APPLICATION OF FEM IN THE ANALYSIS
OF WELDED CONSTRUCTIONS WITH CRACKDEFECTS

G.T. Danenova, T.B. Akhmetzhanov
Scientific Supervisor: Prof., Dr. M.R. Nurguzhin
KaragandaStateTechnicalUniversity
Kazakhstan, Karaganda, B. Mira., 56, 100027
E-mail: g.danenova@kstu.kz

ПРИМЕНЕНИЕ МКЭ ДЛЯ АНАЛИЗА СВАРНЫХ КОНСТРУКЦИЙ
С ДЕФЕКТАМИ ТИПА ТРЕЩИН

Г.Т. Даненова, Т.Б. Ахметжанов
Научный руководитель: профессор, д.т.н. М.Р. Нургужин
Карагандинский государственный технический университет
Казахстан, Караганда, б. Мира, 56, 100027
E-mail: g.danenova@kstu.kz

Аннотация. *В данной работе исследован нелинейный процесс деформирования сварных конструкций с трещиноподобными дефектами. В качестве основного параметра используется энергетический J-интеграл и эквивалентная пластическая деформация. Величину J-интеграла для элемента конструкции с трещиной можно определить численными методами, например методом конечных элементов. Автоматизированный анализ изделий с трещиноподобными дефектами осуществлялся с использованием программного комплекса ANSYS и программного комплекса CRACK, разработанным в Карагандинском государственном техническом университете (КарГТУ).*

Introduction. Now the conception "fitness for purpose" has received serious recognition [1-3]. It offers analytical procedures based on a combination of the appropriate standard tests of materials and numerical methods with modern approaches of deformation and fracture mechanics. The further perfection of methods of calculated prediction of a welded construction serviceability according to the concept "fitness for purpose" requires the complex analysis of many factors that can essentially affect results of the analysis. They are an estimation of real load, set of axes of stress-strain state, residual welded stress and strain, existence of sharp cavities, modern hardness criteria, account of real geometry, mechanical properties and etc.

The methods to predict the resource of welded construction. The computer system of automated analysis and prediction of a residual resource of welded machine-building constructions ANWELD described in the paper is based on the following principles.

1. The expected load is determined on the basis of the dynamic processes research taking place in construction elements. It is realized by the macro-simulation methods for systems with concentrated parameters and the micro-simulation methods for systems with distributed parameters on the basis of ANSYS program.

2. The mode of a product operation is determined by simulation of systems like "the machine - set of technologies". The loading factors of the machine and its elements, quantity of loading cycles, quantity of loading types, and cycle time are estimated. Using the typical Q-circuit and the simulation language GPSS/PC allows to solve the given problem effectively. The multitarget simulating interface is created for automatic generation of GPSS-programs. It doesnot require knowledge of language GPSS from the users.

3. The production technology is realized on the basis of the real geometry descriptions of welded connection (with incomplete penetration, constructive cracks and etc). The finite element method is used for an estimation of residual welded stresses and strains. The KELAPS programis based on this method.

4. The two-parametrical criterion is the standard and widespread criterion of quasi-brittle failure.

5. The structural fitness of a real product to its model is realized mainly using numerical methods of analysis (the finite element method and the boundary element method). Thus the three-dimensional model (3D-FE-model) is used for the analysis of a stress-strain state (SSS) of a product as a whole (macro-level). At a micro-level the bivariate model (2D-FE-model, 2D-BE-model) is applied for an estimation of hardness of welded connections.

