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ANALYSIS OF FACTORS INFLUENCING THE QUALITY OF STEEL CRANKSHAFTS

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Abstract: This paper analyzes the influence of technological and composition factors on the structure and quality of ordinary and quality steels for processing forged crankshaft. It is known that influencing factors which determine the properties of ordinary steels are the carbon content and the microstructure. Beside the predominant effects due to the carbon content and the microstructure, the properties of ordinary steels can be modified by the effects of the residual elements (in addition to carbon, manganese, silicon, sulfur and phosphorus that are always present). The properties of steel can be influenced by the presence of gas, particularly oxygen, nitrogen and hydrogen, as well as by the reaction products thereof. These secondary elements usually penetrate the steel from the used scrap, deoxidants or furnace environment. The gas content depends largely on the method used to melt, on the deoxidation and casting, so that the final properties of these steels depend largely on the method used in their preparation. Thus, the factors that condition the steel properties are primarily the carbon content and its microstructure, which is largely determined by the chemical composition and the subsequent final processing of forging or by the heat treatment operations. Secondly, these properties depend on the residual elements of the alloy, non-metallic inclusions and gas content of the steel, which in turn depends on the steelmaking method.
Keywords: microstructure, residual elements, deoxidizing, nonmetallic inclusions, ferrite, pearlite, cementite, austenite

1. INTRODUCTION

As part of the economy, metallurgy must address the problem of product quality in all aspects, especially in view of the the usage properties and physico- mechanical characteristics. It is clear that at present, the companies in this area should focus on the production of much requested on the market economy. This requires the modernization of existing capacity in line with EU requirements, followed by updating the technologies to the standards prevailing in the EU economy.

2. SCIENTIFICAL RESEARCH

By use under unusual conditions, a change in the chemical composition is made for a better adaptation of the quality of the existing steel to the operating conditions. However in some cases, a new combinations of alloys is need to develop in order to meet the running operating requirements. For example, the aviation industry and cosmic shuttles have encountered more complex design problems, requiring more resistant metals at high temperatures for both force installation and construction. New types of steel have been developed and are currently developing in order to meet these requirements.

2.1. Microstructure and grain effects

Carbon steels having a relatively low hardenability are the mostly pearlitic when they are cast or forged. Therefore the ferrite and pearlite are the compounds of the hypo-eutectic steels and the cementite and pearlite are the compounds of the hyper-eutectic steels. The properties of such pearlite steels depend primarily on the inter-lamellar spaces of perlite and the grain size. Both hardness and ductility increase as inter-lamellar spaces or the temperature of the perlite transformation decreases. The ductility increases with the grain size decreasing.

The microstructure of the cast steel is also determined by the composition and cooling conditions in the same way as in the case of forged steel.

Cast steels usually have a very coarse graine size because austenite is formed at a very high temperature and perlite is usually coarse because the ingot cooling, especially occurs at very low temperatures.

Ferrite in the hypo-eutectic steel is currently precipitated at the initial austenite grain boundaries during the quenching. The cementite in the hyper-eutectic steel is precipitated in the same manner. Such mixtures of cementite and ferrite or pearlite having a coarse graine size have lower mechanical strength and ductility, generally requiring a heat treatment to obtain the desired microstructure [1]. Because of the dendritic segregation that occurs during cast ingots solidification, an irregular microstructure is formed to which low physical-mechanical characteristics corresponds. This structure homogenizing is made by forging and heat treatment (Figure 1 and 2).

The recrystallization characteristics of the austenite and hence the austenite grain size for a given final temperature can be also significantly influenced by the steel-making process and the process of used deoxidation respectively.

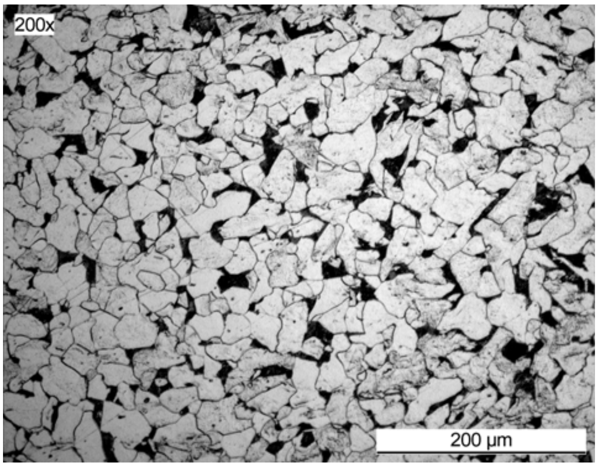

Figure 1. Typical hardware structure of carbon steel with 0,2% C. Nital Attack 2%, Magnification 200:1.

