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Address:
E.O. Paton Electric Welding Institute,
International Association «Welding»,
11, Bozhenko str., 03680, Kyiv, Ukraine
Tel.: (38044) 287 67 57
Fax: (38044) 528 04 86
E-mail: journal@paton.kiev.ua
http://www.nas.gov.ua/pwj

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CALCULATION PREDICTION OF FATIGUE LIFE OF FREIGHT CAR SIDE FRAME UNDER ALTERNATING CYCLIC LOADS

V.I. MAKHNENKO and **I.Yu. ROMANOVA**
E.O. Paton Electric Welding Institute, NASU, Kiev, Ukraine

An example of calculation prediction of fatigue crack growth in a side frame of freight cars at a preset range of random cyclic loads is considered. Relationship between exceeding design conditions of operation of the car and probable cause of its fracture was studied.

Keywords: *fatigue crack, random cyclic loading, side frame, freight car, casting defect, calculation prediction of fatigue life*

In connection with increased scope of railway freight traffic, more attention is given to the «viability» of various parts and components of load-carrying elements of freight cars. Experience of operation of structures developed in Ukraine and Russia is indicative of insufficient cyclic strength of individual components, which results in failure of cars which have not yet completed their design life period [1].

Let us consider a real case of failure of a cast side frame of a freight car (Kabakly Station, West-Siberian Railway, RF, 2009), designed in keeping with [2] and manufactured at OJSC «Azovmash» (Mariupol, Ukraine). Fracture occurred as a result of fatigue crack growth from a technological defect.

Initial information on the fractured side frame is as follows: material is steel of 20GFL type; car run to fracture L = 108,482 km; design average technical speed of car movement $\overline{v}$ = 22.4 m/s; average daily run of a loaded car L_d = 210 km/d; effective frequency of car vertical oscillations f_e = 2.23 Hz; coefficient of run in the loaded condition K = 0.6; average daily number of cycles under load $N_d = (L_d/\overline{v})10^3 f_e$ = 20,906 cycle/d; number of cycles under load during run L to fracture $N = (LK\overline{v})10^3 f_e = 6.48 \cdot 10^6$ cycles; current evaluating repairs were performed at $N_{rep} = N - N_d \cdot 9.5 \cdot 30K = 2.91 \cdot 10^6$ cycles.

Figure 1 shows fracture of a failed frame, and arrows indicate sites of fatigue fracture initiation [3]. According to this work, the site of initiation of a primary fatigue crack (#1 in Figure 1) was a casting defect — surface blowhole, having the length of 2.6 mm, depth of 1.8 mm in the fracture section and located at 31 mm distance from the surface of the outer vertical wall of the side frame. The defect was not detected by NDT means. Site of initiation of secondary fatigue cracks were casting blowholes located at 66, 104 and 125 mm distance from the surface of outer vertical wall and having the dimensions of 2.0 × × 1.5 mm (#2), 4.3 × 2.3 mm (#4) and 4.0 × 1.3 mm (#5) in the fracture section. In addition, there is a surface defect of 3.0 × 2.0 mm size (#3 in Figure 1), not specified by the drawing of the technological stiffener, which in [3] is regarded as the site of secondary fatigue cracks formation.

Thus, five sites of fatigue fracture are located in the fracture section on the surface with the maximum operating longitudinal stresses, which sufficiently conservatively can be described by semi-elliptical cracks of $2ca$ size, where $2c$ is the crack length along the free surface, and a is the crack depth.

Table 1 gives the initial dimensions of such defects and shows the distance from defect centers to the free vertical surface, as well as the distance between the edges of adjacent defects (L_{n-1} on the left, L_{n+1} on the right), in the initial condition and characteristic parameter b of interaction with adjacent defects:

$$b = c + \min \begin{cases} L_{n-1,\,n}; \\ L_{n+1,\,n}, \end{cases}$$

or the free edge (vertical free surface). In [13] it is noted that the described casting contamination defects were evaluated in terms of their admissibility (inadmissibility) based on the principles (approaches) of fracture mechanics of cracked solids, described for the case considered in [4]. From this assessment it follows that the described casting defects are inadmissible, as under the design operation conditions during three years they grow by the fatigue mechanism to dimensions, at which their progressive growth begins, leading to fracture after approximately 2.9 months of service. Unfortunately, absence of such substantiation after the assessment performed in [3], in view of the design conditions of frame loading, gives rise to some doubts as to determination of the main cause for its fracture, so that PWI conducted a study, the essence of which is as follows.

For the above described defects (Table 1) their loading by the spectrum of random cyclic loads described in [2] was considered for average speed of train movement $\overline{v}$ = 22.4 m/s at static stresses in the defect zone in the range from σ_{st} = 105.2 MPa (#1) to σ_{st} = 93.2 MPa (# 2–5), which is in good agreement with the data of [4], where values of the above characteristics are equal to 80–90 MPa.