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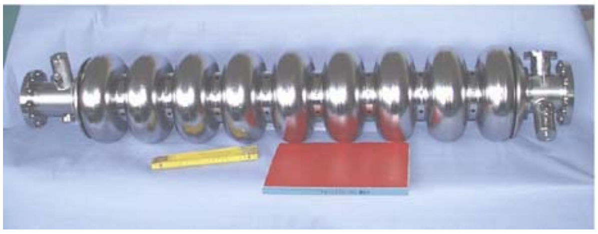

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Fabrication of multi-cell cavities by Spinning

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Abstract

The spinning process developed at INFN-LNL is an interesting seamless alternative among cavity fabrication technologies. A seamless tube is spun from a circular blank and then a multicell cavity is straightforwardly spun from the tube. The procedure is a cold forming process and no intermediate annealing is required. The actual procedure for prototype spinning foresees a fabrication rate on the order of one resonator per day, but it can be increased to several times that rate.

Acknowledgements

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1 Introduction

Seamless cavities can be cold formed by spinning a simple circular blank onto a suitable mandrel. The production rate can be as fast as one cell per hour. No intermediate annealing is required even for spinning of a multicell structure. The mandrel is made collapsible to permit easy extraction from the cavity once the spinning process is finished. The extraction of the mandrel parts from the cavity generally takes a few minutes, depending on the complexity of the cavity shape.

