A CNC milling machine in NRG's Hot Cell Laboratories

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Abstract

Preparations are in progress to install a new milling machine in the NRG's hot cells facility in the course of this year.

The milling machine is CNC controlled and adapted for use in a hot cell environment. Special arrangements are made to comply for this purpose. Since a number of components are not fully resistant to radiation, the machine is wheeled allowing it to be removed from the hot cell if not needed.

Some technical specifications from the various manufacturers will be discussed which finally lead to the selected supplier. Primarily, this only concerns the flexibility of the total equipment to adapt for remote control and not the general technical aspects of the equipment.

The machine will be used mainly to manufacture mechanical testing samples from irradiated materials, obtained from both welding experiments and other irradiated components. Special auxiliary tools are made for this purpose to facilitate the machining of the samples. Next, the convenience to program the system for machining mechanical testing samples to meet the specified requirements is also important.

Before installing the equipment in the hot cell a try out is performed to evaluate the system.

Keywords: Hot Cells; milling machine

1. Introduction

The milling machine in the hot cell facility is particularly used to dismantle irradiation capsules from the HFR. The requirement with respect to the machining capacity and the quality has increased over the years. They are not restricted to dismantling activities, but extended to the production of parts, which have to comply with certain specifications and standards. The possibility to machine test samples obtained from in-service material can be used to verify radiation degradation of material under operational conditions.

Preparations are in progress to install a new milling machine in the NRG's hot cell facility that can comply with present days standard. The milling machine is CNC controlled and adapted for use in a hot cell environment. To minimise the radiation load the machine is wheeled allowing to remove it from the hot cell when the machining campaign is finished.

The selection procedure was discussed, which finally lead to the selected supplier. Primarily, this concerns the flexibility of the total equipment to adapt it for remote control.

The machine will be used to manufacture mechanical testing samples from irradiated materials, obtained from in-service irradiated components and welds made from irradiated plate.

In this respect a number of NRG-projects is involved, for instance the reweldability studies in the frame of the Interweld programme and the European Fusion Technology Programme.

Special auxiliary tools are made to facilitate the machining of the samples. Next, the ease of programming the system to meet the specified requirements is also important.

Before installing the equipment in the hot cell the system evaluation has been carried out.

2. Machine selection procedure

2.1. Main selection criteria

The selection procedure started by contacting a number of potential suppliers. Each is asked to specify their machine capabilities in comparison to our specifications. A number of aspects related to the use of the machine in a hot cell environment are compared, like:

- Compact size. The aim is to find a small size milling machine, which can easily be placed or removed from the hot cell. Another reason to find a small milling machine is that the objects to be machined are limited in size (test specimens).
- No plastics. Moving parts for instance guide ways, wedges and certain parts in ball circulating screws are often made from plastics and often applied today in these types of machines. Average activity levels of 2000 TBq occur in the hot cells, and these materials can therefore not be used.
- Coolant. Certain materials have to be cooled during machining. The use of coolant depends on the machining speed. Therefore, emphasis has been given to the specified speed ranges of the manufacturer.
- General machine specifications. Since the machine will be used to manufacture small size mechanical testing samples, the clamping table can be limited in size. The working range in three directions, maximum table load, speed range, total weight, minimum input accuracy and machining accuracy and program memory are specifications, which have been reviewed.
- The ease to modify the electronics. This is one of the main aspects in the review. To use the machine under remote control conditions, electronics have to be separated and cables to be extended. Extension of cables may not influence the performance of the machine. The number of cables and connectors, and the ease to modify the system is one of the main criteria.
- The user friendliness of the control software.

2.2. Pre-selection

Based on these information and explanations four suppliers are selected to prepare an offer. At the end the decision is made for the KUNZMANN UBM-2 (Germany) milling machine in conjunction with a HEIDENHAIN TNC 407 controller. The main reason is that limited modifications on this machine have to be introduced for use in a hot cell and practically all critical components are made of materials that are relatively well resistant to radiation, or can easily be replaced to become more resistant.

