Evaluation of the Effectiveness of Engineering Production Processes using Pareto Analysis

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Abstract. **The aim of this paper is to illustrate possibilities of using Pareto method in evaluating the effectiveness of engineering production processes. The essence of this issue is dividing materials by using progressive technologies on the specific component and the evaluation of its effectiveness and quality. For the production of component was used method of dividing by the plasma, laser and water jet. To eliminate the irregularities in the quality of the resulting component was used Pareto method. The aim was to determine from the available technical knowledge the most efficient method using established evaluation model of efficiency. The result is the finding that the most effective device for dividing the chosen component is the plasma device.**

Key words: **Production process, Pareto analysis, effectivity, plasma, lasser, water yet, economics analysis**

1. Introduction

Dividing the material by plasma. As plasma gas can be used monoatomic argon or diatomic gases of hydrogen, nitrogen, oxygen or air. The plasma gas is ionized and dissociated by energy of plasma arc. By recombination of atoms and molecules outside the plasma jet, plasma rapidly releases the accepted energy and enhances the thermal effect of the plasma beam on the mechanised object.

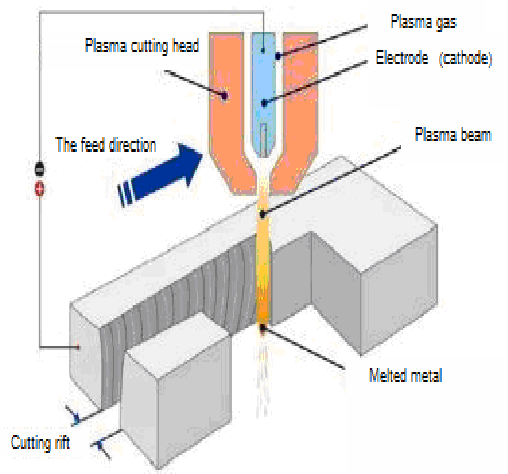

Figure. 1 Schematic representation of the cutting process of material dividing by plasma

All conductive materials can be divided. ESAB CUTTING SYSTEMS provides plasma cutting units with cutting current of 20 to 1000 A cutting thicknesses of 0,5 to 160 mm. As plasma gas is used compressed air, nitrogen, oxygen, or argon/hydrogen, to cut the carbon and high-alloy steel, aluminium, copper and other metals and alloys:

- modern technology on cutting all electrically conductive materials, used mainly on structural steel, stainless steel and non-ferrous metals,
- low thermal deformation due to the high concentration of plasma arc heating,
- high cutting speeds (5-7 fold against flame cutting and low loss of time, no need to preheat),
- by plasma current 0.5 up to 1000 A thickness from 0.5 to 160 mm can be cut,
- economic cutting of construction steel up to 30 mm, perpendicular cuts or bevels,
- the highest cut quality is achieved by soft beam or plasma with water inject.[3]

2. Dividing the material by laser

Dividing by laser (photon erosion) belongs to a group of non-conventional machining methods. Laser cutting is one of the methods for dividing, which largely do not use mechanical work for material removal, but are based on the use of a physical or physico-chemical principles to the removal of material, without force activity on machined material without producing chips. Properties of the laser beam allows when it is focused (by appropriate optical system) to concentrate into a small spot extremely high energy density at the point of impact of the beam (105-1014) [W.cm-2], resulting in melting up to evaporate the material, thereby achieving the desired effect of processing.[1]

The combination of beam power, cutting speed and the type of working gas determines which effect prevails in the cutting process, whether sublimation, or melting, resp. burning-out the material.

Requirement for qualitative shape cutting is circular polarization of the laser beam. Maximum material thickness that can be cut by laser is dependent on the wavelength and laser beam power and also on the type of material.

The basic elements of the laser. Each laser consists of three basic parts:

1 active amplifying environment, which contains atoms, ions or molecules capable of excitation to the emission energy levels and which is capable of providing the inverse population,
2 source of energy, which causes the excitation,
3 optical resonator that provides multiple reflection of photons from the plan parallel cavity mirrors (*figure 2).*

