ELECTRO DISCHARGE MACHINING AS AN ECONOMICAL MANUFACTURING SOLUTION

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Abstract: This paper evaluates some technological solutions to manufacture components from an electromagnetic switch. As suggested in this paper, whenever is possible, is economical to choose electro discharge machining because currently is an affordable technology, competing even with high productivity methods like punching.

Keywords: electro discharge machining, punching, productivity

1. INTRODUCTION

At the beginnings, nonconventional technologies were named like that because were using other methods than metal cutting technologies. In the same time, productivity of nonconventional technologies was at the lowest level compared to conventional ones. In addition, the availability was low and equipment prices were high. Unfortunately, this characterisation was perpetuated in the mind of managers and engineers. Nowadays, nonconventional machines are similar in price and performance related to conventional ones. To support previous affirmation, this paper presents an economic evaluation of a common technology - punching - and electro discharge machining (EDM).
Product analysed is an electromagnetic switch - PTM200, composed of: relay armature U - 1, relay armature I - 2, bending spring - 3, coil case - 4, levers - 5, motherboard - 6 (figure 1).

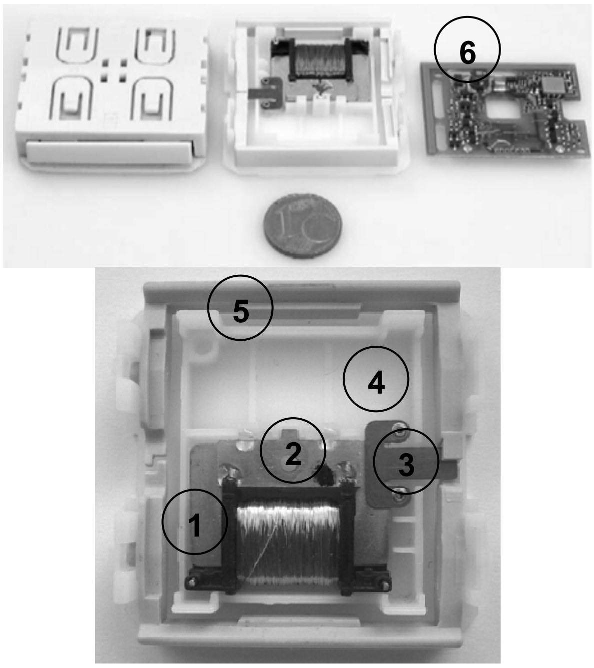

Fig. 1. Electromagnetic switch components

2. CHOOSING THE TECHNOLOGY

Parts, which are analysed within this paper, are: relay armature U - 1, relay armature I - 2, bending spring - 3, presented as technical drawings in figure 2, 3 and 4.

2.1. Punching

Punching is a cutting operation over closed shapes, which is using a die with special step punching knife. High precision dies like this are using a guiding plate as well except that instead using a mobile stop, a special tool is used [1].

First step in designing technology for punching is establishing the cutting strategy. This is necessary in order to design the die components and not at last, to avoid unnecessary lost of material [2]. Punching strategy for three components analysed are presented in figure 5.
Blanks for U and I armatures are steel roll sheets NiFe max 48, with 30x10,000x1.5 mm dimensions respectively 20x10,000x1.5 mm.
For spring, is used a spring steel roll, W 1.4568 with 12x10.000x0.2 mm dimensions. Dies are mounted on ESSA 30t press and for de Ø1.1 holes is using another die mounted on an eccentric press.

