Rotary sizing of tube and pipe on the mill

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Introduction

The sizing methods used on tube and pipe mills have not changed significantly in the past 40 years. However, the demand for product quality improvements at lower costs has pushed the current technology to its limits.

Now there is an alternative to the conventional sizing method. The Rotary Sizing Method (RSM – figure 1) is a method that provides improvements in dimensional accuracy, surface finish and operational control while reducing the capital costs and the operational costs. Consequently, the developers believe the method provides the next step forward in sizing technology for the tube and pipe industry.

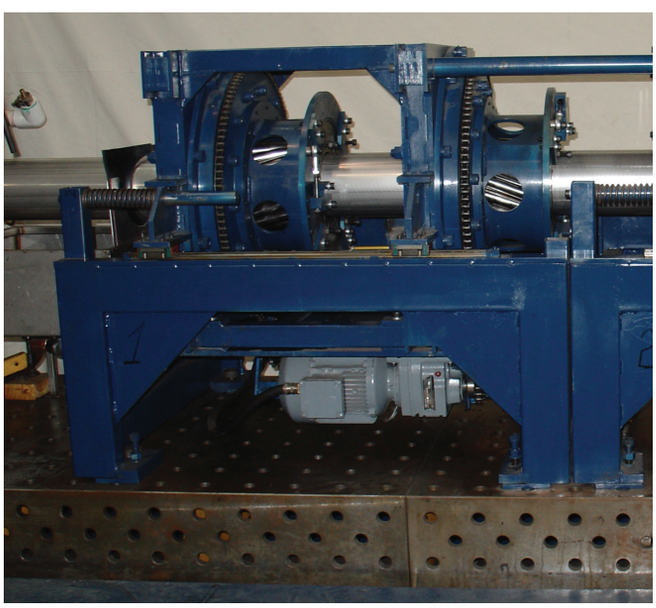


Figure 1: *Rotary Sizing Mill sizing 152mm x 2.0mm 304 stainless tube on a TIG mill in Australia*

This technology is new and covered by worldwide patents. There are currently four Rotary Sizing Mills in operation in Australia – three inline and one off-line. Three of the machines have been operating for at least two and a half years.

What is Rotary Sizing?

Rotary sizing consists of a cage of rollers that encircle the tube while at the same time being set at an angle to the axis of the tube, as can be seen in figure 2. The rollers are free to rotate and are not directly driven; the cage that contains the rollers is driven. The movement of the cage over the tube is the same as a nut over a thread, in that it is driven onto the tube and moves over the tube in a spiral movement.

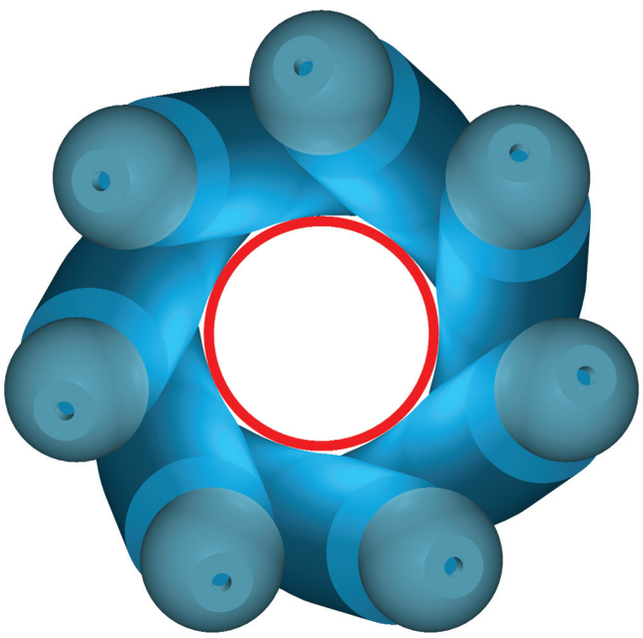


Figure 2: *End view of rollers encircling the tube and set at an angle to the axis of the tube*

The whole tube surface is evenly worked. The rollers are of a very simple design being parallel cylinders that are mounted in bearings in two end plates. By changing the angular relationship between the two end plates, the internal diameter of the rollers is changed. In figure 3, we can note that D2 is smaller than D1, which in turn is smaller than D0.