2.3. Final selection considerations

Compared to other reviewed milling machines the KUNZMAN UBM-2, including the HEIDENHAIN TNC 407 controller, has the following features:

- All plastic components in the guide ways for the adjustable table and X-Y-Z movements are replaced by steel, including the plastic wedges, which is the main modification on the machine. These wedges are used to minimise the clearance in the guides. This also counts for the bearings of the ball circulating screws, including the nuts. Normally the balls are separated using nylon or comparable materials;
- The selected machine has the highest electric power at the desired (as low as possible) machining speed. A minimal use of a coolant is therefore needed resulting in a reduction of contaminated waste. Comparable machines show higher speeds at high power, resulting in a power reduction when speeds are being reduced. Next, the electronic speed control module is easy to remove from the frame to reinstall it outside the cell;
- The electronic measuring encoders, the Heidenhain LIDA 101C, for the X-Y-Z movements of the table are better resistant to radiation. This sealed incremental linear encoder operates on the so-called "*.... photoelectric quasi-one-field-scanning principle of a Diadur grating on metal (instead of glass) in transmitted light. Movement of the scale relative to the scanning reticle generates 2 sinusoidal signals phase-shifted by 90° and a reference mark signal....*". Combined with the use of the newly developed special interface, high resolution can be obtained. Long cables up to 150 m and high frequencies till 500 kHz (normally 30 m and 160 kHz maximum) can be applied without any influence on the resolution. Thus, this type of scanning allows measuring steps of 0.1 μm, where 0.5 μm is normal.
- The control software is similar to the existing machine, which is used outside the cell. Besides, the language is well-known in the workshop and elsewhere within NRG and therefore internal experience and support is available.

3. Machine specifications and modifications

3.1. Machine specifications

The milling machine is a CNC type, which stands for Computerised Numerical Control. More specific the machine is a TNC (Typed Numerical Control) system. This means that the operator directly types his program into the controller.

Some technical specifications are:

Working range	X-axis: 200 mm Y-axis: 150 mm Z-axis: 200 mm
Clamping surface	500 x 180 mm
Max. table load	80 kg
Main drive	Three-phase servo motor, 1 kW
Speed range	0-4000 rpm, continuously variable, 2 switch steps
Speed control	Analogue
Control adjusting time	24 ms

Cycle time of the control circuit in position control	6 ms
Program memory	128 Kbytes
Minimum input	1 µm
Weight	600 kg

3.2. Modifications

Normally, machining equipment is designed to be used in workshops and not in a relatively hostile environment, like highly radioactive hot cells. Therefore, the operation and a number of components have to be adapted for remote handling. On the machine only one part is modified namely the plastic wedges to minimise the clearance in the guidances are replaced into metal.

Next, the following modifications are necessary:

- Separation of all electronics from the main frame, i.e. CNC part and control panel;
- Extension of all cables;
- Adaptations of auxiliary tools.

The machine structure is mounted on a frame, supplied with wheels in order to remove it after a campaign is finished. The wheels can be locked to assure the stability.

Special fixtures are designed for the machining of the various testing samples. Figures 1 to 3 show

