Efficient Machining of S355JR Steel after the Laser Cutting – Case Study

Ján Duplák[1], Katarína Brezíková[2], Róbert Čep[3], Ivan Kuric[4], Vitalii Ivanov[5], Ondrej Petruška[6], Lenka Mrosková[7]
{jan.duplak@tuke.sk[1], katarina.brezikova@tuke.sk[2], robert.cep@vsb.cz}

Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Sturova 31, 080 01 Presov, Slovakia[1,2], Technical University of Ostrava, Faculty of Mechanical Engineering, 17. listopadu 15, Ostrava – Poruba[3]

Abstract. Effective machining of materials is conditioned by proper machine design, selection of suitable cutting tools and materials, determination of suitable cutting parameters, etc. This article focuses on the efficient machining of S355JR steel after laser cutting. During the experiment, S355JR steel is laser cut and subsequently machined by milling technology. Regarding the parameters for steel burning, nine alternatives are determined, from which the three most suitable ones are then selected, taking into account the smallest slope of the lateral edges and the smallest heat-affected zone. The milling of the burnt material is first performed by the simulation method. The results section of this article provides an evaluation of both technical and economic efficiency.

Keywords: Machining, steel S355JR, laser cutting, milling.

1 Introduction

At present, unconventional methods of cutting and machining different types of materials are at the forefront [1-2].These methods are based on a physical or physicochemical principle. The reason for introducing these methods is the currently increasing proportion of materials that are difficult to process or the complexity of components, and so on [3-4]. One of the methods of unconventional material cutting is plasma arc cutting. By using this method for material cutting, surfaces with specific properties are created, and there is also a greater possibility of achieving the desired quality of the surfaces cut than when the material is cut in a conventional manner. [5-6] Figure 1 presents the illustration of using the simulation method for milling.

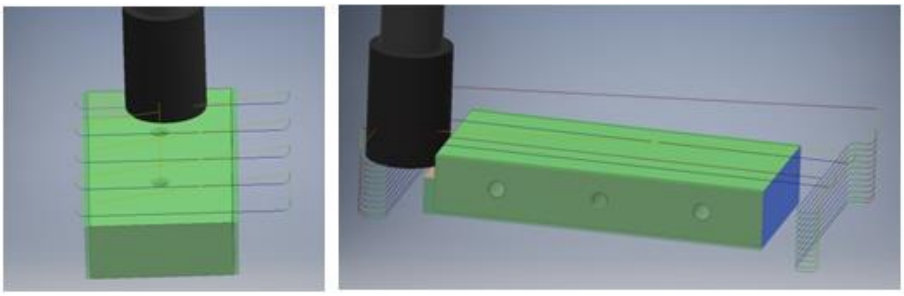

Fig. 1. Illustration of using the simulation method for milling.

MMS CONFERENCE 2017, November 22-24, Starý Smokovec, Slovakia

DOI 10.4108/eai.22-11-2017.2274765

2 Experiment specification

Prior to the implementation of the experiment, it is necessary to define the technological system: machine - tool - workpiece. The following part of the article is devoted to the description of the technological system that was used during the experiment.

2.1 Used machines

In the experiments carried out, two machines were used - a plasma cutting machine (Figure 2) and a CNC machining center (Figure 3), which was used for milling burnt parts.

Fig. 2. CNC plasma cutting machine.

Fig. 3. CNC machine centrum.

2.2 Used cutting tools

The following tools were used to carry out the individual experiments: 90 ° positioning cutter with hole, drill with coolant hole, machine reamer, and short tap. The individual tools are shown in Figure 4.

Fig. 4. Cutting tools.

2.3 Specification of workpiece material

S355JR material - unalloyed quality structural steel, which is suitable for screw-fixed, riveted and welded steel structures used at normal temperatures, was used in the experiment. The mechanical properties (Table 1) and the chemical composition (Table 2) of the above material for a thickness of 30 mm are listed below. [7]

Table 1. S355JR steel - Mechanical properties [8].

Tensile strength [MPa]	470-630
Minimum yield strength [MPa]	345
Elongation (%)	18-20
Fatigue [MPa]	275 - 275

Table 2. Chemical composition of S355JR steel.

C	Si	Mn	P	S	N	Cu	CEV
max. 0.24	max. 0.55	max. 1.6	max. 0.04	max. 0.04	max. 0.012	max. 0.55	max. 0.47

3 Technological conditions used for experiment

When cutting the material, the basic parameters for steel burning were set in the nine variants that are recommended for the material used. By specifying each variant, the size of the cutting current in combination with different feed rates was taken into account. These conditions are listed in Table 3.

