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SOME PROBLEMS OF FATIGUE STRENGTH CHARACTERISTICS OF SINTERED STEEL

Abstract

In the paper the fatigue and structure characteristics of sintered alloyed steel are considered. For conducting the experiments, the samples from powder steel Distaloy AE were made. In the paper by results of cycling tests the fatigue curves for material of $DistaloyAE + 0,5\%C + 0,06\%B$ *and* $DistaloyAE + 0,5\%C + 2,5\%CEP$ *are constructed. Simultaneously, electron- microscopical analyses are conducted.*

The creation of high-strength materials with high fatigue resistance and disinclined to brittle failure is a problem of primary importance from whose successful solution further technological progress depends. The investigations in the field of mechanics and physics of solid lead to development of reliable assessment criteria of inclination of metal to brittle failure and establishment of new important regularities of crack extension at the action of cyclic and static loads as well as to development of new methods of metal hardenings and alloys with the purpose of increase of their structural strength [1].

Fatigue problem i.e. the failure of metals under the action of cyclically changing stresses lower than ultimate strength has arisen more than hundred years ago and since interest in it increases. It is bounded up with the fact that a lot of responsible details of machine and a number of constructions work at the conditions of repeated (alternating, direct) loads and their resource is completely defined by cyclic strength of materials from which they are constructed [2].

The strength of constructed details in real conditions of exploitation essentially depends on the presence in them cracks or other crack-like defects which either are metallurgical defects or are formed during exploitation. In sintered materials the existence of crack-like defects – pores is predefined by technology itself of obtaining such materials [3].

The application of technics of electron-microscopy in investigations of fatigue process allowed experimentally checking different physical fatigue theory and establishing specific character of forming of fatigue failures in metal at repeated loading.

At operation the samples were made from commonly used Distaloy family of steels containing $4\%Ni$, $1,5Cu$ and $0,5\%Mo$, which have diffusion contact with pure iron, keep the highest compressibility. All powders were mixed with 0.5% fine graphite and in most cases with additives which as expected change morphology of pore. Distaloy AE standard sprayed in water was obtained from rough powder $> 45\mu m$ and fine fraction $< 45\mu m$ and compared with the same alloy on basis of iron. Boron powder and carbonyl iron powder are used as alloying elements (CEP). The samples were compacted $600MPa$ in R&D indepartment of Hōganās AB, Sweden. The sintering was led in industrial equipment at $1120°C$ in non-carbonyl shielding medium. Cooling norm between 800 and $500°C$ was $1,0°C/s$.

Fractographic investigations were made in scanning electron microscopy (SEM) made in Germany. The development of experimental data was led with the help of IBM by specific SAFD program.

It is known that hopping of cross-section for a lot of critical parts of machine working at repeated-variable load generates non-uniform distribution of stresses on section, i.e. local stress concentrations. Stress concentration is characterized by "form factor" - theoretical coefficient of stress concentration K_t, which shows how many times maximal stress is more than nominal one provided purely elastic deformations. However, as was established by numerous investigaters, decrease of cyclic strength as a result of concentration K_t doesn't correspond to experimental data. Therefore, a real or effective coefficient of stress concentration K_σ was introduced [1].

Thum and Buchmann criteria in cyclic strength computations are most commonly used and often applied in practice.

$$q = (K_\sigma - 1) / (K_t - 1) . \tag{1}$$

In the papers [5-7] fatigue strength characteristics of sintered alloyed steel are investigated at different aspects.

References contain a lot of data for smooth and heat-treated conditions. Since fatigue cracks usually begin from locations that are subjected to highest stress, to include the factor of stress concentration K_t for gear samples we have introduced the following equation [8,9]

$$K_t\sigma_A (R = 0) = K [K_t\sigma_A (R = -1)]^q . \tag{2}$$

With equation (2) average stress sensitivity can be generalized for gear and smooth samples at axial and bending load:

$$M = \frac{K_t\sigma_A (R = -1)}{K [K_t\sigma_A (R = -1)]^q} - 1 = K^{-1} [K_t\sigma_A (R = -1)]^{1-q} - 1. \tag{3}$$

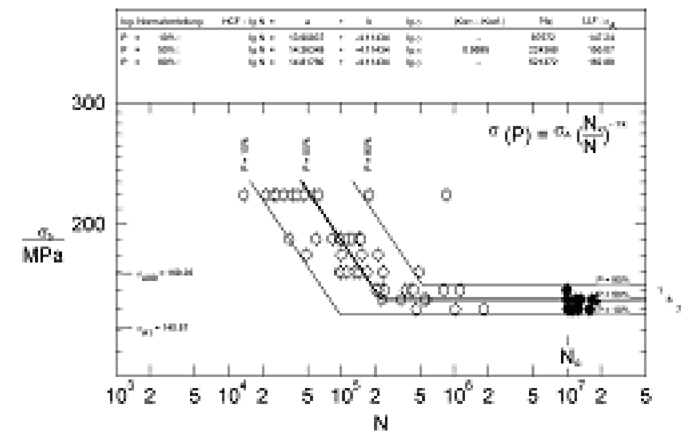

Fig.1. Endurance limit of fatigue and probability of survival of Distaloy $AE + 0,5\%C + 0,06\%B$ materials.

