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Comparative analysis of the processing accuracy of high strength metal sheets by AWJ, laser and plasma

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Abstract. Experimental tests were carried out on two high-strength steel materials (Ramor 400 and Ramor 550). Quantification of the dimensional accuracy was achieved by measuring the deviations from some geometric parameters of part (two lengths and two radii). It was found that in case of Ramor 400 steel, at the jet inlet, the deviations from the part radii are quite small for all the three analysed processes. Instead for the linear dimensions, the deviations are small only in case of laser cutting. At the jet outlet, the deviations raised in small amount compared to those obtained at the jet inlet for both materials as well as for all the three processes. Related to Ramor 550 steel, at the jet inlet the deviations from the part radii are very small in case of AWJ and laser cutting but larger in case of plasma cutting. At the jet outlet, the deviations from the part radii are very small for all processes; in case of linear dimensions, there was obtained very small deviations only in the case of laser processing, the other two processes leading to very large deviations.

1. Introduction

Development of new products and, especially, survival on the market, requires, in addition to providing green products, the development of proper technologies, which respect the environmental standards. In view of this, the interdependence between the industrial systems and ecological systems should be carried out, by incorporating the industrial systems into the natural environment, as well as the use of some environmentally friendly (clean) technologies and processing methods and renewable energy sources.

Using green technologies, that involve high investment costs, can bring economic and social benefits, in addition to the environmental benefits. Thus, from economic point of view, the following advantages can be obtained:

- Reduce material consumption by reducing the thickness of sheets, thus their weight, without affecting their properties;
- Decreased manufacturing costs;
- Increased product quality, at the same efficiency of material.

Processing of metal sheets is widely studied in the scientific literature [1-5] but no one is willing to share the knowledge related to those metal sheets used in making specific products, whose main function is for safety and security. Processing this kind of metal sheets poses special technological problems, especially due to their specific mechanical properties (high strength, high toughness, but ductile fracture and relatively small elongation). Besides, the behaviour of these metal sheets in case of using same technologies leading to their heating is a known problem, but less studied, each producer seeking to minimize the thermal damage.

The goal of this paper is to analyse the suitability of some technologies - abrasive water jet cutting, laser and plasma cutting - to process high strength metal sheets, with the aim of developing and implementing a green and economic solution for armour manufacturing.

2. Experimental methodology

The experimental tests were performed on Ramor 400 and Ramor 500 high-strength steel metal sheets. These materials are usually used in the manufacturing industry of maximum safety equipments, especially in building of armoured cars. Their chemical composition and mechanical properties are presented in table 1 and table 2, respectively.

Table 1. Chemical composition of materials [6].

Material	Chemical composition (max %)									
Ramor 400	C 0.24	Si 0.70	Mn 1.50	Cr 1.00	Ni 1.00			B 0.005		
Ramor 550	C 0.36	Si 0.60	Mn 1.00	P 0.012	S 0.003	Al 0.060	Cu 0.30	Cr 1.50	Ni 2.50	B 0.005

Table 2. Mechanical properties of materials [6].

Material	Thickness (mm)	Yield strength (MPa)	Ultimate strength (MPa)	Hardness (HB)	Elongation A5min (%)	Resilience (Joule)
Ramor 400	6.5	1100	1300	360-450	8	20
Ramor 550	6.5	1550	1850	540-600	7	16

In order to make a comparison between different cutting methods - abrasive water jet, laser and plasma – a part was designed so that to contain outer and inner surfaces, inclined surfaces as well as surfaces following certain radii, as shown in figure 1. This geometry was chosen with the aim of making a more concrete assessment of the quality parameters as well as of the economic and environmental parameters. Quantification of the dimensional accuracy of parts was achieved by measuring four parameters, two lengths (L_1 and L_2) and two radii (R_1 and R_2) of the part, as it is indicated in figure 1.

