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A Study on Forging Technology of Oxygen-Free Copper for Electrode Body Parts of Solar Light

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Abstract*— Forging operations are non-stationary processes occurring as a result of indirect pressure, generally, under conditions of three-dimensional stress and deformation. Furthermore, due to friction and the constraints of the die geometry, deformation is not homogeneous. Material flow and deformation are largely determined by the shape of the tools. It is well-known that a net-shape forging cannot only reduce material waste but can also improve the mechanical strength of the final product. Thus, forging of oxygen free copper for electrode body parts was modeled using finite element simulation and forging experiments were conducted for production of electrode body parts at room temperature. In order to reduce the cost of cutting products, the forging was performed in a closed cavity to obtain near-net or net shape parts.

Index Terms— **Solar light, Electrode body, Oxygen-free copper, Polysilicon, Forging technology.**

I. INTRODUCTION

Cold forging is used to achieve better tolerance, higher mechanical properties, and a better surface aspect that can avoid further machining. But as cold metals are less ductile in general than hot ones, cold forging allows moderate deformation, unless a heat treatment is introduced to restore a deformation capability. In the forging of connecting rods, during this process the perform is totally enclosed in the die cavity so that no flash formation is allowed [1]. There is no material waste in forging. However, tight volume control of the perform is necessary to insure filling of the cavity and to avoid overloading the tooling. In principle, forging operations are non-steady state processes, in which the deformation of the material takes place under three-dimensional stress and strain conditions [2, 3]. The finite element method has become an important analysis tool for bulk metal forming processes because of the advantages in time and cost savings. It is well known that reliability of such simulations depends on accurate material characterization and description of friction conditions which directly affect material flow, forming load requirement, die life, etc [4, 5].

Some of the most common copper alloys used in forging applications are oxygen free electronic, naval brass, aluminum bronze, chromium copper, copper nickel and chromium zirconium copper. Forged copper provides an economical alternative to cast, welded and fabricated copper as well as offering a superior density and freedom from flaws. In addition, copper forgings have non-magnetic properties and non-sparking characteristics that are beneficial to industries such as electronics, automotive, mining, construction, aerospace, and industrial. Copper forgings offer high strength at low densities and can be made through different forging processes, depending on the type of copper alloy. Copper alloys can be forged using closed die forging. Unlike deep drawing closed die forging involves the movement of metal blanks through a set of dies shaped in the required part design [6, 7].

Recently oil shock and global warming due to the increased use of fossil and nuclear energy, chemicals for fuel are growing in importance. This time away from the existing energy supply system emphasizes the need for renewable energy and solar energy industry has been of great interest. The construction of the photovoltaic industry, housing, machinery, electronics, precision instruments, and semiconductor industries including the creation of new markets is expected. The related technologies and demand for polysilicon due to the development of the solar industry are growing. Forging technology of oxygen-free copper for electrode body parts of solar light to activate high efficiency and low cost and productivity of polysilicon was developed. Forging is a manufacturing process involving the shaping of metal using localized compressive forces. Copper forged parts can range in weight from less than a few grams to a few metric tons and usually require further processing to achieve a finished part [8]. Fig. 1 shows ingot furnace and electrode body part of solar light.

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Fig.1 Ingot furnace and electrode body part of solar light

II. MATERIAL PROPERTIES

In order to accurately predict the metal flow it is necessary to use reliable input data for the forging simulation. The stress-strain relation or flow curve is generally obtained from a compression test. Compression test experiment using oxygen-free copper C10100 was carried out to examine the material properties. The diameter and height of the compression specimens were 15 and 10㎜, respectively. The specimens for the test were cut by a wire-electric spark machine. The compressive strength of the specimens was measured through the compression test using UTM with setting load speed as 10㎜/min. Fig. 2 shows specimens of the compression test for oxygen free copper and Fig. 3 shows the result got from the compression test. The primary strategy of material selection has been electrical and thermal conductivity, because the main function of the electrode body part is to keep electrical conductivity for a sufficiently long time.

