HSLA STEELS - COMPARISON OF CUTTING TECHNIQUES

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Abstract

The use of new materials including steel HSLA-High Strength Low Alloy by the automotive industry including manufacturers of semitrailers requires the use of efficient cutting techniques. Cutting sheets of different thickness is a big challenge for manufacturing companies. Mechanical cutting works on thin sheets made of structural steel. For thicker sheets are currently used different technologies of oxygen cutting, plasma, laser and water jet cutting. The article presents the results of the impact of cutting technology applied in the Wielton SA on the change in hardness of steel cutting zone Hardox 400 and 450.

Keywords: Cutting, HSLA steels, hardness

1. INTRODUCTION

Customer requirements, *performance requirements pose new challenges for process* engineers. Manufacturers of automotive semitrailers including leading manufacturer of semitrailers company Wielton S.A. uses in new constructions high strength steel grades including Hardox 400 and Hardox 450. The key in designing construction of new materials is proper selection and proper use of construction materials, particularly for parts subject to wear during operation. Proper selection of construction materials for structural components cannot exist without simultaneous choice of technique by means of which the element will be produced. Very important is to choose the right technology, taking into account operation conditions of the given element [1÷5].

2. HSLA STEELS

Wielton Company S.A. seeks to reduce the kerb weight of semitrailers through the application of new steels, especially with micro-alloy: ferritic, ferritic-pearlitic, ferritic-bainitic, bainitic or tempered martensite. Beneficial mechanical properties of this group of steel are obtained by the use of grain refinement and precipitation hardening with the participation of introduced to steel Nb micro additives, Ti, V, with a total content of about 0.2%. The limitation of HSLA steel is decreasing ductility with an increase of strength. According to the manufacturer information, Hardox steels are defined as "high-quality abrasion-resistant steels". They are characterized by high resistance to abrasive wear, the possibility of specialized machining tools, good weld ability, excellent mechanical properties and resistance to impact loads [6]. The achievement of these properties is possible due to the appropriate chemical composition as well as heat treatment during the rolling process. Mechanical properties of Hardox steels 400 and 450 are presented in **Table 1**. In the enterprise Wielton S.A. Hardox steels found application in: the bottom and sides of open load-carrying body, welded sides of the motor-car body, mudguards, lining of the bottom and sides.

Table 1 Mechanical properties of Hardox 400 and Hardox 450

Steel	Hardness	$R_{p0.2}$	R_m	A_5	KV_{-40}
	HB	MPa	MPa	%	J
Hardox 400	370÷430	1000	1250	10	45
Hardox 450	425÷475	1200	1400	10	40

3. INFLUENCE OF CUTTING TECHNOLOGY ON PROPERTIES OF HARDOX STEEL

In order to check the impact of cutting technology on properties of steel Hardox 400 and 450 the following cutting methods were used in the company WIELTON S.A.: plasma cutting, laser cutting, mechanical cutting guillotine, water jet cutting - made by an external company. Subjected to cutting was sheet with thickness of 8 mm.

Thermal cutting of each steel results in local overheating, decarburisation and partial burn-up of alloying elements in the area of material adjacent to the cutting line - the so-called Heat Affected Zone (HAZ) [7÷10]. The width of this zone depends on the power of heat source (cutting method) and amount of introduced heat (cutting parameters and thickness of the cut element i.e. amount of thermal energy introduced to the material in the time unit). The impact of thermal cutting on changes in properties of the cut material is particularly important in the case of cutting heat treated steel as the effects of heat treatment may be smoothed away in the cutting heat affected zone, and even cracks may occur. Unfavourable influence of heat introduced during thermal cutting processes may be reduced through initial preheating of the element nearby the cutting line.

Plasma cutting is based on warming up material with the electric arc to fluid state and fast blow-out of it with use of a powerful gas stream. An important element here is appropriate, strongly ionized gas, which allows precise transition of an electric arc in the direction of the cut material. This material is subject to both thermal action (arch) as well as mechanical (gas pressure). The advantages of plasma cutting can include: rapid piercing and high cutting speeds, a wide range of cut materials, relatively small heat affected zone, small cutting gap, the possibility of cutting thin materials without fusing the edges. The disadvantages of plasma cutting can include primarily bevelling edges. The problem of bevelling plasma torches has been minimized through the use of plasma torches with rotating gases. Rotating gas causes narrowing the plasma gas stream so that the lower bevelling and more perpendicular edge in relation to the plane of the material. **Fig. 1** shows the sheet edge after plasma cutting.

