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# ANALYSIS OF CUT MILLING OPERATION OF CAST IRON IN ORDER TO INCREASE PRODUCTION VOLUME

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## ABSTRACT
*The analysis and redesign results of cut milling operation of parts made of cast iron was presented in this paper. Taking into account specificity of cut milling operation, in this particular case, and significant number of requests that have to be fulfilled, redesign of cut milling was done. The redesign was done gradually, with the analysis of improvement indicators, comparing the previous and the current situation in each phase. Proper selection of cutting machine, changing of the cutting tools concept, changing of work pieces clamping concept, castings redesign, processing regimes changes and the nature of the radial movements and also the introduction of cooling and lubrication during cutting, significantly increased tool life and capacity on a daily level, while the total operation time and the tool costs in the price of the finished product were reduced.*
**Keywords: cut milling, cast iron, cutting tool life, machining time, production volume**

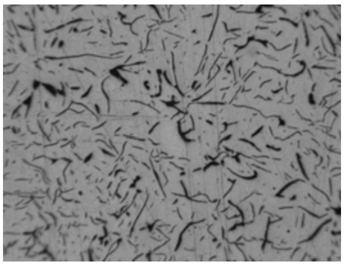
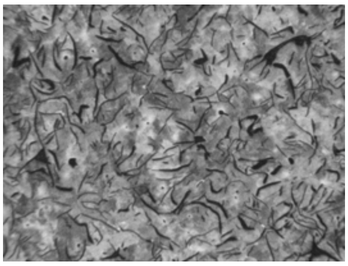
## 1. INTRODUCTION
Tools for cut milling are tools which are equipped with more than one cutting inserts arranged on the periphery of tool, where only certain number are simultaneously engaged with the workpiece. Since the cutting inserts periodically enter into engagement with the workpiece and out of it, and variation of cutting surface, dynamic load is one of the basic features of cut milling operations. The initial workpiece, whose cutting operation was analyzed in the paper, is a castings containing "set" with four components which forms an assembly during final installation. The machining process of castings contains a number of machining operations, wherein the last in a series is cut milling operation, where castings was cut in to four components which represents final products. Generally speaking, cutting

operations are mainly implemented as a prior processing operation, with the primary aim to obtain the initial workpieces. However, cut milling operations which were analyzed in this paper have certain specific characteristics which are reflected in a greater cutting width and significantly greater volume of removed material comparing to conventional cutting operations, as well as components produced by cut milling operations represent the final product.

## 2. EXPERIMENTAL WORK

In order to analyze and redesign of cut milling operation, the different cutting conditions were experimentally investigated. The wok piece was produced by sand casting technology (GJL250) (Figure 1), then machined in operations prior to the cutting, in accordance with the detailed technological process. Chemical composition, mechanical properties, polished and etched microstructure of investigated material were presented in the Table 1.

*Table 1. Chemical and mechanical properties of workpiece*

| Microstructure of cast iron GJL 250 | | Chemical composition % | | Mechanical properties |
|---|---|---|---|---|
|  |  | Ceq | 4,01 | Tensile Strength 261 – 270 MPa |
| | | C | 3,33 | |
| | | Si | 2,01 | |
| | | Mn | 0,64 | Hardness 212 – 223 HB |
| | | S | 0,072 | |
| | | P | 0,027 | |
| | | Cr | 0,109 | |

It can be seen that microstructure of the material consists of graphite flakes distributed in perlite.

Redesign of cutting operations was done gradually, with ongoing analysis of improvement indicators through comparison previous and the current situation in each step of the redesign process.

In the first stage, the current state of cut milling operation was reviewed, where cutting conditions and their effects were analyzed, Figure 1.

The machine used for processing is a horizontal machining center. The main circular motion and support radial movement performs tool, while workpiece is performing support axial movement.

