ABSTRACT. In this paper a strength condition for screw joints with transversal crack is obtained. The algorithm for evaluation a critical value of stress intensive factor by means ultrasonic measurement is presented.

KEY WORDS: Screw joints, Strength condition, Critical value of stress intensive factor, Ultrasonic

1. Introduction

One of machine components is the screw joint. The strength calculations of this component is function of the load and acceptance stress of the material. The stress condition is function of the mechanical stress and the acceptance stress. This one is for screw joint without discontinuity. The strength condition in this case is [1]

\[ \sigma_{\text{WORK}} \leq \frac{\sigma_{\text{ACC.}}}{n_{\text{ASS.}}} \]

where \( \sigma_{\text{WORK}} \) – mechanical stress in work condition \( \sigma_{\text{ACC.}} \) - acceptance mechanical stress for material, \( n_{\text{ASS.}} \) – assurance coefficient. In engineering practice there is necessity of controlling strength calculations for screw joint in exploitation. In this case frequently there is crack in zone body - threading and load is tension. The result of statistics of screw joints in exploitation show that more 65\% of the damage is in zone body - threading. The strength condition in case of screw joints with crack is [2]

\[ K_I \leq \frac{K_{IC}}{n_{ASS.}} \]

where \( K_I \) – stress intensive factor for fixed load, geometry of machine component and crack, \( K_{IC} \) - critical value of stress intensive factor.

2. Stress intensive factor - \( K_I \)

For screw joints (maximal diameter of treading – \( D \) and minimal diameter of treading – \( d \) ) with crack (depth – \( h \), \( D = d+2h \) ) and with tensile load (\( \sigma_\infty \) ) in zone of treading for stress intensive factor there is [2]

\[ K_I = \frac{1}{2} \sigma_\infty \sqrt{D} \left( \frac{h}{D} \right) \pi F(\Delta); \ \Delta = \frac{d}{D} \]
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where \( F(\Delta) = \left( \frac{1}{\Delta} + \frac{1}{2} + \frac{3}{8} \Delta + \frac{3}{10} \Delta^2 + \frac{7}{10} \Delta^3 \right) \Delta^{-1/2} \). If in (2.1.) put \( \frac{d}{D} = 1 - 2 \frac{h}{D} \) and

\[
\frac{1}{2} \sigma_\infty \sqrt{\pi D} = K_0, \text{ then for stress intensive factor } K_i \text{ is}
\]

\[
(2.2) \quad K_i \left( \frac{h}{D} \right) = K_0 \sqrt{\frac{h}{D}} \left( 1 - 2 \frac{h}{D} \right).
\]

3. Critical value of stress intensive factor - \( K_{IC} \)

The existing methods for critical value of stress intensive factor - \( K_{IC} \) evaluation are based on experimental study of samples with tension test. For plastic materials this evaluation is very difficult of access [3] because of necessity of big dimensions of samples. This is reason for search of relationships between \( K_{IC} \) and mechanical properties of the material (yield stress \( \sigma_y \), tensile strength \( \sigma_{TS} \)) and structural parameters (grain size \( D \) and other). In [3] the relationship is received

\[
( K_{IC} )^2 = \bar{D} \tau_y \frac{E}{1 - \nu} \ln \left( \frac{1}{1 - \psi} \right), \text{ where } \bar{D} \text{ - drain size, tangential strength of plasticity } \tau_y, \text{ Young’s modulus } - E, \text{ Poisson ratio } - \nu, \text{ transversal compression ratio of the material } - \psi. \text{ Relationship } \tau_y - \sigma_y \text{ is Mises’s condition } \tau_y^{(M)} = \sigma_y / \sqrt{3}. \text{ The Mises’s condition is near to experiment data. In other side there is conservation law } (1 - \psi)(1 + \delta) = 1, \text{ where } \delta \text{ is longitudinal compression ratio of the material and empirical relationship } \delta = \frac{A}{2\sigma_{TS} + \sigma_y}, A = 420 \text{ J/mm}^2 \text{ [5]. Therefore the (3.1.) is transform to [5]}
\]

\[
(3.1) \quad ( K_{IC} )^2 = \frac{1}{\sqrt{3}} \bar{D} \cdot \xi(E, \nu) \cdot \vartheta(\sigma_y, \sigma_{TS})
\]

where \( \xi(E, \nu) = \frac{E}{1 - \nu} \), \( \vartheta(\sigma_y, \sigma_{TS}) = \left[ \sigma_y \ln \left( 1 + \frac{420}{2\sigma_{TS} + \sigma_y} \right) \right], E, \nu \text{ - elastic modulus, } \sigma_y \text{ - yield strength, } \sigma_{TS} \text{ - tensile strength.}

