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A STUDY ON HEATING PROCESS FOR DEEP DRAWING

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Abstract:

Thermal – assisted machining is an effective solution to improve productivity and product quality which are made from high strength and difficult – to – cut materials. This method is widely used in non-chip machining (forging, stamping, drawing, etc.) that overcomes disadvantages of traditional machining methods. Some studies of hot stamping are conducted by direct heating on the blank or on the mold. The suitable heating method is chosen based on material properties and requirements of the products. However, the heating on the mold method is possible to control local heat or uniform heat on the work-piece while the calculation of heat capacity, heat transfer as well as the heating time to achieve the temperature on the work-piece are necessary to design a suitable mold and heating system. This study describes, generalizes some heating methods and builds a heating system that uses one – end resistance heating rods to heat the deep drawing mold. Besides, effect of heating time on the temperature on the work-pieces and changing the temperature on the work-piece according to various heat levels through the heating control system are researched. Thereby, forming ability is improved and mistakes in machining process are reduced.

Keywords: *One – end resistance heating rods; deep drawing mold; high strength and difficult – to – cut materials; heating system, heating time.*

1. Introduction

Nowadays, thermal-assisted machining has been widely applied in the industry of manufacturing technical products in the fields of aerospace, aviation, automotive, national defense, healthcare, electricity- electronics-electrical automation. The manufacturing industry has developed various preheating technologies such as electrical resistance, oxyacetylene gas flame, laser-assisted machining (LAM), induction heating, and plasma beam, etc. However, these technologies are only suitable for some machining methods but not all. In the following studies, heating models for deep stamping are usually applied in two forms: preheating on the blank or stamping die. In recent years, there have been many studies in the field of heat-assisted outsourcing published in prestigious journals around the world. Yoshihara et al. [1] studied a deep stamping process with a local heating and cooling technique developed to improve forming ability of sheet metal AZ31-O. The equipment could heat the surface of the work-pieces locally and formed cup wall could be directly cooled by a pump.

Alinia et al. [2] studied the effects of four process parameters which were temperature, work-piece holder force, radius of the glide angle of the punch and die. Experiments were conducted based on warm heating method as Box-Behnken designing.

Panicker et al. [3] researched on the sheet forming process of AA5754-H22 aluminum alloy. Experiments were established to improve material ductility through independent heating at stamping die. A significant increase of cup depth was observed when the temperature of the punch and die were set to 30 °C and 200 °C, respectively.

The heating methods with the aim of

improving forming ability, optimizing geometry and technological parameters, increasing product quality have been studied by various studies. However, the number of researches on thermal - assisted method by one – end resistance heating rods is limited. In order to achieve the effect of the deep stamping process at elevated temperatures, studying on the heating system which uses one – end resistance heating rods and the effect of heating time on the temperature on the work-piece are necessary. Thereby, increasing the shaping ability of the material and limiting the damage in machining will be done.

2. Some of heating methods use in the field of sheet metal forming

2.1. Heating on the work-piece

Conventional heating furnaces (electric, gas furnaces).

Roller furnaces often used in hot stamping to heat continuous steel sheets. Compared to beam furnaces, roller ones have the advantages of uniform heating and easy handling of work-pieces. Heating is affected by gas burning and electricity.

Infrared furnaces

Infrared rays are electromagnetic waves with a wavelength longer than light. They are red. Near-infrared rays have a short wavelength of range $0.7 \div 2.5\mu m$ and are used for infrared cameras. The far infrared rays have a long wavelength of range $4 \div 1000\mu m$. In infrared heating, the steel sheets are heated by radiation. Infrared heating process is fast, clean and compact.

Induction heating

Induction heating is a fast heating process commonly used in forging and heat treatment. Kollek et al. [4] used induction heating for the blanks during hot stamping. The initial temperature up to the Curie temperature was influenced by the vertical magnetic field. Accordingly, one side of the coil for heating the next to the base temperature. Researches [5] also used induction heating system during experiments and showed good results.

Resistance heating

Resistance heating is a new replacement for roller furnaces in stamping technology. Mori et al. [6] proposed a hot stamping process by using a rapid resistance heating system to improve productivity. The sheets are heated in just 2 seconds to 900 ^oC. Therefore, it is synchronized with the holding blank for stamping and makes the device more compact because there is no need for a large furnace to drop the blanks for continuous production [7]. Resistance heating is useful for partial heating of work-pieces, used in hot stamping [8].