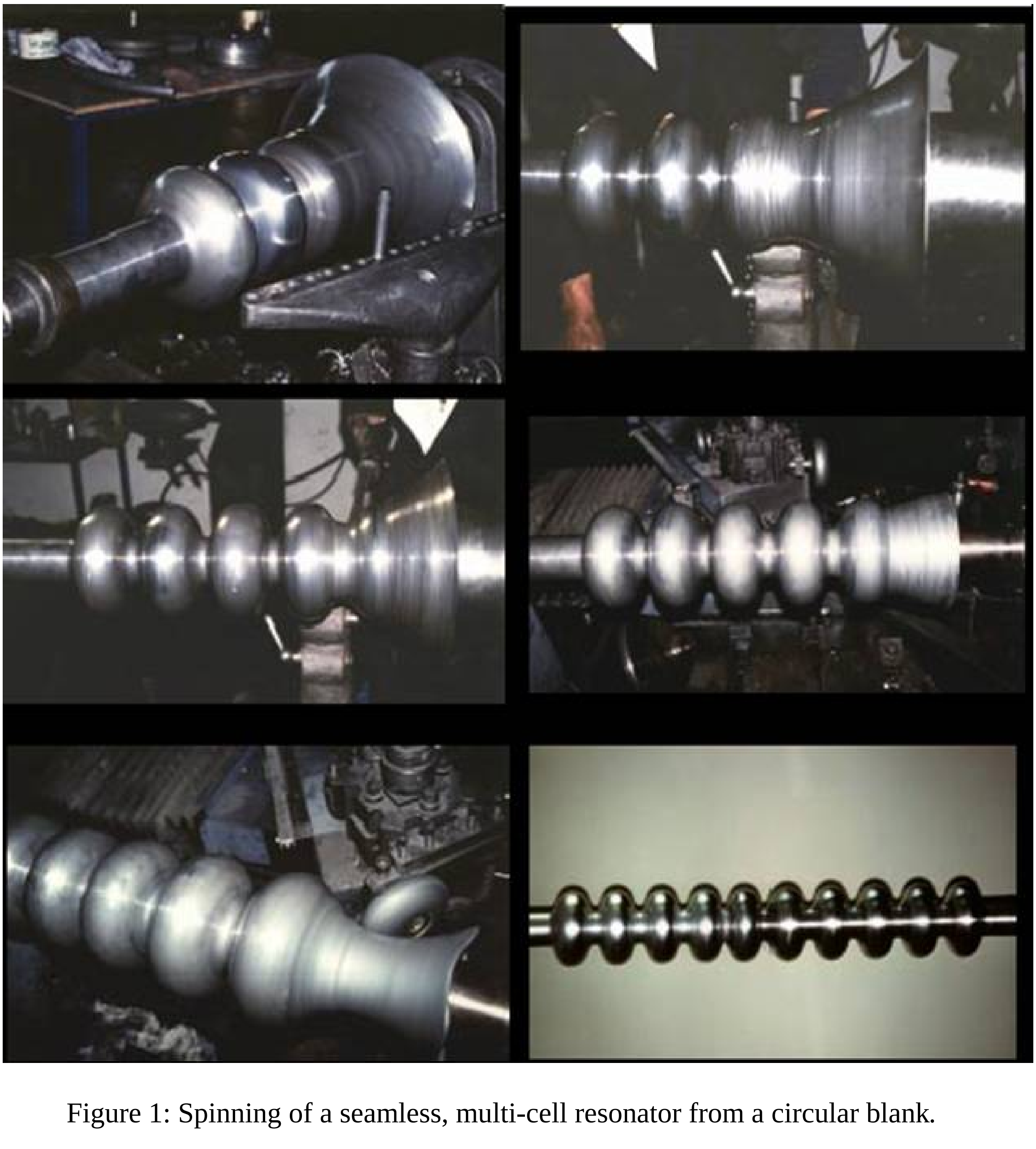

Figure 1: Spinning of a seamless, multi-cell resonator from a circular blank.

The presence of an internal mandrel permits very tight tolerances. As a consequence, the resonant frequency distribution of spun cells has a low standard deviation.

The limiting parameter for all tube-bulging techniques, such as hydroforming or explosive forming, is the material elongation limit. At this limit fracture propagation occurs and will damage the cavity body. For spinning, the material elongation limit is of minor importance because the material is plastically displaced along all three dimensions. Moreover for the spinning process, both texture degree and grain size of the parent material are much less critical than they are for hydroforming. The spinning process has been described in detail in deliverable report 3.1.4.3 “Single cell spinning Parameters defined”. If a larger blank is chosen, a multi-cell cavity can easily be spun. Also in this case no intermediate annealing is required. Figure 1 shows the spinning of a multicell resonator spun from a 3 mm thick tube. This tube was fabricated by flow forming from a 12 mm circular blank. At the current state of technology we have successfully spun in total four multicell resonators, in detail 2 nine-cell and 2 three cell cavities.

1. The fabrication of a seamless tube for the subsequent spinning

Niobium seamless tubes are not commercially available today. The development of such tubes would be compulsory for the construction of 20,000 resonators.

In order to get seamless tubes suitable for the spinning process, we have developed three different methods:

- direct deep drawing
- reverse deep drawing
- forward flow-turning,

1.1 Direct deep drawing

Deep drawing_gives poorer tolerances when compared with flow-turning. But it is preferable for mass production because of the low costs and the reduced manufacturing time. For the deep drawing process, a circular blank is first drawn into a cup. It is then redrawn into smaller diameter parts as sketched in Fig. 2.

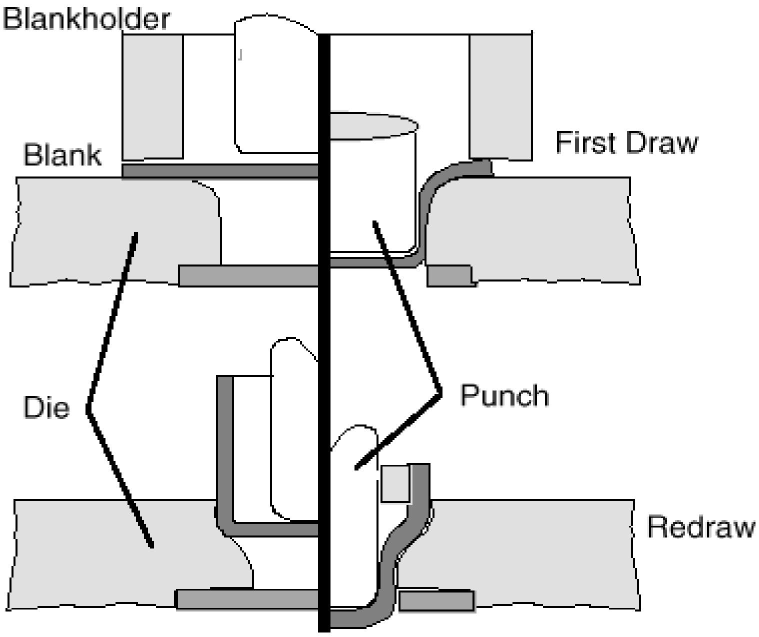

Figure 2: Direct Deep Drawing of seamless tubes from circular blanks.