(a) oxygen-free copper(C10100) (b) Cutting by a wire-electric spark machine (c) Specimens

Fig. 2 Specimens of the compression test for oxygen free copper

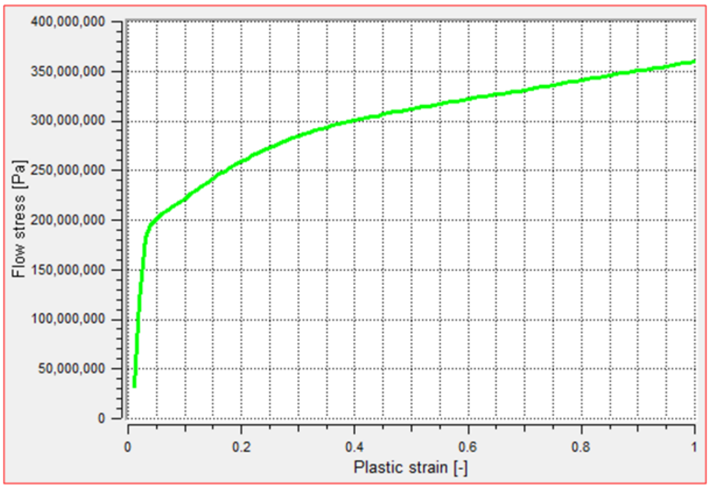

Fig. 3 Stress-strain curve of the compression test for oxygen free copper

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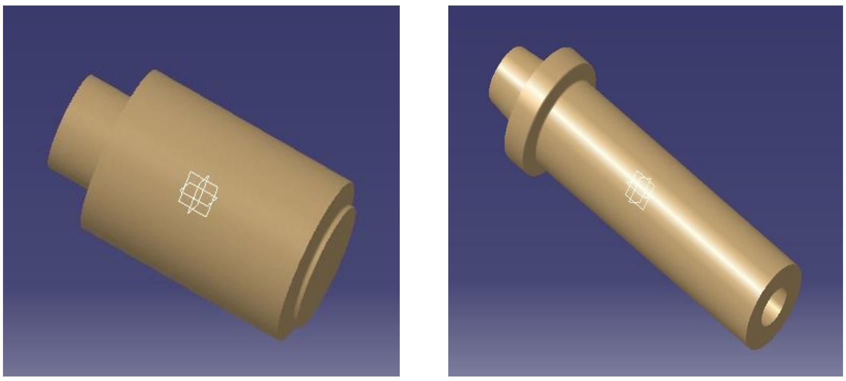
III. COLD FORGING SIMULATION

The finite element method as a powerful numerical technique has been applied to a wide range of engineering problems. When modeling fabrication processes that involve deformation, such as forging, the deformation process must be evaluated in terms of stresses and strain states in the body under deformation including contact issues. The major advantage of this method is its applicability to a wide class of boundary value problems with little restriction on work piece geometry. Without extensive knowledge of the influences of all these variables on forging process, it is hardly possible to design the tools adequately and make a proper choice of copper material and manufacture a product with the desired shape and performance. To reduce this waste of time and cost, process modeling for computer simulation can be used to replace the experimental trial and error process. To design or select the tools and the equipment, such design essentially consists of predicting material flow, determining whether it is possible to form the part without surface or internal defects, and predicting strains and stresses necessary to execute the forging operation. Fig. 4 shows 3 dimensional design of forging processes of electrode body products. Fig. 5 presents forging die for forming electrode body parts

In forging processes the work piece generally undergoes large plastic deformation, and the relative motion between the deforming material and the die surface is significant. Computer simulations can be used to determine the influence from variations in material properties and process parameters. Table 1 shows simulation condition for forging electrode body parts. Fig. 6 and Fig. 7 show effective plastic strain of first forging process and second extrusion process using oxygen free copper according to friction coefficient as a result of the simulation. Fig. 8 shows temperature distribution after forming using oxygen free according to friction coefficient.

Table 1 Simulation condition

Plastic Material	C10100 (Cu 99.99%)
Initial Temp. of Material	20˚C (process condition)
Initial Temp. of Die and Punch	20˚C (process condition)
Condition of Friction	0.05 / 0.10 / 0.15 / 0.20
Press Velocity	50 mm/s
Process Type	Cold Forging
Forging Process	2 Stages



