OPTIMIZATION OF THE CUTTING CLEARANCES FOR PLATE EDGES QUALITY IMPROVEMENT IN THE SHEAR LINE OF THE GERDAU OURO BRANCO PLATE MILL*

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Abstract

In recent years, the market for thick plates has been highly competitive, in this scenario the plates quality is a critical success factor. In this process, the quality of the cut in thick plates is one of the important requirements for the customers, by the visual aspect as well as the technical aspect of the plate application. In the shear line, the cutting is done by shearing to trim tips, subdivide plates, trim side edges, remove samples, eliminate defects, etc. The cut is obtained by the penetration of the upper knife in the plate, causing plastic deformation in a certain region and hardening. If the clearance between the knives is adequate, the cracks will be close to the centre of the plate thickness and will result in a good cut quality. This work will present the theory of cutting of thick plates, the types of shearing, the quality of the edge in the cut, the types and the main characteristics of the knives.

Keywords: Quality plate; processes management; cut; clearance between the knives, continuous improvement.

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1 INTRODUCTION

In the plate mill manufacturing process, one of the steps of the process is the cutting to give width and length to the product. This can be by a mechanical process, using shears or oxyfuel.

Shear Line is the sector responsible for the mechanical cutting process of thick plates. This step cuts as-rolled plates, the product of rolling, into plates, and is important to ensure compliance with the standards specification of products and customers.

The quality of the cut in thick plates is one of the important requirements of quality, by the visual aspect as well as the application of the plate. Understanding the phenomenon that occurs in a cutting process is important for the production process, aiming the maintaining of the good condition of the equipment and cutting.

2 OURO BRANCO PLATE MILL SHEAR LINE

The layout of Ouro Branco Plate Mill Finishing Line can be seen in Figure 1.

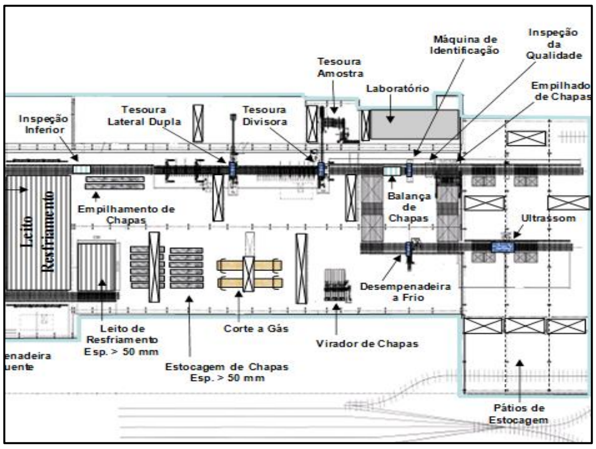


Figure 1: Ouro Branco Plate Mill Finishing Line Layout.

The Ouro Branco Plate Mill Shear Line is composed of 3 shears: Double Side Trim Shear, Dividing Shear and Test Piece Shear. The shears feature a high level of automation and tracking control.

DSTS – Double Side Trim Shear:

The Double Side Trim Shear is responsible for performing the lateral trimming of the as-rolled plate to the objective width of the plate. Figure 2 shows the shear image. In Table 1 and 2 are the technical specification and cutting capacity, respectively.

Figure 2: Double Side Trim Shear.

Table 1: DSTS Technical Specification

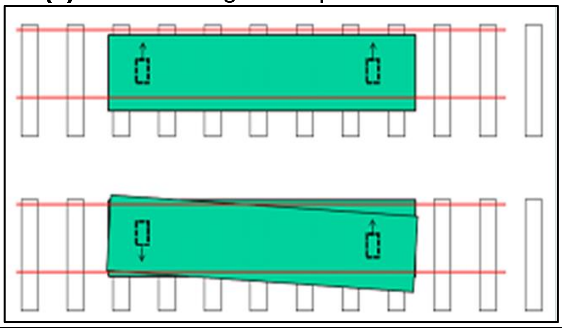
SHEAR TECHNICAL SPECIFICATION	
Cutting force	6.500 kN
Cutting time	2 s
Maximum stroke	1.300 mm/stroke
Cutting rate	Up to 30 cuts/min
Minimum scrap width	20 mm or 1,5 x thickness
Maximum scrap width	150 mm

