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CONSIDERATIONS ON INCREMENTAL PROCESSES OF PLASTIC DEFORMATION

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ABSTRACT: Dieless drawing of wires and bars and dieless bending of pipes are two incremental plastic deformation processes which present some advantages compared to classical ones. Dieless drawing is an incremental process of plastic deformation assisted by local heating. In this process temperature and plastic deformationaffect each other, that is why the deformation behavior is very complicated. The process of dieless bending can be widely used for forming steel pipes with large diameters and also for pipes with non-circular shapes like: ellipse, square, hexagon, etc. In conventional bending process it is very difficult to bend non-circular pipes precisely because the shapes of dies and tools are very complicated and the cost of the process is very high.

KEYWORDS: plastic deformation, drawing, die, incremental

1. INTRODUCTION:

In conventional metal forming processes, large plastic deformation is given to a material using tools such as dies. Some materials present much difficulties in forming because of high strengthes or poor ductilities. In most of forming processes large frictional force acts on the interface between the material and the tool, which has a negative influence in the process.To decrease the flow and to increase the ductility, hot working is often used, but there still remain problems caused by heat resisting tools and lubricants in the high temperatures.

The non conventional processes seem to solve these problems. They are some of hot working and frictionless processes. Two of these processes are: dieless drawing of wires and bars and dieless bending of pipes , which present the characteristics of incremental plastic deformation processes. A particularity of an incremental plastic deformation process is that the deformation stress, power and energy consumed in the process are lower than in the classical processes where the deformation take place in the whole volume of material.

2. DIELESS DRAWING

Dieless drawing is an incremental metal forming process for plastic stretching of bars, wires, by using local heating. Figure 1 presents the principle of the process.

The main advantages of the process compared to the classical drawing are:

-the absence of die which makes the process less expensive compared to conventional process

-there are no intermidiate heating and surface preparing operations

-absence of lubrication problems

-a large reduction of area can be obtained ina single pass(up to 80%)
The main parameters of the process can be classified into.
-control parameters:temperature, drawing force, valocity
-kinematic parameters: strain, strain rate
-material properties: density, heat conductivity, specific heat capacity
-mechanical parameters yield stress
-disturbance parameters:inhomogeneity of material properties, changes of temperature, drawing force and velocity

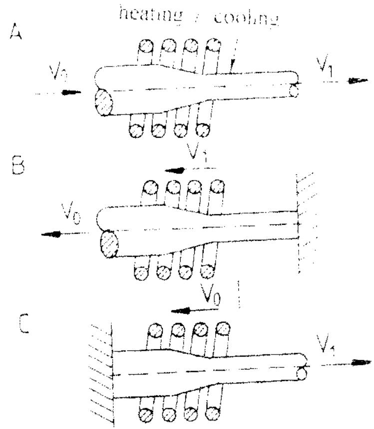

Fig 1

A model of deformation in dieless drawing is presented in figure 2. from which result that in order to avoid the material fracture the following relation should hold in the deforming zone[3]:

$$A_0\sigma_0 = A\sigma = A_1\sigma_1 \quad [1]$$

where A_0, A_1 are the cross sectional areas in the entrance and exit zones, σ_0, σ_1 are the flow stress in the entrance and exit zones.
For simplicity we assume that the process is not stable when:

$$A_1\sigma_1 > A_0\sigma_0 \quad [2]$$

The maximum reduction in area is:

$$r_{max} = \frac{\Delta A_{max}}{A_0} = 1 - \frac{A_{1min}}{A} = 1 - \frac{\sigma}{\sigma_1} \quad [3]$$

Figure 3 presents the variation of reduction with ratio V_1/V_0 for different drawing temperatures[1].
The reductions are much less in the high speed drawing, the temperature gradient becomes less as the drawing speed increases because the cooling rate is limited by the heat conduction.

