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ELECTROMAGNETIC FORMING OF THIN STEEL SHEETS FOR THE PRODUCTION OF METAL PACKAGING COMPONENTS

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ABSTRACT

This work focus on the development of the electromagnetic pulse technology targeting the reliable processing of thin steel sheets, for the production of components for metal packaging. Electromagnetic actuators and dies were developed aiming to study the applicability of EMF for the expansion of an aerosol can body. The results indicate that the EMF process may be suitable for the deformation of thin steel sheets.

Keywords: Electromagnetic forming, impulse forming, tube expansion.

INTRODUCTION

Electromagnetic forming (EMF) is a high strain-rate, non-contact forming technique which makes use of pulsed magnetic fields to apply forces to metal workpieces, preferably made of a material of high electrical conductivity. The principle is based on physical effects described by Maxwell, i.e. a temporally varying magnetic field induces electrical currents in nearby conductors, exerting forces -the so-called Lorentz forces (Psyk, 2011).

EMF has potential benefits, such as increased formability with reduced wrinkling and springback. As a noncontact method, EMF avoids the need of surface protection and workpiece re-working. It does not create smoke or use oils or other polluters. These attributes have encouraged, not only the development of the process itself, but also has captured the interest of the academic community and its use in small batch size productions and in specific applications (Daehn, 2009). However, the use of this technology as a mass production process requires further research work in order to solve some open questions.

The main objective of this experimental work is to contribute for the further integration of this advanced technology into competitive manufacturing routes. For such purpose, an industrial case-study was presented and explored: the feasibility of EMF process in the tube expansion of an aerosol can body, taking in account the needs of the packaging industry. It consists of a thin zinc coated steel tube which should be expanded in order to acquire specific groves and letters for branding purposes.

The goal was to take advantage of the increase of formability which could potentially allow a reduction of the wall thickness of the tubes from 0.18mm to 0.15mm. This reduction of thickness means significant costs savings in terms of raw materials. In addition, the reduced mass follows the trend of lightweight design, i.e., a smaller thickness means less weight which, on the other hand, means less fuel consumption during transportation.

EXPERIMENTAL TESTING

The aim of the present work is to expand a tubular workpiece in order to acquire the shape of a circular forming die using electromagnetic forces. It is intended to demonstrate the increase on formability due to high strain rates, aiming, in future planned work, to reduce the thickness of the metal sheets, saving not only in terms of raw material, but also in terms of packing transportation through the use of lighter containers. The workpiece consists of a thin wall tube with 45 mm external diameter, 91.5 mm length and 0.18 mm wall thickness. The material, a zinc coated steel sheet is typical used in the packaging industry under the designation as 0.18 D2.8/2.0 TS275 according to the EN10202:2001 standard.

The study on the possibility of manufacturing thin steel sheet components for metal packaging by electromagnetic forces started with a set of preliminary tests in exploratory conditions, making use of handmade disposable coils and polymeric dies. The goal was to assess the technical viability of the configuration of the die as well as the behavior of the steel tube when subjected to electromagnetic expansion. For such purpose, a polymeric die (RenShape® SL 7810) was produced by using a rapid prototyping stereo lithography technique (SLA). The die obtained by this process can be seen in Figure 1. Additionally, a handmade coil was produced. It consists of a copper winding around a polymeric cylinder as show in Figure 2.

Fig. 1 - Two halves of the polymeric die obtained by rapid prototyping technique (SLA).

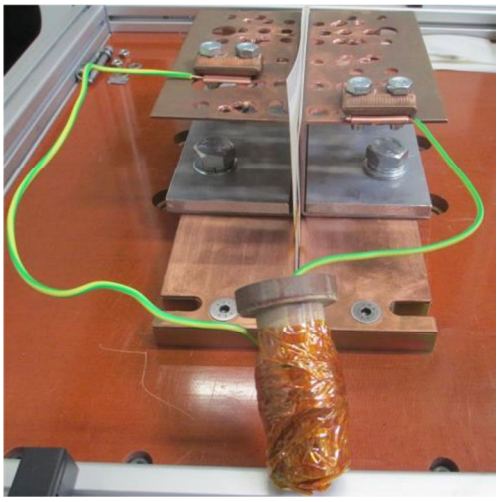

Fig. 2 - Handmade coil developed for the preliminary experiments.