Top picture: first drawing of a blank.
Bottom picture: Redrawing of the cup into a taller one with a smaller diameter.
The configuration on the left shows the arrangement before deep drawing. The configuration on the right shows the configuration during deep drawing. .

Seamless Niobium tubes (208 mm in diameter and up to 700 mm in height) were successfully deep drawn from 3 mm disks of 800 mm diameter. In the case of direct deep-drawing, four steps were needed and again no intermediate annealing was required (Fig. 3).

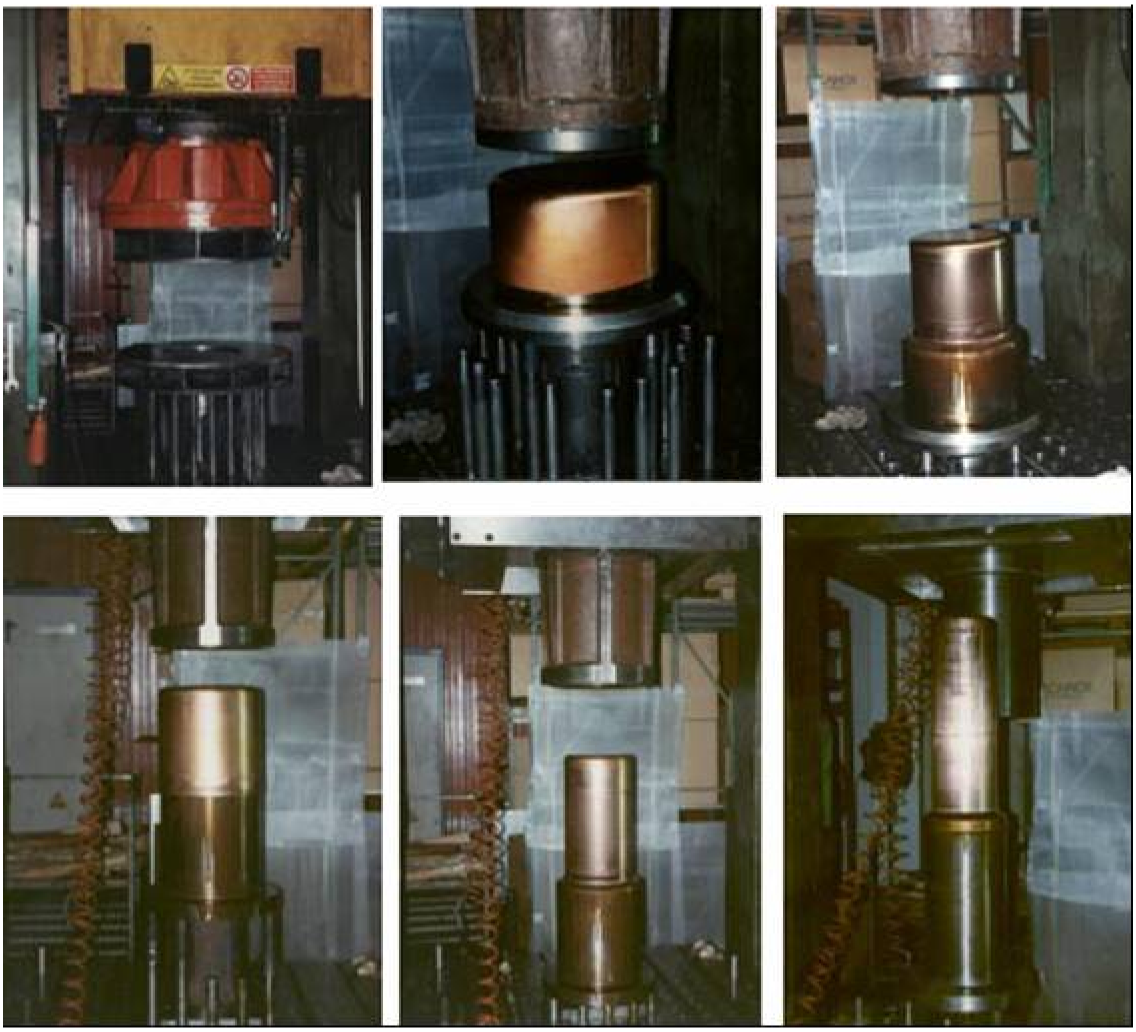

Figure 3: Direct Deep- Drawing of Seamless tubes from a circular blank. Tubes with heights of four times the diameter can easily be obtained without intermediate annealing.

