INPUT PARAMETER INFLUENCE ON PARTS PROFILES OBTAINED THROUGH MAGNETIC SHAPING

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Abstract: It is a known fact that cold plastic deformation processing continues to develop compared to machining, moulding or hot deformation. This statement is justified by the fact that, in relation to the mentioned processes, plastic deformation can lead to a number of technical and economic advantages. To solve some technological problems of low rigidity parts processing and joining of these parts without using traditional methodologies, unconventional processes have emerged or have been developed. These are not intended to replace classic methods of cold plastic deformation, but only to complement them. Currently, high and very high speed deformation processes have been known to produce good results, such as mechanical pneumatic, explosive, electro-hydraulic or electromagnetic processes [1], [2]. Among these, deformation through the use of an electromagnetic field is the focus of researchers. The experimental researches were carried out on three materials: aluminium, brass and copper. We present the influence of input parameters on profiles obtained through magnetic shaping, the relative elongation of the material during drawing operations (truncated cone shape); the influence on the relative elongation of the material during drawing operations (cylindrical shape); the influence on thickness variation during drawing operations (truncated cone shape); on component thickness variation during drawing operations (cylindrical shape) during block shaping operations. Thus, the energy has a direct influence on the relative elongation of brass when it is deformed at high speed, while N and g factors have an influence of only 25% of the energy's influence. In terms of the analysis of the factor's effects on the component thickness deviation, it's indicated an increase in the influence of the component thickness as relative elongation takes into account material displacement in the surface plane which becomes deformed and also thickness variation due to movements of material. This occurs in a perpendicular plane. Otherwise expressed, by increasing the thickness of the deformed sheet, the volume of material moving in this direction is also increasing.

Key words: parameter, profile, magnetic shaping

1. INTRODUCTION

Electromagnetic processing is a high-speed technology that uses magnetic field pulse. It applies forces on tubular parts or sheets made of highly conductive materials. The principle is based on the physical effects described by Maxweel in 1873 [3]. The physicist explained that a temporary fluctuating magnetic field induces electric currents near conductors and, in addition, exerts forces in these conductors (today known as the Lorentz force).

It should be noted that the electromagnetic forming process is based on the use of a source that releases an energy focused on the workpiece. At the moment, due to increased practical and theoretical accumulations, there are various tool-devices that allow high concentrations of electromagnetic flow and distorting energy to certain areas of the piece.

Due to these significant advantages, magnetic shaping applications were introduced in top industries such as automotive, civil engineering, aviation and space, etc.

The process principle is based on the electromagnetic induction phenomenon. According to this phenomenon, when a coil is traversed by an electric current, variable in time i(t) , with a frequency f, it creates a magnetic field B (t) of the same frequency around it. If a massive piece (wire) made of a good electrically conductive material is introduced inside this field, eddy currents are produced (also called Foucault currents). These currents have the same frequency f but their direction is opposite to current i(t) .They are located close to the sample surface due to the skin effect. This effect was first described by Lamb (1883) for circular conductors and was generalized to conductors of any shape by Heaviside (1951) [3]. The depth of current penetration into workpiece δ depends primarily on the specific electrical conductivity of the workpiece and the frequency f of the closed electric circuit:

$$\delta = \frac{1}{\sqrt{\pi \cdot \mathrm{f} \cdot \mu_0 \cdot \mu_r}} \tag{1}$$

For an in-depth study of the phenomena of the electromagnetic field deformation process, the specialists had to know the mechanics of a dynamic process created in high power electrical circuits with parameters that vary during the process. It should be noted that, during the workpiece deformation, an electromotive force is inserted into the coil-inductor. This can lead to a energy transfer reduction from the magnetic field formed for the workpiece [4].

As shown earlier, in processing plants the energy is accumulated in the capacitor through the electromagnetic field (equation 1). When high voltage circuit is interrupted, the capacitor discharges. An energy discharge will occur. The energy will be transferred in a very short time to the coil-inducer. From here, through the electromagnetic field, the energy will move to the workpiece, which will change shape due to the pressure exerted by it. The way the energy is split inside capacitors (energy storage), during its transfer, is suggestively shown in Figure 1.

