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IMPROVEMENTS AND BENEFITS OF UPGRADING CNC MACHINE FOR ENGRAVING AND CLEANING METAL PARTS

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Abstract: The main goal of this research is to demonstrate a design solution of upgrading an existing CNC engraving machine for cleaning metal parts. With this improvement the time of finishing metal parts was reduced and higher quality of the finished products was obtained, with improving the safety usage standards. Special CNC engraving machine was designed, which is used for final processing of metal parts. Also improvements in the automatization of the whole process were implemented. The practical aspect was based on the improvements and adaptation of an existing CNC engraving machine with applying innovative measures, which increase the productivity by automating the process and reduction the risk of injuries of the operators.
Keywords: CNC machine, engraving, upgrading, cleaning, improvements

INTRODUCTION

Metal parts in the car industry for production of catalysts are not final products. Usually the customers have additional quality requirements, and for that reason final processing of the products is necessary.

The request is done on written form with an attached sketch. There is a statement regarding which part of the metal product need final processing, surface cleaning from the chemical coating.

The sketch often contains too little information and this is the main reason, why the best quality method of cleaning is applied in order to prevent complaints from customers. The chemical coating that remains on the metal parts after their production is a big problem in the welding process, because chemically reacts with the weld beam and changes its physical properties. The chemical coating contains very strong acids and bases, depending on the applied method of welding and reacts differently. In that case it is obviously that an additional welding process will be problematic in case of presence of remains of chemical coating.

Analyses were done in order to investigate how metal parts in similar industries currently have been cleaned. Analyses have shown that two methods are usually applied for cleaning metal parts: using a machine to clean the circular parts or applying a robotic arm [15]. In order to select the most appropriate method an analysis of the advantages and disadvantages of the previous methods was done. The advantages and disadvantages of the currently used cleaning methods are given in Table 1. From Table 1 it can be seen that the both applied methods have quite opposite advantages and disadvantages. Depending on the request from the client, an appropriate method which adequately responds to the client requests is used. To select the most appropriate method additional analysis of the order, has to be conducted. The obtained results are presented in Table 2.

Table 1. Advantages and disadvantages of the currently used cleaning methods

Machine for cleaning circular parts		Robot arm for cleaning metal parts	
Advantages	Disadvantages	Advantages	Disadvantages
Costs	Limited shape	Unlimited shape	Costs
Number of cleaned parts	Quality of cleaned parts	Quality of cleaned parts	Number of cleaned parts
Simple equipment			Complex equipment

From the analysis we can conclude that it is necessary to apply a method which can enable a greater range of geometric shapes of working parts. In this case it is necessary to apply a high precision method, which will be able to clean various types of geometrical shapes (elliptical, circular parts). Currently used cleaning methods, could not fully

respond to the customer requests. In order to respond to the customer demands, a new innovative cleaning method was applied, involving the usage of a CNC engraving machine.

Table 2. Analysis of customers requirements

Planned production on a monthly basis	Cleaning capacity	Possible solutions
Current production of elliptical metal parts is 40.000 pieces	Manual cleaning – 18.000 pieces. Monthly capacity of 2-3 operators	Bringing machine for cleaning with dry ice [11]
Planed additional 40.000 elliptical pieces that need to be cleaned in the current year	A cleaning machine with dry ice with a capacity of 60.000 pieces per month (the machine is located outside the country)	Designing a special CNC engraving machine for cleaning metal parts, which will also satisfy the capacity for cleaning the planned number of pieces
30.000 pieces other round parts	Total cleaning capacity of 78.000 pieces per month	Implementing this process in production with the appropriate quality standards [14]
Other forms of parts-8.000 pieces		
Total number of parts which need to be cleaned - almost 120.000 pieces		

UPGRADING OF CNC MACHINE FOR CLEANING METAL PARTS

The cleaning concept consists of using a CNC engraving machine, as a tool for cleaning metal parts with different shapes [2]. The basis of this idea consists of part A (whose shape and diameter can considerably vary), which needs to be cleaned and to be positioned and a CNC engraving machine where the spindle with a metal brush for cleaning B performs complex movements around the part where the cleaning process is necessary (Figure 1).

In order to confirm the concept of using an existing CNC [1] engraving machine as initial equipment, firstly the system for holding the parts which need cleaning, was constructed. Since different parts with different shapes [10] have to be cleaned, the biggest challenge was to make an universal system that can grip all forms of processing parts.

Figure 2 shows the concept of design of gripping mechanism [4] for the parts which need cleaning. This system consists of several elements which have specific role in gripping the parts which have to be cleaned and to be placed on the machine table.