Table 3. Setting specifications – laser cutting.

Alternative	Cutting jet [A]	Feed [mm/min]	Sheet thickness [mm]
1	250	500	30
2	280	500	30
3	300	500	30
4	250	350	30
5	280	350	30
6	300	350	30
7	250	250	30
8	280	250	30
9	300	250	30

After the production of burnouts, the individual blanks were further machined by milling and drilling technology to achieve the desired final shape of the component. The cutting conditions were determined and calculated with respect to the tools used and the material cut. These cutting conditions are listed in the following tables - Table 4 and Table 5.

Table 4. Milling specification.

Specification	Roughing	Smoothing
Cutting speed v_c [m/min]	120	150
Diameter of the cutter [mm]	40	40
Feed f_z [mm]	0.1	0.05
Number of cutter teeth [mm]	4	4
Operating speed [min^{-1}]	955.4	1194.3
Feed rate [mm/min]	382.2	238.9

Table 5. Specification – drilling, cutting, machining.

Specification	Drilling holes for threads	Drilling holes for pins	Thread cutting	Machining of holes for pins
Cutting speed [m/min]	85	85	8	6
Diameter of tool [mm]	6.8	7.8	8	8
Feed [mm]	0.12	0.12	-	-
Number of cutter teeth [mm]	2	2	-	-
Operating speed [min^{-1}]	3980.9	3470.5	318.5	238.9
Feed rate [mm/min]	955.4	832.9	398.1	140

4 Results experiment

From the experiments carried out, it was found that the burning rate of a single sheet varies depending on the feed assigned. In this dependence, three groups of variants with the same burning speed of one sheet and the same price of one piece are created. On the basis of achieving the smallest slope and the thickness of the heat-affected zone, variants No. 2, No. 5 and No. 7 are considered the most suitable variants of the material cutting. When the material is burnt under the conditions of variant No. 2, the rate of slope is 5.1 ° and the thickness of the heat-affected zone is 0.8 mm. The overall technical assessment is given in Table 6. The graphical representation of the most suitable alternatives is presented in Figure 5.

Table 6. Evaluation table I.

Alternative	Semi-finished product	Rake angle [°]	Pieces of the sheet [unit]	Burning speed of sheet	Weight of part [kg]	Price per unit [€]	Heat-affected zone [mm]
1	170x75x30	5.5°		1296		3.3	0.6
2	170x75x30	5.1°		1296		3.3	0.8
3	170x75x30	4.9°		1296		3.3	1.0
4	170x75x30	4.6°		1800		4.6	0.9
5	170x75x30	4.2°	1200	1800	3	4.6	1.0
6	170x75x30	4°		1800		4.6	1.2
7	170x75x30	3.1°		2472		6.3	0.1
8	170x75x30	3°		2472		6.3	1.2
9	170x75x30	2.7°		2472		6.3	1.4

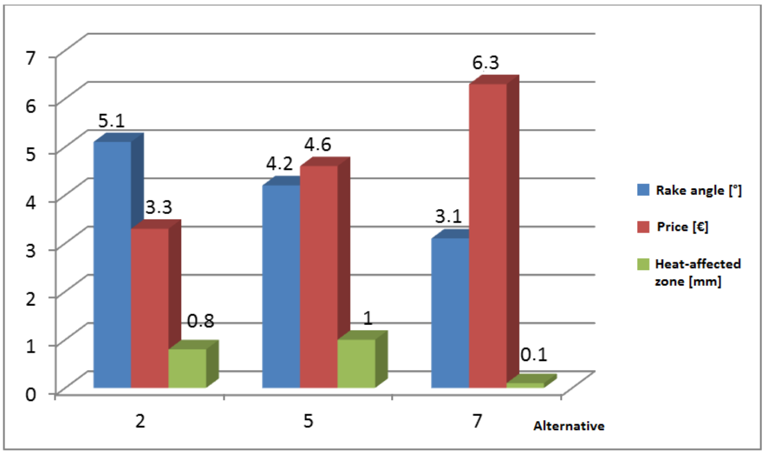

Fig. 5. Graphical representation of the most suitable alternatives.

In order to determine the most suitable alternatives for the plasma cutting process, a second assessment table (Table 7) is set up, recording the tool life (roughing milling cutter) and total durability value.

Table 7. Evaluation table II.