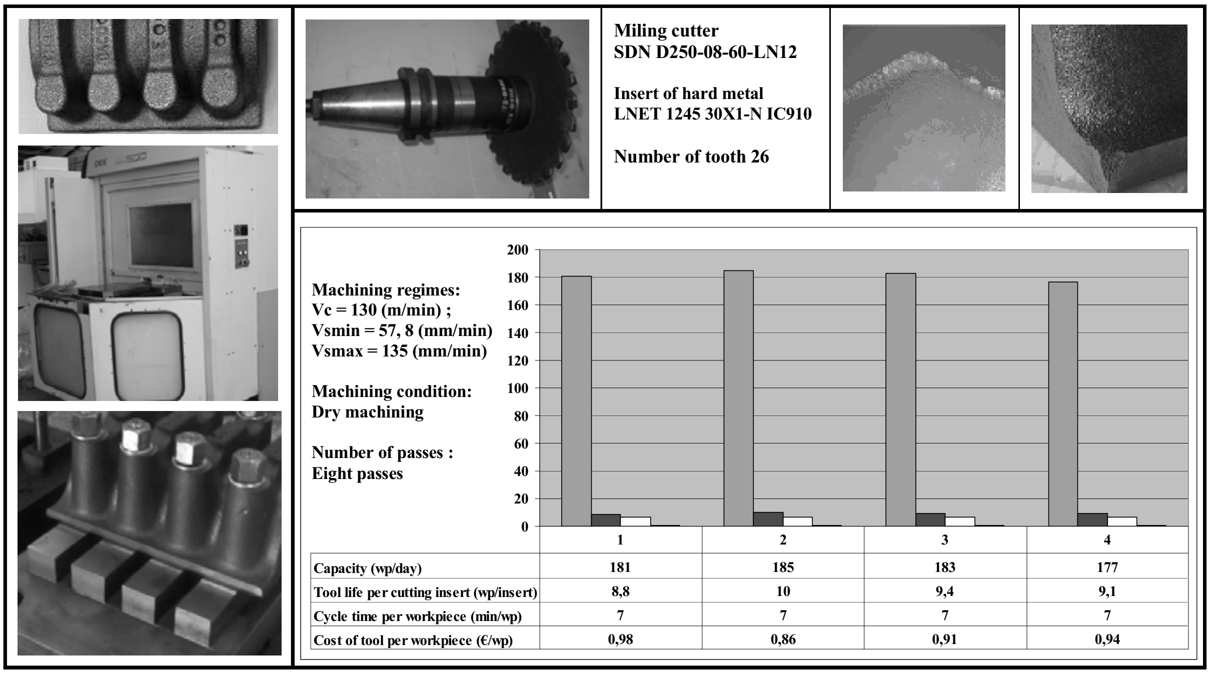
Clamping tool for cutting operation is designed on the basis of the previous operations, taking into account the structural characteristics of the machine. As shown in Figure 1, it was a mechanical clamping tool with screws for centering of workpieces through pre-drilled holes, with the clamping force provided by the nuts. Pre-machined surface of the workpiece leans against the flat part of the clamping tool which is slashed, in order to allow the movement of cutting tool in the axial direction after reaching the given position in the radial direction.

The selection of cutting tools based on the available power of the machine, the geometry of clamping tool and a minimum required width of cut on the workpiece. Milling cutter Φ 250 mm was used as a tool, with a mechanically fixed cutting inserts from hard metal, Figure 1.

Cutting operation of the castings was implemented in eight passages with a constant main cutting speed and different values of the radial cutting speed per passage (constant radial velocity of auxiliary movement along the cutting surface), in order to reduce the total cycle time per the workpiece ( casting ).

In the second stage workpiece was rotated, in the clamping tool, for 180 degrees in the radial plane.

In the third stage the concept of cut milling operation was modified, cut milling operation by only one passage is implemented. This required a modification of the concept of cutting tool and the selection of a new machine in which the processing is realized. Cutting tool consists of five milling cutters, two side Φ 200 mm and three milling cutters in the middle Φ 200 mm. Lateral and middle milling cutters have a different width and replaceable cutting inserts of hard metal with a different geometry, Figure 2. In this stage, method of obtaining the required clamping force was changed, where hydraulic clamping was used, Figure 2.




| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Capacity (wp/day) | 181 | 185 | 183 | 177 |
| Tool life per cutting insert (wp/insert) | 8,8 | 10 | 9,4 | 9,1 |
| Cycle time per workpiece (min/wp) | 7 | 7 | 7 | 7 |
| Cost of tool per workpiece (€/wp) | 0,98 | 0,86 | 0,91 | 0,94 |

*Figure 1. Cutting conditions and their effects in the first stage of cut milling operation*

In the fourth stage the redesign of castings was done. In this phase relieving grooves were introduced in position with appearance of mistakes and unacceptable defects caused by cutting operation.

Concept of clamping tool was changed in the fifth phase, a tool with a single nest, variable radial velocity of auxiliary movement through zones of cutting surface was introduced. Also, cooling was involved in the process of cut milling operation, Figure 2.

## 3. RESULTS AND DISCUSSION

The analysis of the effects of the cut milling operation in the first stage (four repetitions with the same processing conditions), Figure 1., as well as analysis of the effects through the stages of the redesigned cut milling operation, Figure 2., includes capacities on a daily basis, tool life per cutting insert, the duration of the cycle per casting, as well as prices of tools in total processing cost per workpiece.

Unacceptable defects caused by material deformation, tearing off material particles from the contact of two or more machined surfaces, tearing off particles larger then 2mm and dimensional deviation were used as a tool wearing criterion to determine tool life, Figure 1.