(a) 1st forging process (c) 2nd forging process

Fig. 4 3 dimensional design of electrode body products

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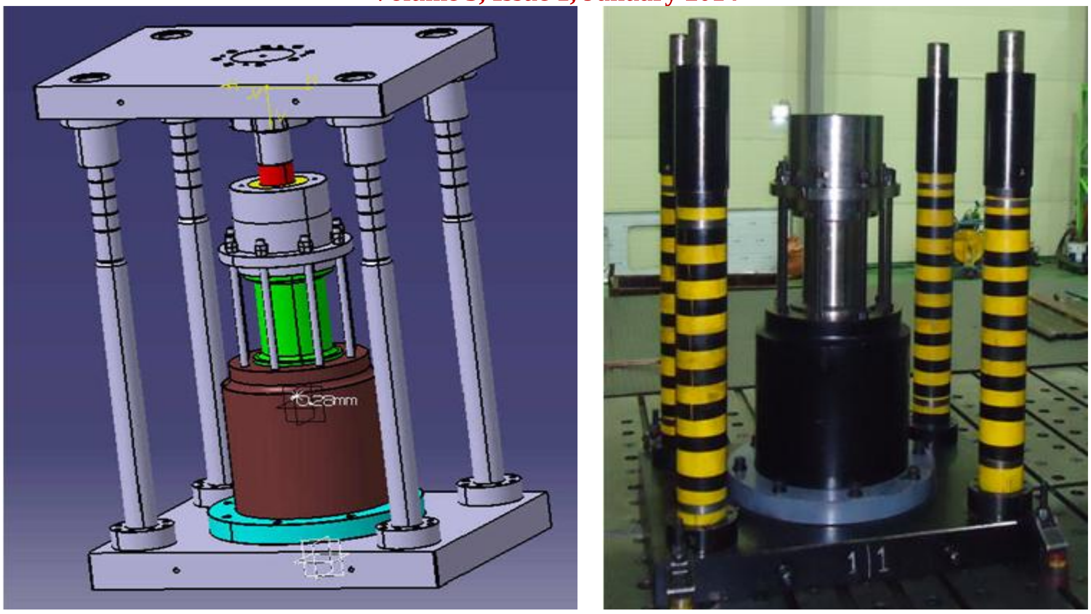
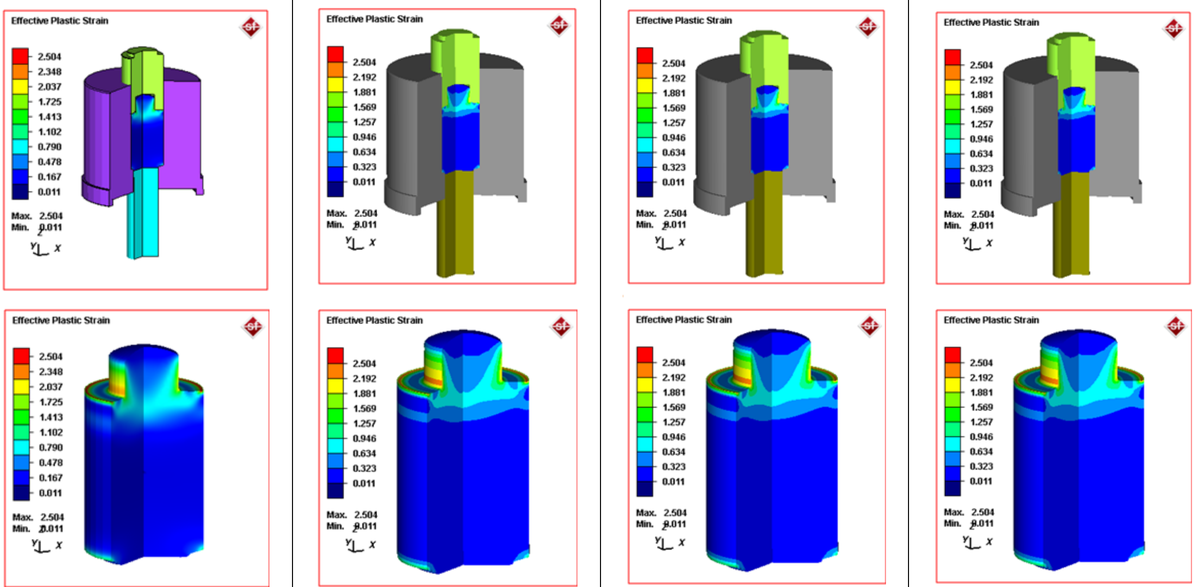
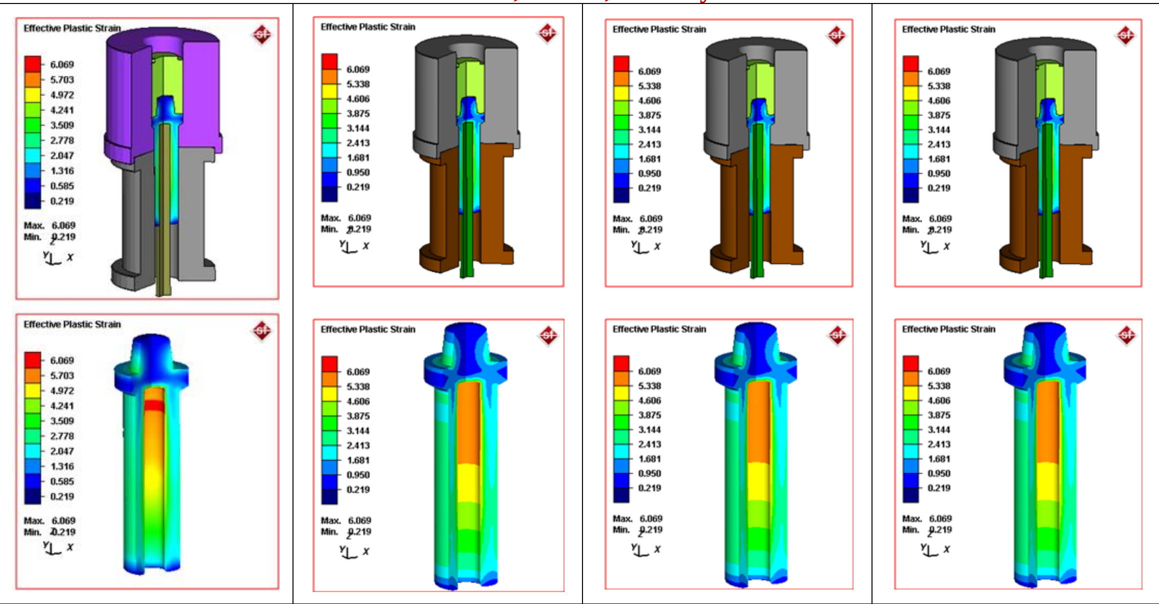