The equipments used to perform the three types of cutting were as follows: a MAXIEM 0707 abrasive water jet cutting machines, an OXYTOME.B 25E plasma cutting machine and a TRUMPF 3030 laser cutting machine. The resulted parts were measured on a TESA MICRO – HITE 3D CNC machine, both at the inlet and at the outlet of water jet, plasma and laser fascicle, respectivelly.

The experimental tests were performed using the optimum working parameters that the used machines have been able to provide. Thus, the working parameters used in AWJ processing of the two materials were: water jet pressure of 300MPa, feed rate of 80mm/min, abrasive material quantity of 500g/min, distance between the cutting head and part of 2mm, focus tube length of 102mm, focus tube diameter of 0.74 mm; the abrasive material was Granat #80. In case of plasma processing with the above mentioned machine, the cutting parameters are presets as a function of the used material and its thickness so that they cannot be varied; therefore, the cutting parameters used during the current experiments were: feed rate of 150cm/min, cut thickness of 1.8mm, plasma arc voltage of 130V, argon pressure of 1.6bar and oxygen pressure of 5.5bar. In case of laser cutting, the working parameters were: power of 3200W, frequency of 20000Hz, feed rate of 2m/min, distance between the laser head and metal sheet of 1.3mm, gas pressure of 0.8bar (the used gas was oxygen).

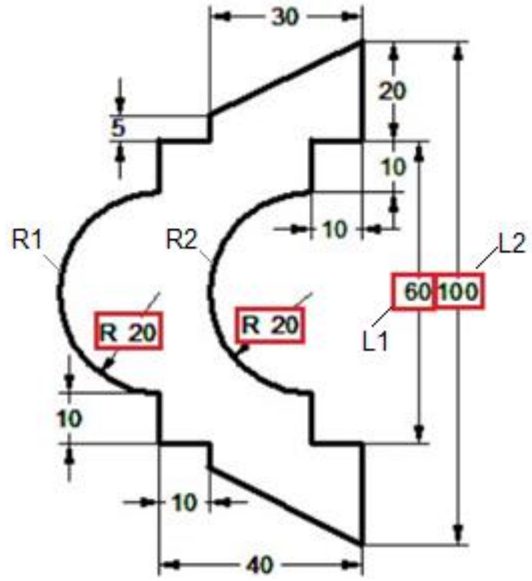


Figure 1. Geometry of the processed part.

3. Results and discussions

Some parts processed by the three unconventional cutting technologies are presented in figure 2. It can be observed that the best quality of the processed surfaces, without any heat affected zone, was obtained by AWJ cutting while the worst quality was obtained by plasma cutting. However, the AWJ cutting has the lowest productivity among the three analysed methods; instead the method is environmentally friendly – there is no heat release, noxious or chemical compounds harmful to the environment or operator. On the other hand, the plasma cutting assures the highest productivity, requires cheap equipments and a simpler maintenance but the processed surfaces need further deburring or other types of machining to obtain the desired quality. The optimum solution is offered by the laser cutting in terms of both, surface quality (even if there is a heat affected zone, but not to the same extend as in the case of plasma cutting) and productivity. The disadvantages of this method are the high cost of equipment and a difficult maintenance.
The deviations from the measured geometric parameters of parts are presented in figure 3.

The deviations from the R1 radius, obtained in case of processing the parts by the three cutting methods, for the two materials, are presented in figure 3 a, b. It can be observed that, in case of Ramor 400 steel, the smallest deviation at the jet inlet was obtained from AWJ processing, while at the jet outlet, the smallest deviation resulted from plasma processing. In case of Ramor 550 steel, the smallest deviation at the jet inlet was obtained from laser processing, while at the jet outlet, plasma cutting lead to the smallest deviation.

