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MATERIAL PROCESSING BY DIFFERENTIAL HEATING AND SIMPLE PRESSING

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ABSTACT

An investigation of a new forming method for the production of complex geornetries is presented. The deformation is effected by the use of simple tools in a fleshless type operation where local heating is applied to the billet surface or volume thus allowing maximum deformation to occur where required. The technique is applied to cylindrical steel billets for the production of symmetrical flanges at the periphery of the workpiece and unsymmetrical local deformation on the surface of the billet. Also, compound flow problems are simulated using aluminium billets integrated with plasticine. The results show that the lateral profile is affected by the level of heating and that local deformation is greater at areas where the material flow stress is reduced. The process is potentially attractive for the production of near net shape complex parts and preforms for the forging industry.

1. INTRODUCTION

In Forging processes deformation takes place in three dimensions and in order to produce a particular shape, metal flow has to be constrained by the geometry of the tools as in closed die forging. In most cases excessive loading is applied in order to ensure complete filling of the die cavity. In the manufacture of complex parts by forging, and in order to reduce the loading requirements the process is carried out at elevated temperature. The production of flash, later removed by trimming or machining, and oxidisarion are inherent in these operations. Also, the heating and cooling cycles affect tool wear and the fatigue characteristics of the tooling arrangement thus reducing die life considerably. Open die forging [1], and wire and pipie dieless drawing [2] are among the processes which are employed to effect free flow and hence demand less loading. A combination of warm and cold processing sequence showed considerable improvement in process and energy utilisation when applied to extrusion of complex parts [3].

Forming of solid metal with a liquid phase core was studied in Japan [4] and it was found that the deformation behaviour is sensitive to the amount of liquid core. Thermal forming using laser heating was investigated in Germany [5] and applied to bending of plates made of two layers.

Differential heating is defined here as a process in which a small part of the workpiece is heated so that the flow stress at that particular zone is reduced. Material adjacent to the heating source will exhibit the lowest resistance to deformation as shown in Figure 1. Flow stress variation through the billet due to local heating will depend upon the billet hearing time, transfer time and heating tools. The relation between temperature and flow stress is non-linear and in addition most materials become strain-rate sensitive at elevated temperature [6]. Simultaneously forming the workpiece during heating reduces heat losses and gives more control over the deformation mechanism. However effective narrow local heating is achievable with a high-energy beam hearing source. The use of such beams is utilised in welding processes where deep welds with a depth to width ratio of 20:1 have been produced by exploiting an effect known as "keyholing" [7].

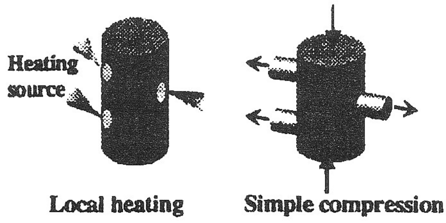

Fig.1 - Differential heating forming

This paper presents observations of an experimental study using differential heating to forming complex parts, and provides the basis for the application of differential hearing to produce a controlled "free" deformation mechanisms.

2. DIFFERENTIAL HEATING EXPERIMENTS

Experiments were conducted on a Rhodes 980kN press. Tool steel flat dies were used in all experiments and the load was measured using a load cell inserted in the top die. The displacement of the ram was measured using a height gauge potentiometer. The temperature in the through heating experiments was controlled by means of a thermocouple. ϕ 25.0 x 37.5mm 0.3% carbon steel (mild steel) billets were used in through heating and induction hearing experiments. The material flow stress was obtained for all testing temperatures and the average values are shown in Figure 2. The maximum strain achieved in the experiments was 1.4mm/mm. It is noticed that the flow stress at 690° C drops to approximately half of the value at ambient temperature. The flow stress for billets heated to quarter the steel melting point was greater than that at room temperature. This phenomena is well known for ferrous metals due to carbon migration in the temperature range of 100°C - 350°C.

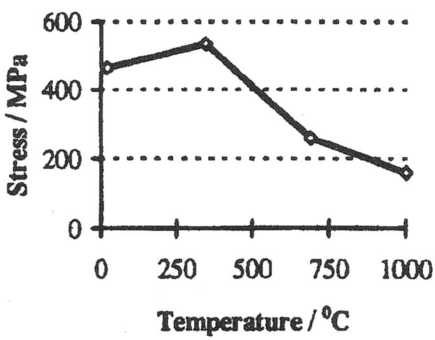

Fig.2 - Flow stress variation with temperature

2.1. Through heating experiments

In order to examine the effect of differential heating on deformation, steel billets were made out of three separate sections, each of a height of 12.7mm. The middle section was then heated in a muffle furnace. The three sections were re-assembled with the heated part in the middle then deformed to a height of 25.4mm. The process was carried out at four temperatures; 1000, 690, 345 °C and room temperature. Figure 3 shows the loading curves for split billets while Figure 4 shows the maximum diameter for each section at varying temperature.