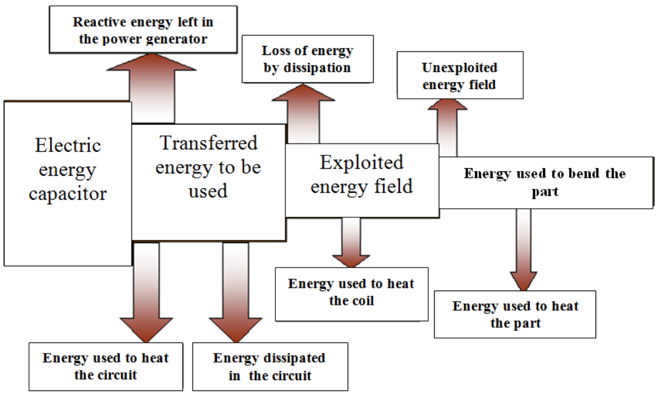


Fig.1. Transfer of energy in electromagnetic energy systems [3]

It can be observed that the energy released during the discharge turns into a parasite electric field, heat and deformation work. There is information [3] that due to losses incurred during the transfer of energy from the capacitor towards the deformation process, process efficiency is between 10% and 40%.

The main system parameters that influence the electromagnetic field processing are: electrical conductivity; deformed plate thickness; the shape and size of deformed parts and mechanical characteristics of machined parts.

2. RESEARCH METHOD AND EQUIPMENT INFORMATION

As input parameters that influence the electromagnetic field forming process, we chose to study the following parameters: discharged energy *E*; the number of coil turns *N*; workpiece thickness *g*.

As process output parameters we chose to study the following parameters: relative elongation of drawing; workpiece thickness after drawing deformation; workpiece height after block drawing.

Starting from the selection of the three input parameters to be studied, we chose to set up a full factorial experiment 2^3.

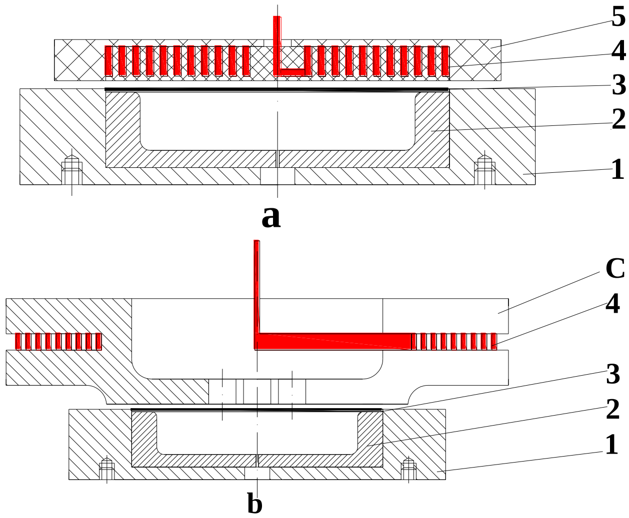
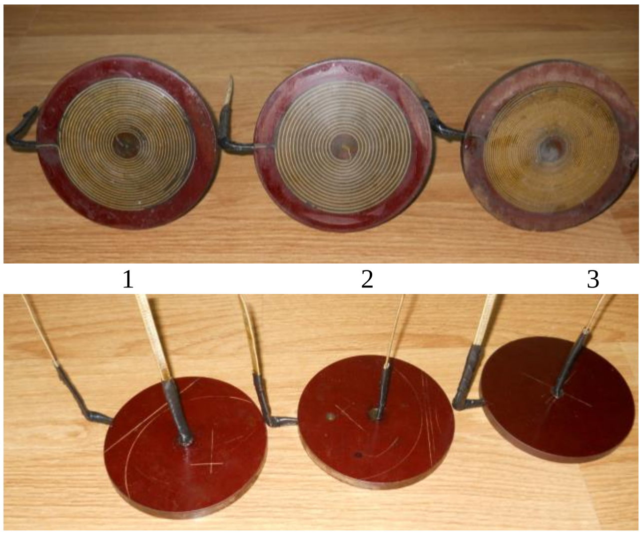
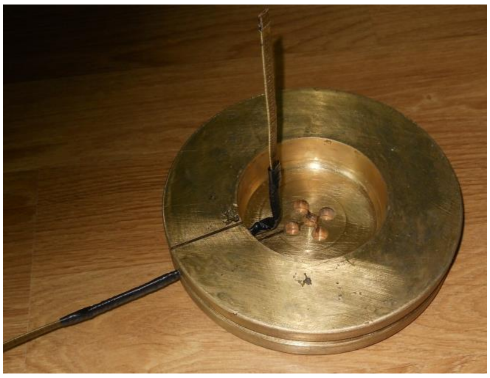


