RESEARCH OF FRACTURE RESISTANCE OF 15Kh2MFA PRESSURE STEEL ON SPECIMENS OF NATURAL THICKNESS

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INTRODUCTION

One of the important questions of safety security appears the brittle fracture prediction of nuclear pressure vessels. This goal is solved during the period of design of WWER (LWR type) power reactors when the corresponding calculation according to INTERATOMENERGO standard (1) is carried out in CMEA member countries.

Tests of plates of natural thickness appear to be the most reliable for the assessment of behaviour of nuclear reactor materials in the frame of structure design. In this case the artificial crack must correspond to the crack used in the calculation (called "calculated" or "postulated" crack) according to the standard (1) (semielliptical crack of the depth equal to 1/4 of wall thickness with axis ratio a/c = 2/3). It is also suitable to carry out the tests of plates with small defects the occurance of which is most probable in the pressure vessel during the service, and with cracks which substantially exceed the calculated crack (up to 100 mm). This last enables us to determine the possibility of the ligament break whose consequences would be the change of surface crack into the through one. As the crack growth is the dynamic process it is also necessary to determine the fast crack arrest resistance.

MATERIALS AND TESTING PROCEDURES

Large scale specimens were manufactured from plates of 165 mm thick from 15Kh2MFA type steel used for pressure vessels of WWER-440 nuclear power reactors. Main characteristics of this steel are given in Tables 1 and 2.

TABLE 1 - Chemical Composition of Material (wt.%)

C	Mn	Si	P	S	Cr	Ni	Mo	V
0.15	0.48	0.35	0.013	0.016	2.77	0.14	0.60	0.34

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TABLE 2 - Mechanical Properties of Material at 20°C

$R_p 0.2$ (MPa)	R_m (MPa)	A_5 (%)	Z (%)	KCV ($J.cm^{-2}$)	T_{ko} (°C)	K_{IC} ($MPa.m^{1/2}$)
550	660	21.2	72.8	210	-25	150÷200

In the paper results of tensile tests of nine plates (150x1,200x1,500 mm) with semielliptical surface defects of 25, 40, 50, 75 resp. 100 mm deep, carried out on a unique loading hydraulic machine ZZ 8000 (80 MN) in ŠKODA in the temperature range of $T_{ko} \pm 50$ °C are presented. The following parameters were recorded: force, temperature, crack opening displacement and the extension measured at 1,200 mm measured length as well as strains in 50 points. Besides the moment of crack start was fixed by two independent methods (acoustic emmission and electrical potential). After the fracture the subcritical crack growth was established.

Moreover, crack arrest tests with temperature gradient of ESSO type were carried out under nominal stresses between 0.1 and 0.5 of yield strength, also in ZZ 8000 testing machine - Brumovský (2).

CONCLUSIONS

As a result of analysis the following conclusions were obtained (Figs. 1 and 2):
- fracture of specimens at room temperature occured at elastic-plastic region of loading;
- subcritical crack growth initiation stresses are for the whole testing interval practically constant and dependent only on crack size : this means that upper shelf of this steel (for thickness 150 mm) is pronounced practically beginning from transition temperature T_{ko} according to INTERATOMENERGO standards (which is very close to the transition temperature RT_{NDT} according to ASME CODE, Section III;
- comparison of experimental results with calculation based on Linear Elastic Fracture Mechanics suggests a high conservatism of calculations,
- fracture of specimen tested at +75°C occured by fast ductile mode after large subcritical crack growth by typical "leak-before-break" type, as this temperature is equal to FTE from Fracture Analysis Diagram;
- conditions of brittle and semi-brittle failure are very far in temperature scale from crack arrest temperature as was received for this type of steel. Even for 150 mm thick specimens this crack arrest tempe-

ture is shifted (for similar nominal stresses) by +50°C higher than temperature dependence of failure stress for specimens with 100 mm deep defects;

- critical stresses for crack growth initiation for "calculated defect" (40 mm deep) are larger than 400 MPa for the whole tested interval, which is more than twice higher than are allowable stresses (218 MPa), thus this defect is fully safe, even for 100mm deep defect its critical stress has safety factor close to 2.

REFERENCES

(1) MKhO INTERATOMENERGO Standard 38.434.55-84 "Components and Piping of Nuclear Power Stations. Code for Strength Calculations. Checking Calculations. Calculation of the Resistance against Brittle Failure". Moscow, 1984.

(2) Brumovský,M. A Two Criteria Approach to Reactor Pressure Vessel Safety and Reliability Evaluation. Proceedings of the IAEA Conference on "Reliability Problems of Reactor Pressure Components". Vienna, 1976.

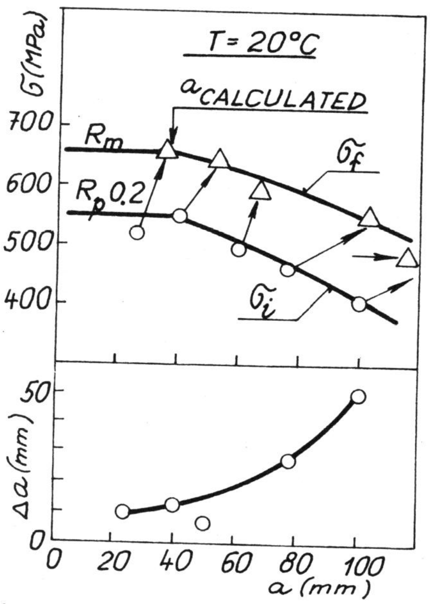

Figure 1 Defect Analysis Diagram at 20°C

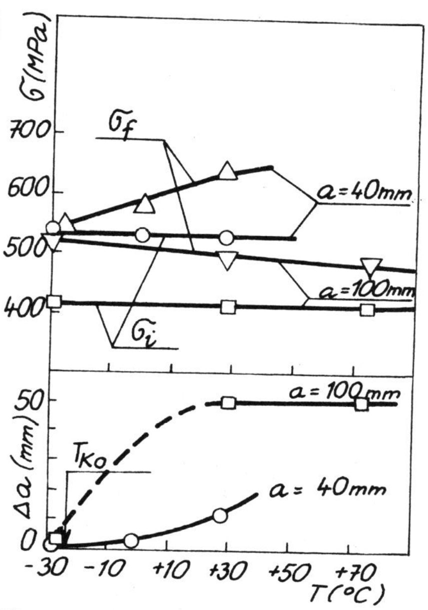

Figure 2 Fracture parameters for 2 defects