Alternative	No. of parts	Durability		Machining time of one part [min]	Machining time of batch [min]	Disputed places
		Milling cutter for roughing	Total durability			
2	70	539	898.8		898.8	depth of heat-affected zone
5	55	423.5	706.2		706.2	depth of heat-affected zone
7	88	677.6	1129.92		1129.92	price
1	96	739.2	1232.64		1232.64	big rake angle
3	74	569.8	950.16	12.84	950.16	big rake angle
4	58	446.6	744.72		744.72	big rake angle
6	91	700.7	1168.44		1168.44	depth of heat-affected zone
8	63	485.1	808.92		808.92	price
9	83	639.1	1065.72		1065.72	depth of heat-affected zone

The economic evaluation is carried out by determining the costs of production per piece of manufactured component for the most appropriate variants. The individual amounts are shown in Figure 6.

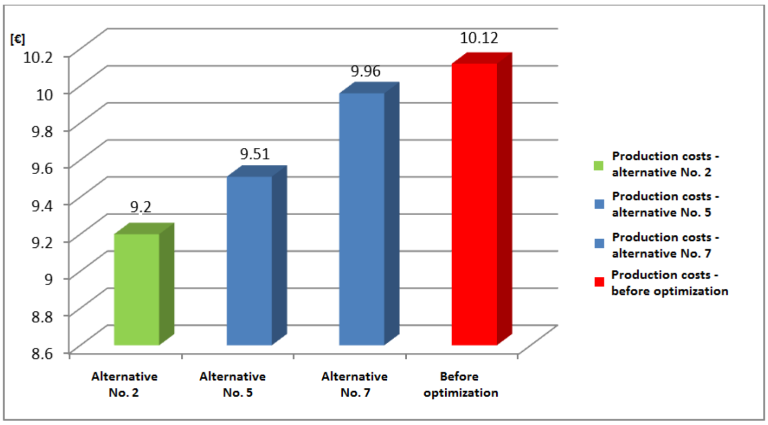

Fig. 6. Graphical representation of economic evaluation.

As can be seen from the graph, the lowest manufacturing costs are set for variant No. 2. In this case, there was a cost reduction of € 0.92 per piece of manufactured component, which represents a cost reduction of approximately 9% of the costs that were set before the optimization.

5 Conclusion

The contribution was focused on the efficient machining of S355JR steel after laser cutting. Through the realization of the individual variants of the experiment, suitable parameters for burning with the consequent optimization of production were found. When selecting suitable parameters, the smallest slope of the lateral edges and the smallest heat-affected zone were taken into account. Finding the right parameters has resulted in both higher efficiency and lower production costs, thereby fulfilling the target set for this experiment.

Acknowledgement

Presented article was supported by project VEGA number 1/0619/15 and APVV-15-0700.

References

[1] Lia, L., Lia, C., Tangb, Y., Yia, Q.: Influence factors and operational strategies for energy efficiency improvement of CNC machining. Journal of Cleaner Production. Vol. 161, pp. 220–238 (2017).

[2] Yilbas, B. S., Shaukat, M. M., Ashraf, F.: Laser cutting of various materials: Kerf width size analysis and life cycle assessment of cutting process. Optics & Laser Technology. Vol. 93, pp. 67–73 (2017).

[3] Hatala, M., Zajac, J., Mitaľ, D., Mitaľová, Z., Radchenko, S., Živčák, J.: Impact of internal residual stresses to dissemination, shape, and size of the ultrasound signal. Testing and Measurement: Techniques and Applications (TMTA 2015). - EH Leiden, The Netherlands : CRC Press Balkema, pp. 15-22 (2015).

[4] Michalik, P., Zajac, J., Hatala, M., Hutyrova, Z., Mitaľ, D., Suslo, L.: Comparison of Software and Calculated Correction of the Tip Radius of Turning Tool for Control System FANUC. Key Engineering Materials. Vol. 669, pp. 270-277 (2016).

[5] Dupláková, D., Knapčíková, L., Hatala, M., Szilágyi, E.: Mathematical Modeling of Temperature Characteristics of RFID Tags with their Subsequent Application in Engineering Production. TEM Journal. Vol. 5, no. 4, pp. 411-416 (2016).

[6] Mitaľová, Z., Mitaľ, D., Botko, F.: Measuring of roughness and roundness parameters after turning of composite material with natural reinforcement. Science report : Project CIII - PL-0007 : Research on modern systems for manufacture and measurement of components of machines and devices. - Kielce : Wydawnictwo Politechniki Świętokrzyskiej, pp. 49-58 (2016).

[7] EN 10025-2:2004. Hot rolled products of structural steels. Part 2: Technical delivery conditions for non-alloy structural steels.

[8] Dzioba, I., Lipiec, S.: Testing the mechanical properties of S355JR steel with different types of microstructure. Maintenance problems. Vol. 3, pp. 179 – 186 (2016).