Compact Tension Sample Preparation Out of Candu Pressure Tube Using the Numerical Controlled Milling Machine

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Compact tension (CT) samples are used extensively in the area of fracture mechanics and corrosion testing, in order to establish fracture toughness values for a material. This paper presents the method of preparation of CANDU pressure tube samples for mechanical tests. For samples preparation a DM 1007 Dyna numerically controlled milling machine is used.

The CT sample must have a notch for an initiation of delayed hydride cracking (DHC) along the longitudinal direction. This notch plays a key role in the determination of the threshold stress intensity factor (KIH).

In order to perform the machining of such a CT sample out of a CANDU pressure tube fragment, some devices were manufactured: the device to fasten the pressure tube during machining, the device to fasten the sample during cutting both ends of it and the device to fasten the sample during notch machining. The pressure tube is fastened to the milling machine table, the ensemble of both being allowed to move in the XY plane, whereas the milling tool is moving independently along the Z axis. The programming of sample machining takes into account the size measurement of the pressure tube and the movement coordinates of the milling machine table. A „Point Finder” is used for coordinates measurement of the pressure tube and a similar tool TS27R, fixed on the milling table, is used for dimensional measurements of the milling tools that will be used.

The machining of the CT sample needs six operations for which six different tools are used. All tools are mounted on the tool changer prior to begin the machining and are changed automatically as needed.

This milling machine (Figure 47) will be installed into a heavy concrete hot cell and will be used to prepare CT samples out of irradiated CANDU pressure tube fragments.

Basic parameters of the milling machine:

- X, Y, Z axis travel: 250 x 175 x 250 mm;
- Table size: 450 x 180 mm;
- Maximum table load: 60 kg;
- Maximum X, Y, Z axis travel speed: 5/5/5 m/min.;
- Cutting feed rate: 0 ÷ 5000 mm/min.;
- Spindle rotate speed: 60 ÷ 10000 rpm;
- Spindle nose to table distance: 95 ÷ 350 mm;
- Automatic tool changer, number of tools: 6;
- Tool holder: type BT-30;
- Maximal tool length: 150 mm;
- Simultaneous X, Y, Z axis control;
- Positioning precision: 0.001 mm;
- Feed rate range: 0.001 mm;
- Software SurfCAM 3 Axis SE (DM1007, EM3116(A) & DM2800; Dyna 4M)

Figure 47: Dyna DM 1007

CT sample preparation sequences

The final CT sample should meet the dimensional accuracy and surface quality required by the mechanical tests standards (ASTM E8M; ASTM E399). For all operations needed to obtaining the CT sample (achieving the upper surface, the lower surface and side surfaces, the adjustment of the specimen surfaces, making the holes, the notch preparation) programs edited in „G" codes have been developed in order to control the milling machine (Dyna 4M)

The sequence of operations performed in order to manufacture the CT sample is as follows:

- The lengths and the diameters of all mills which are to be used (Figure 48) and the length of the „Point Finder" were measured using a device TS27R (TS27R Tool setting probe).
- The pressure tube fragment is fastened horizontally on the milling machine table, using the „Fastening device", so that its axis must be parallel to the worktable and with the X direction. One measures the coordinates of the pressure tube fragment (Figure 49), using the „Point Finder", to determine the height and centre of the tube fragment in order to extract the CT sample (Point Finder Touch Sensor. [6]
- Using the cylindrical mills the pressure tube is made, the upper, lower and side surfaces of the CT sample are achieved. The two holes with 4.25 mm diameter of the CT specimen are made using a 3 mm diameter mill (Figure 50).
- After separation of the CT sample from the pressure tube fragment, it is fixed vertically in „The adjustment device" (Figure 51). The CT sample is fixed so that the plane of the holes axes is parallel with the worktable of the milling machine and the axes of these holes are parallel with the Y coordinate. The sample surfaces are adjusted using a 10 mm diameter cylindrical mill.

Figure 48: Tools measurement using the TS27R instrument

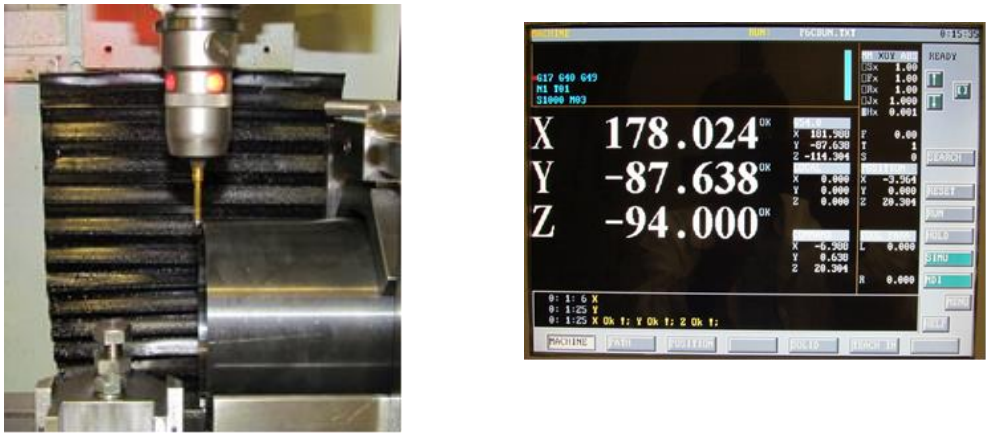

Figure 49: Measurement of the pressure tube coordinates using the „Point Finder”