Exposure heating

In exposure heating, the work-piece is heated by clamping between heated sheets. Landgrebe et al. [9] developed an exposed heating equipment of the blank for hot stamping. The work-piece is not only uniformly heated, but also partially. The heating time to 950 °C in this exposed heating device is 15 seconds.

Table 1. Features of the heating method used in sheet metal forming

Heating system	furnaces (electric, gas furnaces)	Infrared furnaces	Induction heating	Resistance heating	Exposure heating
Heating time	2-5 (minutes) Uniformity	50-70 (seconds) Uniformity	20-30 (seconds) Limited by induction coil length	5-10 (seconds) No heating of both ends	15-30 (seconds) Uniformity
Work-piece shape	Unlimited	Unlimited	As a rectangle	Only a rectangle	Unlimited
Volume	100-200 m^2	100-200 m^2	5-10 m^2	5-10 m^2	5-10 m^2
Productivity efficiency	Low	Low	Medium	High	Low

2.2. Heating on deep drawing mold

Heating model mounted directly on the mold.

This is a local heating method, using heat bars assembled on a die and blank holder as shown in Figure 1. The punch is cooled by a water-cooled system with inlet pressure is calculated based on the mold cooling rate and stamping products.

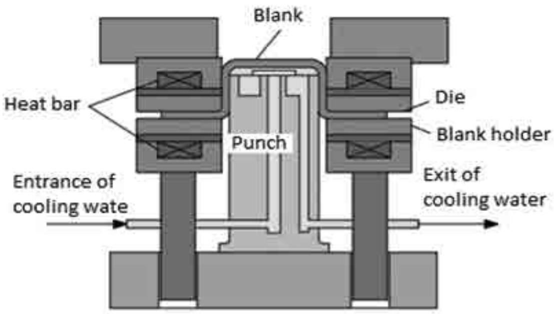


Fig. 1. Heating model on the deep drawing

Heating model through a heating cabinet fitted with mold sets and stamping machines.

The deep stamping experiments at elevated temperatures were performed with hot forming machines which is designed as shown in Figure 2. The construction of the machine includes a vacuum chamber, heating coils, water-cooled systems, mold and hydraulic control, system control, etc. capable performing various types of forming tests for sheet metal at elevated temperatures when appropriate mold installation.

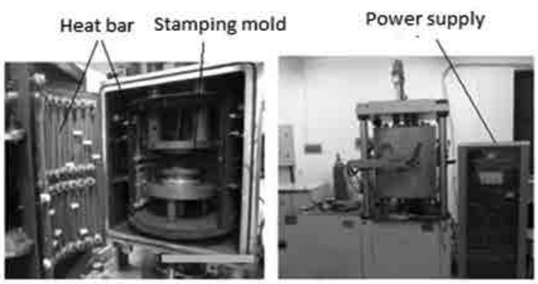


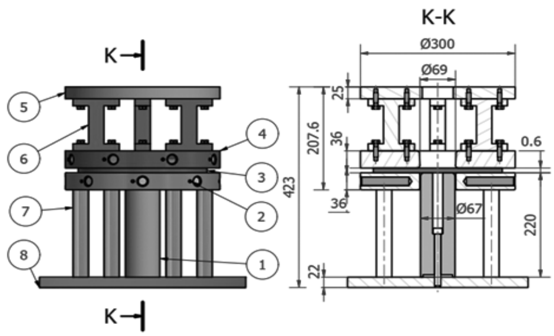
Fig. 2. Heating model through a heating cabinet fitted with mold sets and stamping machines [10]

3. Experiment

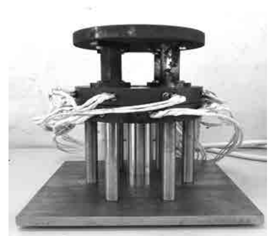
3.1. Heating equipment and deep drawing mold

Based on the research product model, the set of deep drawing mold is designed, machined and assembled as shown in Figure 3. The mold set includes: *1- punch; 2- blank holder; 3- blank; 4 - die; 5 - sole of die, 6 - struts for die, 7- struts, 8- platform.*

The blank holder and die of deep drawing are machined with 8 holes ϕ 18 mm in diameter to insert one – end resistance heating rods with diameter of ϕ 17.9 mm, length of 100mm and thermal capacity of 400W. This set of mold is designed for stamping products with a thickness of 0.6 mm and a diameter of ϕ 67 mm.



a)



b)

Fig. 3. The set of deep drawing mold for blanks as cup form
a) Structure of mold sets;
b) Picture of mold after processing and assembling

Temperature control and heating system for deep drawing mold

The temperature control cabinet for set of deep drawing mold. It uses the REX-C100 + SSR 40DA temperature controller and intelligent PID control. The temperature of the controller follows the thermocouple measurement signal (thermistor) and sets the user deviation value for the operation of the PID, which orders the forward actions to achieve automatic control, automatic temperature effects. The temperature control system also has alarm function and upper limit temperature output.