In the author's experience, the only drawback expected in direct deep-drawing is the high roughness of the tube's internal surface. However, one can easily get rid of it by reworking the tube on a steel mandrel by flow-turning.

1.2 Reverse deep drawing

Reverse deep-drawing gives an internal surface with a sub-micrometric roughness. As seen in Fig. 4, the first operation in reverse deep-drawing is the same as in the direct deep-drawing process. The difference is in the redrawing steps: the punch pushes the tube from the bottom, with the difference that it is plugged externally to the tube rather than internally.

Therefore, after each redrawing, what was the external surface of the tube becomes the internal surface, and vice versa.

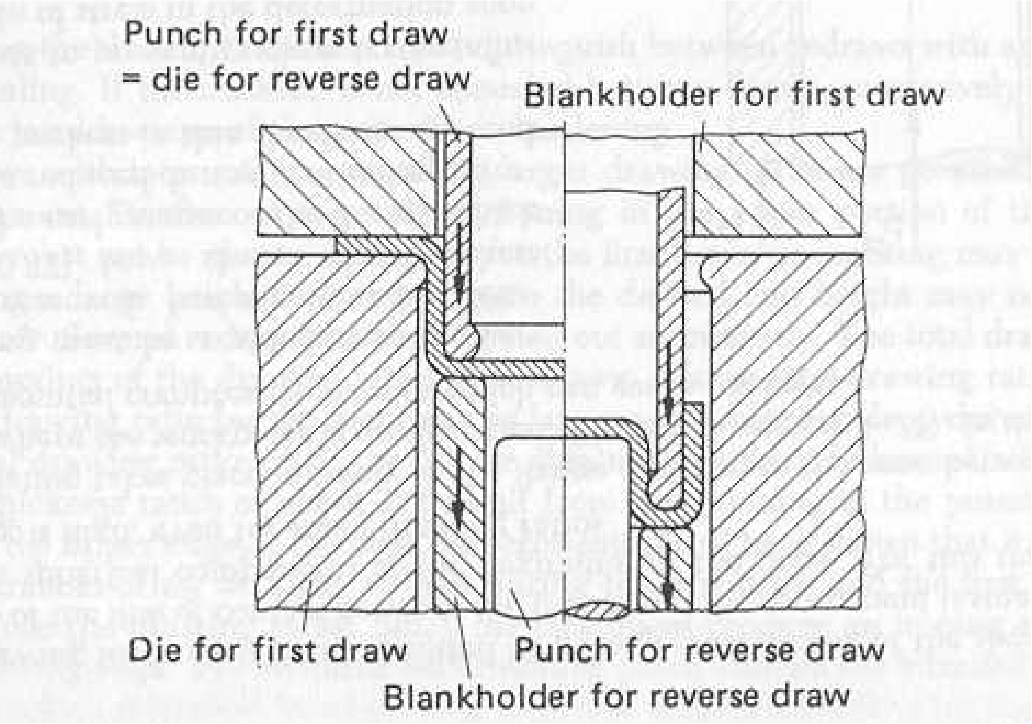

Figure 4: Reverse deep-drawing of seamless tubes. On the left it is displayed the configuration before drawing, while on the right is that during the operation.

The reverse deep-drawing operation is visible in Fig. 5. Copper and Niobium tubes have been drawn again without the need of intermediate annealing.

Figure 5: Reverse deep-drawing of seamless tubes. During each redrawing, the external surface of the cup to be drawn becomes the internal of the drawn part.

1.3 Forward flow turning

We have also produced seamless tubes by forward flow-turning. A circular blank of 8 mm thickness is preliminarily spun into a short thick tube. As second step it is ironed by three rollers onto a mild steel mandrel, as shown for the Copper part in Fig. 6. In just one pass, the pre-formed piece is transformed into a thinner and longer tube. With such a technique the material hardness is substantially higher in value than that obtained by deep-drawing. The thickness is uniform within a few hundredths of a millimeter. The internal roughness is sub-micrometric, depending on the degree of finishing of the mandrel surface onto which the tube is flow-turned. Finalla the tube is thinned by three roller spinning.

