IMPROVEMENT OF REGULATORY PROCEDURES FOR RPV INTEGRITY AND LIFETIME ASSESSMENT FROM THE VIEWPOINT OF BRITTLE FAILURE RESISTANCE

I.F. Akbashev, Yu.M. Maksimov, V.A. Piminov
OKB “Gidropress”, Podolsk, RF, Russia

Recently two new regulatory procedures for RPV integrity and lifetime assessment have been developed in RF. The first procedure is “Procedure for WWER reactor pressure vessel lifetime assessment during operation”, MPK-CXP-2000. This procedure is applicable for RPV cylindrical part under irradiation. The second procedure is “Procedure for WWER-1000 RPV nozzle area brittle failure resistance calculation”, MIKP-2002.

The reasons for development of such procedures are the following:
- to take into account new data on RPV material behavior under irradiation;
- to take into account new data and new approaches on RPV material fracture toughness curves;
- to provide more realistic postulated defects;
- to remove extra conservatism from RPV integrity assessment using valid and well founded approaches.

THIS PAPER PRESENTS THE MAIN APPROACHES OF THIS NEW RUSSIAN REGULATORY PROCEDURES AND THE RESULTS OF CALCULATIONS WITH THE USE OF NEW PROCEDURES. THE FOLLOWING POSITIONS ARE UNDER CONSIDERATION:

POSTULATED DEFECTS

ACCORDING TO PROCEDURE MPK-CXP-2000 THE FOLLOWING DEFECTS (ELLIPTICAL AND SEMI-ELLIPTICAL CRACKS) ARE POSTULATED FOR THE CLAD RPV (DEPENDING ON THE RESULTS OF NDT AND CLADDING EXAMINATION):

\[ a_p = 0.07S + S_c, \frac{a_p}{c_p} = \frac{1}{6} \]
\[ a_p = 0.07S + S_c, \frac{a_p}{c_p} = 0.21S \]
\[ a_p = 0.07S, \frac{a_p}{c_p} = \frac{1}{3} \]

HERE S IS RPV WALL THICKNESS AND S_C IS CLADDING THICKNESS.
FOR UNCLAD RPV THE SURFACE SEMI-ELLIPTICAL CRACK WITH DEPTH \( A_p = 0.07S \) AND SEMI-AXES RATIO \( A_p/C_p = 1/3 \) IS POSTULATED.
ACCORDING TO PROCEDURE MIKP-2002 THE POSTULATED DEFECT FOR WWER-1000 RPV NOZZLE AREA IS THE CRACK IN THE BASE METAL WITH DEPTH $A_0 = 0.07S$ AND LENGTH $2C_0 = 6A_0$.

FOR ALL MENTIONED ABOVE DEFECTS THE CYCLIC GROWTH IS CONSIDERED.

**FRACTURE TOUGHNESS CURVES AND ALLOWABLE VALUES OF STRESS INTENSITY FACTOR**

ACCORDING TO NEW PROCEDURES THE ALLOWABLE VALUES OF STRESS INTENSITY FACTOR ARE OBTAINED FROM FRACTURE TOUGHNESS BASE CURVE. ONE BASE CURVE FOR ALL MATERIALS OF WWER TYPE RPV'S IS PROPOSED. THE EQUATION FOR THIS BASE CURVE IS

\[ K_{IC} = 23 + 48 \cdot \exp[0.019(T-T_K)] \]

ALLOWABLE VALUES OF STRESS INTENSITY FACTOR FOR CRACK WITH THE CRACK FRONT LENGTH $B_i$ CAN BE DETERMINED BY THE FOLLOWING FORMULA:

\[ [K_{IC}] = \left( \frac{B}{B_i} \right) ^{1/4} (K_{IC} - K_{min}) + K_{min} \]

Here $B = 150$ mm and $K_{IC} = 20$ MPa m$^{1/2}$
STRENGTH CRITERIA

STRENGTH CRITERIA CAN BE WRITTEN IN THE COMMON WAY:

\[ K_1 \leq [K_{IC}] \]

ADDITIONALLY THE PRECISE CALCULATION MUST BE PERFORMED

\[
\frac{1}{B} \int_{S} \frac{(K_1(\varphi) - K_{min})^4}{(K_{IC}(\varphi) - K_{min})^4} dB < 1
\]

WHEN THE STRENGTH CRITERIA ARE NOT SATISFIED. THE CONDITION FOR
PRECISE CALCULATION CAN BE WRITTEN AS FOLLOWS:

CALCULATIONS WITH THE USE OF NEW PROCEDURES

THE RESULTS OF BRITTLE FAILURE CALCULATIONS FOR WWER-440 AND
WWER-1000 RPV UNDER PRESSURIZED THERMAL SHOCKS ARE PRESENTED.
THE CALCULATIONS WERE PERFORMED ACCORDING TO PROCEDURE MPK-
CXP-2000 AND REGULATION “STRENGTH ANALYSIS STANDARDS...”, ПНАЭ Г-7-
002-86. COMPARISON BETWEEN THE RESULTS OBTAINED BY PROCEDURE
MPK-CXP-2000 AND REGULATION “STRENGTH ANALYSIS STANDARDS...”,

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ΠΗΑΕ Γ-7-002-86 SHOWS THAT NEW PROCEDURE GIVES THE POSSIBILITY TO EXTEND RPV LIFETIME.

THE RESULTS OF BRITTLE FAILURE CALCULATIONS FOR WWER-1000 RPV NOZZLE AREA UNDER PRESSURIZED THERMAL SHOCKS ARE PRESENTED. THE CALCULATIONS WERE PERFORMED ACCORDING TO PROCEDURE М1КP-2002. STRENGTH CRITERIA OF PROCEDURE М1КP-2002 ARE SATISFIED.