Fig. 5 forging die for forming electrode body parts



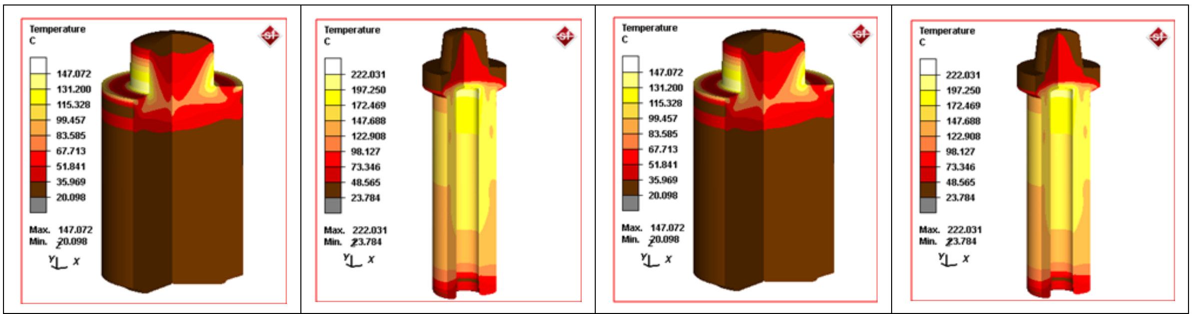
Shear Friction : 0.05	Shear Friction : 0.10	Shear Friction 0.15	Shear Friction 0.20

Fig. 6 Effective plastic strain of first forging process using oxygen free copper

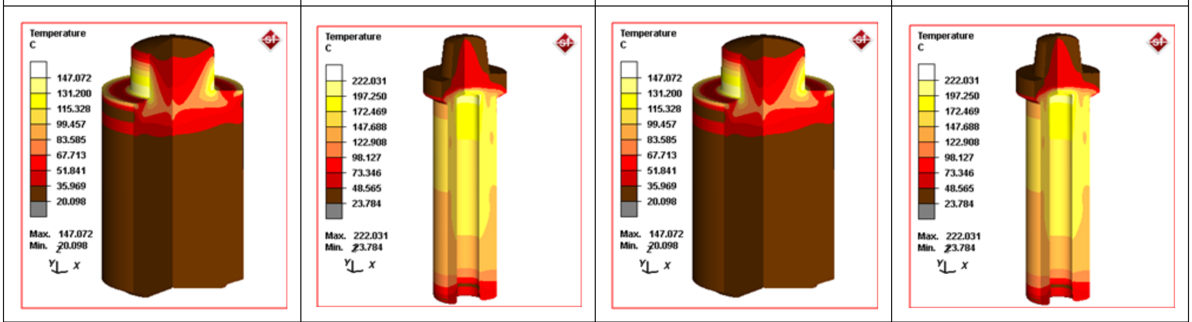


Shear Friction : 0.05	Shear Friction : 0.10	Shear Friction 0.15	Shear Friction 0.20