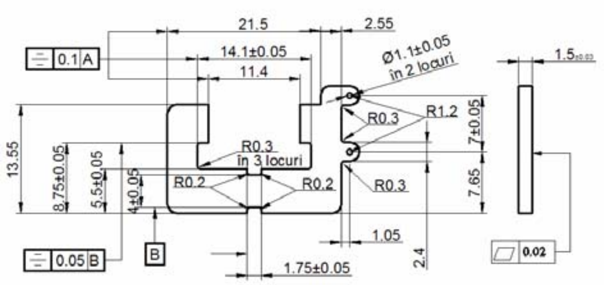

Fig. 2. Relay armature U

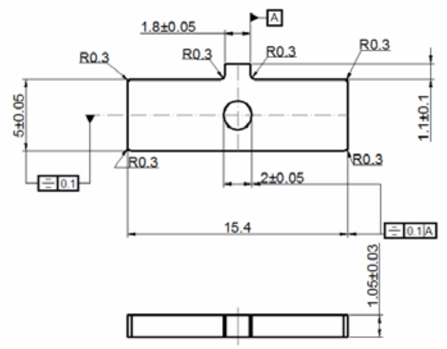

Fig. 3. Relay armature I

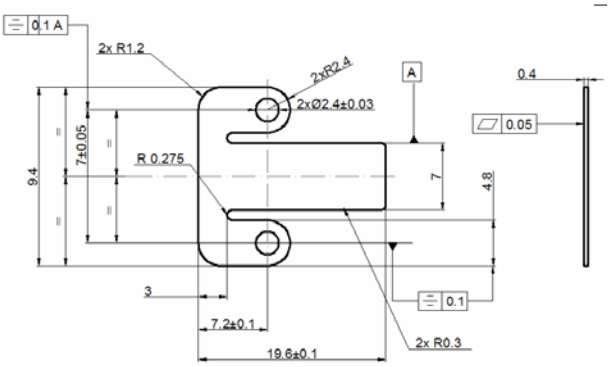

Fig. 4. Bending spring

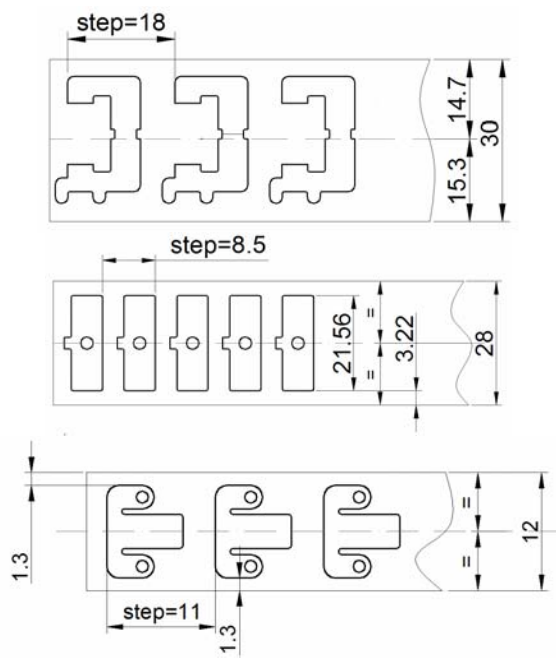

Fig. 5. Punching strategy

For U shape, technological flow is contour punching, punching perforations, holes deburring, polishing, adjustment, degreasing, heat treatment and final inspection. For I shape, technological flow is punching, degreasing, heat treatment, adjustment and final inspection. For spring, technological flow is punching, heat treatment and final inspection.

Material usage for U armature is as follows.

First, the weight of one steel band - Wbu - is calculated with formula (1):

$$Wbu = L \cdot W \cdot Th \cdot \rho = 10000 \cdot 30 \cdot 1.5 \cdot 7.8 = 3.51 \text{ kg} \quad (1)$$

where:

L = length of steel sheet band [mm]

W= width of the steel sheet band [mm]

Th = thickness of steel sheet [mm]

ρ = material density [g/cm^3]

Using the planning strategy presented in figure 5 one band will include 18 U shapes. Consequently, the number of pieces - Np - resulted is:

$$Npu = 10000 / 18 = 555 \text{ pieces / roll} \quad (2)$$

Since the weight of one U shape is Wp = 3 g then the mass of all pieces is 3 x 555 = 1,665 kg.

The material usage grade is:

$$\eta u = Wp / Wb \cdot 100 = 1665 / 3.51 \cdot 100 = 47.43\ \% \quad (3)$$

Using the same reasoning as above and the same formulas as (1), (2) and (3) the results for the rest of analysed parts are:

- for I shape ηi = 75.38%
- for spring ηs = 59.02%

2.2. Electro discharge machining

Electro discharge machining is the proposed technology to obtain three parts described above in order to reduce the production costs.

Both EDM types will be used to machine, respectively wire-cutting EDM for contours and die sinking EDM to obtain the holes.

The machines used for EDM are Electronica SprintCut, a four axes wire machining and Electronica SmartZNC for die sinking EDM.