Fig.2. Shape of induction coils used in the experimental research: a) induction coil without concentrator; b) induction coil with field concentrator; 1-support plate; 2 - active plate; 3 - workpiece ; 4 - inductor; 5 - insulated plate; C - field concentrator.



a)



b)

Fig. 3. Induction coils built for experiments
a) induction coil without concentrator; b) induction coil with field concentrator

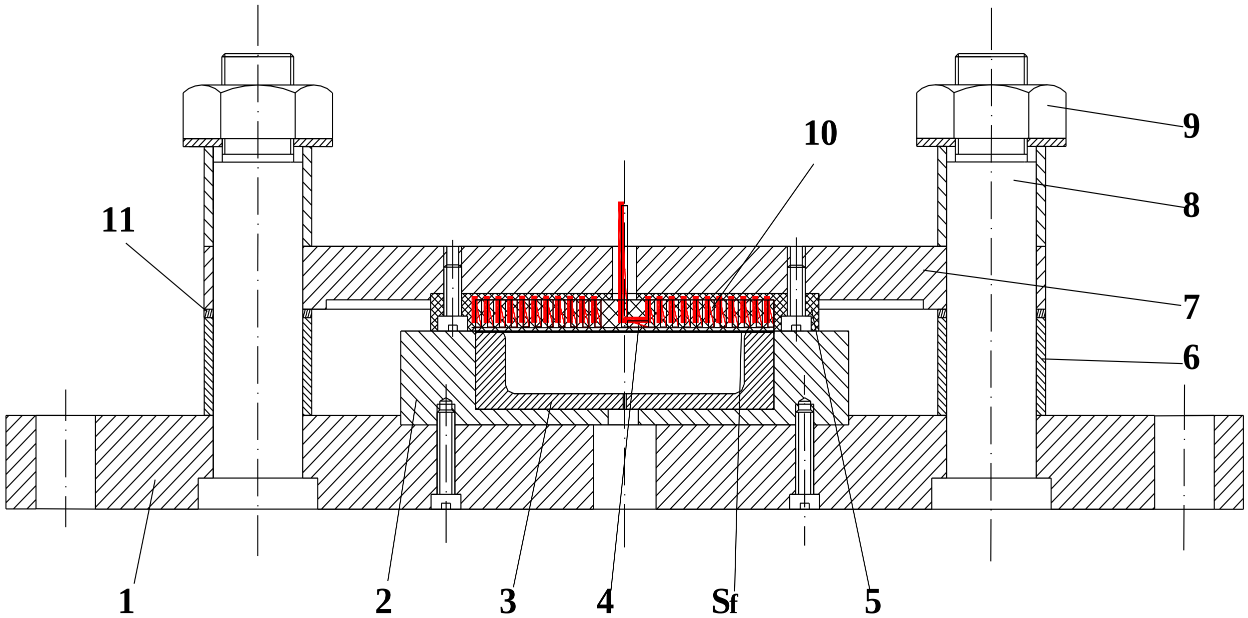
Inductor coil construction is shown in Figure 2. Based on the theoretical elements, the Archimedes spiral coil without field concentrator (Fig. 2a) was designed and built in three variants (Fig. 3a). They all have the same outer diameter (D = 100 mm) but different steps. This lead to different lengths of the conductor winding and the field concentrator coil (Fig. 2b) has been designed and built in a single variant (Fig. 3b). Its outer diameter is D = 200 mm and the diameter of the active area is 120 mm.