Figure 6: Forward flow-turning of seamless tubes. A short, thick tube is spun or drawn from a planar disc

Wall thickness uniformity is more consistent with the former, but in a certain sense it is not required for spinning a cavity.

With the present experience it is difficult to decide which of these techniques is most prommissing for mass production. In the author opinion the most favourable technique could be an initial deep-drawing of a thick blank followed by a wall thickness reduction to the desired thickness by forward flow-turning.

2. Lathe construction for multicell spinning

The new spinning machine for multicell is perfectly working and enables us to get a higher wall thickness at the cavity iris. Indeed, for long time, a thin wall at the cavity iris was representing a problem for seamless fabrication.

Fig. 7 shows the old spinning lathe used up to now for the fabrication of seamless cavities. The lathe turret supporting the rollers moved along an axis of about 45 degrees with respect to the spinning axis. The necking process works only for a half cell because the shear force was applied onto the spun piece by the roller only when this moves forward,. Therefore, the forming process foresaw that for every necking operation, the cavity had to be dismounted from the lathe headstock and be tilted. As consequence the turret could apply its force onto the opposite half cell which has remained untouched during the previous operation.

Figure 7: The spinning lathe used for the fabrication of seamless cavity prototypes. The lathe has only one turret which holds the rollers.

All the previous problems were solved by adding a second turret working in the opposite direction to the standard one, as shown in Fig.8.

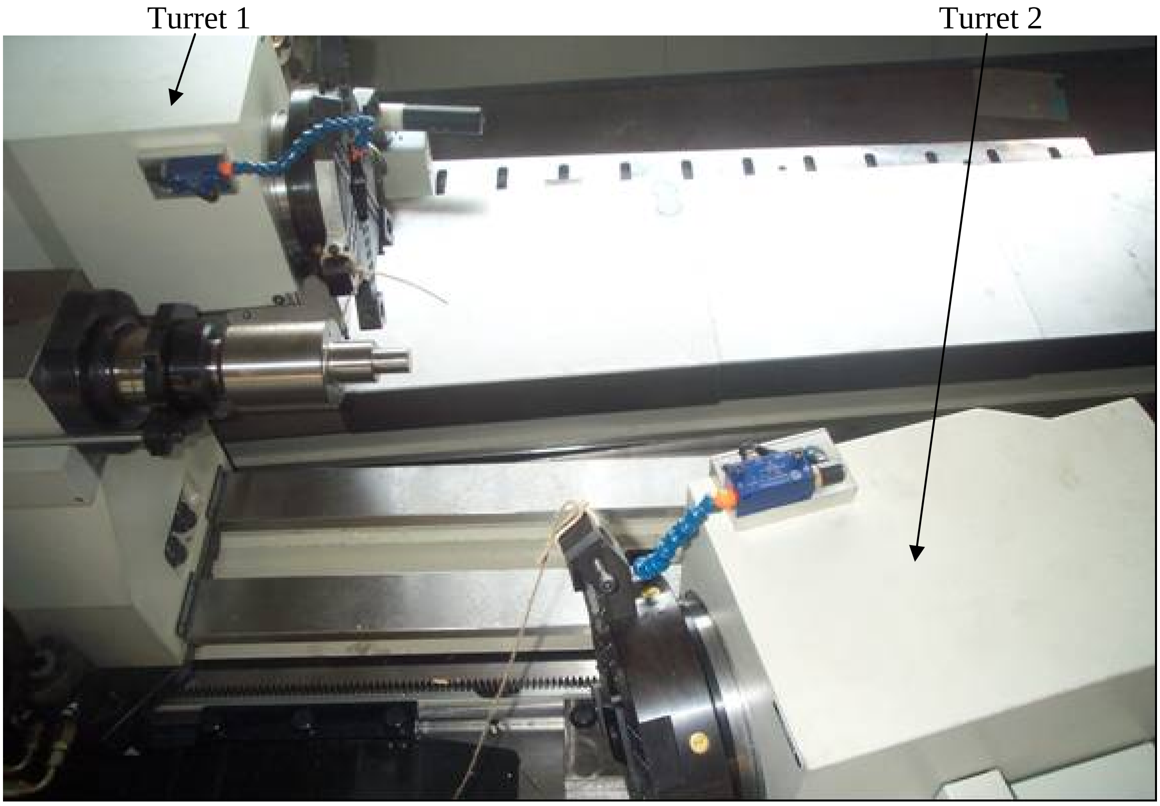

Fig. 8: The new spinning lathe with two turrets which hold the rollers. In this configuration, the rollers can work in opposite direction.

