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# Estimation of Endurance Limits of Welded Joints by the Criterion of Non-propagating Cracks

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**Abstract**

The distinctive feature of the weld joint and heat affected zone is a significant discontinuity of mechanical characteristics, the grain diameter, as well as the presence of various stress concentrators provoking the fatigue cracks occurrence. It is known that the main factor influencing the risk of occurrence and speed of microcracks propagating is the stress condition level as well as structural and mechanical discontinuity of metal weld joints.

This article suggests a model and an approach for the assessment of a reduced stress concentration factor for welded joints with defects such as undercuts, reeds and other stress concentrators in terms of crack propagating under the influence of a stationary variable load.

The results of the suggested model have been checked on carbon and ferrite-pearlite steels. The authors have manage to obtain the fluctuating stresses values on the criteria of non-propagating cracks depending on the size of the defect and based on the endurance limit criterion. The sizes of non-propagating cracks appearing in the area of stress concentration action and depending on the diameter of the circular hole in the plate have been calculated. Comparing to the model mentioned in G.M. Charzynski's monograph, the suggested methodology gives an asymptotic approximation endurance limit to the value $\sigma_{-1}/3$ macro concentrators with increasing stress as a hole. The model has been built for an infinite plate and does not consider changes in the stress field due to the limited size effects.


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*Keywords:* welded joint; endurance limit stress; defect; stress concentrator; breakloose macrocrack; fatigue crack; stress intensity factor.

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## 1. Goal setting

Despite the fact that the level of production of the welding allows obtaining quality welded joints, in practice, we cannot always ensure the absence of technological weld defects, especially in large-sized metal-structures. There is a big possibility to miss forbidden defect on its geometrical characteristics [1-10].

Values of fluctuating stresses of symmetrical cycle external load to the structural element can be represented as endurance limit stress of the element with stress concentration or without it [9]. Limit of endurance of the structural element without stress concentration is equivalent to the endurance limit of the material $\sigma_{fr}$. For a structural element with stress concentrator external load value can either lead or not lead to the development of a crack to critical values Consequently, we have a load value, which provokes the crack appearance in a concentrator, but it is not enough to continue the crack movement to critical dimensions [11-15]. Thus, the minimum value of the variable load, which is already not enough for the development of crack to the critical dimensions, can be considered the endurance limit of the structural element with the stress concentrator, or the "threshold" endurance limit, by the criterion of non-propagating cracks. This "threshold" endurance level will depend on the form and size of the concentrator. Having built a model, with which you can calculate "threshold" endurance levels for concentrators with different forms and sizes, and if you know the material endurance level you can calculate the effective stress concentration coefficients.

Endurance limit stress of the material of the ferrite-pearlite steel class can be calculated taking into account structural-mechanical characteristics [6]. It is proposed in works [1,6,8] on the basis of semiempirical models and structural-mechanical approach to determine the limit of endurance. Authors [7,8] studied the defect size of stress concentrator, which size didn't influence on endurance limit [16]. In these works, authors determine the dependency, which is underlying of engineering approach of evaluation, construction endurance, according to the tests of smooth and notched specimens in air. It allows calculating the radius of a front of elementary propagating semicircular crack, based only on well-known endurance limit of the symmetric cycle [17,18].

## 2. Development mathematical model

Development mathematical model for the description of propagated cracks from stress concentrators in circular notches or holes will allow transferring the results of the study (taking into account the correction) to various welded joints. As far as external load decreases, tending to $\sigma_{-1}/3$ for concentrator with theoretical stress concentration factor equal to 3, it is logical to assume, that even for physically large stress concentrators the appearance of a crack will not be provoked by this concentrator. Thus, for the considered concentrator with a theoretical coefficient of stress concentration equal $\alpha_m$ the cracks will not propagate at stresses $< \sigma_{-1}/\alpha_т$. This is a known limit case for any stress macro concentrator [19].

The results of effective stress concentration coefficients in model [8] are good conform with the experimental data for the zone of geometrically small stress concentrators, here the dependence is presented in the following form [8]:

$$\sigma_{th-1k} = \sigma_{-1} \Big/ \sqrt[4]{1 + \sqrt{F_d / F_0}} \qquad (1)$$

where, $\sigma_{th-1k}$ is threshold stress or endurance limit on an external load, in which the crack is propagated beyond the zone of the action of the concentrator, MPa; $\sigma_{-1}$ is endurance limit undamaged material in the absence of stress concentration, MPa; $\sigma_{-1}/\sigma_{th-1k}$ is an effective coefficient of stress concentration. Other arguments, which are including in (1), was depend from concentrator form which was closed hole in diameter d from 40 to 500 mkm and depth h taking into account the depth of the drill exit [6]. The cross-sectional area of this defect, taking into account the exit of the drill, was calculated by formula: