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Development of Mobile Phone Case with Decorative Surface by Two-stage Forming Process

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Since environmental concern and recycling is prevalent, aluminum alloy used to be extensively applied to structural components and casings for portable electronic devices. For high-end mobile phone, the metallic casing is usually decorated with fine feature to boost its quality and value. Considering about the issues of cost and mass production, this study uses electromagnetic forming process to fabricate fine features on mobile phone case instead of traditional approach such as laser machining or etching.

Via electromagnetic forming process, impact between sheet metal and mold can create very large compressive stresses and these can be used to emboss micro-features in metal. Accordingly we'll illustrate a two-stage process which integrates stamping and electromagnetic forming to develop aluminum alloy case with exquisite pattern on surface.

An innovative actuator coil and the pre-formed tool design will be tested to evaluate the feasibility of this concept. Besides, we will apply CAE analysis software to assist tool design and then discuss the distribution of electromagnetic force. The result of this study will provide a referential guideline for electromagnetic forming tool design.

Keywords: *Electromagnetic forming, micro-features, emboss, actuator coil*

1. Introduction

Along with the awareness in global environmental protection, the demand for the percentage of recyclable parts from consumer products is increasing. Compared with plastic cases, consumers are more satisfied with the quality of metal cases as well as their recyclability. As a result, metal cases are replacing plastic cases and widely applied to electronic products such as laptops and mobile phones. At present, it is more difficult to manufacture a metal case and the unit price is relatively high. In order to increase its added value, the surface is often designed with delicate graphic features. of Stamping technology in Taiwan has achieved a certain level, but the fabrication of decorative surface still relies on traditional manufacturing methods such as laser machining, etching, and coated adhesive tapes. Hence, electromagnetic forming technology was introduced to address the disadvantages and to reproduce the delicate graphic features on metallic surface.

Electromagnetic forming is a high energy rate process. Compare with conventional quasi-static forming process, the material will have hyper-plasticity that dramatically improves formability because of inertia effect [1-3]. Due to rapid impact speed, the forming period can be completed in approximately 0~100 μsec. In addition, the forming energy is come from electromagnetic field, so this process only need a single-sided die and is able to prolong the life of tools. With the above strengths, the electromagnetic forming process is applied to duplicate micro-features on 3C products to create the value and reduce manufacturing time and cost.

Literature review [4] has showed that using uniform coil enable the direct forming of metallic cases but have the drawback of insufficient forming stress on reproducing the subtle features. As a result, this paper proposes an innovative actuator coil design and a two-stage forming process which

integrates stamping and electromagnetic forming to develop aluminum alloy mobile phone cases with exquisite pattern on surfaces.

2. Research Method

This study utilizes electromagnetic pulse equipment and modified uniform pressure coil; the vacuum pump is also used to release air inside the tool to avoid influencing the forming result. The research method starts with the manufacturing of pre-formed cases by the stamping process and then bio-feature is placed on the surface of die by etching or laser machining. Electromagnetic simulation is conducted to evaluate the performance of new design coil.

2.1 Development Procedure

The driving force of electromagnetic forming, named Lorentz force, is the interaction between the induced eddy current of work piece and transient magnetic field generated by coil. Through a non-contact electromagnetic force, the work piece is accelerated to sufficiently high velocity and impact on die surface to duplicate the fine feature. The forming process includes the change in the electromagnetic and mechanical fields. Therefore, the development procedure of a new product shall not only consider the design of the coil and field shaper but also coordinate with a responsive tool as shown in Fig. 1.

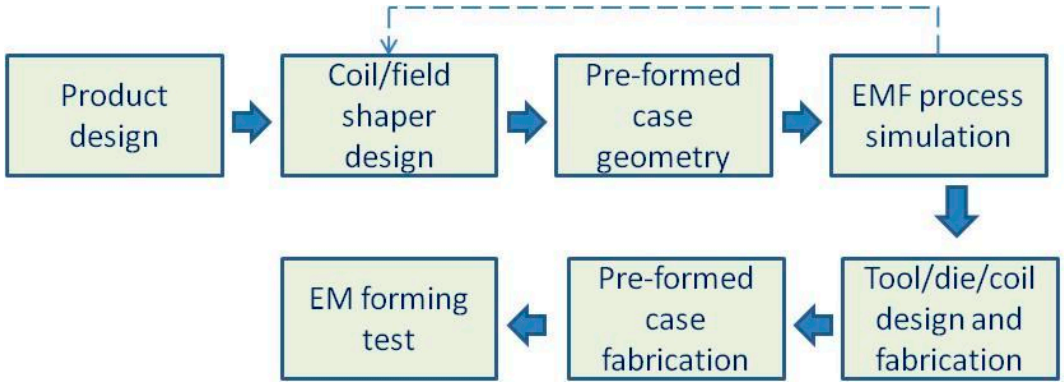

Fig. 1 Product Development Procedure

2.2 Tool and pre-formed case

In this study, we utilize a new design, modified uniform pressure coil, to fabricate a mobile phone case with decorative surface which material is aluminun alloy A5052. The bionic design feature is placed on the surface of die shown in Fig. 2

According to the design of modified uniform pressure coil, both sides of work piece must be tighly connected with U channel .Therefore, extensive flange for pre-formed case is required. In this study, the pre-formed case is done by stamping process and its geometry shall coordinate with the field shaper of coil.(Fig. 3)

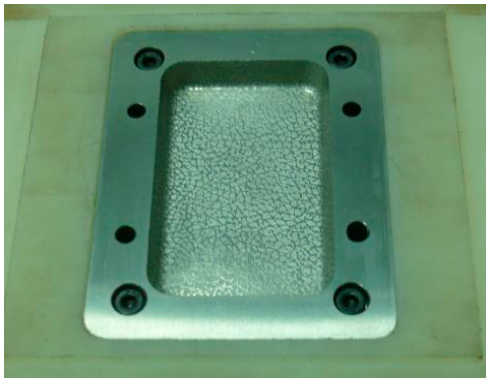

Fig. 2 Die of cell phone case with leather feature Fig. 3 Pre-formed case manufactured by stamping

2.3 Modified uniform pressure coil

In coil design, most of the flat spiral coils have the same problem with the various distribution of electromagnetic force, therefore OSU proposed a uniform pressure coil to solve this problem [5]. However, experiment results indicate that although the uniform pressure coil has a higher forming efficiency than the general design, but there is a gap between every two adjacent wires of spiral coil which leads to an uneven electromagnetic force distribution. When this device is applied to forming work pieces with fine structural pattern, the problem of unclear duplication which attributed to a uneven magnetic field distribution will arise. This study modifies the original uniform pressure coil to improve the force distribution based on the design of field shaper which allows even-distributed current to pass its surface. In addition, with the design of field shaper, the modified uniform pressure coil is flexible on metallic case forming either with a protrusion surface or others special geometry. Fig. 4 shows the principle of a modified uniform pressure coil; Fig. 5 is the assembly of uniform pressure coil.

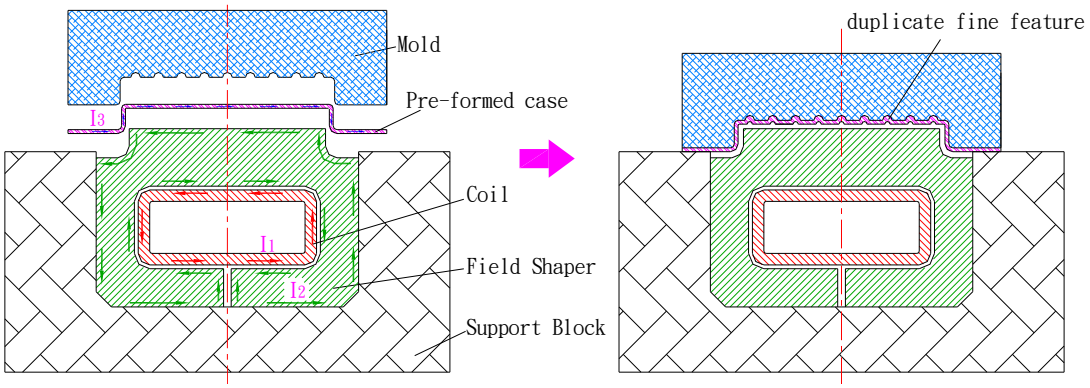

Fig. 4 Schematic of modified uniform pressure coil

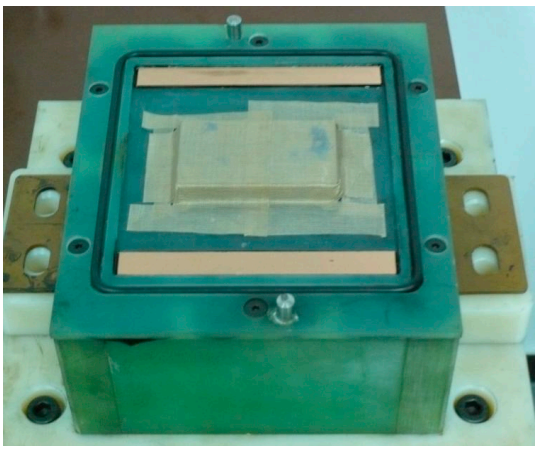

Fig. 5 Appearance of modified uniform pressure coil

2.4 Process Simulation

This study uses commercial software to analyze the electromagnetic field on a pre-formed case which influenced by the modified uniform pressure coil. In order to shorten the development schedule and reduce try-and-error costs, we estimate the distribution of electromagnetic force via CAE

simulation and refer to the analysis to modify the design of field shaper and pre-formed case. Fig. 6 shows the CAD model of a modified uniform pressure coil.

The driving force of the electromagnetic forming process comes from the Lorentz force, the interaction between an induced current and magnetic field. Therefore, in the simulation setup, the field shaper and U Channel should be considered the effect of eddy current. In terms of insulation, there are gaps among the coil, field shaper and U Channel, so the gap distance is directly used to replace the insulation setup. The forming simulation environment is in a vacuum condition, and the profile of discharge current is a gradually decreasing sine wave as shown in Fig. 7. Copper is used as the material of the field shaper and U Channel and the material for the pre-formed case is aluminum. Table 1 shows the electromagnetic properties of material.

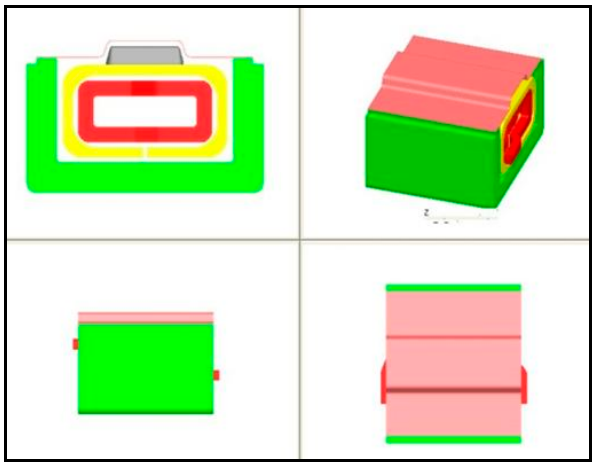

Fig. 6 CAD Model for Analysis

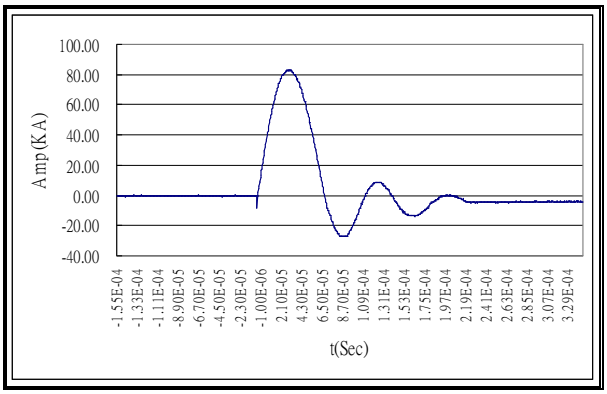

Fig. 7 Discharge Current profile

Table 1 Electromagnetic properties of Material

Properties / Material	Rel. Permeability (Mu)	Conductivity (siemens/meter)
Copper	0.999991	5.8e+0.7
Al	1.000021	2.43e+0.7

3. Result and Discussion

3.1 Analysis of simulation result

In this study we suppose that the modified uniform pressure coil will generate an even-distributed current by the innovative design of field shaper. Actually, the distribution of electromagnetic force is hardly measured during experiment. Hence, CAE analysis is introduced to distinguish current direction and the distribution of electromagnetic force for future reference. Fig. 8 shows the current directions on the modified uniform pressure coils. The current of spiral coil flows anti-clockwise and current inside the field shaper is induced in a reverse direction. Current transmitted outside the field shaper due to slotting shows in an anti-clockwise direction and the induced eddy current which flows through U Channel and work piece is in a clockwise direction. The simulation result of the modified uniform pressure coil shows the current direction as expected. In addition, Fig. 9 shows the distribution of electromagnetic force with a more even distribution and no interruption caused by the

gaps inside spiral coil. Furthermore, the distribution of force indicates that the current density will concentrate on the path with the least resistance.