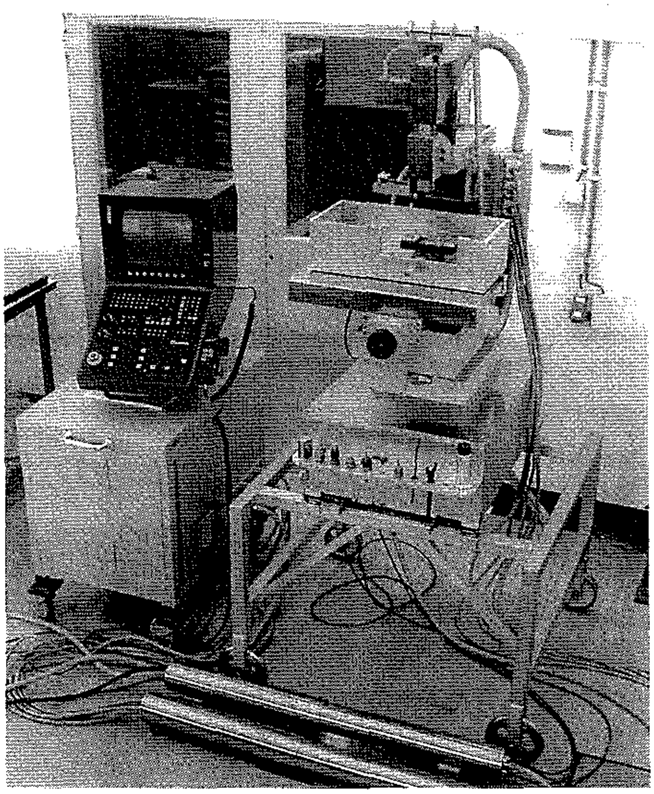

Figure 1 View of milling machine, including extended cables and frame

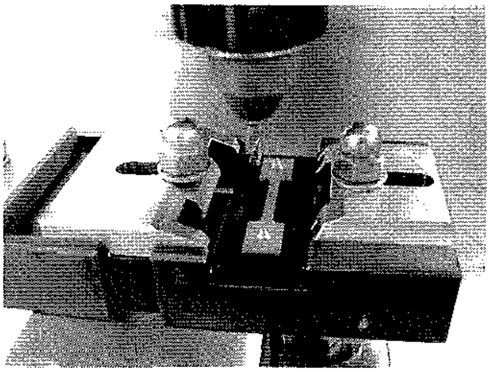

Figure 2 Clamping table for flat type tensile specimens

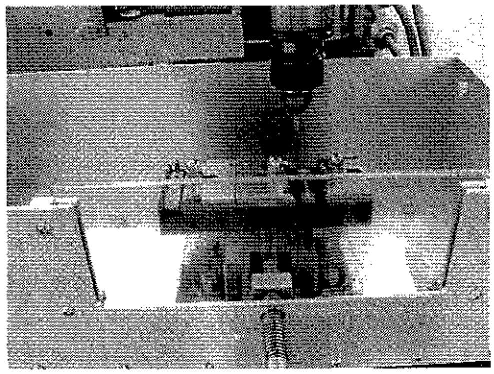

Figure 3 View on clamping table

some of these features.

4. Products

4.1. Materials

The main objective of the milling machine is the possibility to manufacture specimens for mechanical characterisation. In the frame of the re-weldability studies emphasis is given to welded components. The specimens have to be machined from specific locations in the weld-HAZ-plate material structure. This requires a dedicated shielded fabrication facility to machine high quality test specimens from the irradiated materials.

Next, samples from irradiated components in case of surveillance or other ageing related programs are needed. The materials involved range from austenitic stainless steels, ferritic-martensitic steels, like the modified 9-12% Cr-steels, and aluminium alloys.

4.2. Specimen types

The mechanical characterisation is performed by tensile tests, fatigue crack growth (FCG) experiments and fracture toughness tests (FTT). Therefore, various types of specimens are involved.

Tensile tests will be done mainly on flat type specimens, whereas the FCG and FTT experiments are performed with compact tension (CT) specimens. Their dimensions are shown in figure 4.

In case of welded materials the position of the sample with respect to the welded joint is very important. Therefore, etching techniques are used to visualise the weld before positioning the material in the milling machine.

4.3. Results of preliminary tests

During the test period a number of aspects are evaluated. One of the main aspects is the user friendliness of the software program. The basic programming language is developed by the manufacturer and supplied as a black box. Programming a machine sequence is based on the principle of question and answer. In this way all necessary requirements with respect to dimensions, shape, tolerances, and type of tool can be entered. Dimensions are given as nominal values and the first results show that the tolerances achieved are within ±0.02 mm. This is well within the requirements for mechanical testing samples.

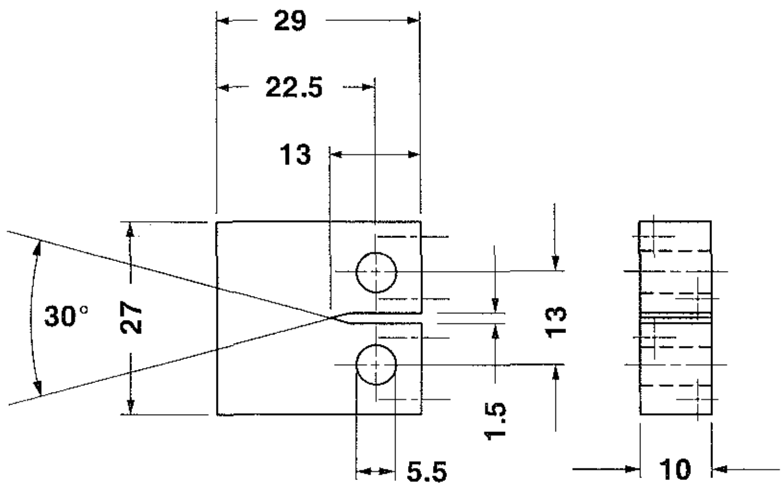

Figure 4 Compact tension specimen

Roughness measurements are not yet performed. However, the expectation is that again the requirements will be met.

