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CALCULATION OF LASER CUTTING COSTS

Abstract: The paper presents description methods of metal cutting and calculation of treatment costs based on model that is developed on Faculty of mechanical engineering in Kragujevac. Based on systematization and analysis of large number of calculation models of cutting with unconventional methods, mathematical model is derived, which is used for creating a software for calculation costs of metal cutting. Software solution enables resolving the problem of calculating the cost of laser cutting, comparison' of costs made by other unconventional methods and provides documentation that consists of reports on estimated costs.

Keywords: unconventional forming process, laser cutting, cutting costs, software for calculating cutting costs

1. Introduction

In modern industry, use of unconventional machining process of metal cutting is being more implemented every day for its optimal characteristics. Cutting and other forms of laser treatments are rapidly becoming most widespread methods of processing. Laser is one of the most successful devices created in the 60's years of 20th century because of many advantages which it posses and of many benefits it provides in metal industry. Accomplishment of this method is shown both in economy and technologicality, quality and accuracy of this process and there are wide selections of this treatment such as cutting, welding, drilling, heat treatments, and engraving. In companies with small production series as well as mass production and in those operating in field of metal processing, laser cutting is becoming

indispensable. Laser cutting has competitive price in comparison with price of other unconventional process because of its speed and high quality. Due to the relatively fair price of laser cutting it has become available for all industries an smaller factories. Consumers of products have more strict demands regarding the speed, quality and price. It is known that in the production, long-term planning is based on the complicated calculations which include not only the processing costs but also the investment costs and the payback time. Detailed analysis of the costs and feasibility of laser processing technology is the basis for choosing the same for both the investor and the buyer of final product. Development of model for estimating costs of laser cutting, and software application provides the company and the client information about costs of laser cutting, right after defining the requests for product and service, during the process of creating new product, or when meeting the client's needs.

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2. Laser cutting - principle of operation

With this form of treatment, cutting tool is laser beam which can be focused on extremely small surface (Gostimirovic, 2012; Lazic, 1990), providing high of density of energy. Due to the specific cutting tools, there is no wear, and the cutting edge has high accuracy.

The principle of laser processing is conducted at a collision laser beam with an opaque solid body, whereby the various physical processes occurring on the surface of the workpiece. There is intense heating of the surface material of the workpiece, melting and evaporation. Applying laser beam to the material comes to 1) the reflection (scattering) of the laser beam from the surface; 2) absorption of radiation on the surface of objects; 3) removal of the products of destruction; 4) cooling the surface of the material of the workpiece upon the cessation of the laser. These phases are shown in Figure 1 (Lazarevic and Radovanovic, 2013):
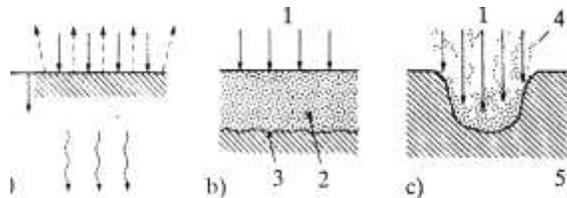
Figure 1. The interaction of laser light with the surface of workpiece

a) the reflection and absorption, b) the melt, c) the evaporation
1 - laser beam, 2 - molten material, 3 - a border zone between the solid and molten material,
4 - removal of material, 5 - the workpiece