In order to reduce the costs the first step in technology design is to find an appropriate arrangement for part over the steel sheet [3]. The optimal solutions are presented in fig. 6. In every picture, symbols were used to indicate the wire path. Margins, in size of 20 mm, were reserved on every metal sheet in order to fix the blanks on machine table.

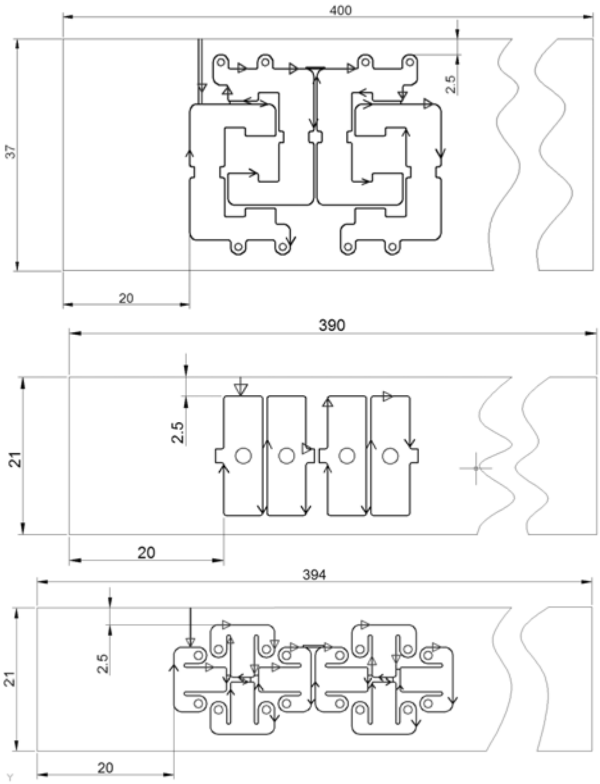

Fig. 6. EDM strategy

In case of electro discharge machining, material usage for U armature is as follows.

First, the weight of one steel band - Wbue - is calculated with formula (4):

$$Wbue = L \cdot W \cdot Th \cdot \rho = \quad (4)$$
$$400 \cdot 37 \cdot 1,5 \cdot 7,8 = 0.17 \text{ kg}$$

were the significance of terms is identical as those presented in formula (1).

The number of pieces obtained from one band is:

$$Npue = 4 / 9 = 36 \text{ pieces / roll} \quad (5)$$

Considering that the weight of one U shape is 3 g the mass of all resulted parts from one band is 3 x 36 = 108 g = 0.108 kg.

The material usage grade is:

$$\eta ue = Wpue / Wbue \cdot 100 = \quad (6)$$
$$0,108 / 0.17 \cdot 100 = 63.53 \%$$

In order to correlate the two technological processes the material usage in case of punching will recalculated for the same amount of material as used in case of EDM.

With a steel band with dimensions 444x30x x1.5 mm and using formula (1), the band weight - Wbu1 - is 0.17 kg. The number of resulted pieces from this band is 444/18 = 24 pieces. Using a punching step of 18 mm and considering that the mass of one U shape is 3 g the whole mass of resulted parts is 3x24=0.072 g.

In this case, the recalculated material usage grade is 42.35 %.

At EDM, for I shape, material usage grade is:

$$Wbie = L \cdot W \cdot Th \cdot \rho = \quad (7)$$
$$390 \cdot 21 \cdot 1,5 \cdot 7,8 = 0.096 \text{ kg}$$

The number of I pieces obtained from one band is:

$$Npie = 4 / 9 = 36 \text{ pieces / roll} \quad (8)$$

Considering that the weight of one I shape is 1.5 g the mass of all resulted parts from one band is 1.5 x 52 = 78 g = 0.08 kg.

In this case, material usage grade is:

$$\eta ie = Wpie / Wbie \cdot 100 = \quad (9)$$
$$0,08 / 0.096 \cdot 100 = 83.33 \%$$

Using the above argumentation for the necessity of the material usage grade recalculation, with the same amount of material at punching, the recalculated material usage for I shape is 67.70%.

Following previous reasoning to calculate the material usage at EDM, for spring, the result is ηse = 67.74% and the recalculated material usage, in case of punching, is 51.61%.