Table 2: DSTS Cutting capacity

CUTTING CAPACITY – PLATE DATA	
Thickness	5 to 50 mm
Width of uncut plate	1000 to 3.700 mm
Width of cut plate	900 to 3.600 mm
As-rolled length	6.500 to 50.000 mm
Yield Strength (up to 40 mm)	1.200 N/mm²
Yield Strength (up to 50 mm)	750 N/mm²

The as-rolled processing is initiated by loading clearance and positioning data from the shear block to the target width. Next, the operator performs the alignment, aided by two laser lines and by magnetic positioners, Figure 3a and 3b.

(a) As-rolled alignment process scheme.



(b) As-rolled alignment aligned between the lasers.

Figure 3: Initial step: as-rolled alignment.

The knives used in the DSTS are prepared by the Cylinder Workshop team. These are mounted on supports and as they are sharpened, they are fitted with shims to compensate for the size of the set. Figure 4 shows an assembly scheme and in table 3 the specification can be seen.

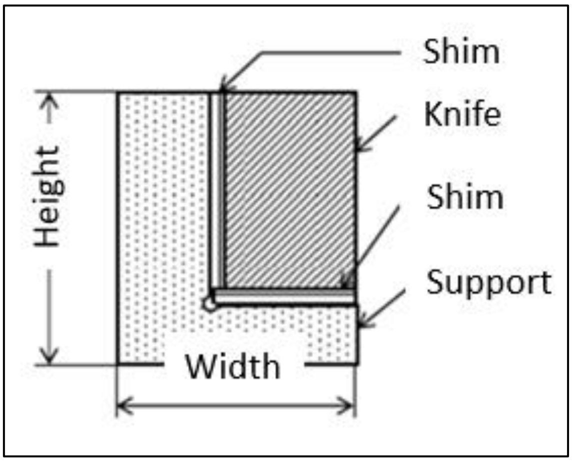


Figure 4: Scheme of cutting knife assembly.

Table 3: Knife Technical Specification.

KNIFE TECHNICAL SPECIFICATION	
Length (top/bottom knife)	approx. 2.080mm
Radius (top knife)	9.500mm
Cutting edges (top knife)	2
Cutting edges (bottom knife)	4
Life expectancy	10.000/grind

DS – Dividing Shear:

The Dividing Shear is responsible for dividing the as rolled into the target length of the plate and generating the strip that will give rise to the mechanical test sample.

The cutting plane is defined by a cutting optimizer. This level 2 system treats the measurement data performed by the PSG (Plate Shape Gauge) meter and defines where the shear should make all cuts. In Figure 5 the Diving Shears can be seen. Table 4 shows the specification data.

There are two length measuring systems: laser and roller meter. The operator selects which system to use.

Figure 5: Dividing Shear.

Table 4: Dividing Shear specification

SHEAR TECHNICAL SPECIFICATION	
Cutting force	16.000 KN
Cutting time	Approx. 4,5 s
Maximum scrap length	500 mm
Maximum opening	Approx. 200 mm
Plate Length	Min.2500mm
Yield Strength (up to 40 mm)	1.200 N/mm²
Yield Strength (up to 50 mm)	750 N/mm²

Table 5 shows the knife specification used in the Diving Shears.

