

High Speed Shearing of Stainless Steel Tube

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Introduction

Today's tube producers in North America, Europe, and Japan are constantly under pressure by the end users to improve quality and performance while reducing cost. The automotive industry is continually increasing demands on stainless tube producers to increase the life expectancy of exhaust components. Recently, the life expectancy for exhaust systems has increased from 3-4 years to at least 5-7 years.

The greatest cause of tubular exhaust system failure has been attributed to condensate corrosion and thermal fatigue. Therefore, tubing utilized for the exhaust systems is constantly increasing in strength and corrosion resistance. Common forms of stainless steel, being produced to meet these increasing demands, are ferritic stainless steel 409, aluminized 409, Armco 18-18Cr-Cb, and austenitic stainless steels.

The use of tubing produced in today's automobiles contains more than 12kg of stainless steel tubing as well as approximately 30m of tube greater than 12.5mm diameter. The control of material and production costs for austenitic (300 series) and ferritic (400 series) stainless steels are extremely important for the success of tube producers.

In order to stay competitive, stainless steel tube producers are eliminating non-value manufacturing operations. The high-speed dimple free shearing of austenitic and ferritic stainless steels is a direct means of reducing manufacturing cost for a tube producer. The utilization of the dimple free flying shear process enables tube mills to cut stainless steel to length and eliminate the non-value added operations of re-cutting.

The Shear Cutting Process

The shear cutting process has been optimized to enable stainless steel tubing to be cut dimple free with minimal burr, cut to length accuracy within $\pm 1\text{mm}$ and high cycle rates. As tube mill producers continue to reduce the steps in the manufacturing process, the benefits of shearing tube to length will provide a competitive advantage. The benefits of shearing tube to length on the mill enable the tube producer to manufacture the lowest cost tube due to:

- Reduction of the number of steps in the manufacturing process.
- Elimination of non-value operations and tooling associated with re-cut centres.



Figure 1: 409 SS exhaust components (photo courtesy of Calsonic, North America Inc)

1 per cent scrap on a tube mill producing ferritic 409 stainless steel at 300,000m/month costs about \$50,000/month.

Re-cut operations produce 2-4 per cent scrap.

- Less in work inventory and faster delivery schedules
- Increased return on company assets

Double Cut Dieset Technology

Cutting tube to length on a stainless steel mill requires the shear to operate at speeds of 40-70ppm for ferritic stainless steels and 15-30ppm for most austenitic stainless steels. Recent advances in double cut dieset technology have enabled mills to produce stainless steel tube dimple free right off the mill. The process yields tubing at high parts per minute that is dimple free with minimal burr.

The double cut dieset utilized for shearing stainless steels is high strength and precision that results in very reliable operation (see figures 2 and 3). The tooling used to shear the tube consists of a vertical blade, horizontal broaching blade and jaws to hold the tube.

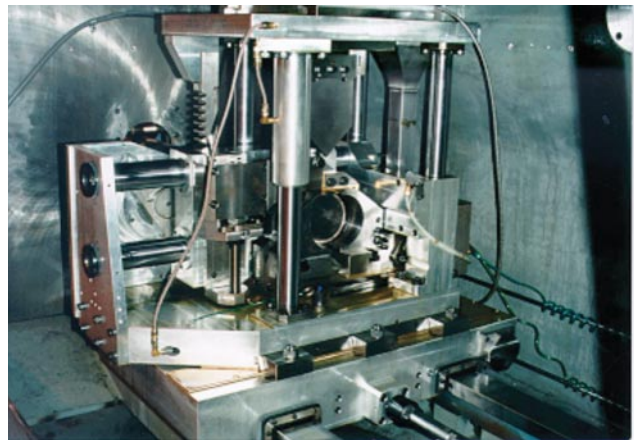


Figure 2: Double cut dieset (photo courtesy of Thermatool)

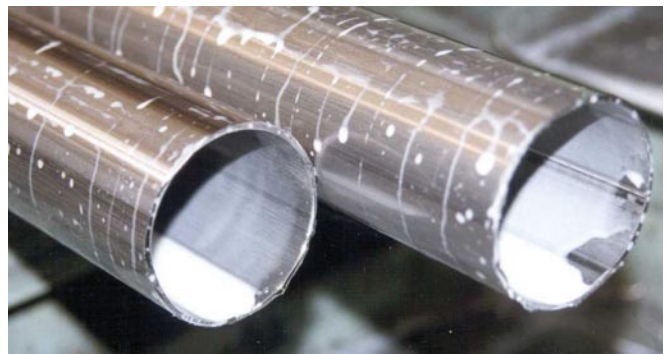


Figure 3: Ferritic SS409 shear cut tube 62.5mm OD x 1.66mm wall

The tooling has been designed to accommodate the 'quick change mill' principles and can be changed in approximately 10-15 minutes.