To facilitate a better overview over material usage grade, for both analysed technologies, the result are synthesised in figure 7.

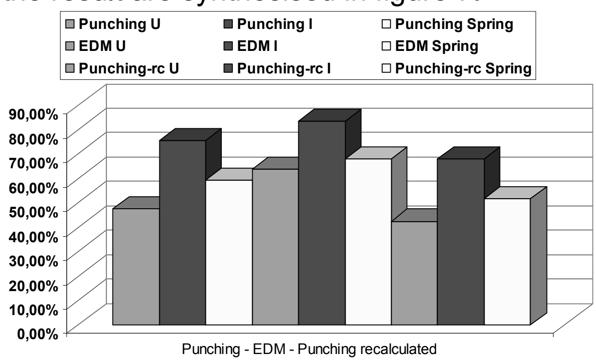

Fig. 7. Summary of material usage grade

2.3. Productivity of electro discharge machining

In order to decrease the machining time for U armature, 40 steel sheets will be stacked together and clamped to EDM Sprintcut machine table. After machining, parts resulted will be stacked again and clamped to Electronica ZNC machine table in order to machine the holes.

Wire EDM software calculates the cutting perimeter, this one being in fact the path length for wire and having a value of 3.735 mm. By using, a regular cutting sped of 8 mm/min the amount of time necessary is 7.7 hours [4]. In this time, 1440 pieces are obtained. At machining time, an auxiliary time of ten minutes is added, this time being required to clamp and detach the parts to and from the machine table.

On every month, the ordered production is 4000 pieces. As a conclusion, 4000 pieces could be produced after 4000 x 8/1440 = 22.2 h ≈ 23 h.

The holes of Ø1 mm will be machined using simultaneously two cooper electrodes. The amount of time involved in holes machining will be calculated by using volumetric method. The volume of one hole through the stack of steel sheets is 56.991 mm (3.14 x 0.55^2 x 60). From Electronica ZNC die sinking technology tables, the recommended erosion speed is 50 mm^3/ min. Consequently, one hole is machined in 1.14 min but because two electrodes are used in the same time, the holes of one U shape are obtained simultaneously. As a result, the entire production batch of 4000 is machined in 57 min. or approximately one hour.

For I shape the technological flow is the same as for U shape exception the fact that the steel band have 21x390x1.5 mm dimensions and the resulted erosion path is 2340 mm. From a stack of 40 steel bands are resulted 2080 pieces. Using the same cutting speed of 8 mm/min the 2080 pieces are machined 4.86 hours. Adding the same ten minutes necessary for auxiliary operations, the completely 2080 pieces are effectively machined in about five hours. Consequently, the amount of time involved in machining 8000 pieces is approximately 20 hours.

In order to obtain the Ø2 mm holes in I armatures the same machining strategy, as in the case of U armature, is used. In summary, the entire batch of 8000 pieces is machined in approximately seven hours using eight cooper electrodes.

In case of spring, the only difference is that the steel thickness is 0.2 mm. As a result, the machining time for 4000 pieces is about 9 hours for contour and about of 1 hour for holes.

As a summary, the machining time for each piece is presented in table 1.

Table 1. EDM Machining Time

Machining time [h]	U	I	Spring
Wire EDM	23	20	9
Die sinking EDM	1	7	1
Total / batch	24	27	10

3. CONCLUSIONS

This paper has illustrated the benefits of EDM technology compared cu a high productivity technology like punching. When the production batch is dimensioned correctly or when the delivery time in not important, electro discharge machining is the cheapest solution given as well to opportunity to design better production systems.

As resulted from figure 7 using a better material arrangement in case of EDM the material usage is higher with 20% that those resulted from punching. Consequently, this is an easy way to reduce the material costs.

EDM machining times, presented in table1, although they are not comparable with punching technology are good enough to be an alternative to conventional technologies.

In case of EDM even the production cost will be lower, and not just because new dies must be designed for every shape or at least new active parts accordingly to the shape of the pieces. At punching, production cost will be weight by the cost of dies and designing costs. If at total production time is added the dies design time and the production time for dies then the times are comparable with EDM. At same time, designing the technology for EDM is simple enough and not required highly specialised personal like those involved in dies design.

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