Table 5: DS Knife Technical Specification

DS KNIFE TECHNICAL SPECIFICATION	
Length (top/bottom knife)	~ 4.030mm
Radius (top knife)	72.000mm
Cutting edges (top knife)	2
Cutting edges (bottom knife)	4
Life expectancy	10.000/grind

TPS – Test piece Shear:

The TPS is responsible for cutting the mechanical test sample from a cut strip on the Diving Shear. As can be seen diagrammatically in Figure 6. In this process, the operation makes use of the MES system to obtain information of the sampling position, in relation to the width, and sample number. A view of the TPS and operating pulpit, Figure 7.

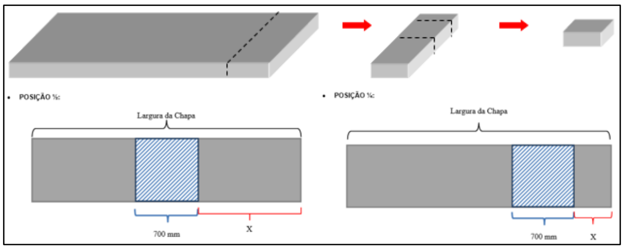


Figure 6: Marking sample mechanical test.

Figure 7: View of TPS and Operation Pulpit.

3 ROUTINE MANAGEMENT OF SHEAR LINE

To achieve the performance results, it is necessary to work on 3 competitiveness factors: Leadership, Knowledge and Methodology. This always happens through people, as shown in figure 8.

Leadership strategically guides teams, sets goals, and allocates the resources needed to achieve them. People always need to seek the full technical mastery of their processes and using an adequate methodology it is possible to effectively apply people's knowledge, aligning efforts and organizing all resources in the search for continuous quality and better results.

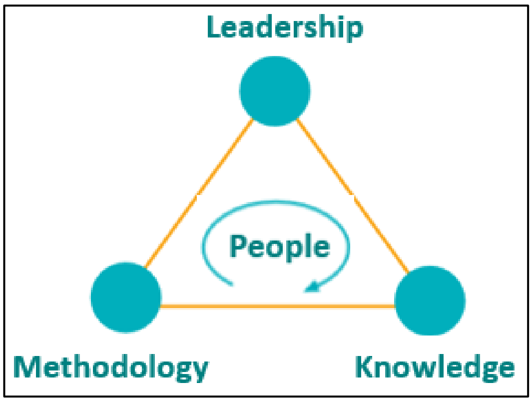


Figure 8: Critical factors of competitiveness to achieve results.

These concepts are applied in the Shear Line.

4 SHEAR CUTTING

General aspects:

Shear cutting, in its many variants, is a separation process frequently used in the plate production and forming industry. It is still the most economical process for large scale production, although other techniques are available.

According to DIN8588, cutting is a method of separating a material in which a tool with two knives, which move against each other, causing shear separation.

The schematic sequence of the thick plate cutting process with shears can be seen in Figure 9.

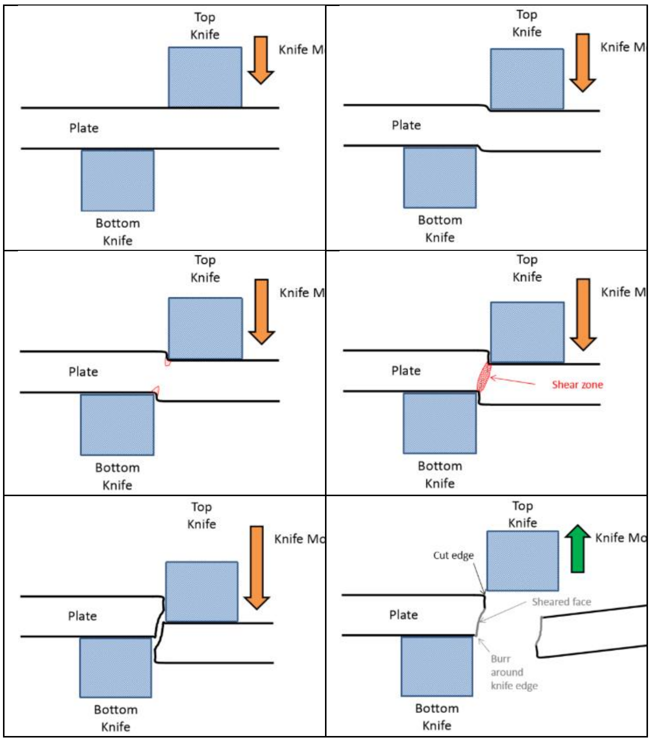


Figure 9: Schematic sequence of the plate cutting process. [3].

