EXQUISITE MODERN MOVEMENT OF TECHNOLOGY IN THE AREA OF METALS FORMING

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Abstract

Metal forming can be regarded as a process, during which materials are treated by “force” and “heating” under a certain external load and boundary condition (loading mode, rate of loading, constraint condition, geometry, contact friction condition, temperature field). Materials vary in formability and structure properties. The change of geometry depends not only on the loading conditions of external forces, temperature, frictional and constraint conditions, but also on the change of properties, such as resistance to deformation and hardening of materials. During the working process, it is still hard to accurately predict the variation of temperature, deformation velocity and friction conditions. The microstructure and properties of materials have more complex variations. The movement of dislocations, grain boundary deformation, crystallization, recovery and recrystallization, second-phase precipitation, texture deformation and grain elongation usually take place at the thermoforming state, which diversifies the properties and the microstructure of materials greatly. Consequently, it becomes a scientific task to predict and control these complex changes of materials in the metal forming process. New metal forming technologies may be developed using new energy resources, new forming mediums and new loading methods for developing new products according to the needs of the automotive, electrical, electronic and aerospace industries. Some examples of these technologies will be presented in this paper.

Keywords: forming technology, incremental forming, tube hydroforming

1. INTRODUCTION

Forming can be described as a process, when there is a change of material shape by effect of largely external forces without changes of volume and without infringement of cohesion. Shape changes and process control of forming depend upon features of the formed material, on conditions of contact with tools, on mechanism of plastic deformation (metallurgical and technological plasticity) and on the used technology, as well as on the requirements to the final desired mechanical (resistance and plastic) qualities of the product. The forming is virtually the oldest extant method of material processing to testify also term epochs; in light of technology the oldest was the smith's method, which is today, (from the viewpoint of quantity) overruled by rolling.

Last 100 years were in both directions, what concerns the technology, as well as used materials, guided by gradual changes, which, by far not last, were fluent casting with the aim of achievement of the smallest thickness so ironically downsizing the room for forming [1]. Technical public, no exactly, but pragmatically, divides forming to “volume" (great changes in every way) and “surface" (with stamping and related operations). In the area “volume" forming is that a afterwards forging, rolling, pushing, ... and series variants above mentioned primary objective manners (at random rolling strips, metal plate, tubing,...)
Costs, quality, production times and the environmental compatibility of processes and products, all play a decisive competitive role in production engineering. They entail new challenges and opportunities for metal-forming production processes. Apart from daily endeavours to improve tolerances or to analyze costs and reduce them by means of continuous rationalization, trends are currently observable in metal-forming technology, which in some cases lead to completely new methods for producing semi-finished and finished products, and which take all the above-mentioned criteria into account. **Fig. 1** summarizes a number of these trends, which will be described with the aid of specific examples below.

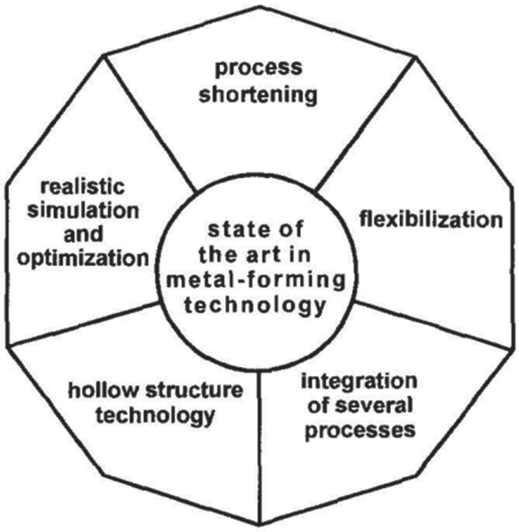

Fig. 1 Development trends in metal-forming technology [2]

Constituent part of this paper is based on technical literature and built - up to the new unit. We will deal only very shortly with individual parts of the pie graph [2].

Shortening processes

A number of positive results can be achieved by process shortening, e.g. shorter production times, lower costs, lower energy consumption, fewer opportunities for waste. One example is steel strip production, hitherto realized on hot wide strip lines, which are now experiencing steadily greater competition from a new type of rolling mill.

Flexibilization

There are various reasons for increasing the flexibility of production engineering and hence of metal-forming technology. Flexible manufacturing centres, in which the most accurate possible semi-finished and finished products can be manufactured as quickly as possible with optimum properties and without high tool and machine effort, are gaining in importance.

Integrating production processes

Completely new production systems can be created in this way, contributing to process shortening, but also to other objectives, such as cost saving, quality enhancement etc. A number of prospective new developments should also be noted briefly: heating to extend process limits; heating immediately after forming; forming and joining.

Hollow structure technology

Systematic use of hollow structures is a feature of competition to achieve optimum lightweight structures in the metal components field. They can be used to combine the good recycling properties of, for example, steel, with significant new weight savings.