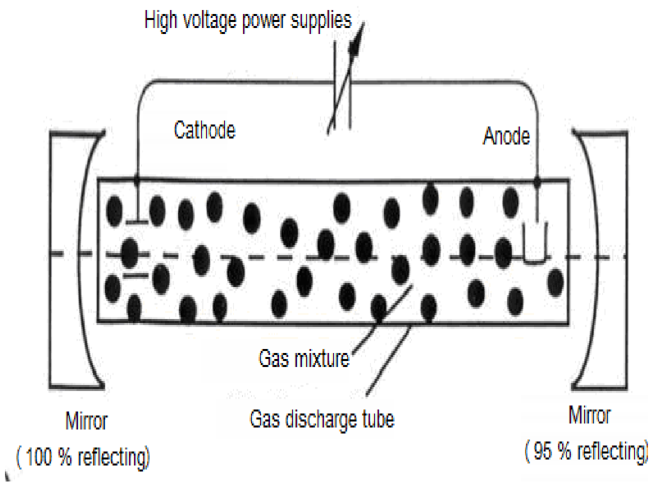

Figure. 2 Basic parts of the laser

The advantages of this technology can be observed mainly on cutting quality and on the level of metallic materials with high thickness processing economy [9]. It is needed to ideally synchronize the nozzle diameter of the water (water jet), and nozzles for abrasive materials (abrasive nozzles), hardness of abrasive material, grain size of abrasive material, the amount of abrasive material and the cutting speed. This kind of data already exists for a variety of materials.[4]

3. Dividing the material by water jet

The biggest plus of this technology compared with other methods of dividing is the process of cold cutting. This is used where the chipless, splintery and thermic processing techniques provide the unsatisfactory results because of the mechanical or physical reasons, or where they fail completely. In contrast to the thermal methods, all of the materials can be divided by using water jet without influencing them by heat [11]. This eliminates the hardening, warping of material, creation of the dripping slag and melting the material, moreover this method avoids the formation of harmful substances, eg. toxic gases. These toxic gases are often created during plasma cutting of plastic materials therefore must be disposed. As for the plates, which are coated with plastic, this cutting technique is very often the only solution that does not adversely affect the coating. Abrasive water jet is achieved so that in cutting head, in the mixing chamber, is a clean water jet mixed with abrasive, thus achieving suspension of water and abrasives, which is focused in the abrasive nozzle and leaves it as a hydroabrasive cutting water jet, resulting in an microsplintery machining of material cutting by a thin stream of water. [8]

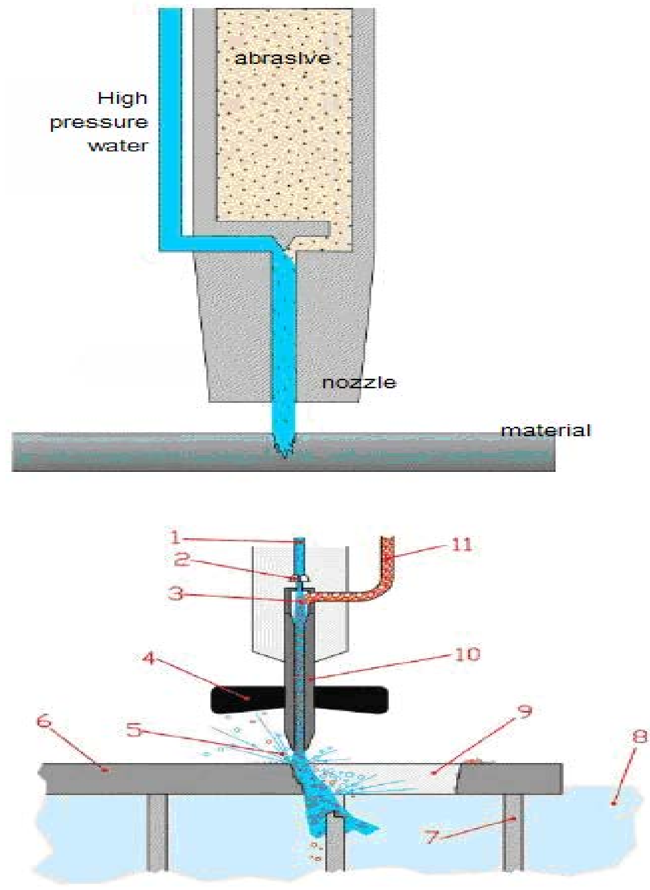

Figure. 3 Scheme of abrasive water jet machining

Scheme of abrasive water jet machining consists of: 1 inlet of high-pressure water, 2 water jet, 3 mixing chamber, 4 protective cover, 5 splash water, 6 Work piece, 7 grid, 8 water sump, 9 cut aperture in the work piece, 10 abrasive - mixing jet – nozzle, 11 abrasive - garnet, olivine, silica sand

4. The method of evaluating the quality of cut by Pareto method

Pareto method is based on the fact that:

- Only 20% of the causes is associated with up to 80% losses, thus attention should be given to 20% of the vitally important causes, thereby solve 80% of losses (task to optimize - minimizing losses from low quality production).
- The core of the product requires up to 80% of production costs, but has only a 20% impact on the customer, respectively on the contrary, environment, advertisement, brand - immaterial part, represents only 20% of production costs , but has up to a 80% impact on the customer (the task to optimize the cost of production and non-production activities).
- From the total production, 20% of the company products provides 80% of the company profits (the task to decide about the optimal composition of the portfolio of current products, but with a reserve - risk for future) [5].