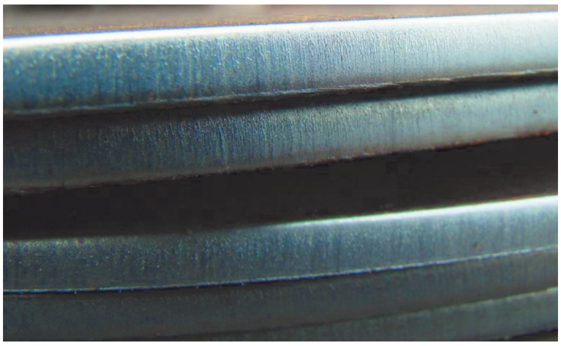

Fig. 1 Edge of the metal sheet after plasma cutting (Messer HyPerformance HPR130)

Laser cutting is a process, in which the energy of the beam of laser radiation are formed in a generator, continuous or pulsed, causes local melting or melting and evaporation of the cut material. In case of laser cutting, the cutting factor is a hot laser beam and technical gas under pressure. The advantages of laser cutting are a very high precision, narrow cutting gap and high cutting speeds.

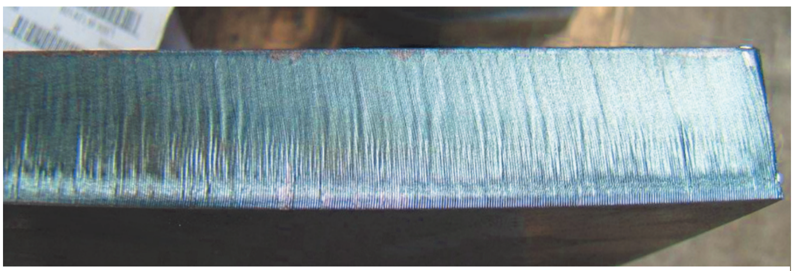

Fig. 2 Edge of the metal sheet after laser cutting (TruLaser 5060)

Fig. 2 shows the edge of the sheet after laser cutting with TruLaser 5060.

Laser cutting has very small influence on the structural changes in the steel. In case of austenitic grades may occur a slight softening of the edges, while in case of ferritic and martensitic steels hardening cut edges. Oxy-cutting consists in warming up steel to the ignition temperature and next oxidation, and blowing up the material with use of oxygen under high pressure. In case of Hardox steel should not be used oxygen cutting without preheating plate which in turn negatively affects the resistance to abrasion. The main advantages of the oxygen cutting are very wide range of material thicknesses and perpendicular edges of the cut, while the disadvantages can include long piercing time and a wide heat affected zone. **Fig. 3** shows the edge after oxygen cutting on the device Hybird 200.

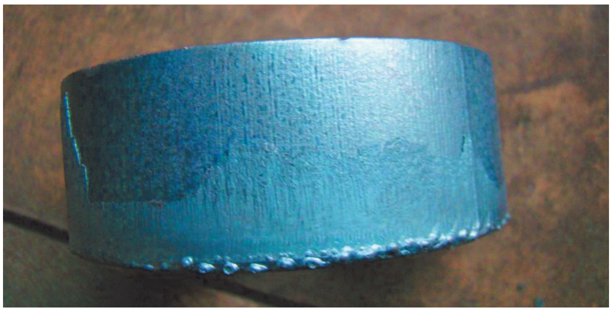

Fig. 3 The edge of metal sheet after cutting with oxygen (Hybrid 200)

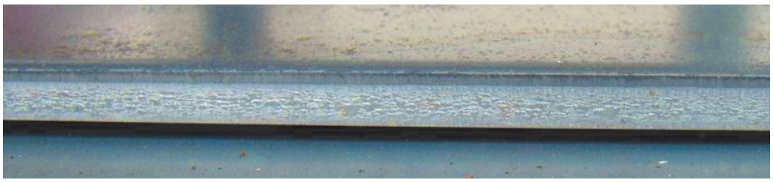

Fig. 4 The edge of the metal sheet after cutting on the guillotine (Durma 3016)

Mechanical cutting guarantees practically perfect vertical cut as well as it is minimizing changes in material properties. **Fig. 4** shows the edge after cutting on the guillotine Durma 3016.