In laser cutting, the air is focused on a small area, more accurately; his energy is concentrated in a 'point' with a diameter of less than 0.5 mm (Figure 2) (Aleksijevic, 2013). At the point where air strikes the surface, the metal melts instantly and partially burns and evaporates. After a short time, the laser beam penetrates completely into the material. Right cutting occurs after the air entered the workpiece. As the beam moves along the contour, little parts of materials melt and make the cut. The molten pieces of metal and slag are deflated down by gas. This process makes real narrow cut that is barely larger than the diameter of the beam. Each cutting process begins in drilled blind spot that is a little farther from the starting point of the contour. The material is blown out due to a high pressure gas used in processing. The gas type and pressure have a major impact on the regimes and cutting quality.
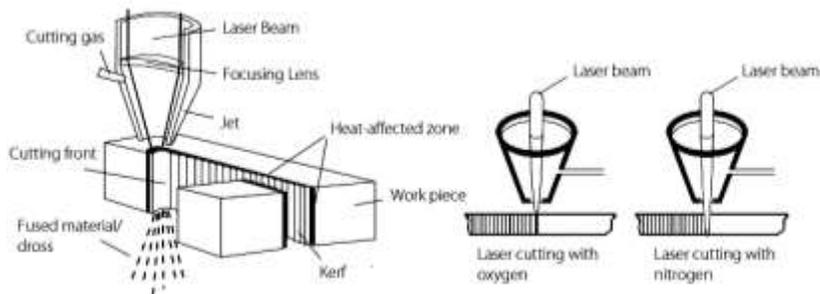
Figure 2. Presentation of laser cutting

B. Nedic, M. Eric, M. Arsenijevic

The big advantage is that there is no direct contact between the tools and pieces, so there is no chipping and wear of tools and does not require additional mechanical processing for edges of machining parts. In comparison to other conventional and unconventional methods, heat affected zone (HAZ) is minimal, cutting edges are smooth and straight, cutting is characterized by high precision, deformations that occur are minimal, it is possible to develop parts of different dimensions and very complex geometry. The disadvantages of this procedure are insufficient knowledge of the impact of the basic parameters for processing, indicating that this procedure was not examined enough, and maximally utilized economically (Powel and Kaplan, 2004).

3. Calculation of cost of laser cutting method

The rapid development of technology and manufacturing equipment and increased market demands for fast response, impose the necessity of model for more precise treatment cost calculation. As one of possible solutions, in Faculty of Mechanical Engineering in Kragujevac, a software was developed, which includes a large number of input parameters, and whit high accuracy, in short time provides detailed information about the structure and the amount of costs for different types of cutting methods (laser, plasma and water jet). This software application is based on complex mathematical model and contains several dozen entry parameters. Application is made so it represents the systematization of numerous cost calculations from different literature resources (Berglund, 2006; Harnicarova *et al.*, 2012; Nagaraja, 2001; Zheng *et al.*, 1996; Eltawahni *et al.*, 2012). In this paper analyzes model of costs calculation of laser cutting, as the most common method, which ensures best treatment quality. The common parameters and symbols are following (Nedic and Eric, 2013):

n – the number of parts that is made
n_s – number of cuts per section
L_{cut} - cutting length for one part, mm
N_{sm} - number of shift workers
P_r – the number of shift workers, RSD / h
P_m – the invested capital
p – time efficiency,%
n_h – number of hours per shift per year, h
T_m – life of the machine, the amortization time
I_{nt} – annual interest
I_{ns} - Insurance
S – required space m^2
P_z – cost of renting space, RSD / m^2
I_m – maintenance,% of invested capital annually
T_{pr} – preparatory time (programming)
P_{el} – electricity prices din / kWh (€ / kWh)
E_l – electricity consumption, kW
v_{cut} – cutting speed, m / min
T_{sp} – cutting preparation time, sec
n_{ml} – the number of nozzles
T_{ml} – ages of nozzle, h / nozzle
P_{ml} – the price of one nozzle, RSD / nozzle

The community calculation:
Electricity costs $C_{el} = E_l\,P_{el}$, RSDh (€/h):
Interest expense $C_{int} = C_c\ 0{,}5\ I_{nt}\ 0{,}01$ RSD/annually (€/annually)
Cost of amortization $C_{am} = P_m\ /\ T_m$ RSD/annually (€/annually)
Working hours of machine $n_r = n_h\ p\ N_{sm}\ 0{,}01$ h
Insurance costs $C_{ins} = P_m\ I_{ns}\ 0{,}01$ RSD/annually (€/annually)
Costs area $C_s = S\ P_z\ 12$ RSD/annually (€/annually)
Maintenance costs $C_o = P_m\ I_m\ 0{,}01$ RSD /annually (€/annually)
The cost of equipment per hour $C_m = (C_{int} + C_{am} + C_{ins} + C_s + C_o)\ /\ n_r$ RSD/h (€/h)
Consumption of nozzles on one head $H_{ml} = 1\ /\ T_{ml}$ RSD/h (€/h)
Costs nozzle $C_{ml} = H_{ml}\ P_{ml}\ n_{ml}$ RSD/h (€/h)
The total length of the cutting $L_{Ucut} = n\ L_{cut}$ m

Total preparation time and movement before cutting $T_{Usp} = (n_s\, T_{sp}\, n)/3600$ h

Total cutting time $T_{Ucut} = (L_{Ucut}\ /(v_{cut}\ \cdot 60) + T_{Usp})\, /\, n_{ml}$ h

Total cutting time (laser) $T_{Ucut} = L_{Ucut}\ /(v_{cut}\ 60) + T_{Usp}$ h

Total labor costs $C_{Ur} = P_r\, (T_{pr} + T_{Ucut})$ RSD (€)

Total costs of electricity $C_{Uel} = C_{el}\ \cdot\ T_{Ucut}$ RSD (€)

The total cost of the machine $C_{Um} = C_m\, T_{Ucut}$ RSD (€)

The total cost of the nozzle $C_{Uml} = C_{ml}\, T_{Ucut}$ RSD (€)

Laser process:
Century lens, Time / lens- T_l
Price lenses- P_l
The price of the working gas, RSD/m^3 (€/m^3) - P_{rg}
Consumption of the working gas, l/min - Q_{rg}
The price of laser gas, RSD/m^3 (€/m^3) - P_{lg}
Consumption of laser gas, 1/min - Q_{lg}
The cost of gas, RSD/h (€/hour)
Consumption of gas, lenses/hour
Costs lens RSD / hour (€/hour)
Total cost of gas, RSD (€)
The total cost of the lens, RSD (€)
Total cost cutting, RSD (€)

4. The application for calculation costs of laser processing

The metal processing industries of today are constantly experiencing problems when calculating costs treatment, especially in service companies which request the necessary rapid response to customer needs. In addition, there are also problems in the design, optimization and monitoring of parts as well as the generation of technical documentation. The function of software should provide complete information regarding the processing work with all the technical documentation. Most often, the software is not able to fulfill all the conditions as they are integrated into a specific machining system with predefined tools, machines and a small number of parameters. Problems appear in the implementation of the software as it is a very long process, hardware requirements are major, softwares are limited to specified processing / application, and often the price of these applications is high in relation to the possibilities. Some softwares are based on a database of a large number of analysis models, costs cutting, with no option to change the parameters.

In order to solve the problem it is necessary to consider all the factors that affect the processing of cutting. The essence is to reduce the time for the technical, technological and economic analysis, to reduce the cost cutting, increase efficiency and reliability.

Application Soft-TSNPO (Nedic and Eric, 2013) outlined in this paper can properly manage costs, and provide assistance with optimization of selection of cutting process, selection of equipment and forming the database of previously executed treatments. This software solution is based on a mathematical model of budget cutting process that was developed at the Faculty of Mechanical Engineering in Kragujevac. This preliminary design simplifies data management, input, update, view, forming reports using different methods of cutting metals.

During the production of software for calculating the costs of cutting Laser Soft-TEMPO following applications were used: PHP, JavaScript, CSS, HTML. It was made as a web application and is based on WAMP (Linux / Windows). The interface for the users is very easy to use, and it requires minimal knowledge for working with web browsers. Figure 3 represents scheme of calculation of cost of laser cutting with input and output parameters.

