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ELECTROMAGNETIC EMBOSSING OF OPTICAL MICROSTRUCTURES

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ABSTRACT

This paper will provide you the brief idea about the conventional embossing techniques. We will try to understand advantages and disadvantages of such embossing techniques. We will see why we need different kind of embossing techniques for optical microstructures. How electromagnetic forming is used to emboss on the optical microstructures. This report will provide the idea of experimental setup of such process in details. We will discuss the results of such experiment. The differences between the results of conventional embossing and electromagnetic embossing will be discussed. We will learn about the limitation of such experiments. Finally we will conclude with the possibilities of future applications of this method.

Keywods:-*Embossing, Electromagnetic forming.*

I. WHAT IS EMBOSSING ?

Embossing: It is the creation of an impression of some pattern or design on theworkpiece (can be anything like cloth, paper or a metal).

For metals, embossing can be defined as metal forming process which produces raised or sunken designs in sheet material without change in metal thickness. Embossing is done by rolling sheet metal between rolls of desired pattern.

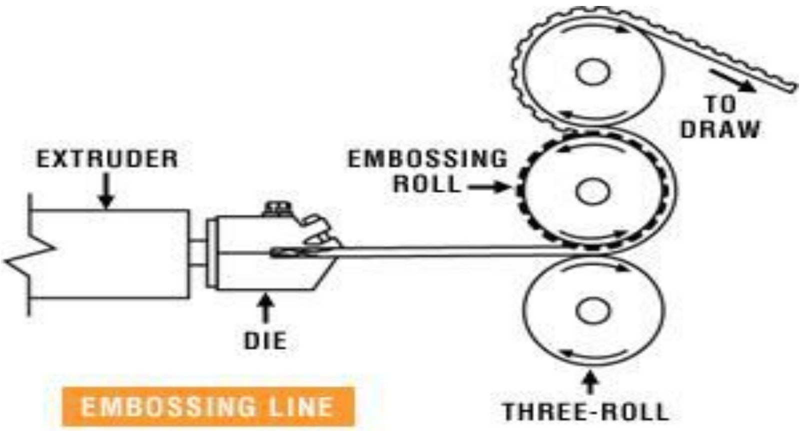

Figure 1 Metal embossing process [1]

Aesthetic and functional are the two reasons for which embossing used. Aesthetic applications includes appliance panels, building products and others whereas functional requirements are such as increasing metal surface area for acoustic orheat applications, improve traction etc. Due to these reasons embossing is extensively used nowadays.

Advantages & Disadvantages

Advantages of embossing are as follows: - [2]

1. It creates dimensional depth and details on workpiece.
2. The embossing die can be used for repeatedly embossing thus reduces overall cost.

Disadvantages of embossing are given below:-

1. It adds cost to printing job because it is an off-press printing.

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2. Thin sheets do not emboss well.

II. INTRODUCTION

Optical microstructures have many applications in areas like, on integrating them on thin metal sheets we can get flexible reflective surfaces which can be used in complex optical components. Optical microstructures can also be used in manufacturing secure product identifiers. For a manufacturer of microstructures it is required to have a good replication process. Thin metal sheets produce challenges in form of decrease in plasticity. Therefore processes like electromagnetic forming (EMF) are developed. This have many advantages like high deformation rate, less wrinkling, the increase of plasticity and the reduction of spring back.

In this paper, the high-speed replication of prismatic optical microstructures with contactless electromagnetic forces is investigated. First, we will introduce diamond micro chiseling (DMF), the method by which the mold for the EMF process is produced.