Simulation and optimization

The development of new products and processes demands intensive parallel analysis of all phenomena with the aid of numerical simulation. Algorithmic optimization is also becoming increasingly relevant as a means of shortening the development process. Both simulation and optimization have made great strides in recent years, and performance is likely to improve still further as computer capacities increase. The state of the art in simulation and optimization is already impressive, and it is outlined in the multi-level overview [3, 4].

2. INCREMENTAL FORMING PROCESS

Incremental forming is a sheet metal forming process characterized by high flexibility; for this reason, it is suggested for rapid prototyping and customised products. In an incremental forming process, a simple shaped tool, moved by a general purpose CNC machine, progressively produces a local plastic deformation in a sheet, fixed rigidly along its periphery by a blocking system; this represents one of the principal advantages of this technique, i.e. the possibility of creating components with various shapes using the same tool. The main parameters that influence the process are feed and feed rate, shape and size of the tool, choice of tool path and lubrication conditions at the tool-sheet interface [5-7].The material used in the experiments is an AA 7075-

T0 - sheet. The characteristic parameters of the stress-strain curve, enabling plastic behavior can be described by the following power law

$$\sigma = 330\ \varepsilon^{0,19} \quad (1)$$

The components, created by using square sheets (100mm× 100mm) are pyramid frusta (**Fig. 2**).

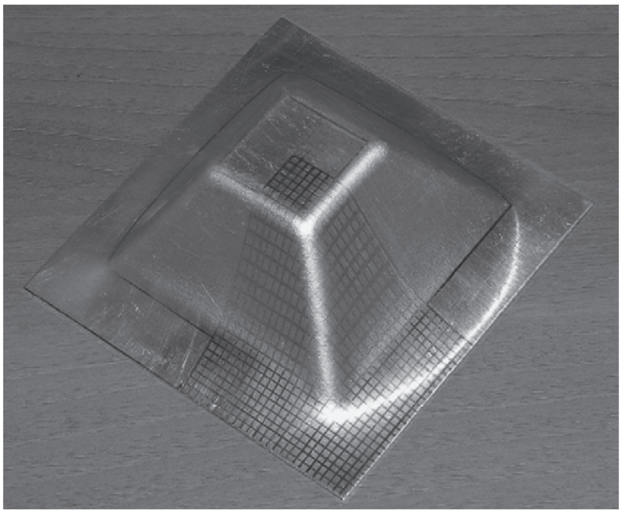

Fig. 2 Pyramid frustum created by incremental forming

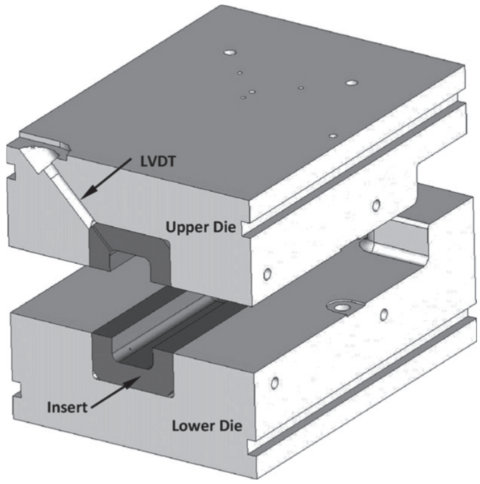

Fig. 3 High-expansion hydroforming top and bottom dies with the 18mm insert attached

The experimental test program provides a preliminary evaluation of the friction coefficients, carried out by sliding tests for different speeds of rotation. These analyses highlight a decrease in terms of forming force peaks on both components, when the tool is set in rotation, in both directions. These differences, depending on the direction of rotation, are significant in terms of the horizontal components trend, because of the friction component associated to the same rotation. The forming force tends to decrease with the tool rotation and for clockwise rotation, and this can be a not negligible aspect. Roughness varies, but not considerably, depending on whether the tool is set in rotation or not, while neither speed nor direction of rotation influence this parameter.

3. TUBE HYDROFORMING PROCESS

An optimization method linked with the finite element method is presented for developing the forming parameters of the tube hydroforming (THF) process for several advanced high-strength steel (AHSS) materials [8]. The optimization software HEEDS was used in combination with the non-linear structural finite element code LS-DYNA to carry out the investigation. Multiple candidates for replacing mild steel in automotive structures have been proposed, e.g. advanced high-strength steels (AHSS), aluminum, magnesium, and composites. Advanced high-strength steels, in particular, are attractive candidate materials, offering higher strength for energy absorption and the opportunity to reduce weight through use of thinner gauges. However, though steels in general are highly formable, the increase in strength achieved by the AHSS materials is associated with a partial compromise in formability. In recent years, tube hydroforming (THF) technology has become a popular method, especially in the automotive industry, for producing complex three-dimensional structural shapes because of its enormous advantages over the more traditional processes.
Two methods are widely used to hydroform circular tubes: low-expansion (low-pressure) and high-expansion (high-pressure) hydroforming processes [9-11].