The two cages are mounted in separate carriages and each cage is rotated by a motor and gearbox that is mounted on the carriage. In the second cage the roller angle is set in the opposite direction and the cage rotates in the opposite direction. This is required to eliminate the torsion stress created in the tube between the welding station and the RSM if only one cage is used. The two carriages are rigidly connected and mounted on rails. The assembly of carriages, cages, motors and gearboxes are free to move on the rails in the same direction as the tube (figure 4).

When the cages rotate the carriages attempt to pull the tube forward and, depending on the speed of the cages and the speed of the tube, the carriages will move along the rails. A pair of springs is mounted between the carriages and the end stop on the weld station end. Using a linear encoder and a feed back loop to the speed controller for the drive motors, the carriage can maintain a preset tension in the tube between the welding station and the RSM.

Using this technique enables the tension in the tube between the weld station and the RSM to be controlled and maintained accurately. This results in the sizing drive being independent of the forming mill drive. The sizing drive will maintain the preset tension irrespective of tube speed or acceleration.

Adjustable diameter

One of the inherent features of rotary sizing is that the diameter created inside the cage of the rollers is infinitely adjustable between the upper and lower limits of the cage. Figure 3 shows the changing diameter due to the changing of the roller to tube angle. The range of adjustment can vary considerably from cage to cage as the cages are designed for a specific range of diameters, wall thicknesses and material yield strengths.

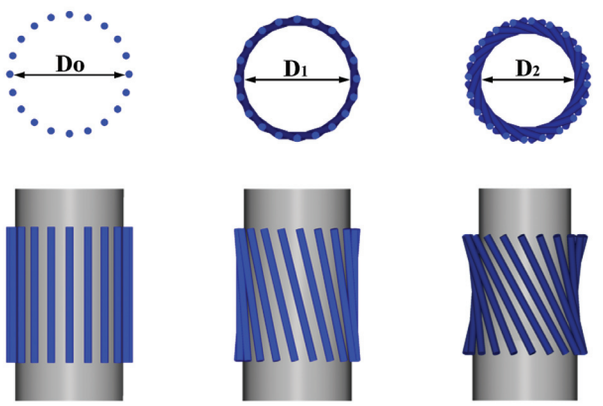


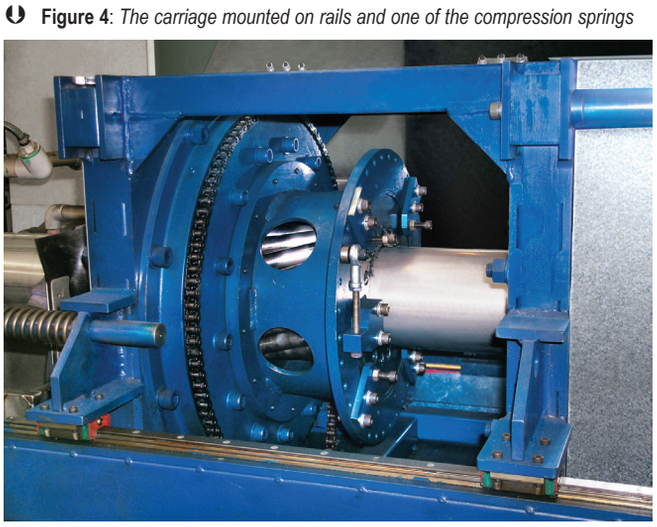
Figure 3: *Example of the effect of changing the roller angle on the internal diameter of the rollers*

The resulting advantage is that the amount of tooling required for the sizing section of the tube mill is drastically reduced because a pair of cages can size several diameters.

Precision diameter and roundness

The ability to adjust the tube diameter to the centre of the tolerance range is a simple matter of adjusting the roller to the tube angle. Added to this is the improvement in tube roundness and reduced diameter variation that the RSM provides. For example, a TIG mill making 70.0mm x 1.5mm 409 stainless tube, achieved a size range of 0.08mm with a sample standard deviation of 0.018mm. These results were from a sample of 40 tubes measured in 4 positions: 0°, 45°, 90° and 135° (figure 5); there were 160 measurements in total. An example of this is displayed in figure 6.