III. DIAMOND MICRO CHISELING

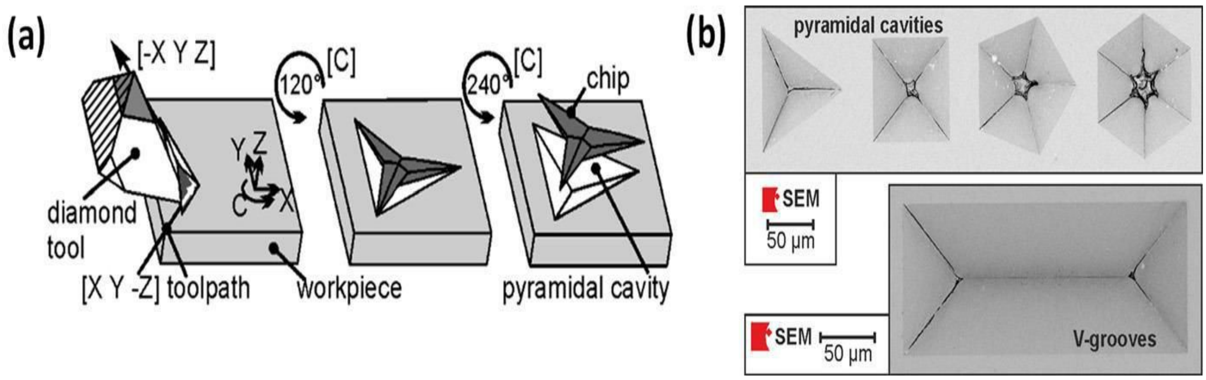

Figure 2 (a) shows the kinematics of the DMC process (b) shows the various structures by using DMC process

This process was invented in 2006, to produce discontinuous optical microstructures with prismatic shape. Examples of such structures are corner cube retroreflectors which are used in many optical applications. All the other processes before the DMC doesn't allow the rotational symmetry (for applying turning or contour boring) and no possibility to execute continuous straight feed motions (for applying fly cutting). In DMC, we try to cut each side of the prismatic structure separately by using a V-shaped diamond tool, see fig.

In the fig. we can see that after cutting the first facet of the pyramidal structure, the workpiece has been rotated by 120° and then after the second facet the workpiece has been rotated again by 120° and after that the chip has been removed, completing the pyramidal structure on the mold.

IV. ADVANTAGES AND DISADVANTAGES OF ELECTROMAGNETIC EMBOSSING

There are many technical and economic advantages of EMF. High deformation rate results in decrease in wrinkling, the increase of plasticity and the reduction of springback. High deformation rate also results in better material flow, which further increase the range of material which can be used in EMF. Use of single sided dies reduce the cost of tools. Since it's a non-contact process contamination of the workpiece can be avoided, as a result surface finish enhanced considerably. The disadvantages of EMF are that we cannot form materials which are nonconductive and the high voltages and current need more safety considerations.

V. EXPERIMENTAL SETUP

The experimental setup of EMF is same as other forming processes which has a male and a female part except that either of the male or female part is replaced by a pulsed strong electromagnetic field generated by a tool

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coil. An electrically conductible workpiece is being accelerated by a high peak current in the coilby Lorentz's forces. We have used an L-C resonator to generate the current peak