Based on the principle of electromagnetic field forming, the processing requires a mould to shape the blank. For this purpose it was necessary to conceive, design and implement a device similar to a conventional mould able to work after a mechanical processing principle. The device itself is a stamping die where the punch is made of high intensity magnetic field generated by a flat coil.

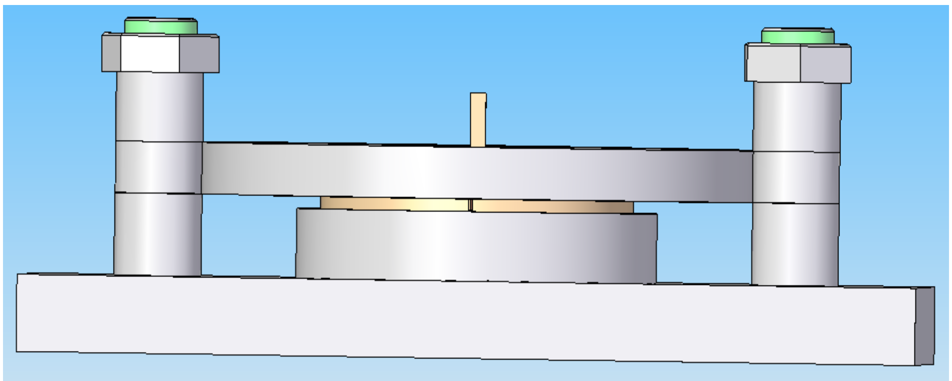
The designed mould with inductor and without concentrator for flat blank deformation is shown in Figure 4. It has a base plate (1), a support plate (2) equipped with the active plate (3). The latter will shape the flat blank S_f. The "Stamp" is coil (10) placed on top of the blank in such a way that the whole field created by it interferes with the blank. Coil made of good electrically conductive material is fixed with epoxy (4). This is considered to be a good insulating material with good mechanical strength. It is fixed to a plate (5) made of insulating material (textolit), the whole assembly being fixed to a top plate (7). Centring of the mobile part is ensured by two guiding columns (8).

After positioning the blank in the working position, the mould is closed using two nuts (9). These can be screwed into the threaded portions on the ends of the guide columns.

To adjust the distance between the coil (10) and the blank S_f, between the bushing (6) and the coil holder plate, different thickness additions are inserted.



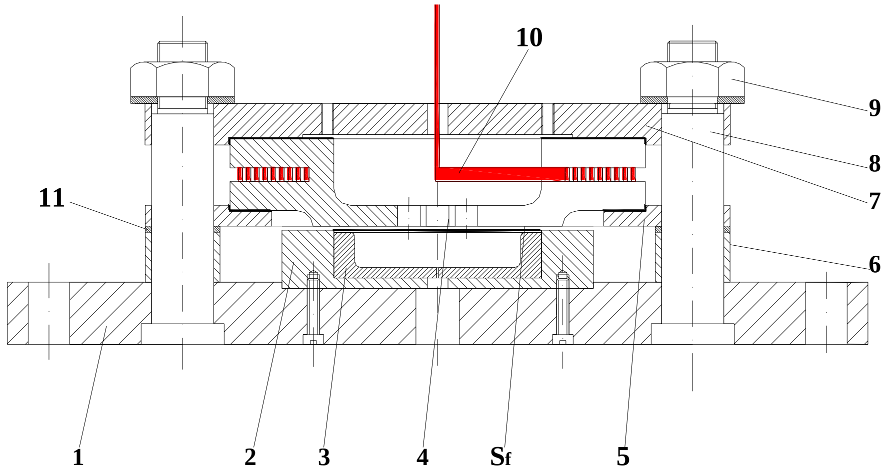
a)