The shear cutting process has been refined to accommodate the increasing demands of ferritic and austenitic stainless steels. The major system components vital to the shearing process include the flying shear press, accelerator, and the dieset and tooling. The flying shear press configuration is a vital part for successful shearing of stainless steel tubing. The flying shear needs to have a very reliable, simple structure along with a low inertia drive mechanism that utilizes radial bearings.

Linear press bearings have not exhibited the reliability demanded by today's tube mills. The output of a modern ferritic stainless steel mill can produce over one million tubes a month when producing at a rate of 60ppm over two shifts a day.

In addition, the press design utilized for stainless steel is longer in length than traditional presses due to the fact that lower ram speeds are needed to slow the velocity of the cut. The lower shearing blade velocity results in an optimized cut and improved tooling life.

The ac dieset accelerator utilized on a cut to length flying cutoff needs to incorporate a low inertia motor coupled with a low backlash rack and pinion. Cut to length accuracy is dependant on synchronization of the accelerator dieset velocity, position control and press actuation with the tube velocity. This process results in a tube cut to length within an accuracy of ± 1 mm.

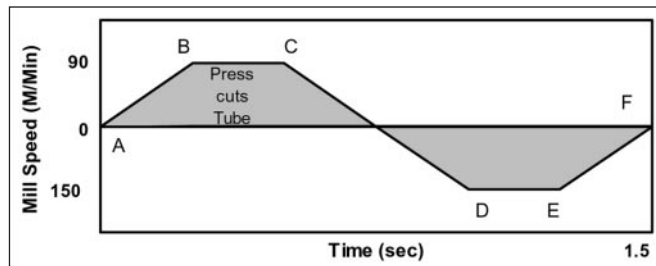


Figure 4: Velocity profile for one shear cut cycle

The shearing cycle depicted in figure 4 describes the events that take place to complete one cut. The cycle shown in this figure is for a complete cycle time of 1.5 seconds, which corresponds to a production rate of 40ppm.

The cut to length process initiates with the double cut dieset in the home position (A). The system motion controller sends a velocity signal proportional to the tube speed to the dieset accelerator motor drive that sends a signal to the dieset accelerator motor (B). Upon reaching the speed of the tube, the dieset position is adjusted via input to the controller from the dieset position encoder(C).

The mechanical press ram is actuated downward via energy transferred by a flywheel and hydraulic clutch. The tube is double cut with the dieset (D). Upon completion of the cut, the press ram returns to the 'top dead center position' a confirmation signal is sent to the system controller via a position encoder (E).

The system controller then completes the cycle by commanding the dieset accelerator to return to the home position and get ready for the next tube to be cut.

Optimizing the Shear Cut Cycle

The shear cutting cycle of stainless steel is greatly improved with the development of variable shearing velocity capabilities, improved lubrication methods, and shearing blade materials and coatings. The cut quality of stainless tubing is greatly enhanced when the velocity of the shearing blade is reduced. Typical ram cutting speeds for low carbon steel have been in the range of 200-220rpm. Whereas optimum ram speeds for ferritic stainless steels are in the range of 100-120rpm and 40-80rpm for austenitic stainless steels.

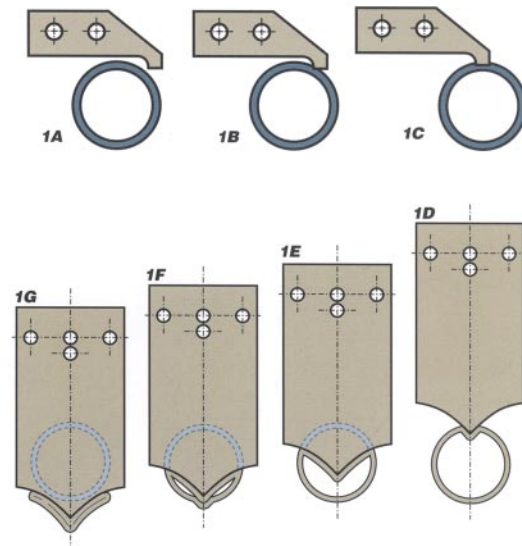


Figure 5: Double shear cut blades

This cutting speed reduction decreases the press flywheel speed, which in turn reduces the available energy for the shear. It is due to this reason that the flying shear press is properly sized to operate at low cutting speeds and still provide adequate energy to shear the stainless steel tubing. Operating the high speed flying shears at these optimum rpms results in typical mill outputs of 40 to 60 cut tubes per minute for ferritic stainless steels and 15-30 tubes/minute for austenitic stainless steel.