Fig. 7 Effective plastic strain of second extrusion process using oxygen free copper



Shear Friction : 0.05	Shear Friction : 0.05	Shear Friction : 0.10	Shear Friction : 0.10



Shear Friction 0.15	Shear Friction 0.15	Shear Friction 0.20	Shear Friction 0.20

Fig. 8 Temperature distribution after forming using oxygen free copper

IV. RESULTS AND DISCUSSION

In order to produce electrode body part using oxygen-free copper material it is necessary to design the forging die applied cold forging simulation. Fig. 9 shows simulation and experiment results of electrode body part after forming using oxygen free copper. A short shot is predicted as a result of forging simulation after forming electrode body parts. A portion of Fig. 9 shows a short shot of oxygen-free copper material and Fig. 10 shows comparison

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between simulation and experiment after forming according to friction coefficient. In case of friction coefficient 0.2, a short shot of oxygen-free copper between simulation and experiment after forming is coincided. The simulations coincide with the experiments with respect to a short shot of oxygen-free copper for electrode body parts as shown in Fig. 9. The short shot of oxygen-free copper for electrode body parts affects depending on material property, friction coefficient, surface roughness of punch and die. In case of friction coefficient 0.1, the coincidence of the final product between simulations and experiments is appeared. Fig. 11 shows electrode body products of first forging process and second forging process.

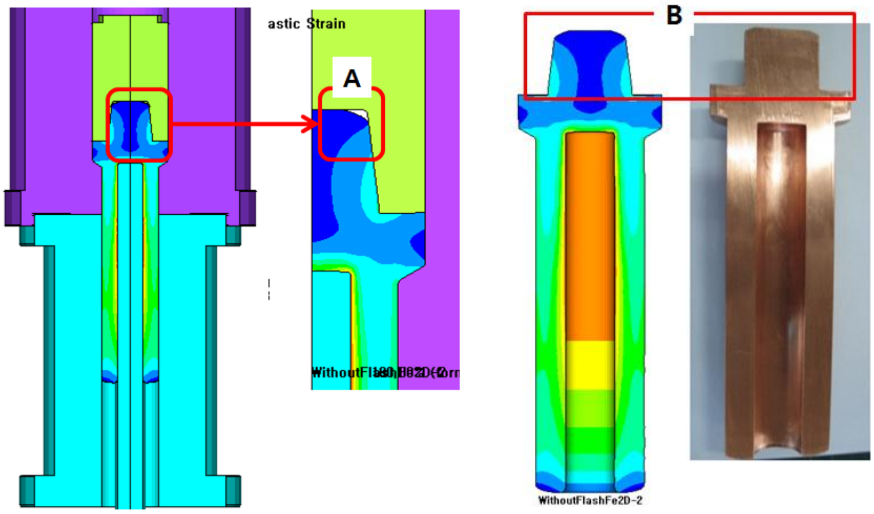

Fig. 9 Simulation and experiment results of electrode body part after forming

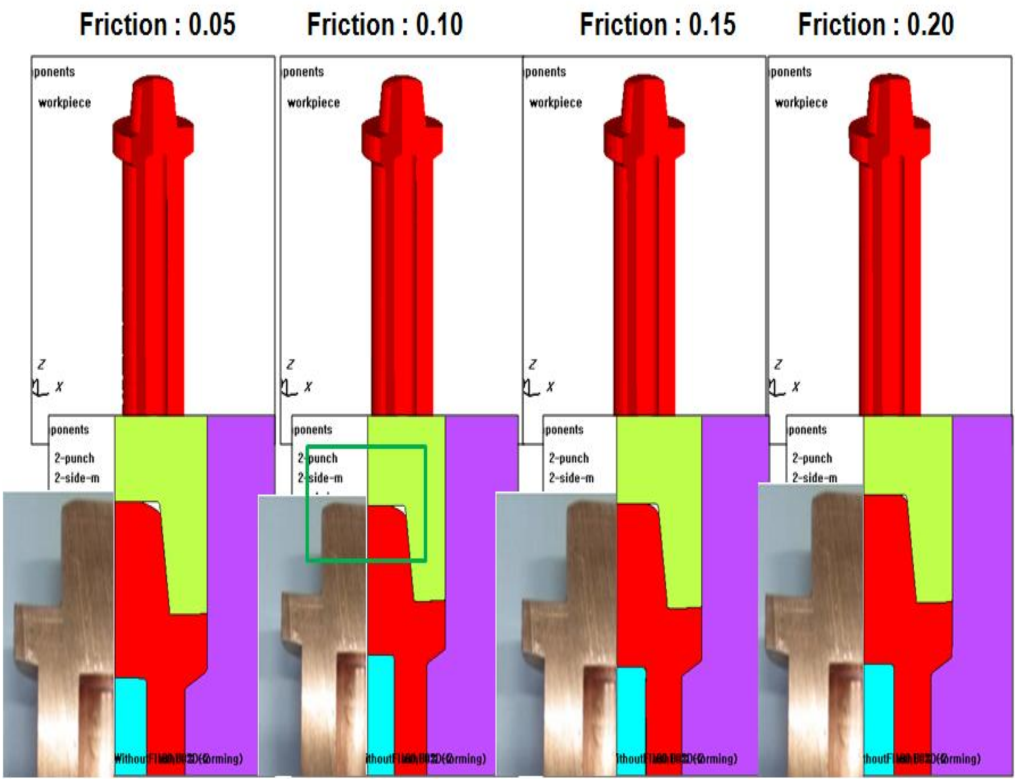

Fig. 10 Comparison between simulation and experiment after forming

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(a) 1st forging process (b) 2nd forging process

Fig. 11 Electrode body products

V. CONCLUSION

In this study, we carried out the simulation and experiments on the forging product with oxygen-free copper material for the electrode body parts of solar light. Material flow and deformation during forming are largely determined by the shape of the tools. It is well-known that a net-shape forging cannot only reduce material waste but can also improve the mechanical strength of the final product. Thus, we predicted to short shot as a result of forging simulation after forming electrode body parts and developed electrode body parts using oxygen-free copper material applied cold forging successfully.

REFERENCES

[1] Victor Vazquez, and Taylan Altan, "Die design for fleshless forging of complex parts," J. of Materials Processing Technology, vol. 98, pp. 81-89, 2000.

[2] Yasunori Saotome, Kaname Yasuda, and Hiroshi Kaga, "Micro deep draw ability of very thin sheet steels," J. of Materials Processing Technology, vol. 113, pp. 641-647, 2001.

[3] Y. M. Heo, S. H. Wang, H. Y. Kim, and D. G. Seo, "The effect of the draw bead dimensions of the weld-line movements in the deep drawing of Taylor-welded blanks," J. of Materials Processing Technology, vol. 113, pp. 686-691, 2001.

[4] M. Kawka, L. Olejnik, A. Rosochowski, H. Sunaga, and A. Makinouchi, "Simulation of wrinkling in sheet metal forming," J. of Materials Processing Technology, vol. 109, pp. 283-289, 2001.

[5] K. P. Rao, and Emani V. R. Mohan, "A unified test for evaluating material parameters for use in the modeling of sheet metal forming," J. of Materials Processing Technology, vol. 113, pp. 725-731, 2001.

[6] Qun-Feng Chang, Da-Yong Li, Ying-Hong Peng, and Xiao-Qin Zeng, "Experimental and numerical study of warm deep drawing of AZ31 magnesium alloy sheet," I. J. of Machine Tools & Manufacture, vol. 47, pp. 436-443, 2007.

[7] H. Takuda, K. Mori, T. Masachika, E. Yamazaki, and Y. Watanabe, "Finite element analysis of the formability of an austenitic stainless steel sheet in warm deep drawing," J. of Materials Processing Technology, vol. 143-144, pp. 242-248, 2003.

[8] Y. T. Im, S. H. Kang, and J. S. Cheon, "A novel technique of friction and material property measurement by tip test in cold forging," J. Engineering Manufacture, vol. 220, pp. 81-90, 2006.