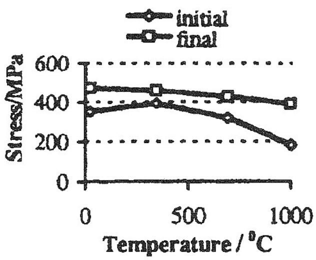

Fig.3 - Forming stresses

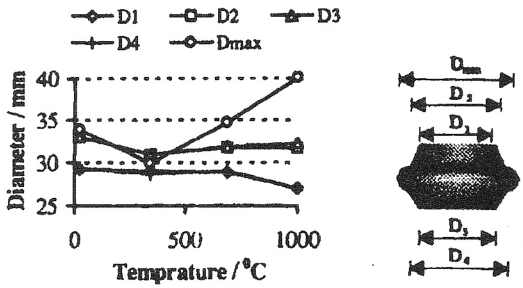

Fig.4 - Change in diameter with temperature

It is clear that the surfaces in contact with the dies exhibited similar deformation. The lowest deformation at the tool/material interface occurred at1000°C where the frictional resistance was higher than the shearing action between sections.

2.2 Induction heating experiments

Similar experiments to those applied on through heated sectioned billets were carried out on full length billets with the middle section heated using a 3.2mm one-turn induction coil. Initial experiments were conducted to measure the time taken for the core of the billet to reach the required temperature. A hole was drilled to the centre of test billets and the temperature reading at three locations were recorded; top surface, lower surface and the centre of the bi l let. Figure 5 shows the comparison between the maximum diameter obtained in through heating and induction heating experiments.

2.3 Local heating experiments

An Oxyacetylene burner set up was used to provide rapid heating to a small section, 5mm in height x10mm in length, through the billet. Flame heating penetrates through the billet faster than induction heating and thus the heat affected zone will be smaller. Varying heating time was applied to a total of 6 billets, which were subjected to strains similar to those of the previous experiments. The results demonstrated the effectiveness of the heating system and Figure 6 gives an example of a cam lobe type profile, which was formed by using flat tools. The maximum local deformation was found to increase with hearing time in this case.

2.4 Aluminium/plasticine experiments

Physical modeling of localised heating was carried out on aluminium billets ϕ 25.4 x 45 mm with 3.5mm diameter holes drilled through the cross section of the billet and filled with plasticine. The holes were positioned at 10,20 and 30mm from the top surface of the billet. With the application of small increments the flow of plasticine was predominent with negligible change in the outside diameter of the billet. Figure 7 shows an example of a complex profile produced by this method. The flow is local, anisotropy and directional due to the temperature gradient through the billet. Furnace and induction heating systems are slow and they require at least 15 seconds transfer tine. Rapid heating however can be achieved using beam heating, such as laser or electron beams where the heating tune is measured in μs and the heat affected zone is minimized.

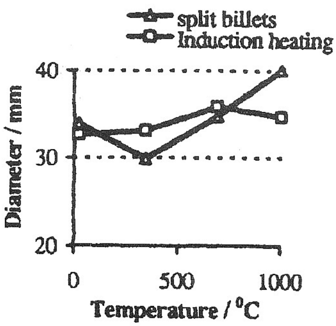

Fig.5 - Billet maximum diameter

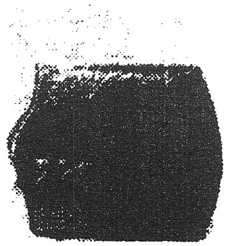

Fig.6 - Local forming

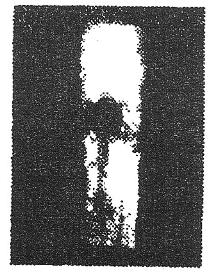

Fig.7 – Free flow simulation

3. CONCLUSIONS

Differential heating forming has been investigated experimentally using different heating combined with simple compression. The process is capable of producing near net profiles with high material utilization factor. Split billet experiments demonstrated the effect of differential heating on metal flow, localised deformation has been produced by the use of fast flame heating, and aluminium/plasticine integrated billets.

4. REFERENCES

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LOKALNO DEFORMISANJE UZ LOKALNO ZAGREVANJE

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REZIME

Prezentiran je novi metod obrade deformisanjem za izradu delova kompleksne geometrije. Deformisanj se izvodi uz pomoć jednostavnih alata i primenom lokalnog zagrevanja na mestima u okviru zapremine komada gde se zahteva maksimalna deformacija. Lokalnim zagrevanjem se smanjuje napon tečenja samo jednog dela pripremka i to onog na kome se zahteva najveći stepen deformacije. Ova tehnika je primenjena na cilindrično čeličnim uzorcima za izradu simetričnih delova sa obodom, kao i za izradu nesimetričnih delova. Takođe simuliran je proces tečenja kombinovanog materijala aluminijum- plastelin.
Rezultati pokazuju da lokalna veličina deformacije u velikoj meri zavisi od lokalnog zagrevanja. Ovaj proces može biti veoma uspešno primenjen za izradu net-shape obradaka kao i za dobijanje pripremaka za kovanje.
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