Ultrasonic Testing of ITER in-vessel components

ITER (International Thermonuclear Experimental Reactor) is an international nuclear fusion research and engineering megaproject, which is currently building the world's largest experimental tokamak nuclear fusion reactor adjacent to the Cadarache facility in the south of France. Its goal is demonstrating scientific and technical potential of generating thermonuclear energy for peaceful uses. ITER shall become the first thermonuclear facility generating commercial heat.

Russian contribution in the ITER Project lies in manufacture and delivery of the major reactor systems, including in-vessel components (60 DOME Divertor and 48% of panels of FIRST Wall), which will be manufacture at Efremov Institute.

Equipments for ultrasonic testing (UT)
- Automatic ultrasonic laboratory facility FAZUS - 2007
- Automatic ultrasonic inspection facility FAZUS - 2010
- UT of large-scale objects 2,5*7*1,0 meters

High validity of the ultrasonic testing of complicated multilayer products is provided by the automated system of ultrasonic visualization using the interference method of object imaging by acoustic waves.

Bronze / Steel - explosion welding
- UT of blanks
- UT of component parts

The method of a holographic interferometry allows to detect and to measure poorly reflecting defects and potentially dangerous sections of multilayered joints. The analysis of interferograms received before and after High Heat Flux Testing (HHFT) of object confirms a transition of potential defect to real defect.

Demonstration of the capabilities of processing the UT results

The numbers on the defectogram are the enumeration of tiles marked by a felt-tipped pen, which filled the brush-like structure of tungsten. The absence of ultrasonic waves propagation around numbers is due to chemical cleaning of mock-up before assembling.

Results of ultrasonic investigation: method of pre-braze cleaning has been improved

Steel XM19 / Steel 316 L(N) - HIP-joint
- Detection and visualization of defects in HIP-joint of Divertor's steel supporting structure with using Phased Array System and data handling by a projection method in spectral space.
- Test objects: The bismacrose sample with curved border consisting of two blanks of steel grades XM19 and 316L(N), which are connected on technology Hot Isostatic Pressing.

Equipment:
- Harling VED 1664 Phased Array System
- UT results

Metallographic examination
- Ultrasonic images of defects and demonstration of defects' confirmation by a metallography.
- Characteristic defect of brazing joint Be/CuCrZr (concentrated porosity) is detect by method of a holographic interferometry.

Beryllium / Copper - brazing joint
- The specificity of UT of beryllium armor:
  - The high velocity of ultrasonic waves in the beryllium
  - High levels of natural "noise" of the boundary Beryllium / Copper
  - The gas sorption of beryllium in water

Beryllium / Copper / Bronze - HIP joint
- UT of technological mock-ups with artificial defects
- The operation zone of explosion welding at 1 mm level (and with due account for interference defectogram) have been proposed and approved by ITER.

The operation zone of explosion welding is a thin wall of "cover" DOME (5 - 7 mm), upon which high requirements for tightness are imposed.