Water jet cutting is so called cold technology and there is no heat affected zone here. Therefore, you can use it anywhere where it is unacceptable excessive heating of the material, as is the case with Hardox steel. With use of water you can get different cutting edges by adjusting the amount and type of abrasive and cutting speed. In order to obtain qualitatively excellent edge cutting speed will be low and in case of speed increase there will be significantly deteriorated the quality of the edge. An important role is played by economic factors. **Fig. 5** shows the water cutting precision class. Wielton Company does not have its own facilities for hydro-base cutting.

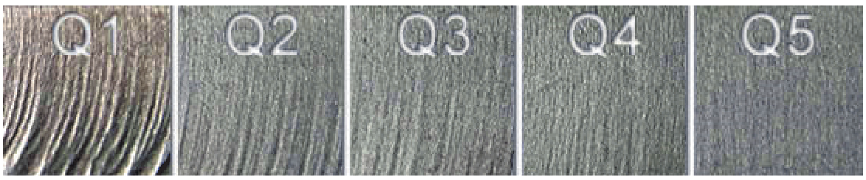

Fig. 5 Water cutting precision class. Q1 seperational cut, Q2 through cut,Q3 clean cut, Q4 good edge finish, Q5 excellend edge finish

Fig. 6 presents a comparison of research results of hardness measurement in cutting zone for individual technologies for cutting of Hardox steel 400 and **Fig. 7** for Hardox steel 450. Obtained results coincide with the results obtained by the authors of the work [11] for Hardox steel 500.

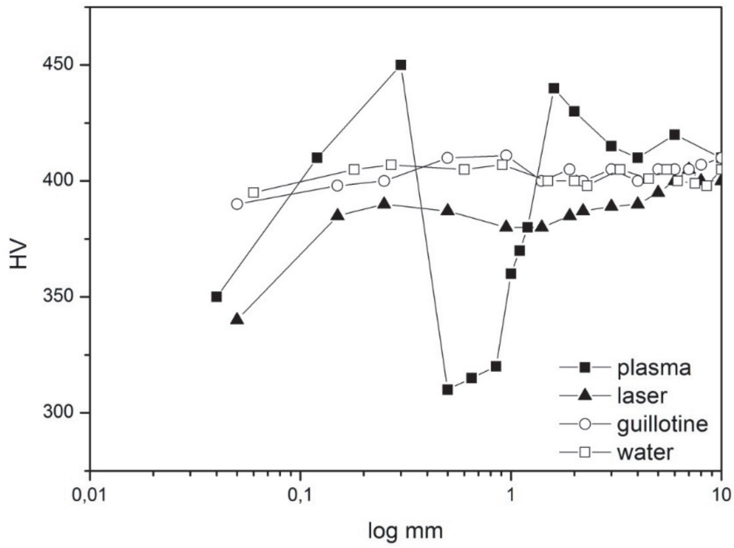

Fig. 6 Hardness penetration pattern in the Hardox 400 surface layer after cutting

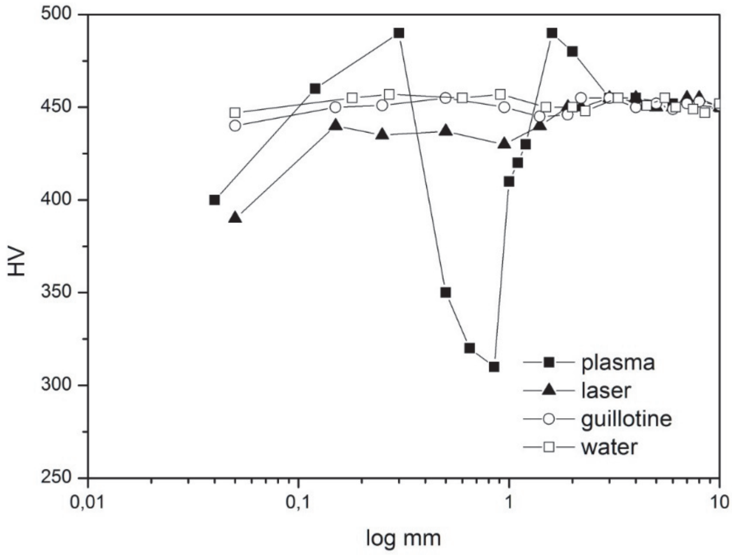

Fig. 7 Hardness penetration pattern in the Hardox 450 surface layer after cutting