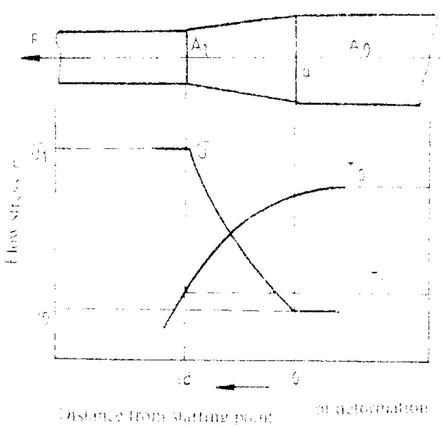

Fig.2

The heating temperature and the cooling rate are the most important factors for the successful deformation. Induction heating is superior to any other heat method in view of the requirement for local heating, the ability to produce high heating rates and because of diminishing the phenomenos of oxidation and decarburation. In case of induction heating, the temperature of material depends on factors such as the power of the induction heating source, the time, the shape of the inductor coil, the distance between the coil and the material, and the material's physical constants(specific heat density, thermal conductivity permeability). The cooling rate is changed by selecting the coolant. For high speed drawing liquid CO_2 can be used.

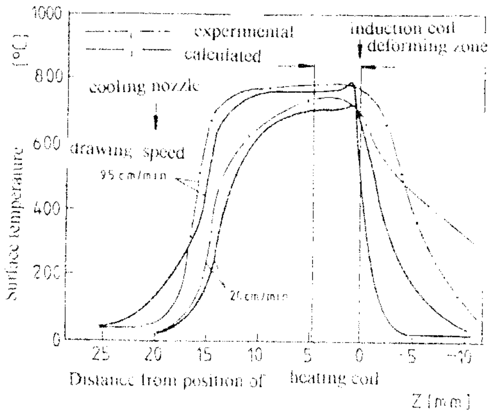

Fig.5

By changing the velocity V_0 or V_1 during deformation, tapered, different cross-sectional bars can be obtained. Dieless drawing of hollow bars is also achieved with the same accuracy as solid bars, the controlling of the wall thickness is possible.

3. DIELESS BENDING OF STEEL PIPES

This process can be applied for bending of circular pipes with large diameters, but it may become a new bending method for non-circular pipes(ellipse, square, hexagon, etc.)[5].
Figure 6 presents the principle of the process.

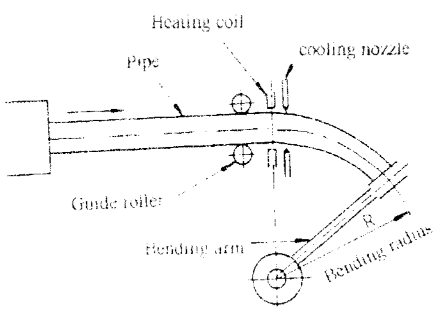

Fig.6

The materials used for experiments were plain carbon steels with the carbon contents 0,11% and 0,23%. For obtaining different heating widths, pipes were heated to 800-850°C and were moved at a constant velocity of 20cm/min[5].
The problem which appear in the process is wrinkling that occurs at the inside of the pipes when the bending radius is very small.
In order to overtake this disadvantage were established relationships between the geometrical parameters of the pipe(width of the deformation zone W, diameter D_0, wall thickness t_0) and the smallest bending radius without defects R_{min}.

Figure 7 presents the relationship between the value of R_{min}/D_0 and the width of the deformation zone W. The value of R_{min}/D_0 decreases as the deformation width is reduced and the values depend on the wall thickness of pipes[5].
Figure 8 shows the value of R_{min}/D_0 against the width of deformation zone, where the width W is devided by the wall thickness t_0. The value of R_{min}/D_0 increases linearly with the increase of W/t_0 and an experimental relation which express this relationship is:

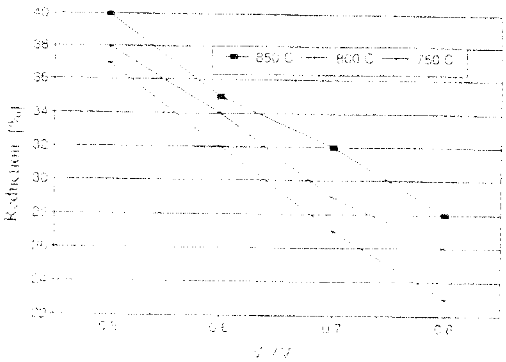

Fig.3

For predicting the temperature distribution in dieless drawing were developed some theoretical models:finite element method, finite difference analisys, Bessel equations method.
For finite element method analysis, the model used is presented in figure 4[3].