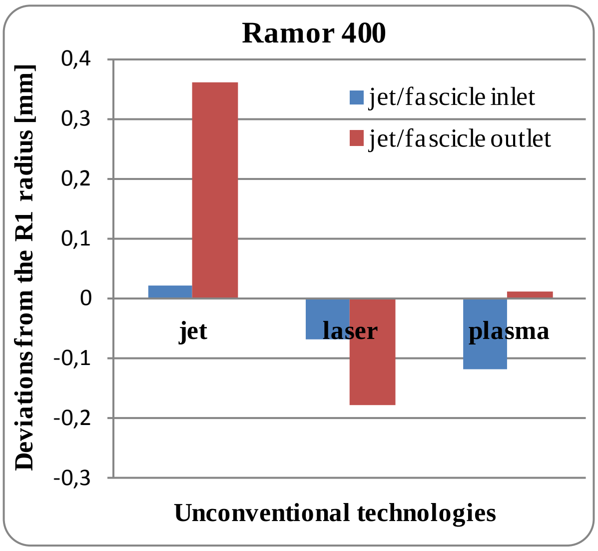
a. Ramor 400 and Ramor 550 AWJ cut parts

b. Ramor 400 and Ramor 550 laser cut parts

c. Ramor 400 and Ramor 550 plasma cut parts

Figure 2. Parts obtained by cutting with different unconventional technologies.

The deviations from the R2 radius, obtained in case of processing the parts by the three cutting methods, for the two materials, are presented in figure 3 c, d. In case of Ramor 400 steel, the smallest deviation at the jet inlet was obtained from AWJ processing while at the let outlet, the smallest deviation resulted from laser processing. As concern the Ramor 550 steel, an opposite variation was registered: the smallest deviation at the jet inlet was obtained from laser processing while at the jet outlet, the smallest deviation resulted from AWJ processing. It is worth mentioning that the overall deviations of parts made by Ramor 550 steel are smaller comparing to those obtained for Ramor 400 steel and for both materials the deviations are opposite in sign compared to those obtained for the R1 radius. This highlights that the geometry of part itself affects the processing quality.



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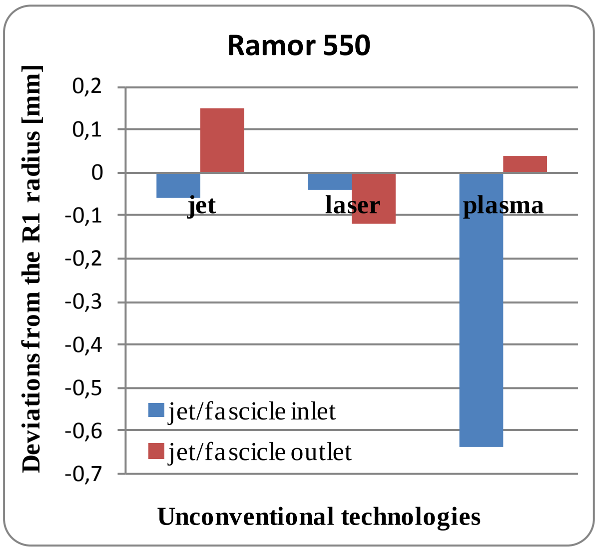

b.