The non-destructive evaluation of values \( \bar{D}, E, \nu, \sigma_y, \sigma_{TS} \) in (3.1.) is by means:

- For grain size \( \bar{D} \) [4,5]
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(3.2.) \[ \bar{D} = \left[ \frac{4\pi^4 V_L^4}{1125 V_L^2 \left( \frac{3}{V_L^2} + \frac{2}{V_T^2} \right)} \right] \cdot \left( \frac{f^2}{f_0} \right)^2 - \alpha_L = 0 \]

where \( f \), \( V_L \), \( V_T \) are frequency and velocities of propagation of longitudinal and transversal ultrasonic waves.

- For elastic modulus \( E, \nu \) \[ E = \frac{3 - 4(V_T / V_L)^2}{1 - (V_T / V_L)^2} \rho V_T^2 ; \quad \nu = \frac{0.5 - (V_T / V_L)^2}{1 - (V_T / V_L)^2} \]

The values \( V_L, V_T, \alpha_L \) are measuring according ASTM E 494:2010.

- For yield stress \( \sigma_s \) \[ \sigma_s = \sigma_s(HB) \sigma_2(V_L; V_T), \]

where \( \sigma(HM) = \frac{3}{2} \left( \frac{1}{2}HM \right) \); \( HM(HB) \);

\[ \sigma_2(V_L; V_T) = \left\{ \frac{1}{2} (1 - 2\nu) + \frac{2}{9} (1 + \nu) \right\} \left[ 2(1 + \nu) \right]^{1/2} \]

The value \( HB \) is measuring according ASTM A 956.

- For ultimate tensile strength \( \sigma_{ts} \) \[ \sigma_{ts} = 0.3HB^{0.989} \approx 0.39HB \]

4. Equipment

The equipment for measurement of \( V_L, V_T, \alpha_L \) are:

- Ultrasonic device US - Key with accuracy of measure time of wave propagation is 0.001 \( \mu s \), f.LECOEUR, France. Laptop with conventional characteristics.
- Ultrasonic transducers with X-cut and Y-cut of piezo-plasine for longitudinal and transversal ultrasonic waves with frequency 5 MHz, f. PANAMETRIX USA.
- Calibration block CBV \( (V_L = 5.93 \text{mm} / \mu \text{s}) \) f. SONATEST, England.
- Digital micrometer – Micromaster with accuracy of measurement \( \pm 0.5 \mu m \), f.Mytutoio, Japan.
- Portable hardness tester M-295 Leeb type DX-TESTOR, with accuracy of measurement \( \pm 1HB \), f.WOLPERT-WILSON, Germany.

5. Measurement

In [6] and ASTM E 494:2010 the methods of acoustic characteristics of the materials (velocity and attenuation of ultrasonic wave propagation) of measurement are presented. One method is by means

(5.1.) \[ V_X = \frac{L_X}{T_X / 2}; \quad \alpha_L = \frac{N_m - N_{m+n}}{2nL_X} \]

where \( V_X = (V_L; V_T) \) in \( \text{mm/} \mu \text{s} \), \( T_X = (T_L; T_T) \) in \( \mu \text{s} \). \( V_L; V_T; T_L; T_T \) respectively velocities ant times of propagation of longitudinal and transversal ultrasonic waves,
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$L_X$ - thickness of measurement material in mm, $N_m$ и $N_{m+n}$ – respectively amplitudes of $m$ and $m + n$ multiplicity back echoes in dB.

6. Strength condition for screw joints with crack

Controlling stress calculation are carry out in case transversal crack in zone body – threading is detected.

In ultrasonic testing [7] there are methods for detected and depth – $h$ of cracks. In this case the screw joint is disjointed.

According (3.2.) the strength condition (1.2.) is

\[
(6.1.) \quad \frac{h}{D} F \left(1 - 2 \frac{h}{D}\right) \leq \frac{K_{Kc}}{K_{0n_{ASS}}}
\]

where $K_{Kc} = K_{Kc} (V_L, V_T, \alpha_L, HB)$ [5].

7. Conclusion

The detected and sizing the transversal crack, with depth – $h$, by beams ultrasonic testing, in zone body – threading, necessity be up to the requirements stress condition (6.1.), where the parameter $K_{Kc}$ by means ultrasonic measurements are evaluation.

REFERENCES