Figure 4: *The carriage mounted on rails and one of the compression springs*



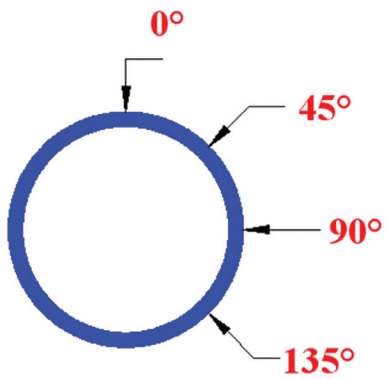


Figure 5: *Tube measurement positions*

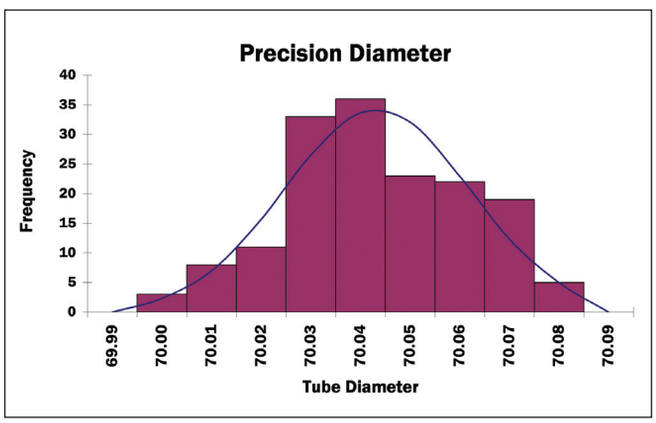


Figure 6: *Precision diameter*

The improved diameter accuracy and roundness is maintained throughout the life of the rollers. There is no deterioration in accuracy as the rollers wear.

Surface finish enhancement

The surface speed difference between the rollers and the tube is very small – approximately 0.5 per cent. This is in comparison to conventional tooling where the speed differential can be in excess of 20 per cent. Roll marks and damage from pick up on the rollers are totally eliminated. This benefit is further enhanced by the fact that the original strip surface roughness has been shown to improve by 30 per cent.

The surface finish of 316 stainless steel 1.6mm thick – measured using Ra, Rz and Rzj – improved in all measures by at least 30 per cent

Ra improved from 0.5825µm to 0.4325µm:	35 per cent
Rz improved from 3.535µm to 2.6312µm:	34 per cent
Rzj improved from 2.33µm to 1.777µm:	31 per cent

Ra = arithmetrical mean roughness;
Rz = maximum peak to valley;
Rzj = ten point mean roughness

Trials were also carried out on the following material with the following results:

Hot dipped galvanised pipe, 2.8mm thick (sized off-line)

Ra improved from 0.383µm to 0.161µm:	58%
Rz improved from 4.057µm to 2.649µm:	35%
Rzj improved from 2.592µm to 1.372µm:	45%

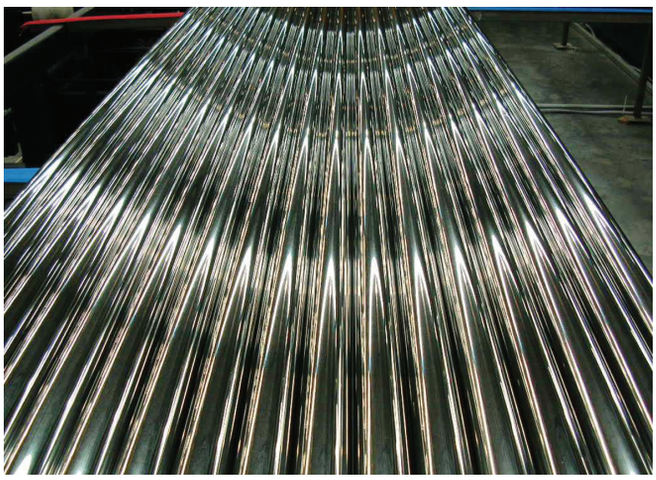


Figure 7: *RSM sized and polished tubes*

Black Steel Pipe, 3.2mm thick

Ra improved from 2.272µm to 1.518µm.	33%
Rz improved from 14.685µm to 12.122µm.	17%
Rzj improved from 11.352µm to 7.57µm.	33%

Seamless stainless pipe, 3.6mm thick (sized off-line)

Ra improved from 1.388µm to 0.209µm.	85%
Rz improved from 10.390µm to 3.510µm.	66%
Rzj improved from 6.475µm to 2.114µm.	67%

Please note: the improvement on the black strip was not as good as would be expected. This is explained by the scale from the strip forming a boundary coating between the rollers and the tube.

