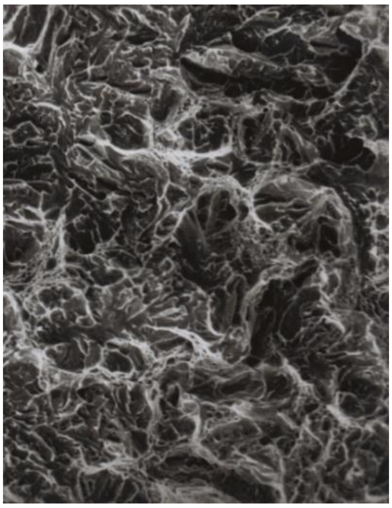

***Fig. 7** TGQ frac. zoom.: 320x [2]*

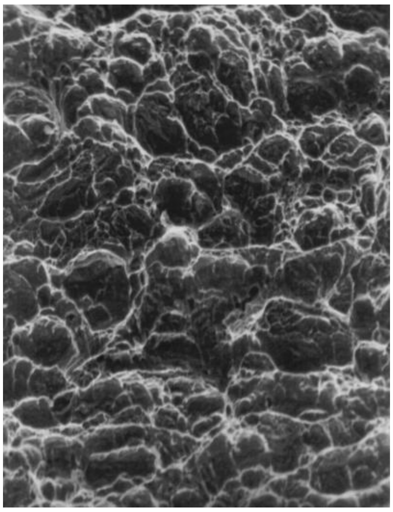

***Fig. 8** TGH frac. zoom.: 320x [2]*

For samples that were not susceptible to brittle fracture, acceptable content of retained austenite (up to 5%) was measured. For cracking samples the measured content of retained austenite was significantly higher [2, 3].

The obtained results were used for specification that in the case of defective samples there were not complied optimal conditions of heat treatment and the result was concerned with the increase of content of retained austenite. According to our opinion, similar mechanism initiated brittle cracks, which are comparable to cracks in the previous case. It means that the occurrence of crack is closely connected stress impact where the given stresses occur due to pressing in or due to welding because of heat-deformation cycle. We can suppose, that cracks are formed as late, it means that they occur some time after installation or welding [2, 3].

1.3 Collet

The dental drill collet is another case of untypical cracking of component. Collet is made of material 1.4034, which is characterized as martensitic, chrome, stainless steel. Collet has the shape of a hollow cylinder with a wall thickness of 0.4475 millimeters, where part of cylinder was removed and 2 ° chamfer of two so-called arms (Fig. 10) [4].

Component has been hardened and tempered to hardness of 640 HV, while the high toughness was preserved.

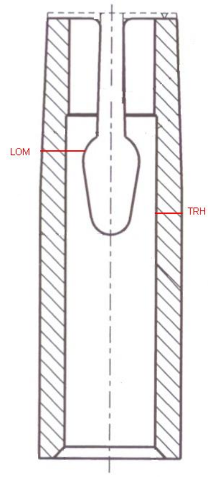

Fig. 10 *Drawing of collet with emphasized fracture and crack*

The collet rupture occurred in short time after starting of its operation. After selecting the collet from the case, it was found that one of the so-called arms was broken off. The microscopic evaluation released the crack of another so-called arm and the given crack was spread from outer side of collet (Fig. 10, 11) [4].

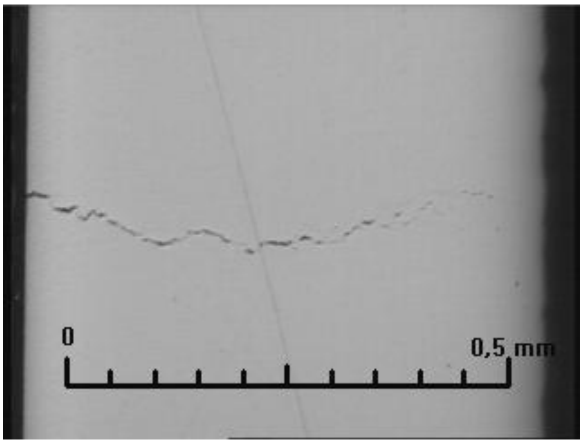

Fig. 11 *Progress of crack in the unbroken part [4]*

The microstructure is composed of low-hardened martensite and fine globular carbides [4]. Micromorphology of operating fracture was formed only by IGF rupture (Fig. 12). Fracture surface was prepared by laboratory breakage of collet rest and this fracture surface was formed mostly by low-energy transglobular hole (TGH) rupture, while the presence of intergranular facettes were not observed (Fig. 13) [4].