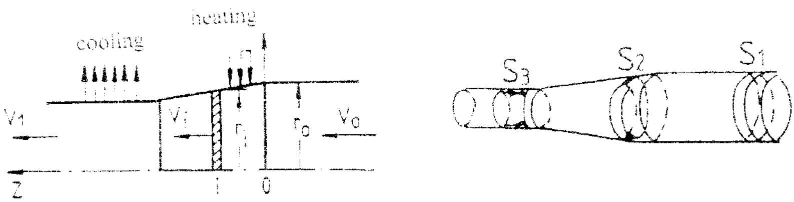

Fig.4

The fundamental differencial equation which includes the heat conduction, the heat input and the heat convections by material flow and the coolant is expressed by the following relation:

$$\lambda \frac{\partial}{\partial r}(r\frac{\partial T}{\partial r}) + r\lambda \frac{\partial^2 T}{\partial r^2} - r\frac{\partial}{\partial z}(c\rho T V_z) = 0 \qquad [4]$$

where r,z are the coordinates which express the radial and longitudinal directions, λ- thermal conductivity, T- temperature, c- specific heat, ρ- density, V_z- the longitudinal velocity of an element.
Figure 5 shows a comparison between the experimental and theoretical values of the surface temperature at different drawing rates[3]. It can be seen that the theoretical results are in good agrements to experimental ones.
The physical - mechanic properties and the dimensional precision of the products resulted from dieless drawing are chiefly determined by three groups of parameters: mechanical parameters(drawing stress, drawing speeds), thermal parameters(temperature, cooling rate), geometrical parameters of the semiproduct and of the heating-cooling system. By increasing the drawing stress, the diameter variation to the prescribed dimensions increases. The diameter variation on the deformed length(200mm) were of ± 0.1mm for the studied materials[2]. These variatons may be determined by a strict control of the temperature or by using final calibration.

$$\frac{R_{min}}{D_0} = 0{,}15\frac{W}{t_0} \pm 0.25 \qquad [6]$$

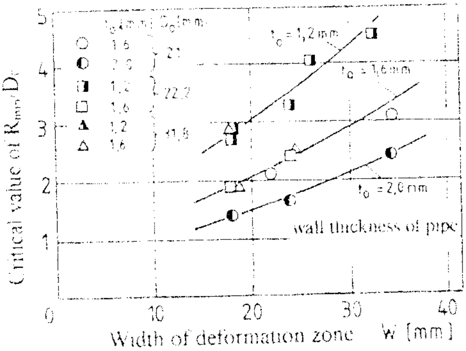

Fig.7

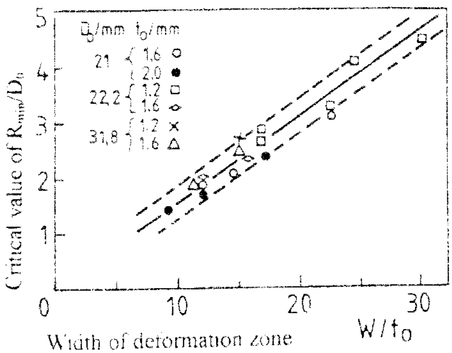

Fig.8

4.CONCLUSIONS

Dieless drawing of wires and bars and dieless bending of pipes are two processes of incremental pastic deformation, which due to their technological and economical advantages can be developed.
The reductions obtained in dieless drawing depends on the thermo-mechanical regime given by the temperatures difference T_0-T_1, the speeds ratio V_0/V_1 and by flow stresses ratio σ_0/σ_1. Very important for the successful operation are the heating/cooling rates and the temperature distribution.
Some applications of the process were demonstrated experimentally; for example the production of smooth uniform bars(solid and hollow), tapered bars and bars of various cross-section

A new bending method of pipes without the use of dies was developed. It is a method suitable for circular and non-circular pipes. It was demonstrated that pipes can be easily bent to a small bending radius without defects. The minimum bending radius R_{min} decreases as the width of deformation zone is reduced.

5. REFERENCES

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