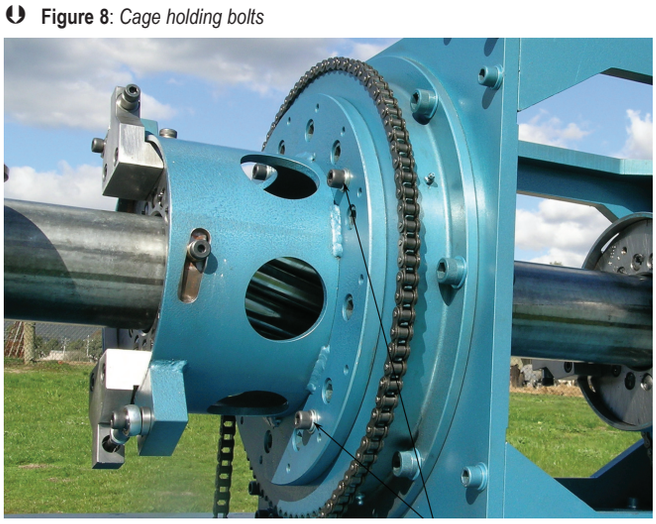
On rougher original surfaces the improvements are greater. In the case of black strip the scale has to be washed out to stop it blanketing the tube and reducing the surface improvement.

The quality and the value of the product are improved at no additional cost to the manufacturer. Therefore, post-polishing costs are reduced.

Quick-change tooling

Changing diameter on the Rotary Sizing Mill takes two forms.

Figure 8: *Cage holding bolts*



1. If the diameter change is within the range of the fitted cages, the only action required is to change the angle of the rollers to the tube. This form is faster than any other known method of sizing roll change.

2. If the new diameter is outside the range of the fitted cages then the cages have to be changed. Two cages have to be removed and replaced

This would typically involve loosening four bolts per cage and the use of a crane to lift out the cages and fit the new ones. The time taken is similar to a traditional raft change. More sophisticated systems could be developed if faster changeover times were required. The cage in figure 8 is for a manual adjustment off-line machine.

Even and smooth sizing action with reduced residual stress

The tube that is processed by the Rotary Sizing Mill is evenly worked. Any point on the tube is subjected to a very similar deformation. The cage of rollers may contain many rollers but only a few rollers in each cage will come into contact with any one point on the tube.

Each roller provides an increasing amount of deformation to each point on the tube. The sizing action is further enhanced with the two cages rotating in opposite directions and the rollers making a criss-cross path over the tube. The cold working of the tube is reduced and is evenly distributed over the whole surface of the tube. The result is a tube that is less stressed and has greater remaining elongation available for post forming operations such as flaring, bulging, bending and hydroforming.

Energy savings

The results of trials have shown that the RSM mill uses 50 per cent less power than a conventional mill to achieve the same result. This is due in part to the reduced friction between the tube and the tooling as the speed mismatch is almost eliminated.

On a tube mill making a tube 200mm x 6.0mm, sizing the tube by 2mm and running at 40m/min, the kW saving can be 100KW. At Euros 0.10 per kW hour, the saving can be Euros 10 per running hour. Running 8 hours per day by 240 days per year equates to a saving of Euros 19,200 per annum.

Reduced machine size

The RSM's footprint is considerably smaller than the conventional tube mill. The motors and gearboxes are mounted onto the carriage. The transmission is through a commercial gearbox and the output rotates the cage using a chain or gear drive. This reduction in size is the result of reduced power requirements, with only two drive inputs required compared with a conventional sizing mill where there are six inputs required using twice the power.