Lubrication of the vertical and horizontal cutting blades is essential to ensure maximum blade life and cut quality. The lubrication process utilizes a mineral-based oil that will dissipate the heat away from the blade.

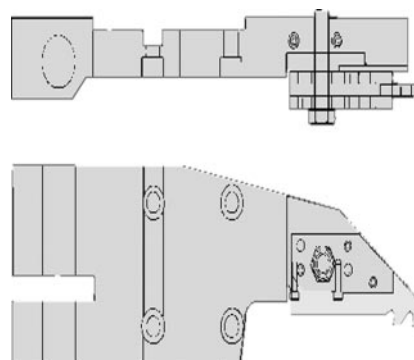


Figure 6: Two tip scarfing blade

The majority of the heat generated in shearing stainless steels is transferred to the blade, whereas, for low carbon steels, more heat is transferred to the slug (chip). The lubrication of the cutting blade occurs slightly before each cut cycle and continues for at least 0.500 seconds.

Tooling:	Ferritic SS		Austenitic SS	
	Tube wall < 0.075 in	Tube wall > 0.075 in.	Tube wall < 0.075 in	Tube wall > 0.075 in.
Vertical blade tip configuration	Radius	110 degrees	Radius	70-90 degrees
Horizontal blade tip configuration	Single	Single	Two	Two
Vertical blade to jaw clearance	10%	15%	20%	20%
Horizontal blade scarfing depth	50-75 %	50-75%	75-80%	75-80%

Table 1: Tooling parameters to dimple free shear cut stainless steel

This results in less than 5 gallons of blade lubricant utilized per shift for a high speed flying shear operating at 40-60ppm. Proper blade lubrication will dramatically improve the blade life by more than a factor of two when compared to a non-lubricated blade. In addition to the use of lubricants, some austenitic stainless steel mills have utilized a cold air vortex nozzle directed at the blade to aid in the removal of heat from the blade.

Cutting blade materials and coatings also have a significant influence on effective shearing of stainless steels. The development of high-speed cutting steels such as M2 and ATSiII combined with a coating of TiN (Titanium Nitride) have greatly enhanced the life expectancy of the vertical and horizontal blades. Proper heat-treating and flatness control of these high-speed cutting materials is extremely critical to the success of high speed shearing.

Typical blade life expectancies for ferritic stainless steels is approximately 8,000 to 12,000 cuts per blade and approximately 1,000-2,000 cuts per blade for austenitic stainless steels. The ferritic stainless steels such as 409, aluminized 409 and Armco 18 Cr-Cb have UTS in the range of 60-75 ksi (414-517 MPa), whereas, the austenitic stainless steels can be as high as 94 ksi (650 MPa) UTS. The ferritic stainless steel shears more like a low carbon steel when compared to the austenitic stainless steels.

The austenitic stainless steels exhibit high elongation combined with relatively low yield strength. This combination of material properties results in more tooling wear for shearing of austenitic stainless steels when compared to ferritic stainless steels. Further development and testing of blade materials such as powder metallurgy high-speed steels combined with recent advances in two-step coatings (hard base coat and lubricating top coat) have shown promise for future gains in tooling life.

The selection and set up of tooling for shearing of stainless steel is dependent on the type of stainless steel as well as the size and shape of the tube. The ferritic stainless steels such as 409, aluminized 409 and Armco 18Cr-Cb are most effectively sheared with the following tooling: vertical blade with a radius tip geometry combined with a single tip horizontal blade. To ensure proper slug flow, the spacing of the vertical blade to the dieset jaws is optimized with a gap of 10 per cent of the tube wall thickness, per each side of the blade.

The austenitic stainless steels are most effectively sheared utilizing a vertical blade with a radius blade tip combined with a two-tip horizontal broaching blade (See figure 5). The vertical blade to jaw clearance for shearing austenitic stainless steels is optimized with a gap of 20 per cent of the tube wall thickness. The scarfing depth of the cross cut broach has a significant effect on the ability to shear

tubing dimple free. Table 1 summarizes the key parameters to effectively shear stainless steel.

Conclusion

The high speed-flying shear cut of stainless steel tubing results in significant cost savings and improved schedule deliveries when compared to non-value added secondary operations.

In today's demanding and consolidating market, process simplification is a competitive advantage that will differentiate the industry leaders from the rest of the tube mill producers.

References

"High-Speed Shear Cutting of Stainless Steel Tube" by Mick Nallen, Thermatool Corp, East Haven, CT, USA and Peter Bond.

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