In the paper [10] the obtained experimental data and investigations led by us show that sintered materials obtained on the basis of powder steel *Distaloy AE* confirms linear relationship between strength at direct and alternating loads.

The fatigue curves (Weiler curves) are constructed by results of cyclic test. The fatigue curves for $DistaloyAE + 0,5\%C + 0,06\%$ and $DistaloyAE + 0,5\%C + 2,5\%CEP$ materials are shown in Fig.1 and Fig.2. The obtained curves for different series of samples involve fatigue limit in 10, 50 and 90% survival probability. The points on diagrams correspond to raw data, each open circle shows destruction of sample, but each complete one shows integrity of sample. For test of alternate load it is made 60 samples of six level of stresses on curve, which allows to estimate data statistically and define enough reliable fatigue limit for survival probability 50%. Load was stopped for 10^7 cycles. The fatigue limit obtained for survival probability 50% composes $155MPa$ for $DistaloyAE + 0,5\%C + 0,06\%B$ materials, $209MPa$ for $DistaloyAE + 0,5\%C + 2,5\%CEP$ materials.

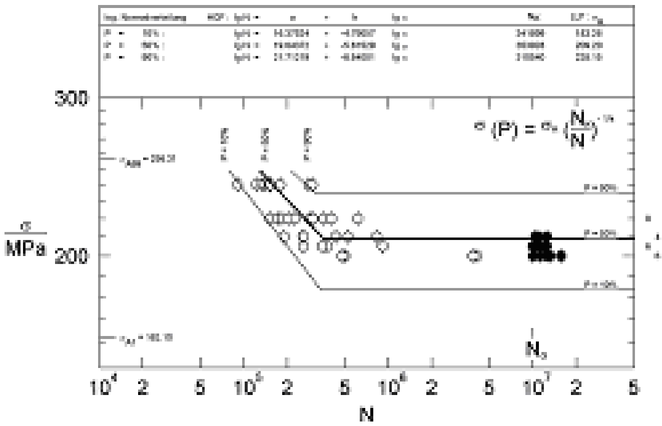

Fig.2.Endurance limit of fatigue and probability of survival of Distaloy $AE + 0,5\%C + 2,5\%CEP$ materials.

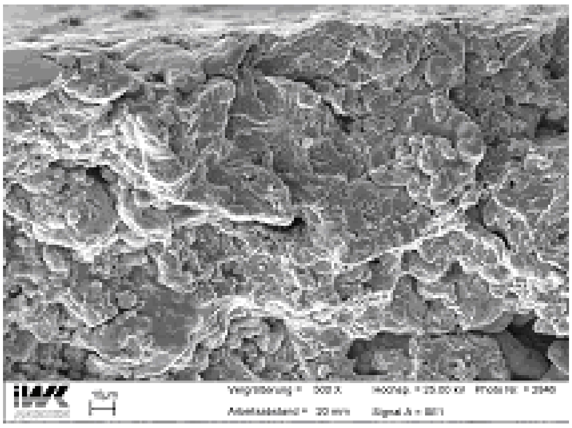

Fig.3. Fractography of sintered material from powder steel Distaloy $AE + 0,5\%C + 0,06\%B$

Fractographic investigations of materials allowed to discover difference in character of their fracture (Fig.3 and 4). Fracture test showed fracture is multi-stage and has fatigue character. Our fractographic investigations show that fracture of porous material happens quicker at smaller average plastic deformation than of compact one since deformation near pore will be defining.

The most general character of all fractures consists of nonhomogeneity of their construction. Only highly brittle fracture of materials can be considered to be homogenous fractures. More general reason of nonhomogeneity of fractures is connected singularities of fracture process. Even in practically complete homogeneous materials it must be taken into consideration original nonhomogeneity of stress and deformed state and change of this state and rate of crack developed in fracture process.

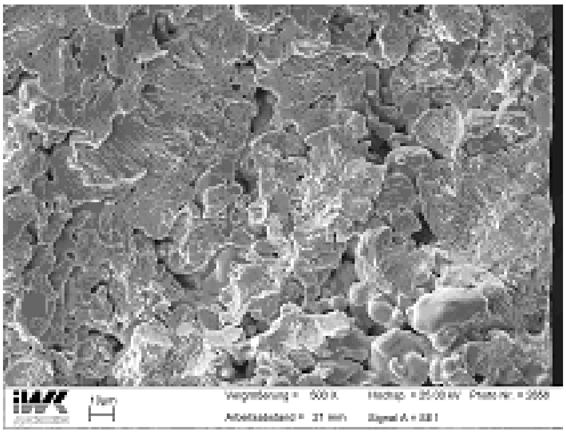

Fig.4. Fractography of sintered material from powder steel Distaloy $AE + 0,5\%C + 2,5\%CEP$

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