There are no universal shafts, roll shafts, distributor gearboxes and tooling spacers. The whole RSM will fit within the sizing mill base

of a conventional tube mill. The only exception is in very large mills where the motor gearbox may be separate.

The space saving advantages of the RSM is further enhanced by the reduced amount of tooling that has to be stored.

Reduced tooling costs

The roller design is a simple parallel roller that is easy to manufacture and recondition on simple tool room equipment. Figure 9 shows the simple roller design.

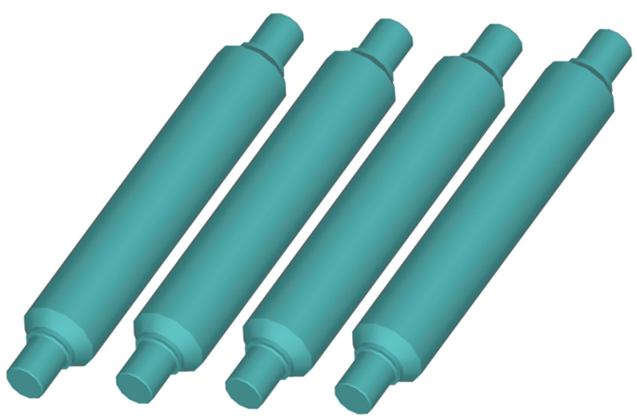


Figure 9: *Rotary sizing mill rollers*

As the roller wears, the quality and precision of the tube does not deteriorate – an advantage over the conventional sizing method. Checking roll wear is a simple matter of measuring the roll diameter. The greatest advantage is in the reduced amount of tooling required.

For example, comparing a conventional mill with a size range from 30-100mm and tooling for 30 diameters, the number of roll pieces is reduced from 300 to 76, a saving of 224 rolls. That is, 224 rolls that do not have to be purchased, stored, checked and controlled.

The 76 RSM rollers are contained within 10 heads so there are only 10 heads to be monitored, checked and maintained. This is similar to having dedicated rafts for each tube size. Due to this, RSM does not require roll spacers. Another bonus is that, with the RSM, any diameter between 30-100mm can be made with no additional sizing tooling.

Lower capital costs

The cost of purchasing the RSM and tooling is considerably less than the conventional sizing section. Although it is difficult to generalise, for the larger tube mills the savings on the equipment can be as high as 70 per cent while the saving on a smaller mill is less at around 40 per cent.

Figure 10 shows the cost comparison between a conventional tube mill sizing section and the RSM. The conventional mill cost is 100 per cent (blue) and the RSM cost is shown comparing equipment only, ie excluding tooling, all cages and rafts on both mills (maroon) and also equipment including tooling, all cages and rafts for both mills (yellow).

Lower operating costs

Operating costs are reduced in many areas.

1. Energy savings
2. Floor space saving due to smaller footprint
3. Space saving due to less tooling and no rafts
4. Tooling replacement cost less
5. Tooling maintenance cost less
6. Changeover times less
7. Reduced scrap on set up
8. Less scrap from roll marks and pick up
9. Less scrap from diameter tolerance issues

Design capabilities of RSM

There are five main criteria for determining the design of the Rotary Sizing Mill. They are tube diameter, diameter range, wall thickness, yield strength and mill speed.

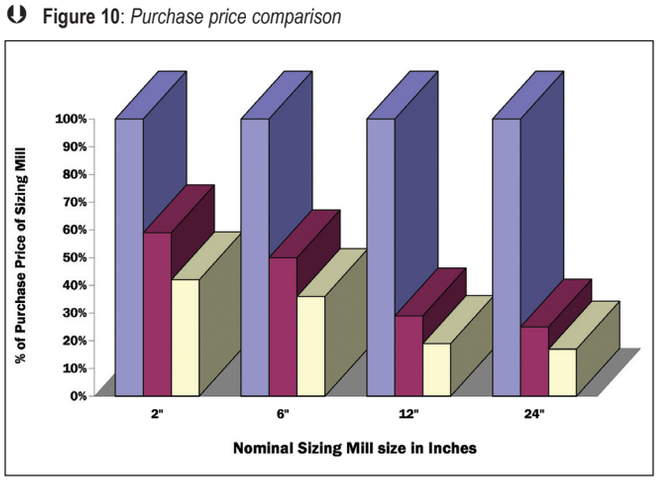
Analysis of the tube diameter, wall thickness and yield strength are required to determine the number of rollers and the size of the rollers required. The diameter range that the cage is required to cover is also taken into account at this point.