The obtained machining coolant mass during the test period has not been measured yet. The applied speeds and materials (stainless steels and ferritic-martensitic steels) were machined with a limited amount of coolant and therefore not yet representative for hot cell operation conditions.

4.4. Production of a flat type tensile specimen

The machining sequence for the flat type tensile specimen is given as an example. The material in the example is a welded joint and pre-treated to fit in the machining template. The material form is then 50 x 10 x 1 mm. In the template the first sequence is to drill the two holes. Then the material is fixed in another part of the template, where half of its shape is formed. After this, the plate is turned around so that the other half can be machined. Finally, the definite profile of the sample is obtained. From the dimension measurements the tolerances are well within the specifications. Figure 5 shows this sequence.

5. Status and prospects

With the introduction of the new milling machine in the hot cell the machining capacity under remote control conditions becomes more advanced. A variety of testing samples can now be fabricated from irradiated components in order to obtain more realistic mechanical properties of materials irradiated under operational conditions. Thus, plant life extension studies can be performed in a better way, more reliable data for plant surveillance programs, and data to verifying the radiation degradation models, can be obtained.

Potential customers have already shown interest to determine the mechanical properties of used reactor vessel and internal materials. Next, reweldability studies and reconstitution of test samples are of interest.

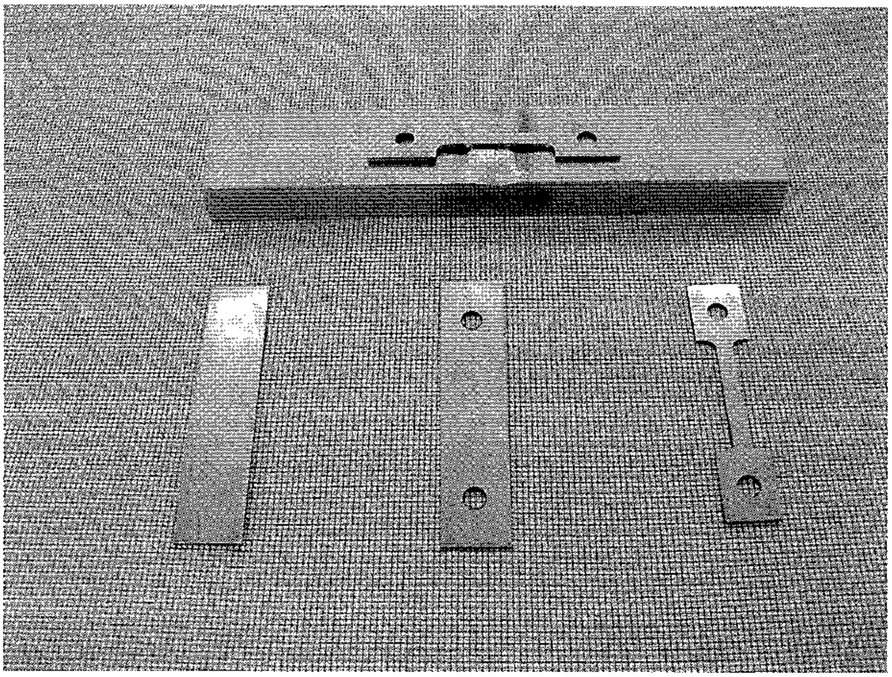

Figure 5 Various steps to produce flat type tensile specimens

At this moment the performance of the machine is assessed by a number of tests. First of all, the programming characteristics are evaluated and followed by machining real specimens. The auxiliary tools are tested on their remote control capability and usefulness. The program is checked iteratively. Displacement commands (X-Y-Z directions) are measured and compared with the effective results.

It is intended to install the machine in the hot cell by the end of this year.