Pareto principle enables an insight into the essence of the most varied phenomena, to distinguish significant phenomena from non-significant, to identify the main problems and their causes, and thereby determine the direction to corrective actions. By this it becomes a logical and meaningful decision-making tool. Those key factors are called "vital" for solving the problem, others are "non-significant", in that phase of the solution it is not generally necessary to deal with them. Of course it is possible that after mastering the vital problems of the first phase of the solution, initially non-significant problems become vital in the second phase.[2]

That is the dynamism of this approach that with time the importance of the issues may change and actually is changing.

4.1 The evaluation of quality defects using Pareto method

I chose Pareto method as a method of evaluation and comparison of the cut quality on the chosen types of device [12].

Reporting period was in the range 20. 01. 2012 – 6. 02. 2012. Following deficiencies which have consequences in terms of product quality were recorded: A - malfunction of the pressure regulator, B - cut errors, C – blackout, D - wear of burner, E - shape deformation, F - operator error, G - another fault

Table. 1 Types of defects

Date	defect
21. 01. 2012	B
21. 01. 2012	C
21. 01. 2012	A
21. 01. 2012	B
21. 01. 2012	A
21. 01. 2012	D
22. 01. 2012	B

The aim of the method is to exclude the most common cases of malfunctions on machines. Analysis is performed using the Pareto chart, which is generated by a combination of histogram of ordinal variables ordered by the frequency of options and Lorenz curve.

Table 2 Frequency of defects

Defect	Frequency
A	36
B	67
C	15
D	11
E	8
F	6
G	3
Total	146

Table 3 Arrangement of defects causes

Sorting table of frequencies	
Defect	frequency
B	67
A	36
C	15
D	11
E	8
F	6
G	3
Total	146

From the obtained values we create a histogram:

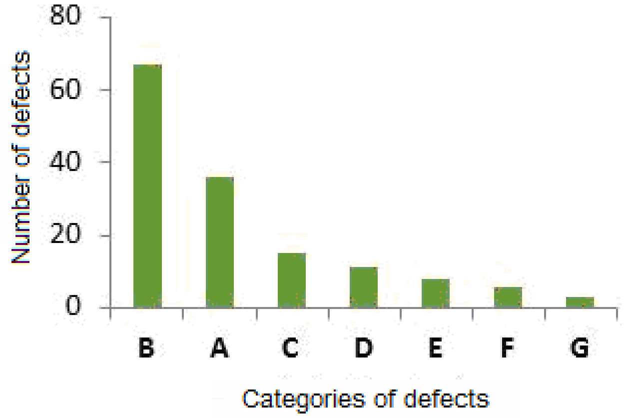

Figure 4 Histogram of values

Table 4 Values of defects frequency

Sorting table of frequencies			
Defect	Frequency	Relative frequency	Cumulative relative frequency
B	67	0,4589	0,4589
A	36	0,2466	0,7055
C	15	0,1027	0,8082
D	11	0,0753	0,8836
E	8	0,0548	0,9384
F	6	0,0411	0,9795
G	3	0,0205	1,000
Total	146	1,000	1,000

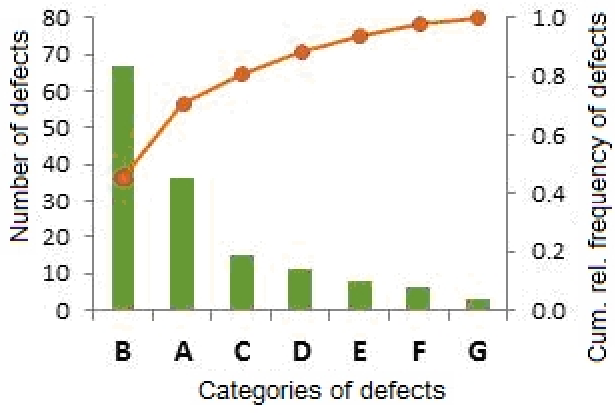

Figure 5. Chart of the most common errors

The graph shows that the largest impact on quality, is about 46%, has a incorrect cut