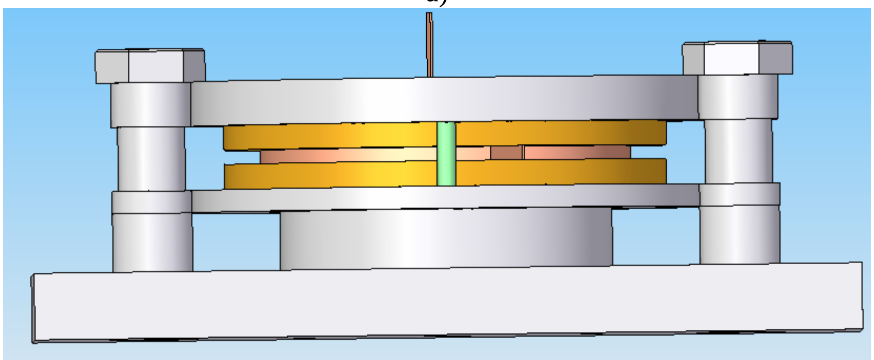
b)

Fig. 4. a) Layout of the working mould with inductor, no concentrator for planar deformation of blanks; **b)** 3D view of the work mould 1 - base plate; 2 - support plate; 3 - active plate; 4 -epoxy resin; 5 - insulated plate; 6 - bush; 7 - top plate; 8 - guide column; 9 - nut; 10 - inductor; 11 - surplus;

Figure 5 presents the designed mould containing an induction coil with flat blank deformation concentrator.



a)



b)

Fig. 5. a) Drawing of the working mould with induction coil and concentrator for flat blank deforming**; b)** 3D view of the work mould; 1 - base plate; 2 - support plate; 3 - active plate; 4 - field concentrator; 5 - supporting plate; 6 - bush; 7 - top plate; 8 - guide column; 9 - nut; 10 - inductor; 11 - surplus

It should be noted that the induction coil with field concentrator is fitted with an insulating material between the field concentrator and plates (7) and (5) (rubber, lacquer, epoxy resin, etc.). Its purpose is to contain the electromagnetic field of the concentrator thus increasing process efficiency.

3. RESULTS AND DISCUSSIONS

3.1. The influence of input parameters on the relative elongation of the material during drawing (truncated cone shape)

Is should be noted that the elongation has been obtained by measuring the ordinates of the points taken into consideration (the height thereof) as shown in Figure 6.

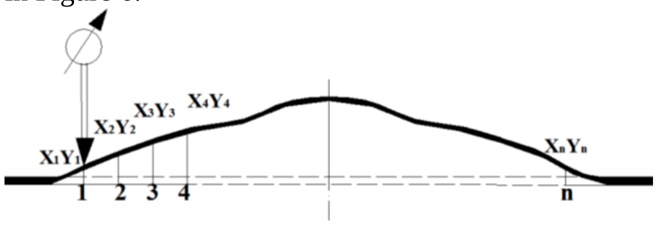


Fig. 6. Ordinate measuring methodology for the points taken into consideration

3.1.1. Processed material: aluminium

After using this material, conditions of experimentation and results are presented in Tables 1 and 2. The blank profiles stamped at different operating conditions are presented in Figure 7 and 8.

Table 1. Experimental conditions and results obtained from aluminium part stamping

Experimentation conditions	Part number							
	IIA1	IIA2	IIA3	IIA4	IIA8	IIA6	IIA7	IIA8
w thickness in mm	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5
E energy discharge in Joules	150	150	150	150	600	600	600	600
No. of turns of the coil	16	16	26	26	16	16	26	26
Profile length, in mm	62.1	60.12	63.1	60.66	*	62.74	*	63.98
Relative elongation in (%)	**3.5**	**0.2**	**5.1**	**1.1**	*	**4.5**	*	**6.63**