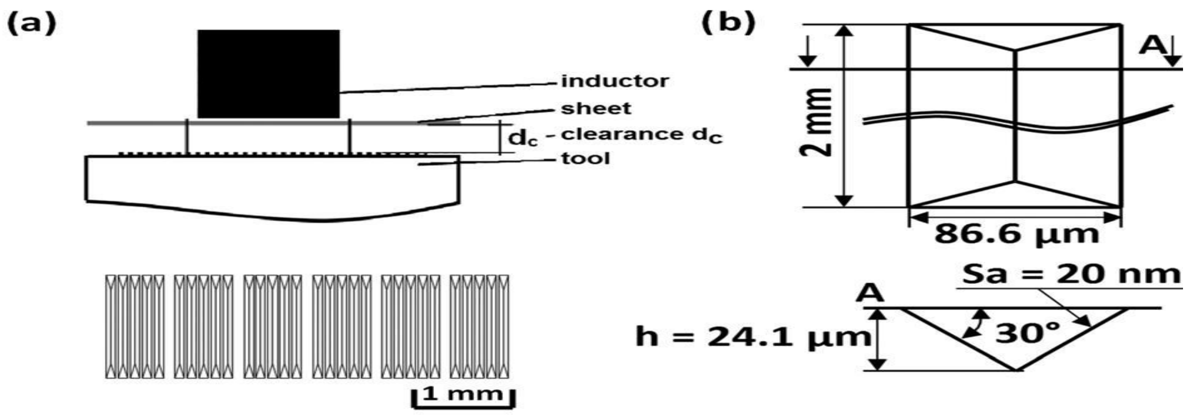

Figure 3 (a) side view *(b) V-groove geometry*

The initial energy of the process is given by the loading energy (EC) of the capacitor and controlled by its capacity (C) and the initial voltage (U0). According to the skin effect, the current peak (Imax) is required to rise to its maximum in a very short time (tr) to enable a shielding of the magnetic field by the thin sheet metals with the thickness (s0). To shorten (tr), the capacity (C) and the inductance (L) of the reduction of coil is necessary. A reduction of (C) causes less energy and a lower current peak, respectively, a lower magnetic field intensity (H) such as a smaller inductance (L) of the coil effects a lower (H). Hence, the body forces are reduced. Furthermore, the local heating of the micro metal sheet by high eddy currents, which can melt or even vaporize the material, is challenging.

VI. OBSERVATIONS

Before discussing the result we will explain the skin effect which will help us better understanding of result and process parameters. "Skin effect is a tendency for alternating current (AC) to flow mostly near the outer surface of an electrical conductor, such as metal wire. The effect becomes more and more apparent as the frequency increases."

As mentioned earlier we took Al99.5 sheets of thickness s0=50 µm and s=300 µm for the experiment. Embossing 50 µm sheets with maximum load and keeping clearance (dc) equals to zero, complete replication of microchannel pattern could not be achieved. While in case of 300 µm sheets, full height replication was achieved under same conditions. The following graph shows the difference in extent of pattern replication in two case:

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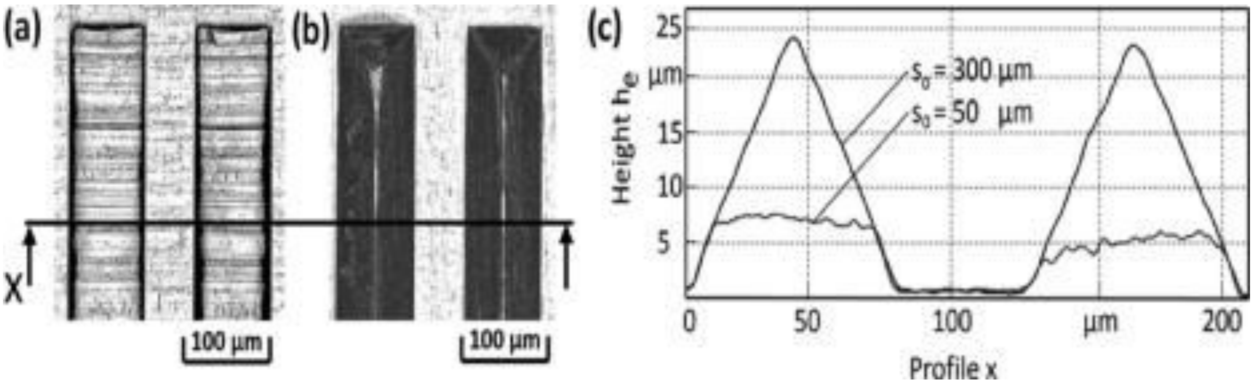

Figure 4 Embossing results (EC=1800 J, dc =0 mm): (a) s0=50 µm, (b) s0=300 µm, and (c) profile

This behavior is result of skin effect, as increasing the sheet thickness causes the increase in resultant force. Hence with thicker sheet better replication of tool profile is observed with same amount of process energy. In this case the imprint on sheet perfectly matches with the tool geometry and same can be verified by following:

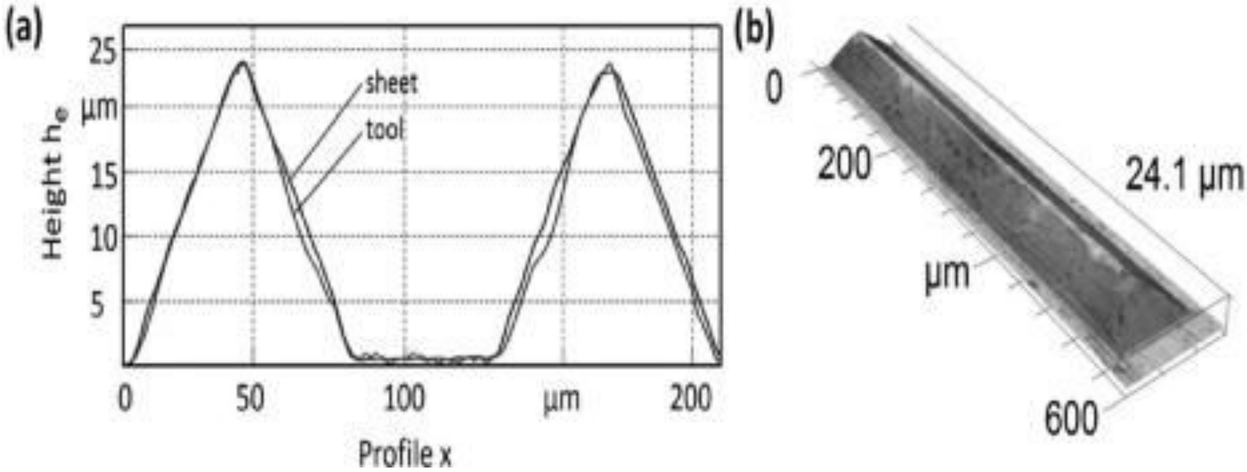

Figure 5 Profile of embossed microstructure (s_0=300 µm, E_C=1800 J, d_c =0 mm): (a) contour of sheet and tool and (b) single V-groove

To improve the quality of embossing in case of 50 µm sheet, they increased the effective thickness. Five layered driver sheet with each thickness 50 µm, making total thickness 300 µm was used. The result obtained were equivalent to that with 300 µm sheets. For different clearance the results are almost same when the effective thickness is same. Also the supplementary driver sheet experience very less deformation, hence it can be used multiple times.

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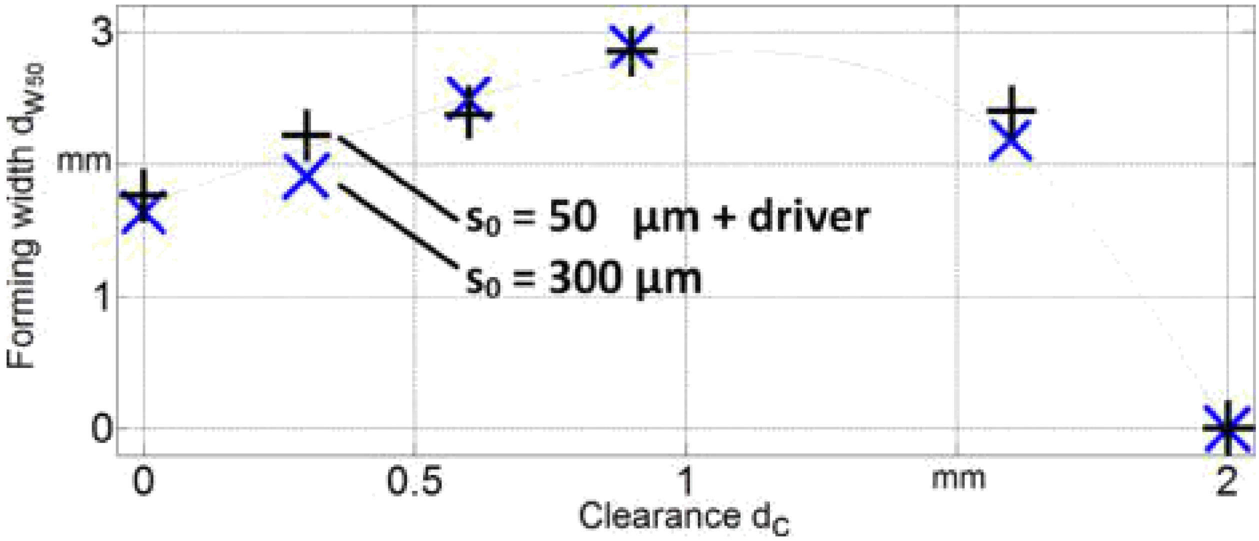