Regions formed in shear cut:

In the process of cutting a plate with blades, the material presents in the cut profile four very distinct regions:

1 - Region of deformation: a rounded corner in the contour in contact with one of the plane sides of the plate, and that corresponds to the deformation in the plastic regime;
2 - Shear or cut region: a bright polished strip around the cutting contour, with a constant thickness and corresponding to the region that was cut;
3 - Fracture region: an irregular band, slightly inclined, that corresponds to the section where the fracture occurred, since the resistant area decreases until the total separation of the parts is given;
4 - Burr: part of the material that is dragged by the tool, remaining adhered to the edge.

Figure 10 shows the characteristic of each of the regions in the cutting profile.

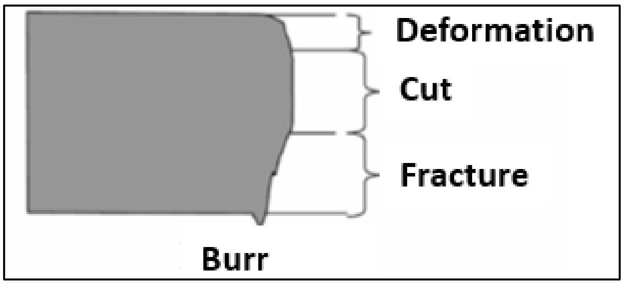


Figure 10: Regions of a shear profile [3].

In the shears, the knives are separated by a gap or clearance. The cut is obtained by the penetration of the upper knife in the plate, causing plastic deformation in a certain region, as seen in Figure 9.

The knife edge provides a stress concentration where the fracture begins along the shear plane in the region of the plate that the knife does not penetrate.

If the clearance between the knives is adequate, the cracks will be close to the center of the material thickness and will result in a quality cut.

Shear edges cannot compete with machined edges, however, if the tools used are sharp and the equipment adjusted properly, it is possible to obtain trimmed edges acceptable for a wide range of applications.

Higher precision is often required in cutting finish operations on steel plates. For ease of subsequent operations and assembly, the cutting edges must be of good quality (acceptable burr height and good surface finish) and perpendicular to the surface of the plate.

In the fracture surface of a good cut, the line separating the cutting region (smooth and shiny) from the fracture region (rough and matte) is expected to be regular and rectilinear. In addition, the edge must be free of marks or damage from defects in the knives.

In Figure 11 we can see a knife with edge damage and cut edge result.

(a) Knife with broken edge.

(b) Defect at the cutting edge**.**

Figure 11: Edge damage of the Double Side Shear knife and effect on the cutting face.

The appearance of the cut edge:

According to ASM Metals Handbook, there are five classic aspects to the acceptable edge profile, depending on the criteria and the application, shown in Figure 12.

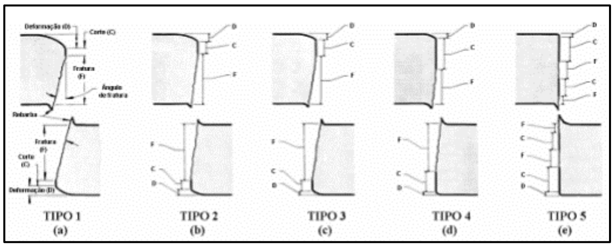


Figure 12: Edge types produced by punching cutting of low carbon steel plates (ASM, 1993).