The mill speed is important because there is a limit to the rotation speed of the cage. As a rule of thumb, the cage moves along the tube one diameter for every revolution of the cage. Therefore, high-speed mills making small diameters are outside the operational limits of RSM. In these situations Kusakabe recommend the Modular Sizing Mill – a driven three roll sizing stand.

The recommendation by Kusakabe is that the RSM is suitable for all high-speed ERW mills above 100mm and all TIG, laser and slow speed ERW mills above 30mm. For high-speed tube mills below 100mm the Modular Sizing Mill (MSM) is the most suitable.

The outside diameter capabilities of the RSM are currently limited to the range of 30-650mm. Larger diameters are not an issue, although diameters less than 30mm are possible within a small range of wall thicknesses, yield strengths and mill speeds. Wall thicknesses are currently limited to 0.8-16mm. Wall thicknesses outside this range are possible in limited situations with some loss of flexibility.

Figure 10: *Purchase price comparison*



Advantages of operational engineering

The Rotary Sizing Mill offers some very promising improvements in tube mill control that have been difficult to achieve in the past.

1. It is possible to control the tension in the tube between the welding station and the Rotary Sizing Mill accurately. This is a standard feature on all inline installations of the RSM. For inline annealing applications this tension control can be designed to be very accurate.

2. The sizing adjustment can be achieved while the mill is running and the possibility exists to install closed loop control of the tube diameter.

3. Weld seam position control is possible by controlling the torsion induced into the tube between the welding station and the RSM. The possibility exists to install closed loop control of the weld seam position.

4. The manufacture of section or profiled tube is possible due to the tremendous amount of thrust that can be exerted by the RSM. The force that can be applied may be restricted by the column strength of the tube, in which case driven shaping stands may be required.

Installation and retrofitting RSM

Due to the Rotary Sizing Mill being smaller and using less power, it is easier and cheaper to install into new installations. The footprint and foundations are smaller and the electrical connections smaller. Furthermore, the drive and electrical controls are completely independent of the forming mill.

Where the RSM is replacing an existing sizing mill it can fit onto existing mill beds and even on to mill rafts if required. This type of installation can be carried out in a very short period of time due to its total independence of the RSM from the forming mill.

Off-line applications

The Rotary Sizing Mill offers opportunities in off-line operation where tubing can be rectified, with different size tube for a tighter diameter tolerance. Alternatively, the tube can be sized to diameters that are not economical to run on a tube mill. Larger reductions in diameter can be achieved by passing the tube through the RSM several times.

Summary of benefits

1. Adjustable diameter
2. Accurate and precise adjustments
3. 30 per cent improvement in surface roughness
4. Quick change tooling without the cost
5. Tube material smoothly and evenly worked
6. 50 per cent power consumption saving
7. In excess of 50 per cent space saving
8. Reduced tooling cost and simple design
9. Reduced tooling maintenance cost
10. Less tooling and easier to control
11. Lower purchase cost – up to 70 per cent
12. New diameters easily catered for
13. Precise tube tension control
14. Possibility to control weld seam position
15. Lower installation costs
16. Very fast retrofit times
17. Off-line applications exist

About the company

Kusakabe Electric & Machinery Co Ltd is the innovative supplier of choice to many tube and pipe manufacturers around the world, with tube and pipe mills and associated equipment in 26 countries. Kusakabe was founded in 1916 and built its first tube mill in 1960 and has grown and developed in both product range and technical sophistication in conjunction with the tube and pipe industry in Japan and abroad.

The capability of tube and pipe mills has improved due to Kusakabe's continued commitment to research and development. Kusakabe now offer tube and pipe manufacturers a vast selection of tube and pipe mills and associated equipment. The company's sizing mills range includes rotary sizing, modular sizing, roll cassette sizing, rotary turret sizing in addition to conventional sizing. Rotary sizing offers manufacturers the opportunity to provide their customers with a higher quality product at a lower cost.

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