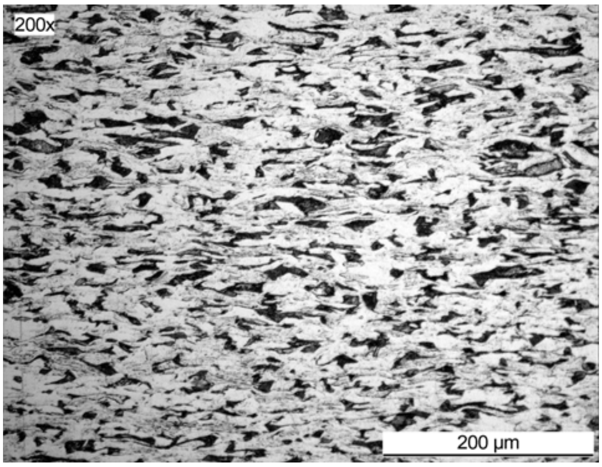

Figure 2. Fibrous structure of steel with 0,2% C after forging. Nital Attack 2%, Magnification 200:1.

2.2. With regard to aging

Steel aging occurs as a spontaneous increase of hardness at room temperature, a process that is accelerated by increasing the temperature slowly. In general it is supposed that this phenomenon is based on the disintegration of a supersaturated solid solution. In a system in which the solubility of dissolved solid phase sharply decreases with temperature, this one can be retained in supersaturated solid solution by rapid cooling, but the time will tend to precipitate out of solution. Such precipitates in early or total stage is considered to be the cause of the steel aging. This precipitation is accelerated by the strain, which often plays an important role in aging steel.

Carbon, nitrogen and oxygen are the elements in the carbon steels which causes aging. Perhaps all these elements are involved in the phenomenon, but it is difficult to separate their individual effects.

It was found that the steels which are strongly deoxidized with aluminum or aluminum and titanium do not easyly get aged while the semi-killed and Bessemer steels are more susceptible to this phenomenon [2,3].

2.3. The effect of residual elements

In addition to carbon, manganese, silicon, sulfur and phosphorus which are always present in ordinary steels there may be other elements in small quantities as hydrogen, oxygen and nitrogen, which are introduced in steel during the steel-making process; nickel, copper, molybdenum, chromium and tin, which can be found in the waste and aluminum, titanium, vanadium or zirconium can be introduced during the deoxidation.

The effects of oxygen and nitrogen were shown, their main effect is exerted on aging phenomenon.

The hydrogen has the precise effect of weakening the steel, a phenomenon whose mechanism is not well known. Although the hydrogen can diffuse to the surface of the steel at room temperature in some sections small enough when the time is sufficient, a low ductility was found out by tensile testing when the tests were made immediately after forging; the ductility increases with aging at ambient temperature and after short periods at temperatures a little higher. Of course this effect is more pronounced in large sections because of the longer time required for the diffusion of hydrogen on the surface. This effect is also more pronounced for hydrogen content higher than 0.0005%, as it is the case of forged steel that were cast into ingots by an ususl process. The content of hydrogen (and other gases) in the steel ingots may decrease by vacuum degassing.

Hydrogen in excess of 5 ppm (0.0005%), also plays an important role in the phenomenon known as chips which are manifested as cracks, usually during cooling after forging. The phenomenon is more pronounced in large sections and high carbon steels. This phenomenon can be avoided by slow cooling after forging. This slow cooling operation probably favors the phenomenon of diffusion of hydrogen in steel and thereby minimizes the sensitivity to flake formation. In the manufacture of rails, this controlled slow cooling operation is currently a standard procedure which eliminates the possibility of the formation of the flakes and the occurrence of transverse cracking defects.

The alloying elements, such as nickel, chromium, molybdenum and copper, which can be included from the waste, will increase to some extent the hardenability of steel, and are generally present in very small percentages. These features, however, change the heat treatment characteristics.

As noted, aluminum has a favorable effect, working towards the structure homogenization and decreasing the sensitivity to aging by strain. This has the disadvantage, however, to facilitate the graphitization which is a disadvantage for the steels being used in high temperature. Other elements that may be included as deoxidants: titanium, vanadium or zirconium are found in so small amounts that they generally do not have any other effect unless they are added in larger quantities in order to serve a particular purpose [4,6,7].