- Edge type 1: region of extensive deformation (10 to 20%) and depth of shear (10 to 20%). The fracture represents approximately 75% of the thickness and the fracture surface must have a high fracture angle (14 to 16º). This type of edge is satisfactory only in cases of low criticality applications where the quality of the edge and the flatness of the part are not relevant;

- Edge type 2: presents moderate deformation (8 to 10%), shear rotates between 15 and 25% and of the fracture between 60 and 75%, in relation to the thickness. The angle of fracture is smaller than that of the previous type (8 to 11º) and is the type of cut that allows the greater durability of the cutting tool.

- Edge type 3: the deformation is small (6 to 8%) and the depth of the cut is between 25 and 40% of the thickness. The region of the fracture represents something around 50% and the angle of fracture is small (7 to 11 °). In this case, the residual stress is low making it suitable for application in steels with great hardening capacity and that will subsequently suffer severe conformation. A free edge of residual stress decreases the possibility of cracking during conformation.

- Edge type 4 presents a small deformation region (4 to 7%) and penetration represents approximately 50% of the thickness. The fracture should be between 35 and 50% and look coarse. The surface must have a low fracture angle (6 to 11º). This type of edge is suitable for cases requiring subsequent finishing steps such as machining and / or grinding.

- Edge type 5: the smallest possible deformation region is reached (2 to 5% of the thickness). The cut represents 50 to 70% of the thickness of the cut piece, however, divided into two portions interspersed with regions of fracture. The fracture, adding the two regions, corresponds between 25 and 45% of the cut thickness. This type of edge is required in cases where a straight edge is needed, without further finishing steps. In this case the service life of the cutting tool is extremely short.

In thick plates, the highest concern with the quality of the cutting edge is related to the burr generated. The main variable of the process that interferes in the formation of this is the fit of the gap or clearance. The usual clearance value is 10% of the thickness of the processed material. Knife life or wear, plate quality, and amount of trim in the as rolled are variables that influence the value of the gap to be adjusted.

Figure 13 shows the presence of burr, unapproved cut edge.

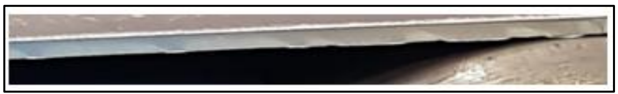


Figure 13: Presence of burr in high strength material.

5 CONCLUSION

Process knowledge is important to meeting product and customer requirements.

The Plate Mill Shear Line came into operation in less than three years, and all this work and commitment from the people contributed to achieving evolution in the quality result.

REPORT DOUBLE SIDE TRIM SHEAR							DATA		TEAM
SAFETY (DDS)									
REFUSED TASK		YES			NO				
LAST CHANGE MAIN KNIFE	CUT	TONNE	DATE OF CHANGE				SHIFT		
LATEST EXCHANGE SCRAP KNIFE	CUT	TONNE	DATE OF CHANGE				SHIFT		
MAIN GAP KNIFE	LF		LM		MAIN GAP SCRAP KNIFE	LF		LM	
SEND									
DEVIATION									
PRODUCTION (Nº OF PLATES)									
DSTS	INITIAL ID		FINAL ID			Nº		TONS	
SUBSTITUTE									
OPERATOR		OPERATOR			OPERATOR				
SUBSTITUTE		SUBSTITUTE			SUBSTITUTE				
INTERVAL		INTERVAL			INTERVAL				
REASON		REASON			REASON				
Occurrences / Comments									

Figure 14: Daily Monitoring Report.

REFERENCES

1 PRIMETALS, Training Manual, 2015.
2 SUMITOMO, Training Manual, 2013.
3 OLIVEIRA, D. L., Otimização do corte de pontas de um aço livre de intersticiais laminado a quente usando tesoura do tipo guilhotina. Dissertação (mestrado) - Universidade de São Paulo (USP) – SP, 2011.
4 ASM Metals Handbook. 9th ed. Metals Park, Ohio: ASM, 1993. v.14.
5 Technology Management Manual, GERDAU – 2008.