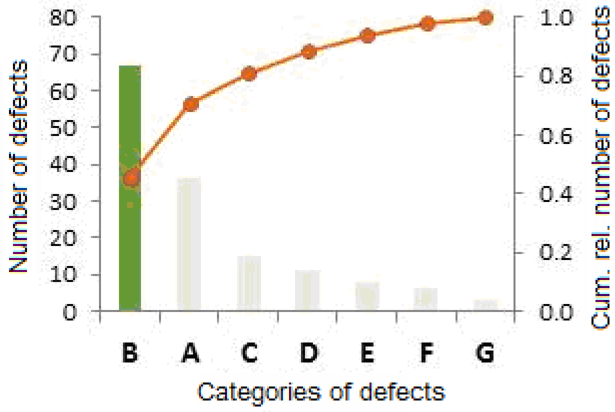

Figure 6. Lorentz curve

Based on this analysis the company should focus on the elimination of defects A, B and C

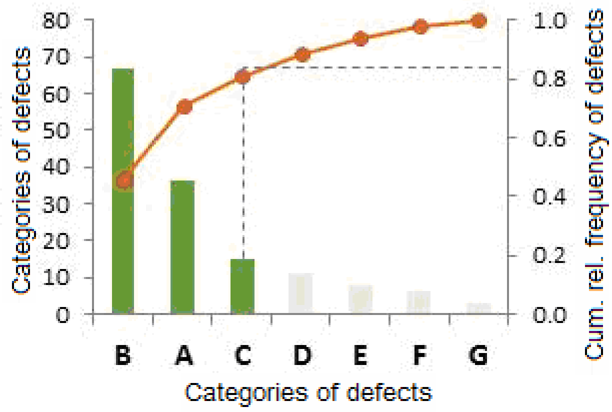

Figure 7 The resulting graph of the most common defect

5. Evaluation model of technical efficiency of material [10]

Efficiency of dividing materials largely depends on the work environment in which cutting takes place, on the values of the parameters and conditions of dividing materials and on the requirements for operation. Individual parameters and conditions are set according to the desired surface roughness values and accuracy, according to the required radius for cutting internal radiuses and the thickness and type of work piece. Above a certain value the amount of heat coming from a material increases and that causes enlargement of the depth of the layer with changed properties against the original material. This creates a surface layer.

Among the essential characteristics of engineering products' quality belong:

• usefulness,
• life,
• reliability,
• moral condition,
• economic efficiency,
• industrial design

The observed output of the cutting may be considered as machined surface. Evaluation of its effectiveness is based on an assessment of the quality of the cut.

The quality of the cut and the number of monitored parameters are further defined by:

• characteristics of the material, thickness of heat affected zone and the formation of surface micro cracks,

• geometric properties such as surface roughness, frequency and amplitude of surface furrow, gradient of cutting surface, rounded top and bottom cutting edge,

• the presence of a compressed layer and drops.[6]

As the most important indicators to evaluate the cut quality are considered:

• surface roughness Ra characterizing the geometric properties of the cut,

• TOO heat-affected area, which thickness and structure characterizes the properties of a material after machining.

5.1 Process and method of evaluation of technical efficiency

The function analysis of selected object allows understanding its nature, context and level of fulfillment of its mission. The aim is to recognize its value in use, the structure of functions that affect it, detect weaknesses in the performance of these functions and to identify the main direction of further improvement.[7]

Evaluation of technical efficiency of progressive technologies:

• determination of technical indicators that characterize the quality of the cutting edge,

• determination of significance of individual technical indicators

• decision about the desired tendency to grow or decrease technical indicator,

• enter the desired etalon - parameters of specific component,

• calculation of indexes of technical indicators of progressive technologies due to the fundamental values of a standard technical indicators,

• calculation of weighted indexes due to significance of the indicator and its impact,

• expression of levels of progressive technologies relative technical efficiency,

• determination of the most effective progressive technology in terms of technical efficiency and technical parameters of components achievable with this technology.

As an example, we introduce the design of the table to organize the technical evaluation indicators, as well as various material cutting technologies and machinery on which the whole evaluation process was performed, of course, it is only an example of the compilation of the table, the technical parameters of individual devices are not presented due to the large range.

Table 5 Technical indicators for evaluating the technical efficiency of progressive technologies [7]

Indicator	**Measure unit**	**Weight of indicator**	**Required tendency**

Table 6 Technical efficiency of individual devices

Technology of the cut		**Laser Trumatic 3020**	**Plasma Cortina DS**	**Water jet WJ 3020**

6. Conclusion

In this paper, we wanted to illustrate the possibilities for evaluating the effectiveness of engineering production processes in short by comparing the three production technologies of dividing material by the two evaluation methods on the one component. From the above evaluation as the most efficient production technology appears plasma device. Of course in one paper can not be described the whole evaluation process, it is an extensive process of content.

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