In the first and second stage, lower radial velocity are used in passages that generate the final lateral surface of the workpiece, while the larger value of radial velocity was used in the generation of side surfaces of the workpieces that will be removed in the next pass of cutting operation ("excess" of material caused by the difference in width which needs to be removed by cutting and a maximum width of cut that can be realized by milling cutter).

In the third and fourth stage, cut milling operation was implemented by only one passage with a constant value of the radial speed. In the last stage, cut milling operation was implemented with introduction of the variable speed of radial movement through the zones of cutting surface in order to reduce cutting forces and the total cycle time.

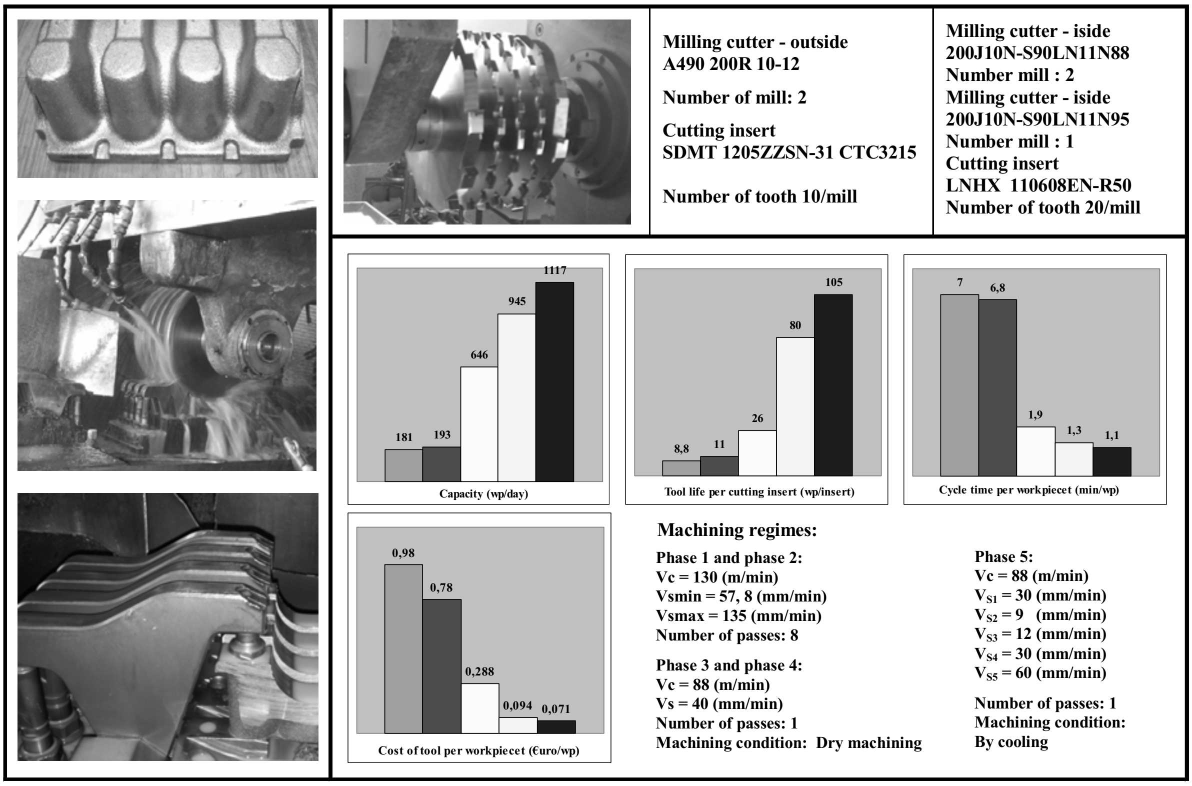



*Figure 2. Comparative analysis of cutting conditions and their effects through the stages of the redesigned cut milling operation*

Comparative analysis of cutting effects through the stages of the redesign, as seen from left to right in Figure 2, shows the growth trend of capacities on a daily basis and tool life per cutting insert, as well as reducing trend of cycle time and participation of tools cost in total machining costs.

The highest increase of capacity and tool life, as well as the highest decrease of cycle time and the tool costs in the overall cost of processing, Figure 2., were obtained in forth phase by initial workpiece redesign.

## 4. CONCLUSIONS

- Modification of the cutting tool concept, changing of workpieces clamping concept and changes of processing regimes significantly increased tool life and capacity on a daily base, while reduction of cycle time and the tool costs in the overall processing cost were observed.
- Redesign of the initial workpieces resulted in the highest increase in tool life and production rate as well as reduction of tool costs in the overall processing cost.
- The introduction of the variable speed of radial movement through the zones of cutting surface and application of the cooling and lubrication significantly improved analyzed effects of cutting operation.

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