Fig. 3 shows a sectional view of the high-expansion die used to hydroform the tubes with the 18mm corner radius insert attached [8].

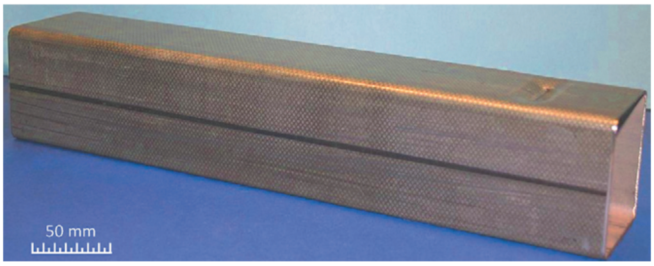

Fig. 4 Experimental results for DP600-T 1.8mm tube formed with the high-expansion process and the 6mm corner radius die using the optimized forming profile

A key difference between the two processes is that the low-expansion process introduces only limited circumferential expansion with no end-feeding required to form the tube. In the high-expansion method, the circumferential strains are large, causing excessive tube thinning and therefore end-feeding of the tube, i.e. that the extra tube material pushed into the die is used to counter the thinning problem.

Tube hydroforming of circular tubes was performed using square-shaped dies with two different corner radii inserts: 6 and 18 mm. Materials used include the following: conventional deep drawing quality (DDQ) steel of wall thickness 1.8 mm; high-strength low alloy (HSLA-350) steel with wall thicknesses of 1.5 and 1.8mm; and AHSS materials comprising the dual phase (DP) alloys DP600 with wall thickness of 1.8 mm and DP780 with wall thickness of 1.5 mm. Advanced high-strength steels and dual phase steels are attractive candidate materials, offering higher strengths for energy absorption and weight reduction. Tube hydroforming of these high-strength steels is, however, difficult, especially in the high-expansion processes.

4. ALUMINUM FOAM SANDWICH PANELS

The requirement to manufacture complex parts using materials more advanced and lighter than the traditional ones pushes the researchers to the development of innovative materials, technologies and manufacturing processes. The forming of the assembled aluminium foam sandwich (AFS) panels would determine an improvement in the manufacturing of parts and panels [12]. A sandwich structure usually consists of two high stiffness and high strength face sheets or skins with a large volume and low weight core layer in between.

As far as AFS is concerned, its production process generally consists of two main steps [13]: after the compaction of the powder mixture the two surface layers of conventional material are roll clad to the semi-finished formable material. This semi-finished composite with a core layer of foamable material can be shaped by conventional forming techniques. After the final geometry is achieved the formed part is heated above the foaming temperature and the semi-finished foamable core layer expands obtaining the finished AFS.In order to develop the experimental methodology ALULIGHT® foam panels have been utilized; the panels were prepared in size of 46 ×100 ×13.5 mm.

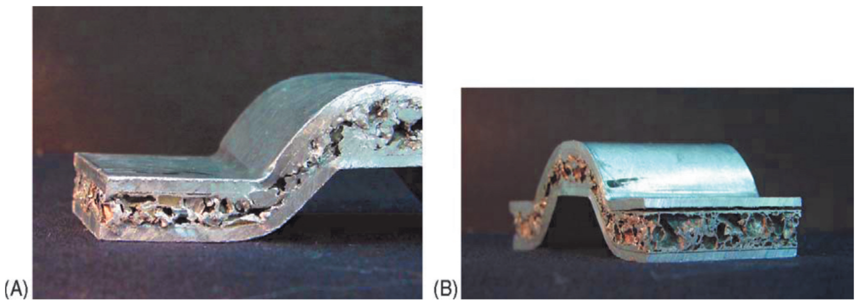

Fig. 5 (A) Foam extrusion; (B) de-bonding effect [12]

The foam and the skins were in aluminium alloy, containing 1 % of magnesium and 0.6 % of silicon (AlMg1Si0.6). The skins were 2 mm thick and were joined to the core by epossidic resin adhesives. An average value of the foam density was evaluated by weight tests obtaining 920 kg/m^3, equal to 34 % of fraught aluminium density.Interesting results have been obtained in terms of foam thickness showing the possibility to develop simple forming processes on such composite parts as the aluminum foam sandwiches.

CONCLUSION

The presented paper describes in its first part the basic data on material forming, which are followed by an overview of individual inter-related directions of development of this discipline, although based on older literature sources, but still valid. Individual directions are based on the pie chart structure. In the second part of the paper some modern methods are described. As the first the possibility of progressive deformation by one rotational tool is presented, as well as production of spatial shapes (here for example pyramids). This method is time consuming, but for special shaped products it appears to be a suitable alternative to conventional extrusion or assembly and welding of several parts. The next part deals with the process of hydroforming. A square closed profile is produced from round tube by internal overpressure. In this case computer simulation used for optimisation of tools, speed of the process and used pressures, finds its application. Finally, we present a modern method for production of Al sandwich panels.

ACKNOWLEDGEMENTS

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