HEAT TREATMENT QUALITY CONTROL OF STEEL BY USING OF MODERN TESTING METHODS

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ABSTRACT
Heat treatment of steels leads to the significant structure changes, which in case of material embrittlement can negative influence on useful properties during exploitation.
In this work are described typical practical cases, where fracture surfaces evaluation on SEM look like the modern testing method. This method can expressly identify the technological reasons of brittle fracture properties decrease after heat treatment.
Keywords: steel, fracture, SEM

1. INTRODUCION

In terms of ISO 9001 we can qualify the heat treatment as one of so called "special processes". The group of special test processes must guarantee necessary quality degree. The quality of heat treatments products and also the quality of the technological process are controlled by means of mechanical and metallographic test methods. The most frequently used mechanical test methods are the hardness test, tensile test and notch toughness test where the tensile and notch toughness tests assign to special cases. By the metallographic method the character and uniformity of microstructure are controlled, and so are the decarbonization, eventually and carbon saturation of products. A disadvantage of hardness test and microstructure is the fact that they do not say explicitly anything about important materials characteristics – about brittle fracture properties of materials, which are determined during the exploitation of converted products. This could be solved by using the notch toughness test on a scale but for the case when we know the correlation between the notch and fracture toughness. The complete mechanical and metallographic methods are quite expensive and time-consuming, and producers often do not realize this.

2. MICROFRACTOGRAPHICALLY SEM FRACTURE SURFACE

For brittle fracture properties assessment the most advantageous method of fracture surface monitoring is the SEM controlling. Many years ago the visual evaluation was used, for which the significant parameters were relief, fracture glossy surface and degree of microplastical deformation. The instrumentation development also brought the expansion of the possibilities of surface fracture evaluation.

By using SEM we can achieve the high resolving power by big magnification. Then we can appreciate the micro mechanism failure of the created fracture surface. The fracture surface is possible to create by a simple laboratory refracting of a test sample or the product. The most advantageous case is the fracture evaluation after the notch toughness test, because from the number of experimental results we can evaluate correlation between surface micromorphology and mechanical values for concrete material [1]. According to the same boundary conditions there are microstructure changes occurred due to the change of micro mechanism failure, when we can evaluate the anomalies of metallographic section.

For optimal converting with tempering martensite structure the material failure by transgrannular dimple mechanism is used, where dimples are mostly initiated by inclusions. Dimple sizes and shape are predicated by the size, shape and number of inclusions and also by the fracture matrix toughness, see figures 1, 2.

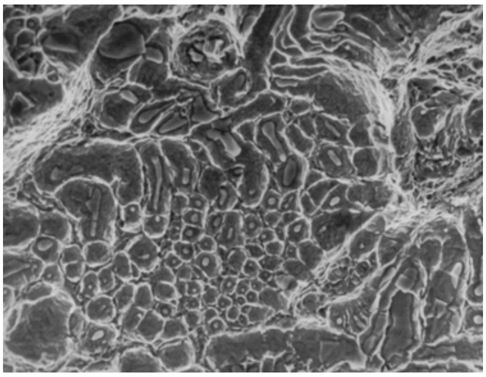

Figure 1. Transgranular dimple fracture - - dimple size dependence versus size of inclusions

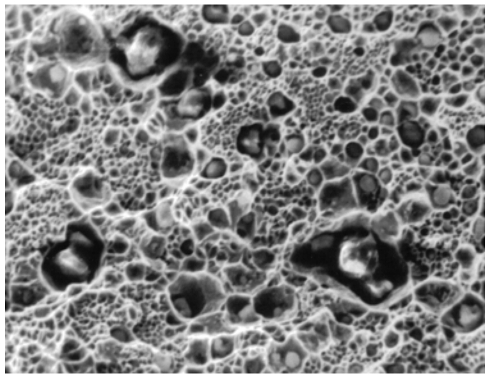

Figure 2. Transgranular dimple fracture – - great deal of inclusions

This fact enables us to get an indirect assessment of the material fouling by inclusions, to indicate their local clusters and to uncover the cases of particles precipitation on austenite grain boundary. Practical experience have shown that by the combination of suitable hardness /tensile/ and tenacities transgrannular dimple mechanism failure does not occur to abortive brittle fracture products, which is a guarantee of long lastingness.