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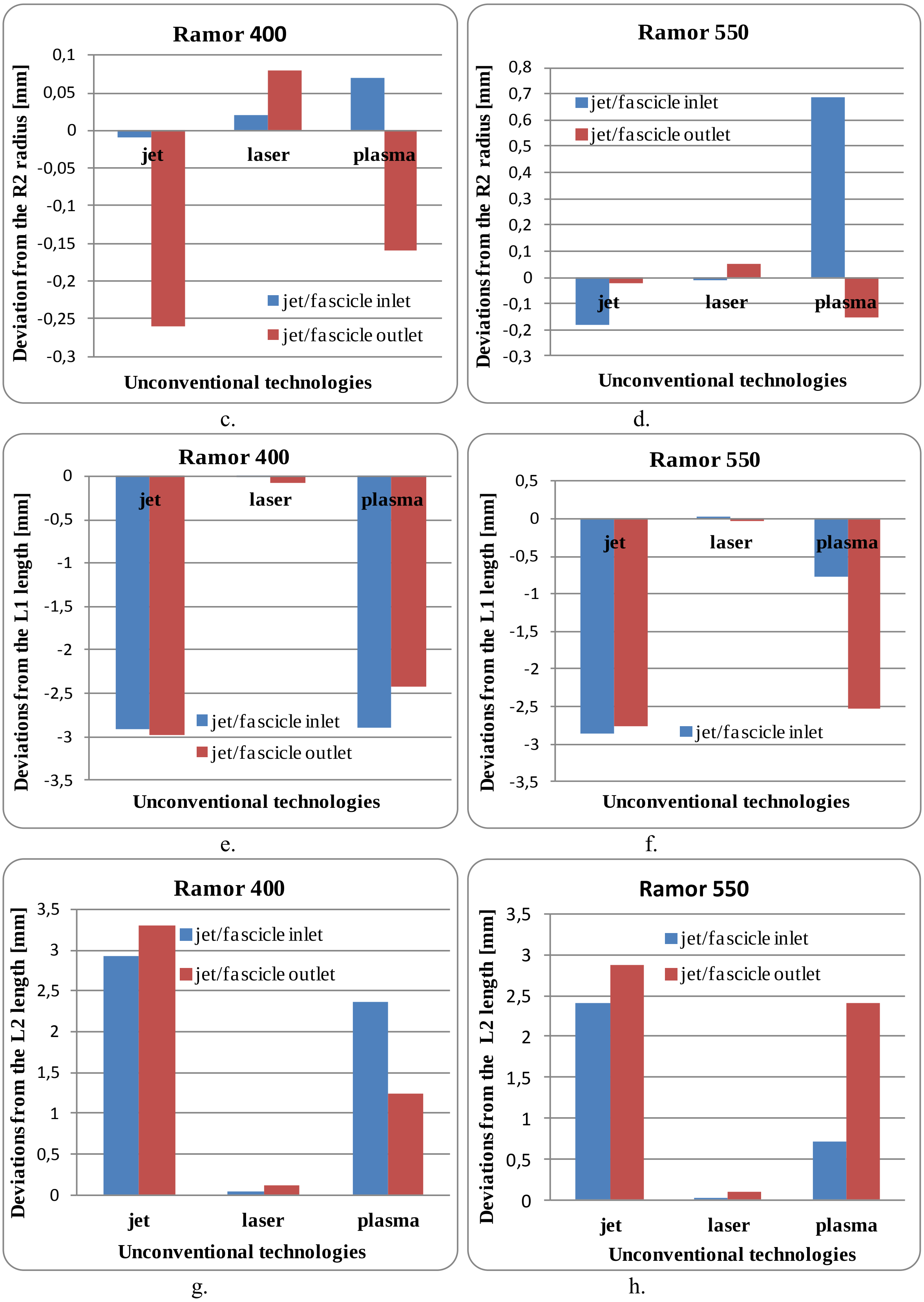

Figure 3. Deviations of geometric parameters of parts.

The deviations from the two lengths (L_1 and L_2) obtained in case of processing the parts by the three cutting methods, for the two materials, are presented in figure 3 e-h. It can be observed a similar variation of the deviations for the two materials (except some differences for plasma cutting), the smallest values being obtained in case of laser processing where the deviations are insignificant compared to those obtained by the other two cutting methods. As the previous results, in case of Ramor 550 steel processing, the overall deviations are smaller compared to those obtained for parts made by Ramor 400 steel and for both materials the deviations from the L_2 length are opposite in sign compared to those from the L_1 length.

4. Conclusions

The suitability of three unconventional processing methods – AWJ, laser and plasma - to cut high strength metal sheets and their effects on the parts accuracy were addressed within this paper. Two materials - Ramor 400 and Ramor 550 – were tested. It was found that the laser cutting method provides the best results in terms of part accuracy correlated with a good productivity. However, the more environmentally friendly technology that keeps, in addition, the integrity of the processed material, is AWJ.

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