CONCLUSION

Cutting of metal sheets of different, often large thickness, is a major challenge for the majority of manufacturing companies. Mechanical cutting, possibly drawing is good for thin metal sheets and mostly is applicable cutting straight edges. For thicker plates are currently used different technologies of thermal or water cutting. They are: oxygen cutting, plasma cutting, laser cutting and water jet cutting (hydro abrasive). Each of these technologies has its own characteristics and range of applications in which it is the most economical. Therefore, deciding on specific cutting technology there should be taken into account e.g. steel grades, possibly other types of materials, their thicknesses and assumed cutting precision. Only knowing these parameters can be chosen, the most economical in given applications, cutting technology. In case of Wielton S.A. is used plasma cutting and laser cutting, from guillotine cutting company resigned in favour of laser cutting. Taking into account special character of production is gaining technological advantage laser cutting due to the possibility of cutting small pieces. Water jet cutting despite the lack of impact of heat affected zone is not used, due to economic factors (**Table 2**).

Table 2 Comparison of economic factors of laser and water jet cutting

	Laser cutting	**water jet cutting**
Cost of purchasing [EUR]	440 000	25 0000
Cost of machine-hour [EUR]	51.10	53.50
Cost of 1 m cutting of 5mm sample [EUR]	0.35	1.35

Carried out studies showed that changes of properties in zone of laser cutting and plasma cutting occur in a very narrow area of 2 mm. Water jet cutting does not cause any changes in the structure or hardness. Application of this cutting method depends entirely on technical possibilities and cost calculation of using technology. **Table 3** shows a comparison of available cutting technologies.

Table 3 Comparison of cutting technology

Cutting Technology	**Guillotine cutting**	**Plasma cutting**	**Laser Cutting**	**Water jet cutting**
Range of cut materials	It is possible to cut sheets up to thickness of 15 mm - only for black metal sheet / structural.	black steel, alloys steel, non-ferrous metals and their alloys	black steel, alloys steel, non-ferrous metals and their alloys (range varies according to source technology)	all materials
Cutting characteristics	The method of cutting metal sheet is optimal where is not required high precision of on-dimension (accuracy to 3 mm) + no heat affected zone	+ average and good angular characteristic + small heat affected area + minimum number of scale + cutting with a high accuracy	+ excellent angular characteristic + minimum heat affected area. + lack of scale + cutting with very high accuracy; cutting gap with the smallest width	+ excellent angular characteristic + no heat affected zone + eco technology + cutting with very high accuracy; gap with a minimum width
Cutting speed	+ high cutting speed - no possibility of puncture hole	+ high cutting speed up to 30 mm thickness + very short time required for puncture of the hole - average quality of the holes	+ cutting with very high-speed up to 6 mm thickness + very short time of punching + excellent quality of holes	- low cutting speed -4000 bar; higher - 6000 bar + no deformation + cutting of all materials + very large range of thickness of cut materials
Cutting Technology	**Guillotine cutting**	**Plasma cutting**	**Laser Cutting**	**Water jet cutting**
Costs	Straight-cutting sheets in case where high dimensional precision is not required. Method cheap but not very precise. Cockles is formed, the need for finishing working	economical method and good quality for materials from structural steel with thickness of less than 30 mm, alloy steel and non-ferrous metals. Excellent relation speed / quality / price	cutting cost depends on used source technology. Very low unit costs for long series. Economical method and good quality for materials from structural steel with thickness less than 6-8 mm, alloy steel and non-ferrous metals	economical method and good quality for individually performed parts. The method totally universal
Cutting thickness range	to the thickness of 15 mm - only for black metal sheet / structural	0.5-100 mm	0.5-30 mm	0.5-500 mm

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