The most frequent reason of the optimal technology failure of converting which activates totally or partly the material embrittlement, is its overheating in quenching process. Due to the high austenite temperatures the original austenite grain size grows. The increase of the size is accompanied by the decrease of the total surface of austenite grains, which causes their enrichment by embrittlement, surface-activating elements.

Another microfractographical demonstration of the overheating at the quenching process is also the occurrence of intergranular cleavage facets, see figure 3.

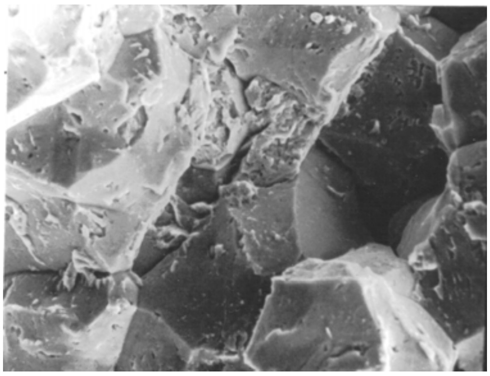

Figure 3. Intergranular cleavage fracture – overheating quenching state

The microfractographical fracture surface control provides the possibility of simple control of austenite temperatures with 10 – 20 °C, which is practically impossible to do by another method [2]. It is enough to prepare for concrete material fracture standards for the quenching temperature. The size of the observed intergranular facets is very sensitive identification of such an important technological parameter [3], [4]. Another technological reason, which caused the intergranular cleavage facets initiation, is the increase of austenitic grains. The degree of material embrittlement can be evaluated as intergranular cleavage facets of the total fracture surface. If the intergranular cleavage rate is 50%, the product cannot be subject to exploitation because the risk of its destruction is very high. The accepted ratio of the intergranular cleavage fracture should be evaluated by a constructor, in dependence on its exploitation; by our practical experience the rate must be less than 30%. If the product is austenitizing inappropriately, or cooling off very slowly, this state is marked as an upper quenching state /in a structure a free ferrite is common/. There occur the transgrannular cleavage facets on the fracture, figure 4.

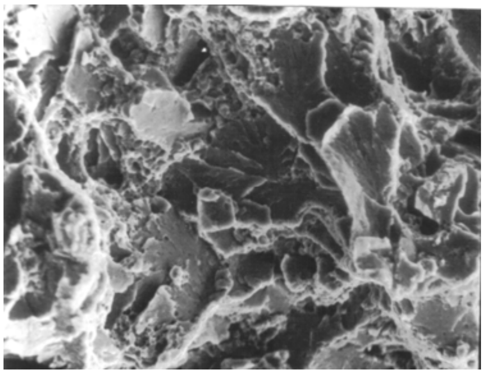

Figure 4. Transgranular quasicleavage fracture – an upper quenching state

By this mechanism the failures are the terms, when as a consequence of the heat treatment decarbonization occurs. Similarly and effectively way the incurable carbon surface saturation can be identified, when the intergranular cleavage facets or remarkable change of microplastical deformation ductile failure are present. The decarbonization or carbon saturation cases of material can lead to problems, when the tempering temperature is estimated after quenching following different hardness. The fracture testing reliably detects this defect. Very important is the fracture surface evaluation on the SEM by materials, which are liable on the tempering embrittlement development [5]. The tempering embrittlement and its danger are not possible to estimate by the hardness test, microstructure evaluation or tensile test. By the SEM method we can assess the high temperature or low temperature tempering embrittlement on the evaluated fractures. Microfractographically, this is again shown by the intergranular cleavage fracture, the difference is that the intergranular facets are not perfectly smooth any more, but show a low degree of the microplastical deformation, which is demonstrated by larger segmentation, figures 5 and 6.