Note that this type of actuator has a limited life-time, capable to stand only two or three current discharges. All the tests were performed with a capacitor bank pulse power system. The system is equipped with two capacitor modules in parallel, each one with a capacitance of 40 μF, giving the machine a total capacitance of 80 μF. The maximum energy storage is 25 kJ when charged to the maximum voltage of 25 kV. The maximum output current is 400 kA.

Varying discharge energy, in the range of 1.5-7 kJ were tested. 7 kJ was estimated as the maximum that the coil is capable to stand without severe failure. Despite the temporary character of the handmade coil, it is important to avoid the severe failure in order to preserve the integrity of the polymeric dies. As is well known, the coil is subjected to the same magnetic pressure that is responsible for the deformation of the workpiece, plus the thermal load resulted from the joule effect which can lead to coil failure.

The results of this preliminary tests are presented in Figure 3. As can be seen, the groove was not completely filled and the lettering is not fully defined. Yet, the results were considered promising given the exploratory nature of the setup.

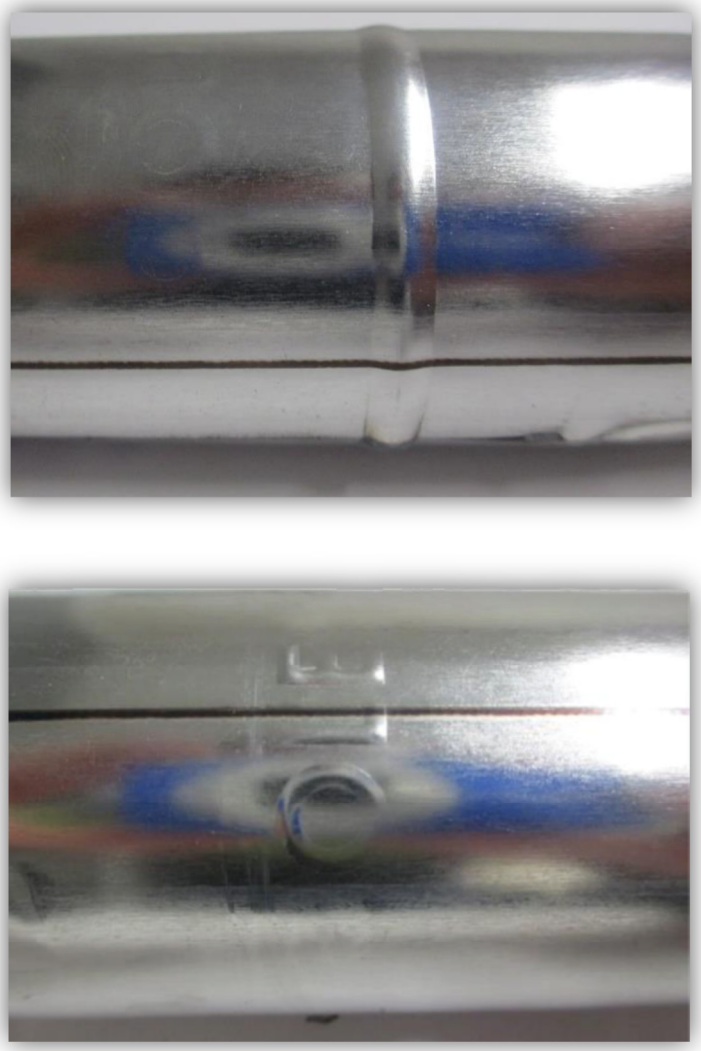

Figure 1: Results of the preliminary tests: Tube electromagnetically expanded by a handmade coil against a polymeric die at 7 kJ.

CONCLUSION

Although the development of electromagnetic forming processes is often driven by applications such as lightweight structures and dissimilar material joining the advantages of magnetic pulse technology may be attractive to other sectors such as packaging industry. The work presented in this paper investigated the processability of thin steel sheets by electromagnetic forces for production of components for metal packaging: the tube expansion of an aerosol can body.

The results suggest that the use of the high speed of deformation may increase the ductility of the material, being a good indicator that the electromagnetic forming process can be an effective solution for the embossing of details in this type of applications.

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