CRACKING OF LARGE-SIZE MACHINE ELEMENTS

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The paper presented deals with estimation of service life of large-size machine elements with casting defects or fatigue cracks. This estimation is based on fracture mechanics theory.

The number of load cycles till fracture of rings with casting defects (wormholes - Figure 1) has been determined and a good agreement with service (practical) data was obtained. In the case of mill stand housing with discovered cracks (Figure 2) the predicted rolling time and failure probability were determined by rolling with an overloading of 50 % i.e. on the level of initiation stress σi. Based on Paris law the number of cycles till fracture of the loading ring of a cast steel L356 cement furnace and loaded by reaction forces 2 Q = 2 x 3,04MN can be calculated:

$$N_f = \frac{2.\Theta^{m/2}}{(m-2).\ C.\Delta\sigma^m.\pi^{m/2}.M_k^{\ m}}\left[\frac{1}{a_o^{\frac{m-2}{2}}} - \frac{1}{a_k^{\frac{m-2}{2}}}\right]$$

Average values for this case are:

$\Theta = 1.65$; $m = 3.50$; $C = 5.191 \times 10^{-15}$; $M_k = 1.07$

$\Delta\sigma = \sigma_{max} - \sigma_{min} = 60{,}2$ MPa.

The calculated number of cycles till the second crack developed from the original $2\ a_o \times 2\ c_o = 7.23$ mm size to the critical defect size $a_k = 89$ mm (Figure 1) is:

$N_f = 1.776 \cdot 10^7$ cycles. The ring has been in service till the second crack resulted fracture after $N_e = 1.678 \cdot 10^7$ cycles. The asymmetric factor was:

$R = \sigma_{min}/\sigma_{max} = -2.73$.

In the case of housings made of cast steel L 35II and loaded by forces F = 30 MN and $F_H = 0.423$ MN

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(Figure 2) the stresses and the related mechanical properties are as follows:

$\Delta\sigma = \sigma_{max} - \sigma_{min}$ = 52.5 MPa - stress range,

$\sigma_i = \frac{Zrj}{\alpha_k}$ = 82.6 Mpa - local stress at the notch tip with a radius of ρ = 100 mm,

α_k = 2.1 - equivalent shape factor,

$\bar{Z}_z$ = 172 MPa - mean value of fatigue limit,

$s_{Z_z} = \nu_z \cdot \bar{Z}_z$ = 17.2 MPa - fatigue limit standard deviation

$s_{\sigma_i} = \nu_\sigma \cdot \sigma_i$ = 8.4 MPa - stress standard deviation,

$\nu_z ; \nu_\sigma$ = 0.08 - 0.12 - corresponding variability coefficient

R_m = 500 -550 Mpa, R_e = 280 MPa, $K_{I_c} \cong$ 40 MPa $\sqrt{m}$.

The critical length of the crack was estimated taking into account a correction for plasticity:

$$a_k \leqslant \frac{K_{I_c}^2}{1.2.\pi.\sigma_{max}^2}\left[1 - 0.177\left(\frac{\sigma_{max}}{R_e}\right)^2\right] \cong 150 \text{ mm}$$

Depth of the maximum crack observed after 12 years in service was $a_o \cong$ 30 mm. Expected number of cycles till catastrophic fracture with the determined factors:

m = 3.65; C = 1.827 . 10^{-15};

θ = 1.3; M_k = 1.0 would be:

$N_f = 3.846 \cdot 10^6$ cycles.

The mill housing is working in three shifts at pulsating load /R = 0/ N_e =/0.83 + 1.27/.10^6 per year depending on rolling process. Predicted rolling time is:

$$T = \frac{N_f}{N_e} = 4.6 - 3.1 \text{ years.}$$

Probability of fatigue fracture of the mill housing may be calculated from the fatigue strength and the acting stresses assuming normal distribution.

$$P = 0.5^{\left(\frac{u}{2} + 1\right)^{2.46}} \leqslant P_W = 10^{-7} - 10^{-9}$$

where:

$$U = \frac{\bar{Z}_z - \bar{\sigma}_i}{\sqrt{S_{Z_z}^{\ 2} + S_{\sigma_i}^{\ 2}}} \rangle \ u_w = 5 - 6 \text{ - quantile of normal distribution}$$

$$P = 1.89 \ . \ 10^{-6} \rangle \ P_w = 10^{-7} - 10^{-9}$$

For the case presented the probability of fatigue fracture of the mill housing is higher then the admissible one for objects of this type.

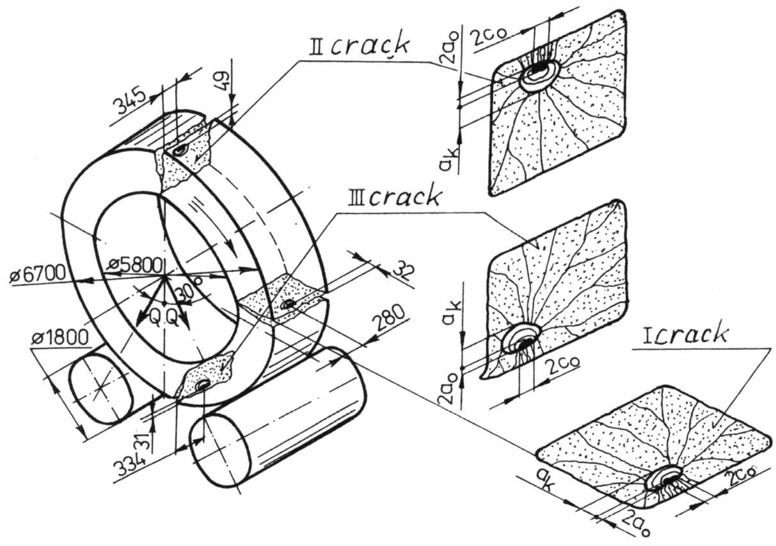

Figure 1. Casting defects and cracks in the ring.

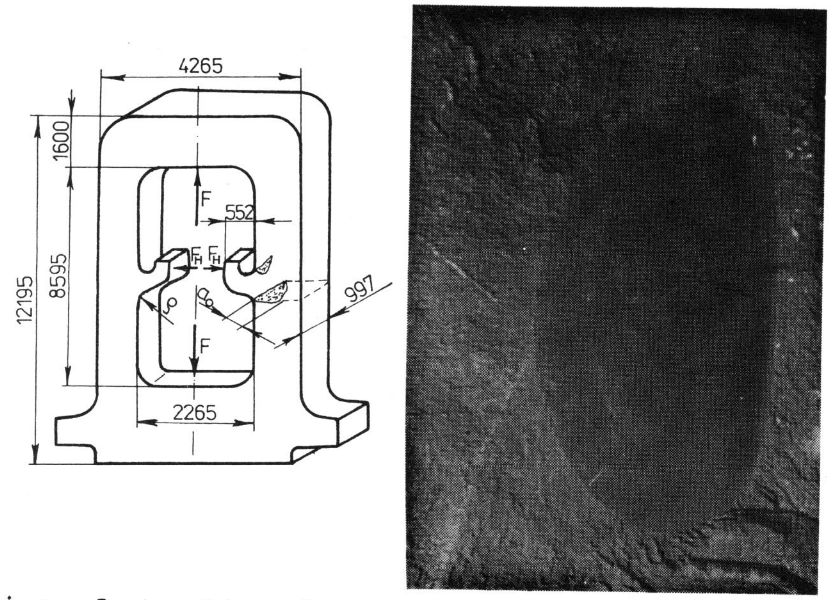

Figure 2. Location of cracks.