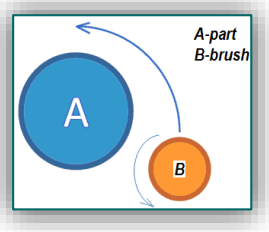

Figure 1. Movements of the metal brush around the piece [7]

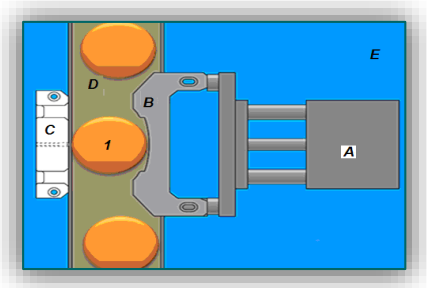

Figure 2. A conceptual design for gripping parts which need cleaning

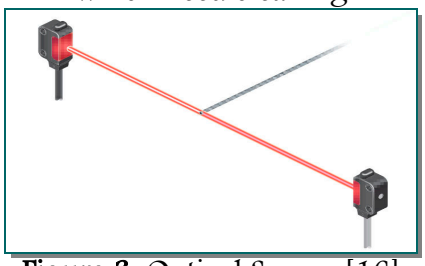

Figure 3. Optical Sensor [16]

A movable arm element B is attached to the air cylinder A. The mobile arm has the shape of the one side of the working part which needs cleaning. The working parts travel on a conveyor belt D, until the moment when the part comes to the center of the static element C. An optical sensor is positioned on that place, which operates using a transmitter-receiver (Figure 3).

When the sensor signal is interrupted, an optical sensor detects a piece [9] and the conveyor D stops, while the center section of the part is located just in the middle of the movable element B. The sensor sends a signal that there is a piece in front of it and also sends the information to the air cylinder A to move. The piece moves to the static element C and it acts on it with constant pressure from the air cylinder A. Figure 4 shows a 3D model of the proposed idea for gripping unit.

Because large amounts of metal parts need cleaning, it was decided this system for cleaning metal parts to be incorporated into the CNC engraving machine with multiple cleaning heads. According the size and needs for cleaning metal parts, the optimal solution was upgrading of a CNC engraving machine with 4 cleaning heads. Figure 5 shows a 3D model of an upgraded CNC engraving machine with 4 cleaning heads.

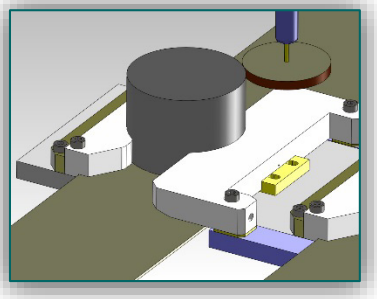

Figure 4. A 3D model of the proposed idea for gripping unit

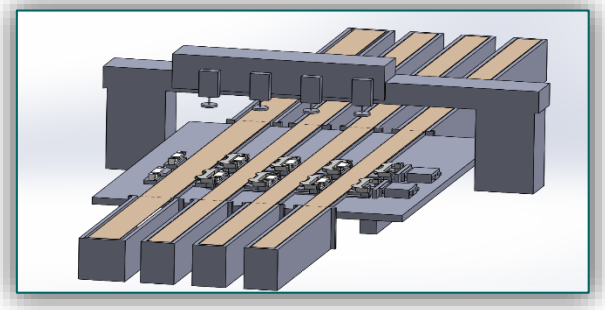

Figure 5. A 3D model of the implemented system for gripping parts on the engraving machine [6]

Figure 6. A photo of the upgraded CNC engraving machine [5]

All necessary simulations were done on the 3D model in order to check the functionality of the system [3]. All performed tests demonstrated positive results. After that, the next step was implementation of upgraded existing CNC engraving machine. Figure 6 shows a photo of the upgraded CNC engraving machine.

The real model justified the expectations and demonstrated that various forms of working parts can be cleaned at high speed. After the design, the process of complete cleaning with detailed overview of each step [12], was defined. For each step the necessary time was specified, and the total time for cleaning of a particular product was defined.

After the upgrading of CNC engraving machine, a significant step is also the optimization of the overall cleaning process, where all steps are discussed in details and additional improvements are introduced.

IMPROVEMENT OF THE PROCESS FOR CLEANING METAL PARTS

The metal parts should be cleaned from both sides. After the implementation of CNC engraving machine [13] and its daily use in the cleaning of metal parts, a logical step was a defining standard working procedures for each of the working positions, standard number of operators and jobs, standard time for the working cycle of the machine and finding a technical solution for elimination of the manual work [8].