3.2. Experimental diagram

The model of heating and measuring on deep drawing mold as Figure 4 and image of experiment as Figure 5.

The deep drawing mold set is manufactured and attached to one-end thermistor bars which are heated through the control cabinet when the thermal capacity is changed. The thermal sensor (Ts) is mounted on a die as shown in Figure 4 and connected to the control cabinet, which is used to measure the temperature and set the limit temperature on the work-piece through the control cabinet.

To determine temperatures at specific locations on the mold, K-type temperature sensors are used in this study. The measurement signal from the thermal sensors is connected to a data receiver and then transmitted to the storage computer. This data collection unit is USB-4718, which measures up to 8 points simultaneously. In this study, the thermal sensors are located at 5 positions as above the work-piece (Ts1), the die (Ts2), the blank holder (Ts3), sole of die (Ts4), and punch (Ts5). The temperature changes over time will be collected. The measured data will then be used to plot temperature charts that change over time.

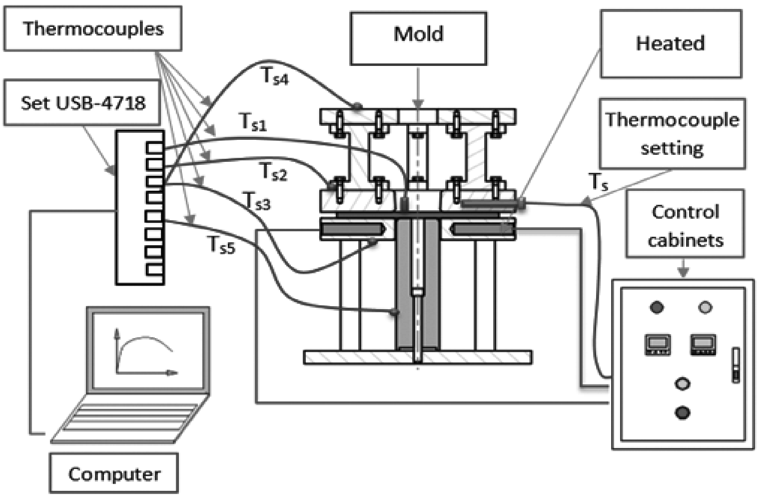


Fig. 4. The model of heating and measuring on deep drawing mold

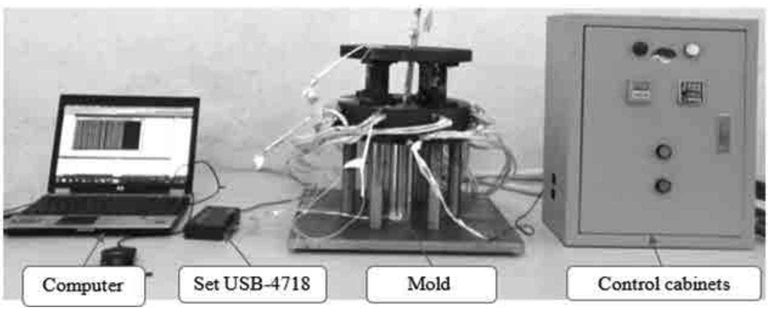


Fig. 5. Experiment image of heating and temperature measuring for deep drawing mold

4. Results and discussion

In another study, the relationship between mold temperature depending on the work-piece temperature was studied, in which the set temperature on the blank for stamping process was 250 °C. A sensor has been placed on the work-piece surface to transmission the work-piece temperature signal to the control cabinet and maintain this temperature throughout the deep drawing process. The temperature probes of Set USB - 4718 mounted on the mold shows that, when the work-piece temperature remains at 250 ^{o}C, the maximum temperature on the mold at the position of the TS sensor is 300 ^{o}C (the position of the sensor as shown in Figure 4).