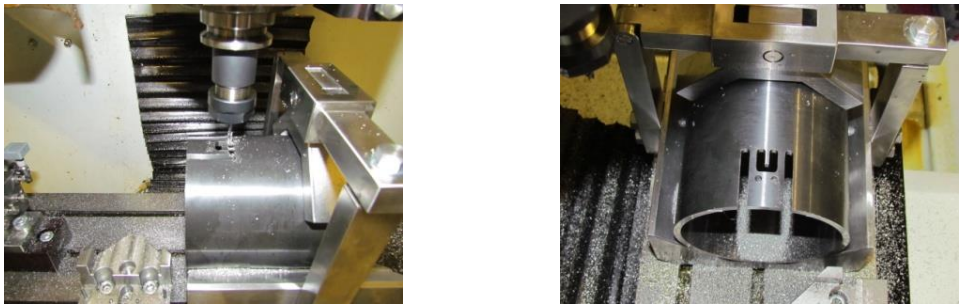

Figure 50: Separation of the CT sample from the pressure tube fragment

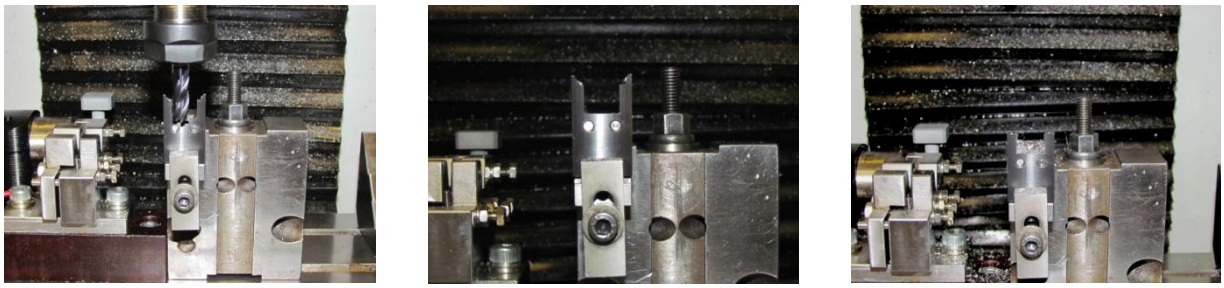

Figure 51: Adjustment of the sample surfaces

- In order to manufacture the notch, the CT sample is placed horizontally in „The notch preparation device”. In the first step, the channel of the central crack is made, using a disk mill with a diameter of 80 mm and the thickness of 1.5 mm. The second step consists in achieving the profile with the angle of 60° at the tip of the crack, using a profiled disk mill (Figure 52).

Figure 52: Notch preparation

Results

After all this mechanical procedures, the CT sample out of a CANDU pressure tube fragment is ready (Figure 53).

Taking into account the recommendations of ASTM 399 (Figure 54), the pressure tube dimensions and the specific work conditions, we obtained a specimen with the following specifications: specimen width = 20.4 mm, crack depth = 11 mm, specimen thickness = 4.1 mm, angle between the crack flanks = 60°, total length = 30 mm, diameter of the mounting holes = 4.25 mm, distance between mounting holes = 9.36 mm, the radius at the tip of the crack = 0.08 mm.

Figure 53: CT sample manufactured out of non-irradiated CANDU pressure tube

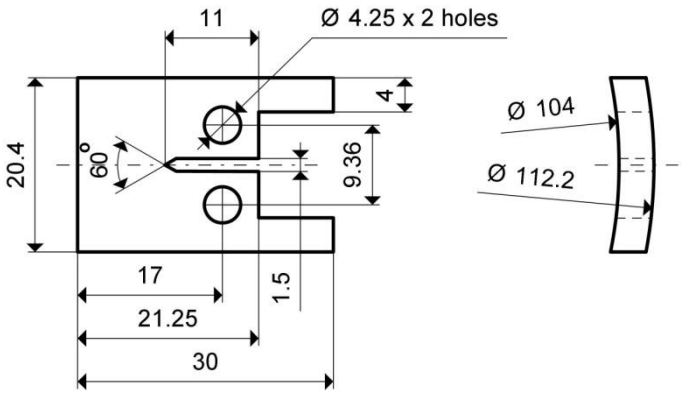

Figure 54: CT sample ASTM 399

The CT samples were obtained out of non-irradiated CANDU pressure tube fragment (made out of Zirconium-Niobium 2.5 %). For this purpose, mills and cutting conditions fitted to the Zirconium-Niobium 2.5 % alloy, precision tools for dimensional measurements („Device for measuring tools", „Point finder"), dedicated devices („The fastening device", „The adjustment device" and „The notch preparation device") were used. The CT samples manufactured in this way correspond to the technical specifications of the standard ASTM E 8M and ASTM E 399.

The milling machine will be installed into a heavy concrete hot cell and will be used to prepare CT samples out of irradiated CANDU pressure tube fragments.

References

ASTM E 8M. Standard Test Methods for Tension Testing of Metallic Materials. 2015. ASTM E8/E8M-15a.

ASTM E 399. Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness KIc of Metallic Materials. 2012. ASTM E399-12e3.

Dyna 4M – Machine control & Programming Manual

DM1007, EM3116(A) & DM2800 – Operation & Reference manual

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TS27R tool setting probe. Renishaw, 2006. H-2000-2171-05-A.