WHEEL FATIGUE PROBLEMS SUBJECTED TO COMPLEX LOADING

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Structure and physical-mechanical properties of subsurface layers formed under the effect of a combination of different factors in wheel steel in the zone of contact with the rail are analysed. The purpose of this study was to reveal initial causes of fracture of the wheel under the simultaneous impact of three factors: (1) material of the rim is in a complex stressed state induced by (2) surface cold working, where (3) the surface is affected by any of the thermomechanical impacts associated with heating, e.g. by plasma or due to friction of brake blocks or rails, and formed in blocking of the wheels during braking.

Shrouds of the formed wheelset are in a tensile condition, the tension amounting to a level of yield stress of the material. A metal layer up to 7-10 mm thick, hardened due to cold working, with hardness increasing from 285 NB (base material) to 330-370 HB on the surface, is formed on the working roll surface during operation. Local heating and cooling of such a surface at a temperature above 400 ^{o}C, when the material loses its elastic properties, may result in substantial changes in physical-mechanical properties of a thin (100-500 μm) subsurface layer of the shroud material. This shows up exteriorly as an absolute loss of ductility, embrittlement and formation of a network of cracks looking like a fish scale, and at a level of the fine structure – as accumulation of defects and disordering. In addition, this is accompanied by increase in the ability of surface microcracks to propagate deep into the shroud. If such microcracks are formed in the unfavourable field of tensile stresses of the first kind, this may lead to fracture of the shroud. Such fractures can be subsumed to the full extent under the category of the unexpected ones the true cause of which is deeply "hidden".

The efforts included completion of a package of calculation and experimental studies. Solving the problem of thermal elasticity and thermal ductility was based on a calculation of transient states of thermal stresses through solving the problem of transient thermal conductivity by using the finite difference method. Optimal break-down of a section into triangular finite elements was achieved on the basis of analysis of several variants of the break-down grid. Peculiarities of structure of the wheel material were investigated by different methods. The method of quantitative metallography was employed to analyse variations in grain sizes. Analytical scanning electron microscopy was used to investigate the character of distribution of chemical elements in the zone under consideration, determine chemistry in local regions of phase precipitates and segregations and study the fracture surface. Fractography was used to generate information on the character of fracture, presence of brittle or tough fractures and causes of embrittlement. Direct transmission examination of a fine structure was performed using the JEOL instrument JEM-2000CX. This examination was aimed at deeper and more detailed analysis of peculiarities of structure, morphology and distribution of different types of finely dispersed phases, their composition, as well as the character of distribution of the crystalline lattice defects and formation of dislocation heterogeneities, including local stress raisers. Strength and ductile characteristics of the surface layer metal were evaluated on the basis of the sclerometry results. Given that the heat-affected zone has an insignificant length and is characterised by drastic changes of mechanical properties in its different zones, the method was developed for local evaluation of mechanical properties of the material by recording the scratching strain diagrams. This method was employed to determine basic mechanical characteristics of metal at different distances from the surface: yield stress, tensile strength, effective rupture strength, etc.

The generalised experience accumulated from operation of wheelsets is indicative of the fact that there are certain specific features in their damages and in structure of defects of metal which determine these damages. The above factors have a direct effect on safe and efficient operation of the wheelsets.

The mechanism of initiation of microcracks in high-temperature surface hardening of shrouds of locomotive wheelsets was studied. In the unfavourable situation such microcracks may lead to fracture. A similar situation occurs in heating of the roll surface of the wheel by friction of brake blocks in the case of emergency braking. This is a new and vast area, which cannot be covered in an abstract. However, it makes sense to give here the main results of the studies. Direct transmission examinations of a fine structure of the heat-treated surface layer of metal provided understanding of the mechanism of formation of dangerous microcracks and fracture of a complex-loaded part with a sufficiently high safety factor. Direct electron microscopy of the structure and phase composition of the subsurface layer metal in a location of transition from the hardened zone to the base showed the following.. Cracking is associated with the following main factors:

(1) formation of "expanded" elongated non-metallic inclusions of the sulphide type, oriented normal to the external treated surface (this relationship can be clearly seen in fractography);

(2) formation of local internal stresses in structural components characteristic of the base metal (pearlitic grains), which start showing up at a depth of about 100 μm from the surface.

The performed analysis allowed an explanation of the mechanism of initiation of microcracks with the probability of subsequent fracture of a wheel. This made it possible to assign the technology for surface plasma treatment of the wheels which guarantees increase in their wear resistance and operational reliability.