2.4. Behavior at high operating temperatures

The name "High operating temperatures" is involved in many types of operations in numerous industries. Few of the most common examples of machines with crankshafts among their components that operate at high temperatures are different types of presses in hot working, diesel or other internal combustion machinery, engines for ships and aircraft, etc. New combinations of alloys with chromium, nickel, molybdenum and other special items are developed for these cases in order to meet the operating requirements. These machines that are to function under stress at high temperature where the creep property occurs, use the mentioned steels in high amounts. Although the plain carbon steel has a creep limit below the alloy steels used in high temperatures, it is used mostly in operating conditions up to a temperature of 600 ^{0}C when the rapid oxidation begins and its substitution with a chrome alloy steel is necessary. The low alloy steels containing small percentages of chromium and molybdenum have a creep limit higher than the carbon steel and it is recommended to obtain certain resistant materials. At temperatures above 550 ^{0}C, the required percentage of chromium which gives the steel adequate resistance against oxidation, increases significantly. The steels with 2% Cr and addition of molybdenum, are used up to 650 ^{0}C while the steels containing 10-14% Cr can be used up to about 700-750 ^{0}C. At higher temperatures austenitic stainless steels with 18% Cr and 8% Ni are commonly used, their resistance against oxidation is considered appropriate up to 850 ^{0}C. For working temperatures between 850-1100 ^{0}C, steels with 25% Cr and 20% Ni and 27% Cr are recommended.

When operated at high temperature, no significant changes in the size or shape of grain usually occures in the steels, but significant changes can happen in their microstructure. These changes are manifested by the formation of new phases, spheroidization and agglomeration of carbides and nitrides, as well as graphitization (Figure 3).

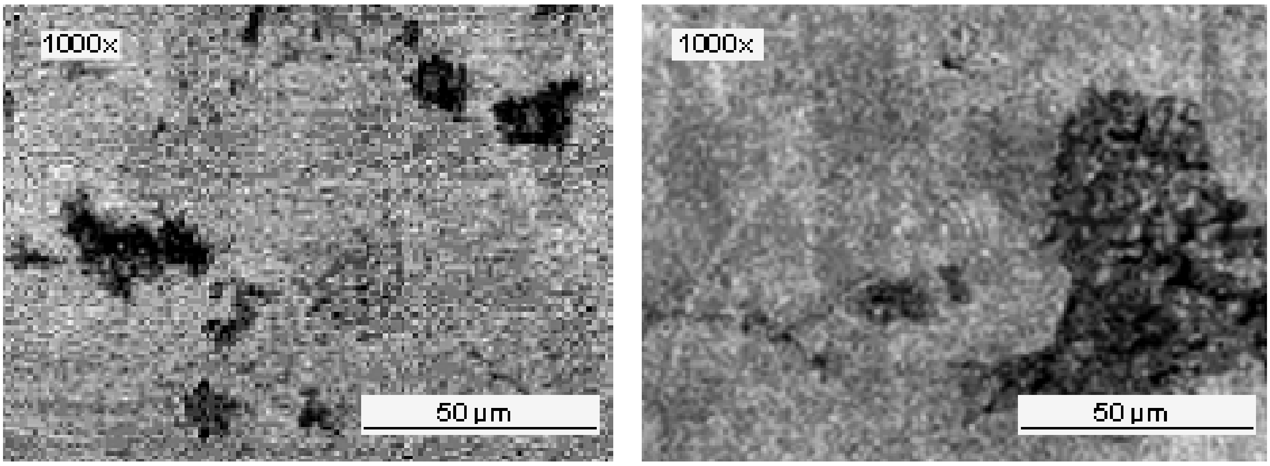

Figure 3. Globulizat annealed molybdenum steel (left). The same steel showing graphitization after heating at 600 ^{0}C for 1000 hours (right). Attack Nital 2%, Magnification 1000:1.

For the carbon-molybdenum steels, the spheroidization occurs at temperatures above 550 ^{0}C, and a graphitization can occur especially especially at fine-grained steels killed with aluminum. The addition of chromium tends to stabilize the carbides, reducing or eliminating the graphitization and delaying the spheroidization [14,15].

3. CONCLUSIONS

The composition and technological factors which determine the properties of both ordinary and quality steels and their influence on the structure are analyzed. The influence of secondary elements which penetrate the steel, usually from the scrap steel used in preparation, from deoxidants or furnace environment is also examined.

The paper specifies the effects of phenomena such as the effects of the microstructure and the grain, and their influence on properties. The dendritic segregation that occurs during cast ingots solidification, also causes an irregular microstructure to which low physical-mechanical characteristics correspond. This structure homogenization is made by forging and heat treatment.

The recrystallization characteristics, and thus the austenite grain size for a certain final temperature can be also significantly influenced by the steel-making process and by the used process of deoxidation.

The treated effects of the aging phenomena are of particular importance for the various uses of steel, and also have a certain amount of forming (trimming) or tenacity, to which a possible weakening due to aging by strain should be considered, when the material is subject to effort during its manufacture or use.

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