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METALS AND STRENGTH ISSUES

Prediction of the Remaining Service Life of the Bends of the Steam Conduits at Various Stages of Creep

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Abstract—The present paper reports the generalized results of an investigation concerning microdamage of metal (Cr-Mo-V steels) in the bends of the steam conduits after their service under different conditions and after their rupture. The basic temperature-time and force dependences of kinetics of the bends failure on the quality of their manufacture, operating conditions, and level of cumulative microdamage are constructed. These dependences may be helpful when evaluating the remaining service life of the steam conduits.

Keywords: bend, steam conduit, creep, microdamage, equivalent stresses, parametric dependence, remaining service life

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In order to find a technically justified solution of the problem related to the remaining service life of the bends of the steam conduits, it is necessary to have a databank on the kinetics of the development of a bend failure depending on actual operating conditions, metal condition, and the level of cumulative microdamage.

For the purpose of obtaining such data, there were generalized the results of the investigations of microdamage of metal in about 600 bends of the steam conduits made of 12Kh1MF and 15Kh1M1F steels after their service under different conditions. From the generalized results there were identified some temperature-time and force dependences of kinetics of the development of rupture in the bends made of 12Kh1MF and 15Kh1MF1 steels after their service under different operating conditions. On the basis of the generalized results some temperature-time and force dependences of the kinetics of the development of failure in the bends made of steels in various structural conditions have been identified.

When evaluating microdamage, the following scale of scores [1] was used: score of 1—individual pores, score of 2—multiple pores, score of 3—individual pore strings, score of 4—multiple pore strings, score of 5—microcracks, and score of 6—macrocracks.

The temperature-time dependence of the proportion of the bends ruptured in the course of operation (group I) and the proportion of the bends that had accumulated microdamage of various levels on their outer surface (group II) is shown in Fig. 1. It is seen that for the bends belonging to different groups the parametric dependences have the same extremal character, with an extremum located in the same temperature-time interval. The coincidence of the positions of the extremum for both the impaired bends and those bends that had accumulated microdamage shows that the development of microdamage is one of the key factors responsible for bend failure.

From the statistical data on the actual level of microdamage of metal of the bends under different operating conditions, the kinetics curves for microdamage accumulation were constructed. The function of distribution of the microdamage level is a proportion of the used service life, i.e., the ratio between the current service life and the rupture life.

The curve for accumulation of microdamage of the pipe bends made of 12Kh1MF steel for all sizes under study (β = 1.296–1.36) and with various structural conditions of metal is shown in Fig. 2. From this curve one can evaluate the remaining service life of the pipe bends made of 12Kh1MF steel with different levels of microdamage. Thus, after the incipience of multiple pore strings (the score of 4) the remaining service life of the bends is 10–15% of their rupture life.

The dependence of the position of a curve on the relative thickness of the pipe wall β is shown in Fig. 2b. The expected advantage of thick-walled pipes over thin-walled ones (more recent beginning of the pore formation) is realized to the point of accumulation of microdamage with the score of 3 (individual pore strings). Upon further development of microdamage, beginning with the score of 4 (multiple pore strings) no difference in kinetics of its accumulation depending on the value of β was detected (with the adopted method of processing the results).

The effect of the structural condition of metal was estimated for the pipe bends with close values of the relative wall thickness (β = 1.296–1.306), which have in the as-delivered condition, the ferrite-carbide (as-rejected condition, the score of 6) and ferrite-bainite (as-accepted condition, the scores of 3–5) structures