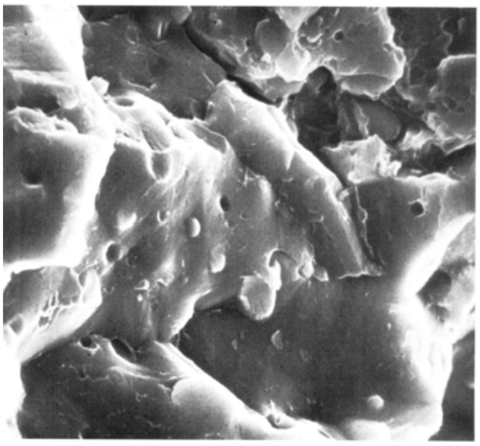

Figure 5. Intergranular cleavage fracture – - low temperature temper brittleness

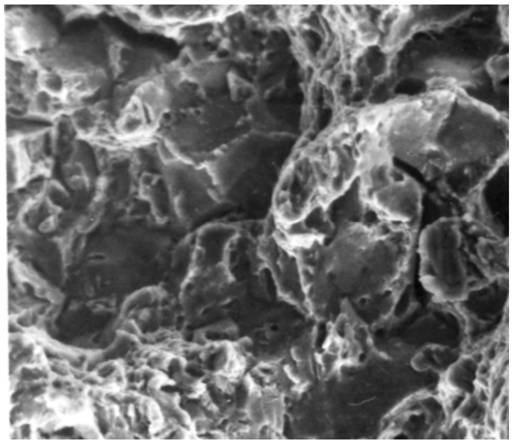

Figure 6. Intergranular cleavage + transgrannular dimple fracture – hightemperature temper brittleness

The fracture surface of products has characteristic morphology, which is isothermal quenching on bainite structure. In the present case there is a fracture line growth by the transgrannular quasicleavage, see figure 7, and we can fractographically differ it from the state with the structure of tempering martensite, figure 8, which is in most cases often difficult.

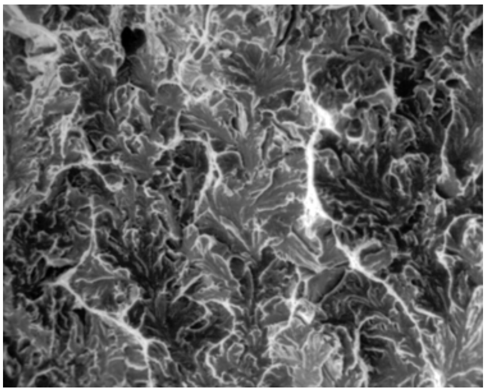

Figure7. Transgranular quasicleavage fracture of tempering bainite.

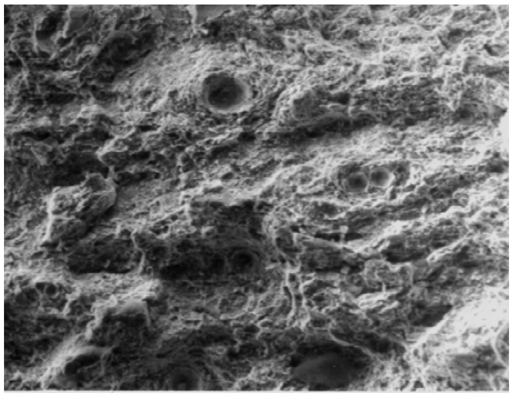

Figure8. Transgranular dimple fracture of tempering martensite

3. SUMMARY

The microfractographical fracture surface control on the SEM is a progressive testing method, which allows operating the quality control of heat treatment of steels.
By the products which were converting it is possible to detect the superheating degree by austenitic process, decarbonization and carbonization, quenching of low temperatures, evolution of low temperature and high temperature temper brittleness such as the difference of tempering martensite and bainite structure.

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