* irrelevant

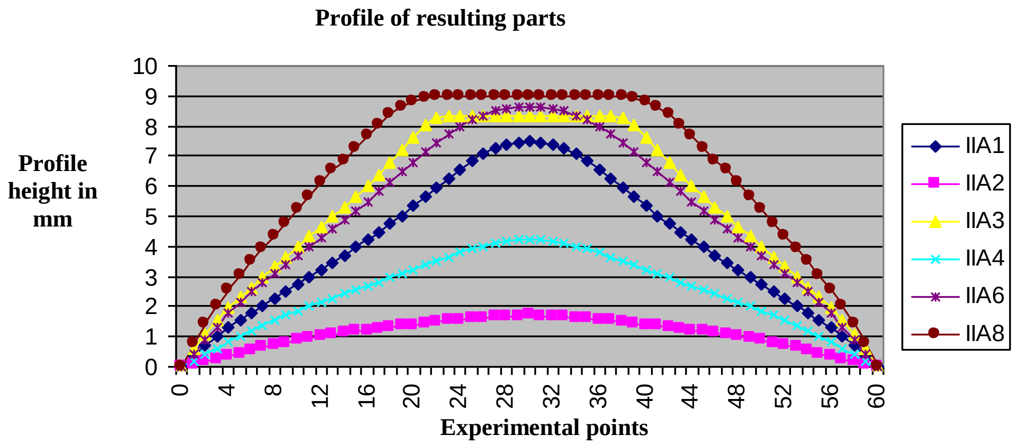


Fig. 7. Stamped part profiles

Table 2. Experimental conditions and results obtained from the stamping of aluminium parts

Experimentation conditions	Part number							
	IA1	IA2	IA3	IA4	IA5	IA6	IA7	IA8
W thickness in mm	0.3	1.5	0.3	1.5	0.5	1.5	0.5	1.5
E energy discharge in Joules	340	340	340	340	940	940	940	940
No. of turns of the coil	16	16	26	26	16	16	26	26
Profile length, in mm	65.46	61.08	65.6	62.24	*	64.86	*	67.62
Relative elongation in (%)	**9.1**	**1.8**	**9.33**	**3.73**	*****	**8.1**	*****	**12.7**

* Irrelevant

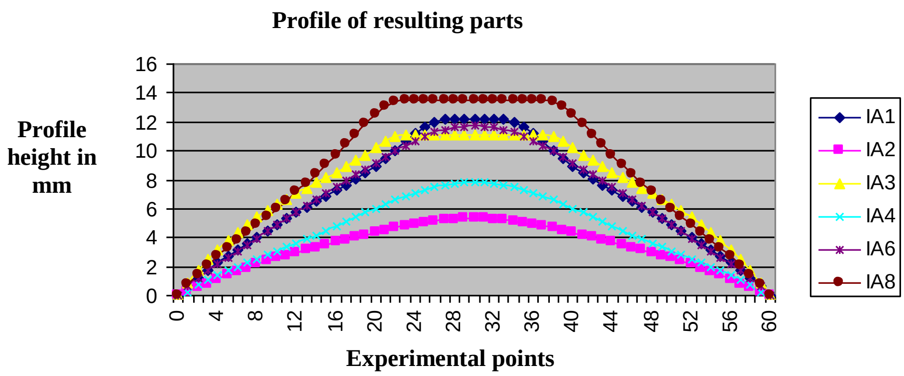


Fig. 8. Stamped part profiles

3.1.2. Processed material: copper

In case of this material the results are presented in Table 3. The blank profiles stamped at different operating conditions are presented in Figure 9.

Table 3. Experimental conditions and results obtained from the stamping of copper parts

Experimentation conditions	Part number							
	IIC1	IIC2	IIC3	IIC4	IIC5	IIC6	IIC7	IIC8
w thickness in mm	0.25	0.4	0.25	0.4	0.25	0.4	0.25	0.4
E energy discharge in Joules	150	150	150	150	600	600	600	600
No. of turns of the coil	16	16	26	26	16	16	26	26
Profile length, in mm	61.64	60.9	62.94	62.06	*	*	*	*
Relative elongation in (%)	**2.73**	**1.5**	**4.9**	**3.43**	*****	*****	*****	*****