However, during the deep drawing process, determining the temperature directly on the blank is very complicated and difficult to implement. Therefore, research has proposed an experiment model to determine the work-piece temperature at the time of machining through the mold temperature is essential that as shown in Figure 4.

Figure 4. In this study, the temperature is setting and maintained through the control cabinet with Ts = 300 °C to heating the mold. The heat transfer process from the mold to the work-piece is determined through two cases as below:

Case 1, for the first blank of deep drawing process, the heat transfer from the mold to the blank is analyzed. In which the mold is heated from 25 °C to 300 °C and transfers heat to the work-piece at the same time. The results of the measured temperatures at the locations are shown in Figure 6a. Case 2, for the next work-pieces of the deep drawing process that are transferred the heating when the mold has reached a temperature maintained at 300 °C. Heat measurement results at locations such as Figure 7a.

Comparing the heat transfer process in 2 cases shows that in case 1, the mold temperature reaches 300 °C after 1237 seconds and the work-piece reaches 250 °C after 2061 seconds. This is a relatively long time. In case 2, time for work-piece reaches 250 °C is 611 seconds (equal to 29,6% of the heating time for the first blank). The growth of temperature on the blank then increases but was not significant (<5%).

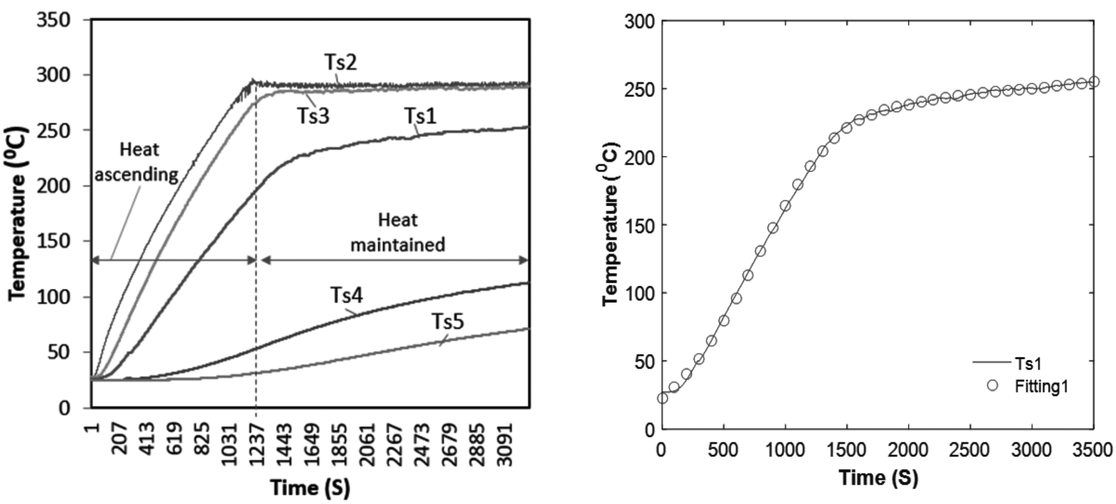
To determine the time it takes to achieve different temperatures on the work-piece, the study has constructed a mathematical model of relationship between temperature and heating time by Matlab software for both cases as follows.

Case 1: The mathematical equation applies for the first heating (The blank is heated with the mold).

$$f(x_1) = a_1 * \exp\left(-\left(\frac{x_1 - b_1}{c_1}\right)^2\right) + a_2 * \exp\left(-\left(\frac{x_1 - b_2}{c_2}\right)^2\right) + a_3 * \exp\left(-\left(\frac{x_1 - b_3}{c_3}\right)^2\right) \quad (1)$$

Table 2. The constants of equation 1

Constants	a_1	b_1	c_1	a_2	b_2	c_2	a_3	b_3	c_3
Value	213.2	4164	1166	197.6	2523	1189	135.6	1250	909.8