Figure 3. Scheme with input and output processing parameters
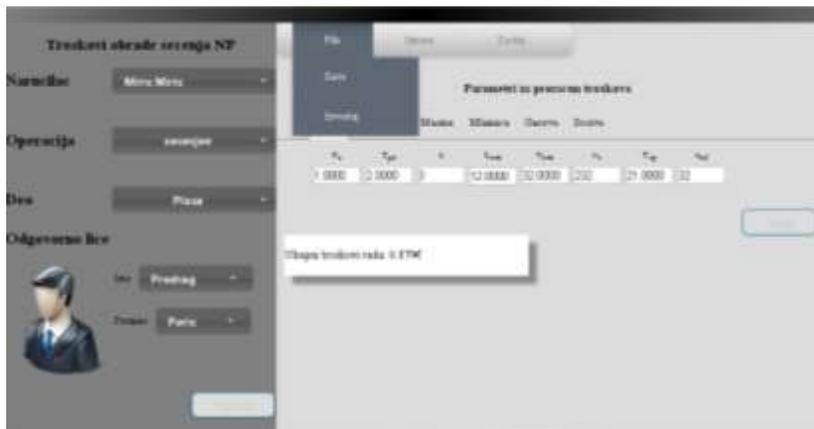
Figure 4. Home page of software Soft-TSPNO

After starting a new software Soft-TSPNO home page presents three parts (Figure 4). The first part is the navigation tab - this tab provides the option of entering new data (ADD), modifying already entered data (CHANGE) and generating reports on costs (FILE). The second part is the data that describes the operation, piece of the purchaser as well as the responsible person who performs the operation. The third part is used to input data required to calculate the total cost of laser cutting. It is necessary for working program to enter all the parameters that are required for calculation according to presented model.

Field CHANGE offers more options and all are related to changing the previously entered data on the home page application, such as contracting authority, operations, part of the responsible person. Data that can be changed are: code and name of the operation, width, length and thickness of the

panel as well as a number plate, code and title of the work, the number of parts to be cut out, cut length, note, the quality of treatment, the most basic information about the purchaser and the responsible person.

Figure 5. Overview of some cards

After entering the data needed for calculating the costs of laser cutting, generation of data on the costs and obtaining the report in the form of lists or graphics is performed (extension .txt and .chart), Figure 6:
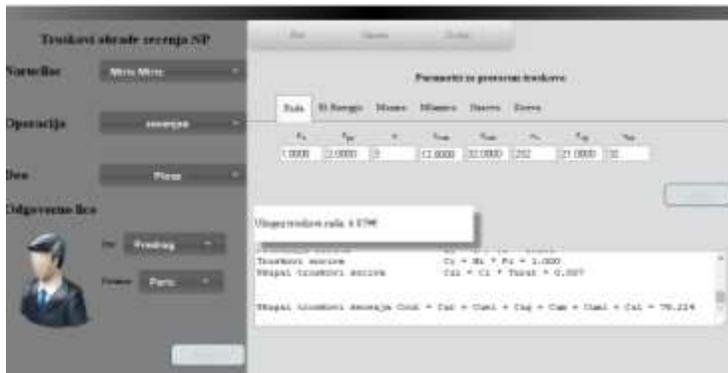
Figure 6. The 'REPORT'

Formed report next to calculated values of costs cutting laser, also contains information that were uses in the calculation, namely, accounts and reports each pattern in the model, which provides the possibility of analyzing each part of the operations and its costs.

5. Conclusions

The laser cutting process has many different capabilities and advantages that can prove very effective in the cost battle. This method ensures an optimal mix of quality, productivity and operating costs for various materials, wide range of thickness and competitive price of metal forming. In association with software Soft-TSPNO it is easily handled, and allows more ways of optimization in process of calculating costs of laser cutting. Additionally, this software generates detailed information about costs of laser cutting in each segment of the production process, for both company and client.

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