Figure 6 Variation of the clearance dc, EC=1800 J

Using 2x2 [2] rectangular inductor, full structure height is obtained over width of 0.5 mm even without any clearance. Other experiments and simulation shows that force distribution is uniform over this range. While in lateral direction the embossing height decreases.

From the graph it can be derived that an optimum embossing width is obtained for a clearance of 0.9mm when 1800 J of loading energy is being applied. Utilizing optimum value the forming width can be increased from 1.6 to 3mm. While the complete embossing can be obtained for width from 0.5mm up to 1 mm. The variation in profile height is within 1.2 µm for optimum clearance value. The average surface roughness of 1000nm is obtained.

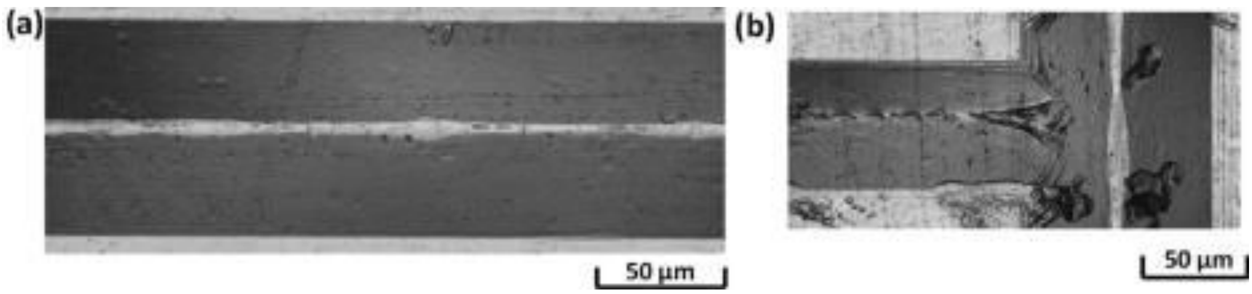

Figure 7 Embossed structure (top view)

(a) surface quality of facets, dc=0.9mm, s0=50 µm +driver

(b) cross-structure

VII. RESULTS

The electromagnetic embossing method has several factors affecting process performance and efficiency. The skin effect plays an important role in amount of force applicable. Embossing very thin sheets may give poor results but driver sheets can be employed to get better results. Driver sheets suffer very less deformation, hence are reusable and efficiently overcome this problem. Even without any clearance a good replication is achievable.

With variation in clearance, the efficiency and the embossing width can be altered. Increasing the clearance increases the forming width and optimum value of clearance depends upon the loading energy. After optimum value, there is reduction of embossing quality. The reason for this could be air drag, rebounding, greater

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difference between electromagnetic pulse and material flow. Due to induced eddy currents, the delay time between current induction and deformation can also be the reason for reduction in plasticity.