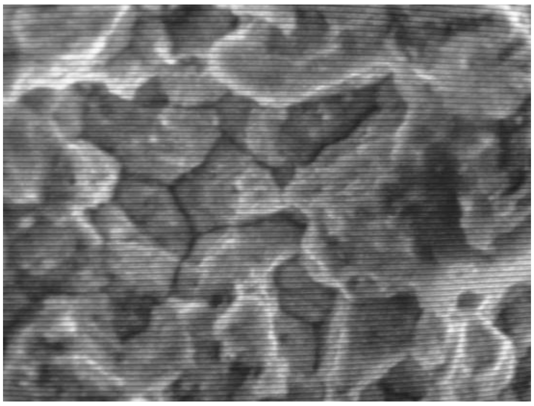

Fig. 12 *IGF fracture zoom: 1500x [4]*

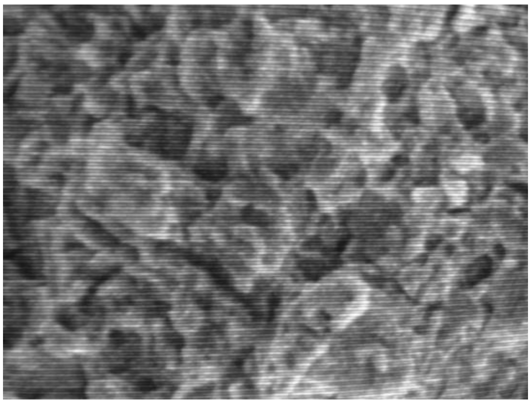

Fig. 13 *TGH fracture zoom: 1500x [4]*

Using analysis of finite elements method (FEM), it has been confirmed, that the component is loaded in bending after insertion of drill into the collet. Comparing places of the fracture, and cracks with FEM model, it was confirmed that the fracture and crack were found in places with the greatest stresses during the exploitation (Fig. 14). On the base of the obtained results, we conclude that a rupture of components was caused by unprofessional handling of the device.

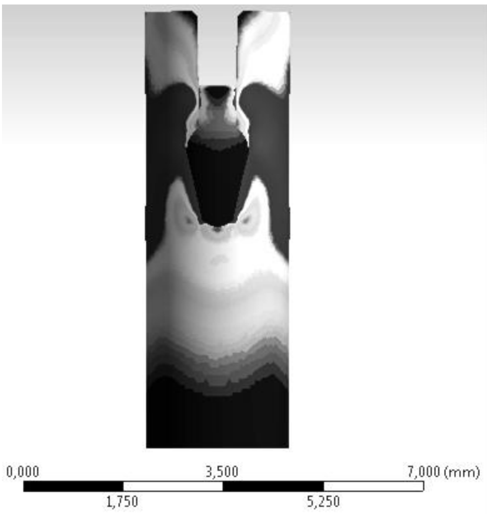

Fig. 14 *FEM model of collet with stress conditions*

2 Conclusion

The paper presents several examples of untypical brittle fractures, which occur in thin-walled components during their exploitation. Micromorphology of operating fractures, where the act of bending stress can be found, showed for all components that there is intergranular fissile rupture. The micromorphology of laboratory fractures which were prepared by fast impact breakage was transgranular pit fracture and it was for the component where the heat treatment under a tough condition is normally used. In the case of untypical embrittlement of components, we detected, in all cases, coarsening of the austenitic grains and increased content of retained austenite in comparison to components which were under the optimum heat treatment. According to this analysis, we expressly provided that the embrittlement of the material and its subsequent rupture is the result of the transformation of retained austenite to martensite under bending stress. Explanation of the mechanism of embrittlement of thin-walled components is very important because the reduction of size is a global trend nowadays.

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