In this actual configuration, the cavity remains mounted onto the lathe during the whole spinning operation. But the operator has to move around the lathe depending on the half cell he has to spin. This makes the fabrication procedure shorter in time, less expensive and therefore easier to industrialize. However, working with two rollers needs further investigation of the spinning process. The spinning time is strongly reduced, but all the procedure parameters must be revised *ab initio*. The material wall thickness at all irises should never be smaller than the initial tube thickness. This is possible by a severe control of

- the roller working pressures,
- the spinning angular velocity,
- the roller feed speed
- and finally of the pressure between headstock and tailstock as displayed in figure 9

Fig. 9: Phase of the double turret necking process during the spinning parameter definition action.

3. Uniform thickness of multicell cavities

The procedure for getting a uniform thickness all over the cavity wall has been definitely set up. The trick consists in conjugating the spinning operation with the upsetting technique. In other words, the uniform thickness is obtained by increasing the pressure between late tailstock and headstock during spinning. Ore more simple: by shortening the overall length of the resonator during spinning enough material can be pushed to the critical iris region. This method permits a god wall thickness uniformity along all the eight irises and the nine neighboured equators, as sketched in the following picture.

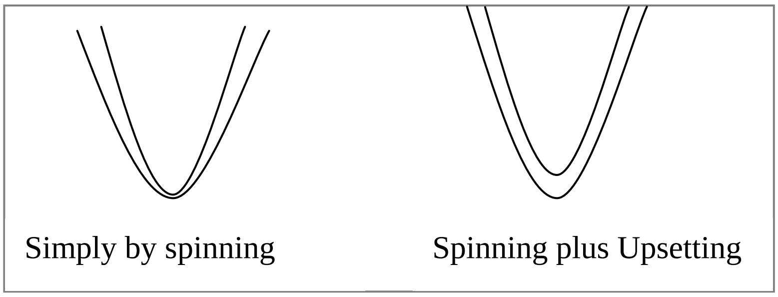

Figure 10: Upsetting has been the miraculous solution that has solved all the thickness uniformity problems.

However a problem appears in the two end half cells close to the cut-off tubes. Here this method is not applicable. There is indeed a narrow circle where the wall thickness is thinner and this is just in half cell to tube conjunction. Initially this problem was under-evaluated. It turned out to be very crucial when tumbling a multicell cavity (see figure 11). The thinner wall between half cell and tube was immediately consumed by the abrasive action of silicon carbide media so that the cavity was destroyed.

Fig. 11: The nine cell after the tumbling

Figure 12 sketches the reduction of wall thickness at the end cell to beam pipe transition.

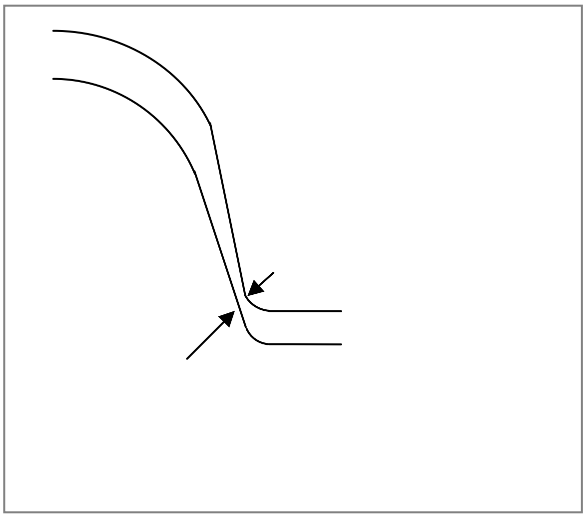

Figure 12: Thickness weakening effect at the iris

In order to solve this problem, we are currently building a further collapsible die to be added to the collapsible mandrel. The additional mandrel part has the shaper of a frustum and is shown in figure 13.