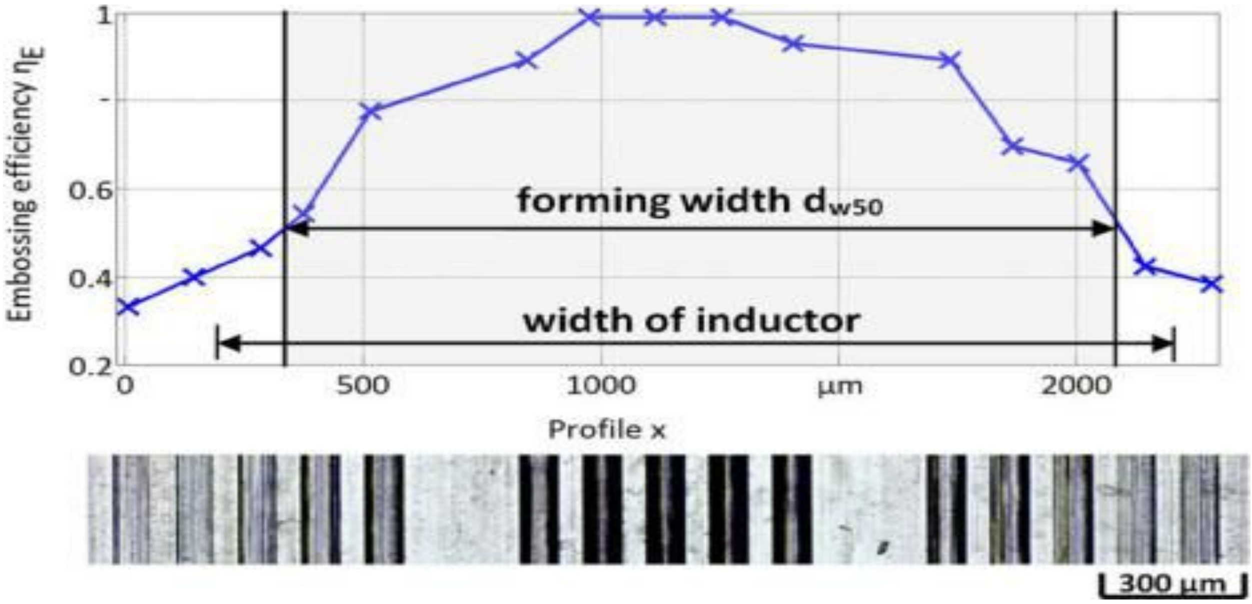

Figure 8 Profile of embossing result, d_c =0mm, s_0=50 µm + driver, E_C=1800 J

A perfect replication of desired geometry along with good surface finish is achievable. Also, this is possible with zero clearance, hence minimizing the effect of kinetic energy in the process. Several factors like joule heating, adiabatic effects, electro plastic effect, rebounding, air cushions and the impact behavior of tool leads to this kind of response. However effect of individual factors on process is a bit unclear.

VIII. FUTURE SCOPE

This technique is recently developed and is very powerful in itself but still it has some scopes of development in the future by which it can become even better. We need to look closely to the different physical effects which are produced by this technique. It is still unclear that how much the effects such as intensity of electromagnetic field, sheet thickness and the clearance contribute to forming process and how can these effects influence in controlling the process.

IX. CONCLUSION

Electromagnetic Forming is recently introduced to the world of micro forming due to the advantages it has shown in the macro forming world especially its higher deformation rate and the less cost of the tools used has made the path easy for this transformation . Due to the high deformation rate replication of optical microstructure by electromagnetic embossing takes less process time and also the material flow rate is also improved. By this process we were able to receive results which were not possible yet. Micro-embossing of 50µm and 300µm thick EN AW-1050A (Al99.5) micro metal sheets by using an electromagnetic pulsed field was made possible by this process. Also a successful replication of V-grooves with a width of 86.6µm and a structure angle of 30º was made possible by this process. This process produced a optical surface finish of Sa ≈ 44nm.The main plus point about this process is that a good replication of the optical microstructure is possible without an actual clearance between the sheet and the tool.

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