It was necessary to examine the scope of tasks for each of the operators working on the CNC machine and at the tracks of the material flow.

In this analysis the number of pieces that passed through the operators hands were observed. Higher number of pieces, enable greater opportunities for making errors and omissions. Manipulation and catching the pieces are steps which operators do not notice during the operation. Therefore, the observation was made by another person from distance. The lean tool that was used for this analysis is called Yamazumi - line balancing. The role and involvement of operators who are the most familiar with their work is crucial. So their creativity it comes to the fore with this tool. A very important step that should not be forgotten before the start of the observation, is the communication with operators which will be involved in the measurement. An important part of this phase of the project was the involvement of operators as the best source of accurate information and experts in the relevant field. Data collection was conducted by two methods of measurement. Firstly, by observing of a video recording and secondly, by direct observation of the work of the operators on the workplace. Dual monitoring was done in order to obtain accurate confirmation of collected data. The calculation of the required number of operators on each of the working positions was done by dividing the total time required to perform all work steps at each working position with the time of one machine cycle (see Table 3). The required number of operators is rounded to the next integer value.

Table 3. Calculation of the required number of operators for each of the working positions

	Position 1	Position 2	Position 3	Position 4
Time of work steps (sec)	40	8	8	31,9
Machine cycle (sec)	18	18	18	18
Number of needed operators	2.22~3	0.44~1	0.44~1	1.77~2

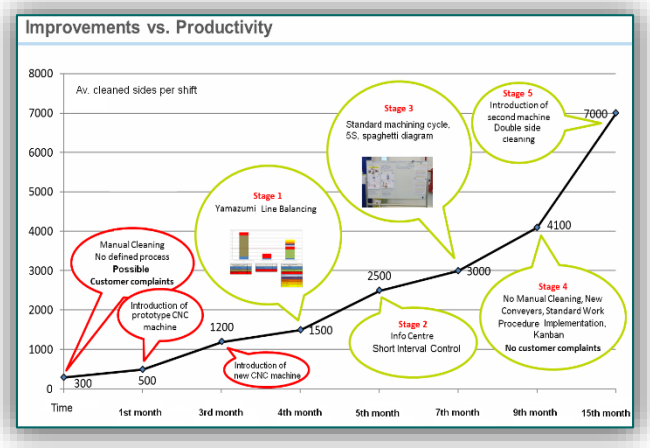

Figure 7. Influence of improvements on the productivity

Once the required time for each position was individually defined, the required number of operators for each of these positions, was also established. After the results of the measurements were obtained for each position, an analysis of the data was conducted. Using the collected data, several successive improvements in the cleaning process were made.

- First improvement - An analysis of the initial balance was conducted. A schedule for operators was made in order to get a more balanced work.
- Second improvement - An extension of the exit conveyors was made and tools for cleaning were defined.
- Third improvement - Analysis and standardization of the machine cycle for parts cleaning.
- Fourth improvement - extension of the conveyors front part in order to get more parts on stock. A Kanban system for inventory control was also introduced.
- Fifth improvement - Adding a second machine for cleaning parts from the both sides and definition of the overall process.

All these improvements were made subsequently, one after the other. So, after the each implemented improvement, an additional analysis of the overall cleaning process was made, in order to identify the weak points and to find ways to eliminate them. The relation how the improvements affected on the productivity is presented in Figure 7, where the improvements are presented by stages.

CONCLUSIONS

This innovation project is an excellent example how a simple CNC engraving machine can be upgraded and used for different purposes. Although the overall project, seems very simple, in fact it is a brand new concept for cleaning metal parts, which offers a new direction in the automotive industry. This concept has already been accepted in two factories and it is applied in the same manner. Modern production requires fully functional equipment. The fulfillment of these conditions is only possible if the specialization of the equipment is raised to a high level and the production time of products is drastically reduced, as it is the case with the above mentioned CNC engraving machine.

To achieve this goal, it is necessary to know the specific elements of the production process and the applied technical and technological solutions. Different design solutions in practice show different results in terms of quality and time of the finalization of the products under specific conditions of exploitation. But considering cost-effectiveness, it can be said that this design was the best solution. With upgrading the existing CNC engraving machine and optimization of the process of cleaning, the number of the cleaned parts increased from 300 to 7.000 pieces per day.

After this achievement in the process of finishing metal parts, it is expected overall process to be improved with more complex equipment, which can allow finalization of much larger and more complex parts.

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