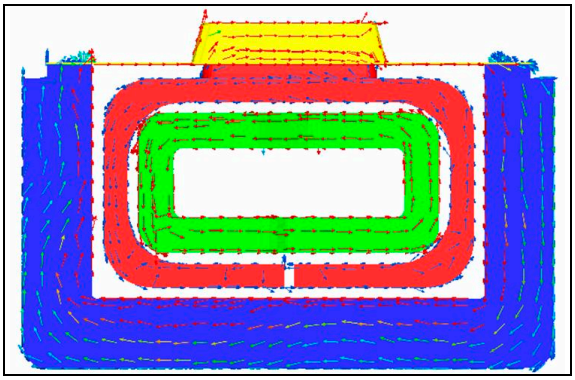

Fig. 8 Directions of Electronic Current

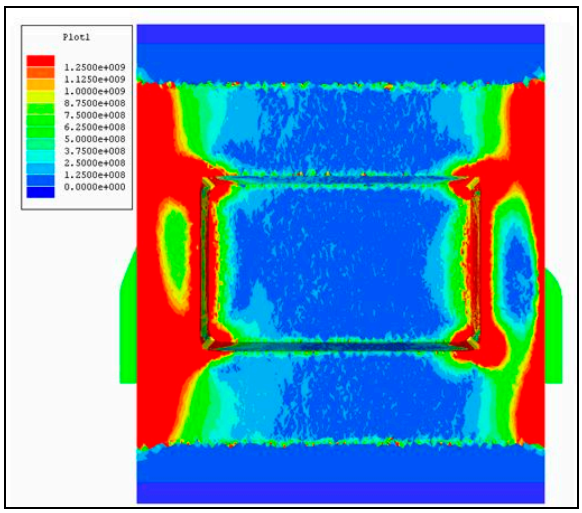

Fig. 9 Distribution of Electromagnetic Force

3.2 Experimental result

Fig. 10 are two mobile phone cases with bionic patttern on surface. The results of electromagnetic forming experiment demonstrate the feasibility to reproduce fine features on metallic surface. However, leather-featured case shows that the performance of side walls is not as good as the top surface. In addition, there is no feature duplicated all over the corners. Because the corners of pre-formed case are highly deformed during drawing process, the corner area needs more forming stress to impact material on die surface.Besides, the cell phone case with veined pattern rebounds slightly on the top surface due to improper force distribution.

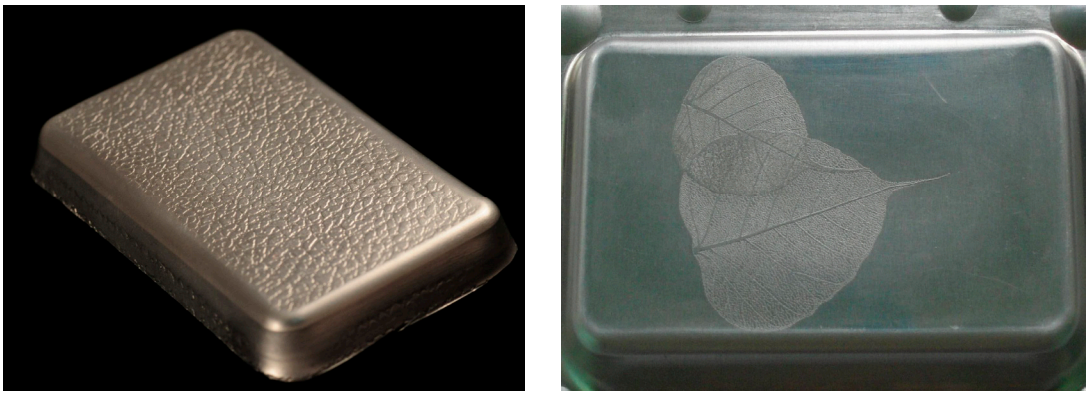

Fig. 10 Bio-feature on Mobile Phone Case(L: leather feature, R: veined pattern)

4. Conclusion

In this study, we proposed a modified uniform pressure coil and evaluate its performance through simulation and experiment. According to the test results, the two-stage forming concept which integrates stamping and electromagnetic forming process demonstrates its feasibility applied to fine features duplication on metallic case.

Electromagnetic force distribution and rebound will significantly affect the accuracy of product's final geometry, so optimizing the design of coil, field shaper and pre-formed case is necessary.

In the future, a new actuator system with different force distribution shall be utilized to enhance the forming efficiency. With the coordination of pre-forming geometric design, the actuator system could generate a well-distributed electro- magnetic field thereby achieving an optimal forming result.

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