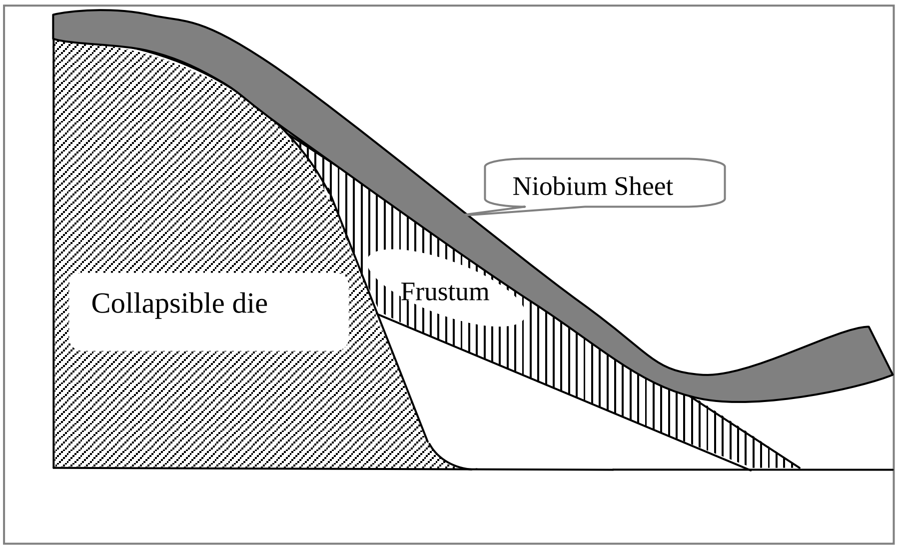

Figure 13: The addition of a second die (frustum) in order to avoid the thinning of the wall at the transition from end cell to beam pipe

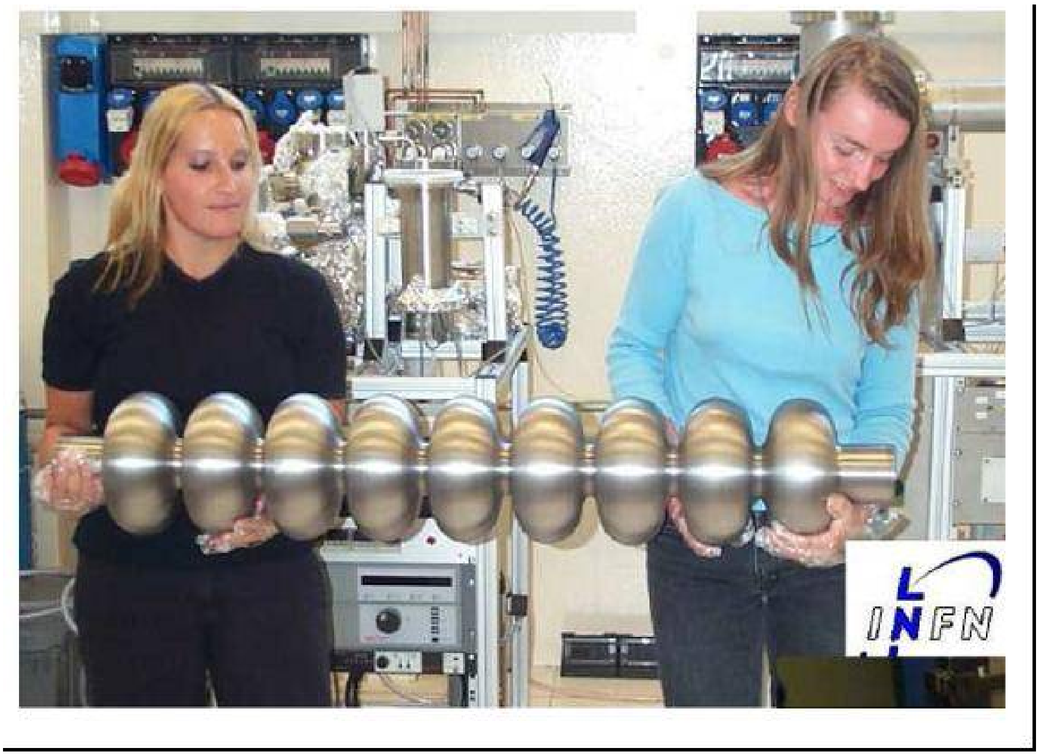

Figure 14 Niobium 9-cell cavity fabricated be spinning technology

CONCLUSIONS

Spinning technology offers a method to produce seamless cavities. Furthermore this technology promises low cost mass scale fabrication of resonators. Spinning resonators from seamless tubes is a technology that is ready to be transferred to industry.