* Irrelevant

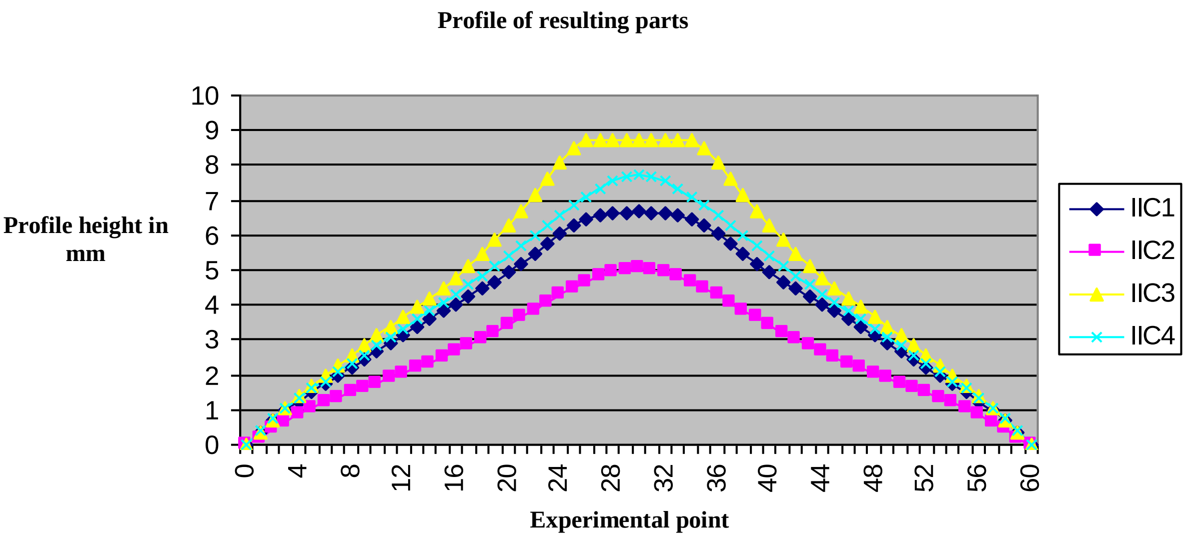


Fig. 9. Stamped part profiles

3.2. The influence of input parameters on the relative elongation of the material during drawing (cylindrical shape)

3.2.1 Processed material: brass

From this point of view the results are presented in Table 4. The parts stamped in different working conditions are shown in Figure 10.

Table 4. Experimental conditions and results obtained from the stamping of brass

Experimentation conditions	Part number							
	IB1	IB2	IB3	IB4	IB5	IB6	IB7	IB8
w thickness in mm	0.15	0.5	0.15	0.5	0.15	0.5	0.15	0.5
E energy discharge in Joules	340	340	340	340	940	940	940	940
No. of turns of the coil	16	16	26	26	16	16	26	26
Profile length, in mm	60.62	60.9	60.86	61.54	62.6	63.54	63.7	64.06
Relative elongation in (%)	**1.03**	**1.5**	**1.43**	**2.56**	**4.33**	**5.9**	**6.16**	**6.76**

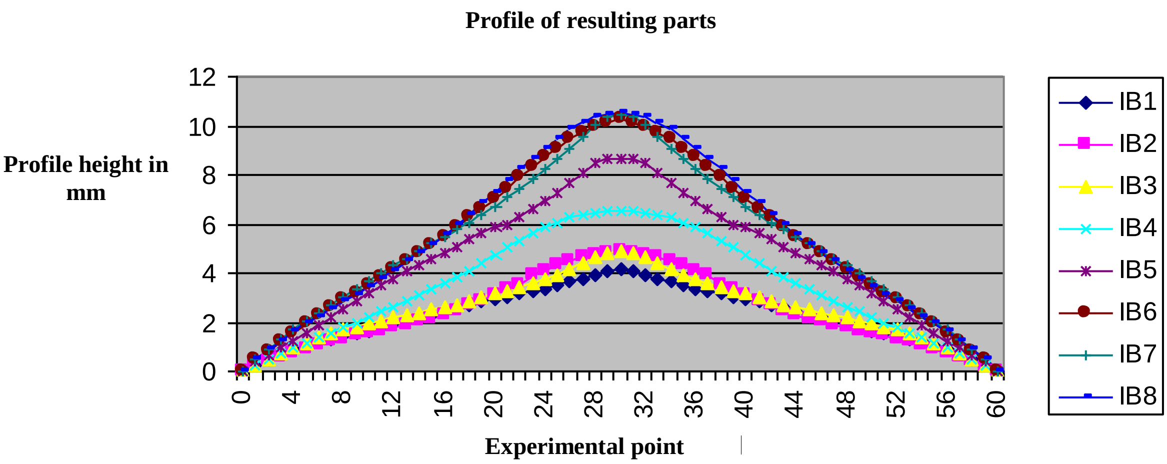


Fig. 10. Stamped part profiles

3.2.2 Processed material: copper

Table 5 shows the obtained experimental results and Figure 11 shows the resulting piece profiles.