Calculation of energetic J-integral. The non-linear process of deformation of welded constructions with crack defects is investigatedin the paper. The energetic J-integral and the equivalent plane strain are used as main parameters. The value of J-integral for a construction element with a crack can be determined by numerical methods, for example, by the finite element method. The automated analysis of products with crack defects is realized by using CRACK-program that was created by engineers of the Karaganda State Technical University. The main parts of CRACK-program are the following:

1. The non-isothermal theory of fluidity.
2. The non-linear fracture mechanics.
3. The finite element method.

The calculation results have shown that it is possible to accept a linear model with an error (10-15%) for a curve of hardening. That allows to exclude the hardening parameter*n*from our model. Thus the value deviation of J-integral is considered as a calculation reserve. Using the CRACK software based on the FEM, the methods of rational design of experiments and the regression analysis we have offered the formulas for calculation of elastic-plastic J-integral for the pattern with a central crack and the pattern with one edge.

Calculation of equivalent plasticdeformations. The investigation of law of plasto-elastic deformation of a welded joint with crack like defects was performed relying on method of the finite element with the help ANSYS program. The model used here is the model of the theory of current combined with the von Mises condition of fluidity used in the bilinear law of hardening of materials.This model is generally used for large-strain applications of initially isotropic materials. Among possible rather large variety of welded joints only three connections are considered in this work: junction joint, T-joint and lap joint. For various types of steels researches have been conducted. The dependencies $\varepsilon'=f(P/P_{lim})$ and $\varepsilon'=f(a/T)$ were obtained. They have shownthat the factor ε' almost does not depend on a steel type. The factor ε' is conditionally constant number at an applied load and a crack length.

The analytical dependences have been receivedon the basic of the performed research.These formulas are for the case of a plane stress and the case of a plane strain between the ε'factor and the following factors:

- Ratio of a crack length to a sample width;

- Ratio an applied load to ultimate load (P/P_{lim}).

Figure 1 presents plastic equivalent strainsfor case of a plane stress for the junction joint in case of the maximum pressure.Their analysis shows the used δ_k – model relating to the calculation on static strength of welded joint can result in essential errors.

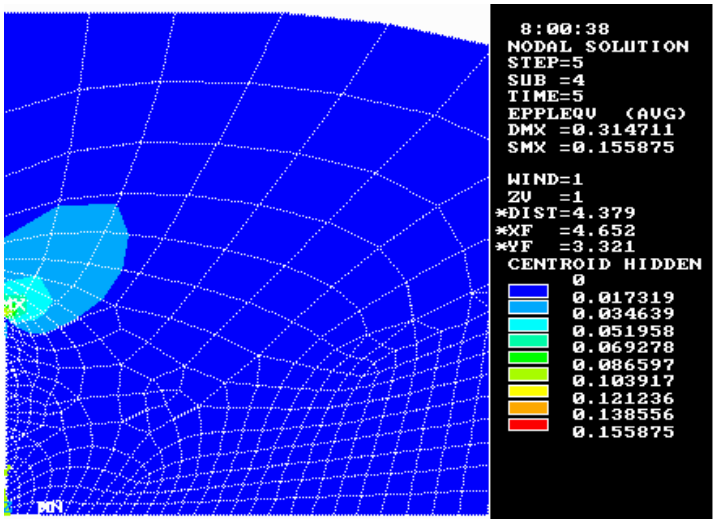

Fig.1. The plastic equivalent strains ε_{eqv} for cases of a plane stress

Conclusion. The method of automated analysis and prediction of a residual resource of welded constructions was developed on the basis of the concept "fitness for purpose".

The prediction of serviceability of welded constructions for quasi-brittle problems should be based on the stress intensitycoefficient. For non-linear problems it is necessary to use energetic J-integral and equivalent plastic strain ε_{eqv} as a fracture mechanics criteria.

The formulas for calculation of a stress intensity coefficient , energetic J-integral and equivalent plastic strain $\varepsilon_{eqv,}$ are offered using the program complex CRACK based on the FEM, the methods of rational design of experiments and the regression analysis.

The two parametrical criteria of fracture mechanics, an energetic J-integral, an equivalent plastic strain ε_{eqv}, conclude all main mechanical properties of a material (yield point, parameters of hardening). That allows to use the numerical analysis of an effect of a materials application with different statistic properties.

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