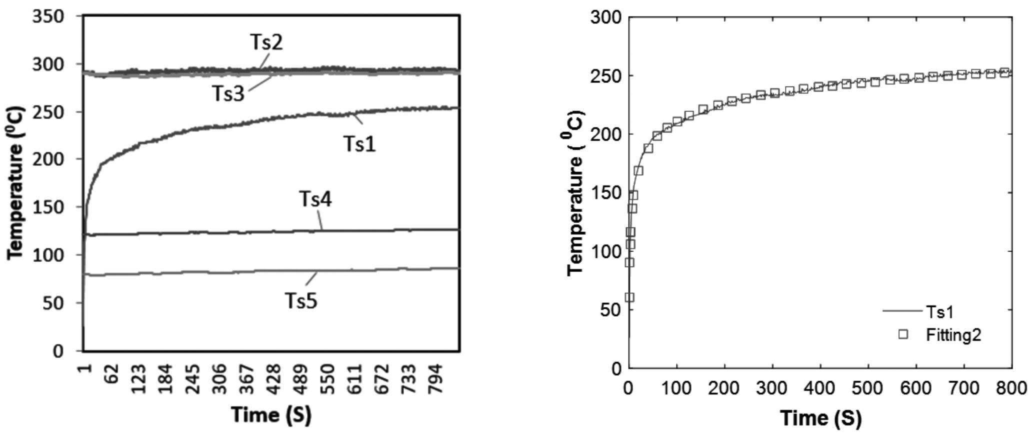


a) b)

Fig. 6. The blank is heating with the deep drawing mold

a) Heating graph at positions on the mold

b) The graph shows the blank temperature and heating time



a) b)

Fig. 7. Heat is transferred from the mold to the work-piece when the mold reaches the set temperature. a) Heating graph at positions on the mold; b) The graph shows the blank temperature and heating time

Case 2: The mathematical equation applies for the next blanks

$$f(x_2) = a * x_2^b + c \qquad (2)$$

Where a, b, and c are the coefficients determined from experiments. By using fitting method by Matlab software, these coefficients are found, corresponding to -316,1; -0,14; 376,9.

5. Conclusion

Researches on a heating systems with one – end resistance heating rods and the effect of heating time on the temperature on the blank during deep drawing process have been done in this study and reached some results as below:

The heating system by one – end resistance heating rods is an efficient and economical one for the stamping process.

Designing and successfully manufacturing sets of deep drawing mold using one-end resistance heating rods and control cabinet system capable of controlling temperature, setting as well as maintaining the temperature at appropriate heat levels for sheet metal forming process.

Construction a mathematical function presents the relationship between temperature and heating time. From there, determining the temperature on the blank at corresponding times is easier without experiments, its useful for supporting and improving the ability shaping products during deep drawing.

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NGHIÊN CỨU VỀ QUÁ TRÌNH GIA NHIỆT CHO GIA CÔNG DẬP VUỐT

Tóm tắt:

Gia công vật liệu có gia nhiệt là là giải pháp gia công hiệu quả trong nâng cao năng suất và chất lượng sản phẩm được làm từ các loại vật liệu có độ bền, độ cứng cao. Phương pháp này được ứng dụng rộng rãi trong gia công không phoi (rèn, dập, vuốt, miết .v.v.).. Những nghiên cứu về gia nhiệt trong dập nóng được tiến hành bằng cách ra nhiệt trực tiếp trên phôi hoặc gia nhiệt trên khuôn, tùy thuộc vào tính chất vật liệu và yêu cầu của sản phẩm từ đó lựa chọn phương pháp gia nhiệt hợp lý. Đối với phương pháp gia nhiệt trên khuôn có thể kiểm soát về nhiệt cục bộ hay nhiệt đồng đều trên phôi, tuy nhiên việc tính toán công suất nhiệt, truyền nhiệt cũng như thời gian gia nhiệt để đạt được nhiệt độ trên phôi dập là rất cần thiết để thiết kế bộ khuôn và hệ thống gia nhiệt phù hợp. Trong nghiên cứu này mô tả và khái quát hóa một số phương pháp gia nhiệt, xây dựng hệ thống gia nhiệt sử dụng thanh nhiệt điện trở một đầu dùng để nung nóng bộ khuôn dập vuốt và nghiên cứu về mức độ ảnh hưởng của thời gian gia nhiệt tới nhiệt độ trên phôi dập vuốt, thay đổi được nhiệt độ trên phôi theo các mức nhiệt khác nhau thông qua hệ thống điều khiển gia nhiệt. Từ đó tăng khả năng tạo hình của vật liệu và hạn chế những hư hỏng trong gia công.

Từ khóa: *Thanh nhiệt điện trở một đầu; Khuôn dập vuốt; Vật liệu có độ bền, độ cứng cao; Hệ thống gia nhiệt; Thời gian gia nhiệt.*