Table 5. Experimental conditions and results obtained from the stamping of copper parts

Experimentation conditions	Part number			
	IC1	IC2	IC3	IC4
w thickness in mm	0.4	0.4	0.4	0.4
E energy discharge in Joules	340	940	340	940
No. of turns of the coil	26	26	16	16
Profile length, in mm	64.92	68.74	63.22	67.24
Relative elongation in (%)	**8.2**	**13.59**	**5.36**	**12.06**

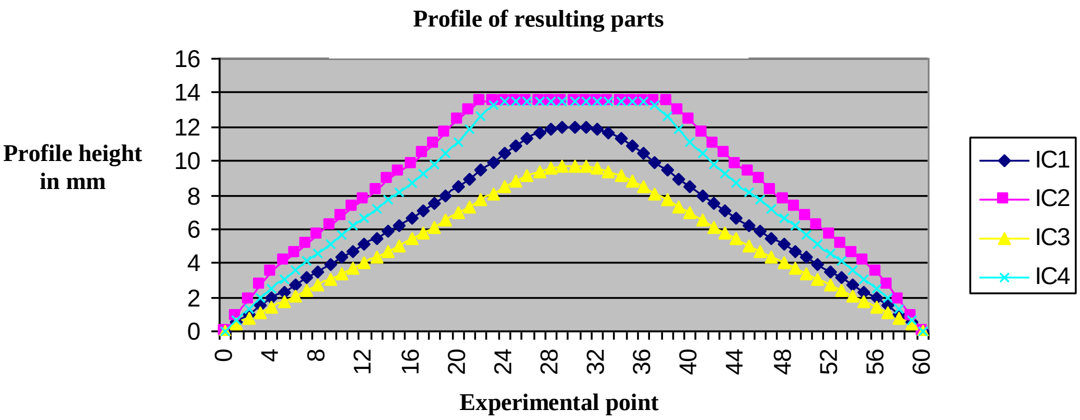


Fig. 11. Stamped part profiles after drawing (cylindrical)

4. CONCLUSIONS

Following the obtained results, it can be concluded that the energy has a direct influence on the relative elongation of brass when it is deformed at high speeds. The influence of the other two factors, N and g is lower than 25% of the influence of energy (E). In terms of the analysis of the influence of the effect of factors on workpiece thickness deviation, the blank thickness influence increases. The reason might be that relative elongation is relative to the movements of material in the plane of the deformed surface. It is also relative to thickness variation due to movements of material in a perpendicular plane. In other words, increasing the thickness of the deformed sheet also increases the volume of material moving in this direction.

5. REFERENCES

1. Banabic, D., Dorr, IR (1992), *Deformability of thin metal sheets, thin limit curves Method*, Bucharest, OIDICM Publishing House.

2. Luca, D., (2002), *Non conventional processing using magnetic shaping and finite element modelling*, Tehnopress Publishing House, Iaşi.

3. Psyka, V., Risch, D., L.Kinsey, B., Tekkaya, A. E., Kleiner, M., (2010), *Electromagnetic forming - A review*, Journal of Materials Processing Technology, Available at: http://www.sciencedirect.com, Accessed: 14.02.2011.

4. Sindila, Gh., (1985), *Theoretical and experimental research on plastic deformation in electromagnetic field*, Ph.D. Thesis, Polytechnic Institute of Bucharest, Bucharest.

5. Gina Mihaela Sicoe, (2013), *Numerical Modelling of the Process of Cold Plastic Deformation with Planetary Rollers*, Int. J of Modern Manufacturing Technology, Vol. V, No. 1, 2013, pp. 105-113.

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