Flexural-hinge micro-positioning device for synchrotron experiments

Flexural hinges are used more and more in microsystem technology. Recently, the Néel Institute's technical services (SERAS) were requested to manufacture and to simulate the behaviour of a compact positioning device to be dedicated to an X-Ray beamline at the European Synchrotron Research Facility (ESRF), Grenoble. The purpose of this assembly is to position a sample in the X-Ray beam with an isotropic precision of a few microns. It is mounted on a robotic manipulator, which is part of a bench for transfer of crystal samples to the goniometric head of an X-Ray diffractometer. The main technical challenge of the system lies in a hardened steel part of complex shape.

For precision microsystems, mechanical functions such as guidance and positioning need to be reconsidered in order to operate without friction. The flexural hinge ("*charnière*") or "flexor" satisfies this requirement. But, although this technology has been known for many years, detailed information about its implementation is relatively scarce. Among the available solutions, the "circular notch" shown in the insert of Fig. 1 offers many advantages. The mechanical part is bent elastically around its thinnest section - the hinge. There is no friction (so no lubricant needed), and no backlash ("*jeu*"). The monolithic hinge requires no assembly, the device can be very compact and very precise.

The multiple hinge positioning mechanism described here (Figs 1 and 2) was requested for the French beamline for Investigation of Proteins (FIP- BM30A) at the ESRF. Its purpose is to give the final position of the sample in the X-Ray beam. The fixed part of the hinge (tinted green in Figs 1,2) is mounted onto a robotic arm ("GRob") which gives the coarse position. Two, linear, stepper-motion, piezo-actuators drive displacement of the moving part of the hinge (pink in Figs 1,2) over a 5 mm diameter area with micron precision. The moving part is equipped with a pneumatic device which attaches the sample holder. The plane of movement (horizontal in the photos) is vertical in the experiment, so a very strong part is needed to support the hanging weight of the sample holder.

Based on the ESRF's design, the goals of our participation were to check the technical feasibility for machining the main flexor component, to manufacture the first prototypes and to carry out numerical simulation to optimize the design. The design required a hardened steel part of complex, articulated shape with 16 hinges (Fig. 1). This component was to be machined with an Electrical Discharge Machine (EDM) process, leaving a 100 micron thickness of steel for each of the hinges. Extensive tests and three prototypes were necessary to work out the operational procedure and to achieve the geometrical specifications.

The other main problem is the high mechanical properties of the 100Cr6 alloy used (yield strength 2200 MPa after heat treatment), incompatible with the hardness of standard tooling, especially for machining the tapped holes. The following manufacturing process in four phases enabled us to obtain a part satisfying all the requirements: (1) outline contouring, drilling and tapping of holes; (2) hardening heat treatment to achieve the required tensile properties (yield strength, hardness); (3) final surface grinding to reach the tolerance on the part's surfaces and thickness; (4) outline and section machining of the 16 hinges with the EDM process. In phase (4), approximately 30 machining programs were necessary to realize the final flexor part (Figs 1 and 2). It represents 70 hours of cutting.

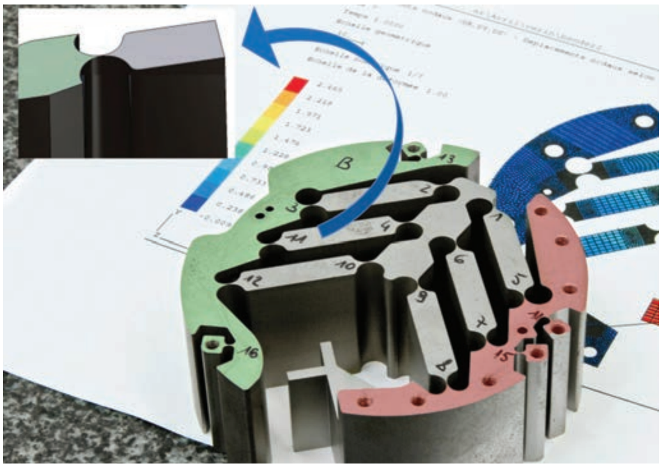

Figure 1: First prototype of flexor part at end of phase 4, before assembly (fixed part tinted green, moving part tinted pink). Insert at top left shows detail of a circular notch. In the background a plot of the finite elements model of the displacement field.

In tests of the first prototype, metal fatigue occured after a relatively small number of cycles. Finite element calculations were performed to understand the strain mechanisms, to determine the stress areas and to give recommendations for a new design. Due to local yielding these calculations were necessarily non-linear. The recommendations were to increase the overall thickness (height) of the part from 15mm to 30mm, and to change the design and position of the tapped holes and the mechanical stop clearance.

This work involved J-L. Ferrer and M. Terrien (design) at the ESRF and P. Jacquet (machining) and V. Roger (calculations) at Néel Institute. The machining project ran for 8 months and is completed. Work is now focused on control and command aspects before the device becomes fully operational.

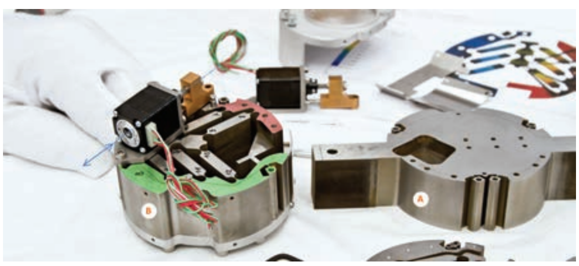

Figure 2: The final prototype of the Flexor during assembly, shown equipped with one piezoelectic actuator. At right, the metal part at the end of phase 2 (heat treatment).

CONTACTS

Philippe JACQUET
philippe.jacquet@grenoble.cnrs.fr

Emmanuel ROY
emmanuel.roy@grenoble.cnrs.fr