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Recent development in orbital forging technology

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ABSTRACT: The main subject of the present work is investigation of possibility of extension of classical orbital forging technology to obtain more cost effective forging process. Orbital forging is the process used for forging of shaped parts by applying the incremental forging method. Results of simulation of orbital forging are compared in the present work with the result obtained from a conventional forging process. 3D finite element (FE) simulations are used in the present project to evaluate the capabilities of the orbital forging process and proper die design, and to predict the forging loads the. Selected results of simulations are presented in the paper. These results are the basis for the further comparison and discussion about possible modifications of conventional orbital forging approach.

Key words: incremental forming, orbital forging, orbital press

1 INTRODUCTION

Advantages of incremental bulk forming are well known in the literature [1-5]. This technology is commonly applied in industrial conditions, to reduce loads and to increase workability during forging in comparison with the conventional monotonic process. Another advantage is the possibility to forge hardly formable materials and to obtain high deformation degrees. On the other hand, many steps are necessary in this process to obtain final shape of the product, what extends the manufacturing time. Typical examples of processes of incremental forming are cross and profile rolling, open die forging, rotary swaging or orbital forging (Figure 1) [6]. Analysis of advantages and limitations of orbital forging and investigation of possible improvement in this technology are the subject of this work.

Orbital forging, presented in Figure 2, is used for forging of shaped parts by applying the incremental method. In this technology a sample is placed between an orbiting upper die, that moves towards the sample, and a non-rotating lower die. The lower die is properly shaped and is used to transfer the shape of the final part. The first modification of this technology is to move the lower die axially toward the upper die, that in this case is fixed axially but still its axis makes orbital motions.

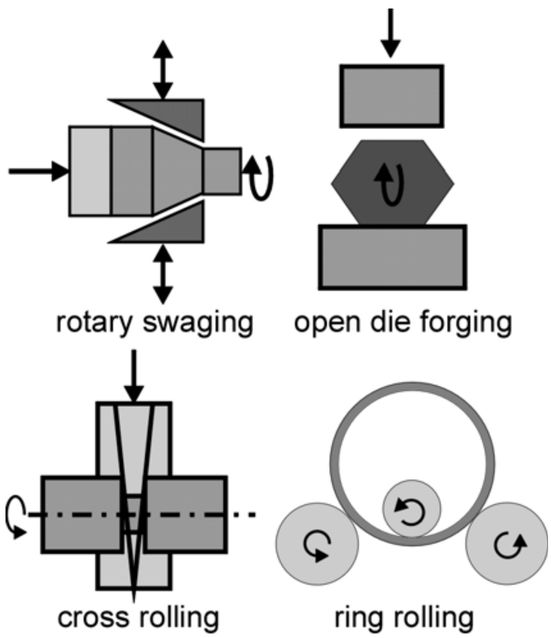

Figure 1. Examples of incremental forging processes.

These two technologies have similar advantages in comparison to conventional forging. The main advantage is load reduction and possibility to obtain very large deformations without the danger of material failure.

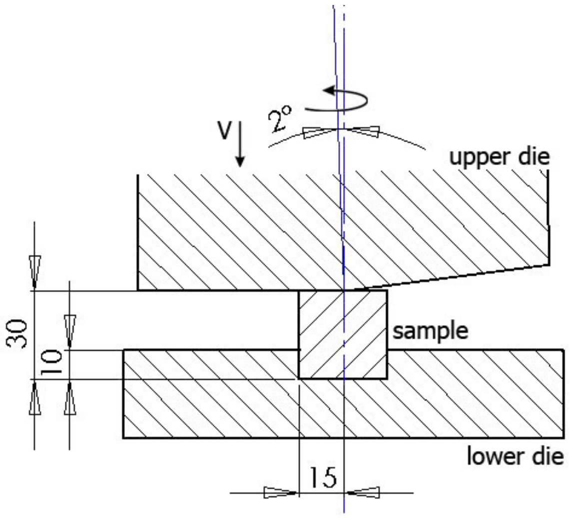

Figure 2. Schematic illustration of the orbital press. Main dimensions used during numerical simulation are given in mm.

High smoothness of forging surface, material economy, simple design and easily exchangeable tools are also advantages of this technology. Forging of wheel disks with hubs, gears, bearing rings, rings of various contours, bearing-end covers etc., are typical applications of the orbital process [2,7]. However, due to the nature of this process, some surface deformation may occur in front of the moving upper die. That in some cases leads to micro crack initiation. Due to orbital movement, failure can also initiate at the circumference of the sample.

A variety of orbital forging processes are introduced in the industry in the word. The approach proposed by Marciniak [8], where orbiting upper die moves towards the sample, is considered below. Possibility of changing an inclination of the die is the main feature of this process. The objective of the work is to investigate potentials and limitations of this technology and to recommend modifications.

2 SIMULATION OF THE ORBITAL FORGING

Main process parameters used in simulation of deformation in the orbital press are gathered in Table 1. Numerical simulations were performed with the commercial Forge2005 software. Results obtained for this process are compared with those obtained for a conventional monotonic forging process. Strain distribution and final shape obtained after the end of the orbital process are shown in Figure 3. Comparison made at the cross section of the strain values obtained using two forging approaches are presented in Figure 4.

It is seen in Figure 4b that due to orbital movement of the upper die strains in the upper part of the sample are lower than in the conventional method. Similar values are observed only in the region currently loaded by the rotating tool. Limited region of deformation in the orbital press reflects also in the distribution of the strain rates (Figure 5). Presented above differences in metal flow during deformation, may also be related to the differences in temperature distribution (Figure 6). In the orbital press high temperatures appear at the circumference. Temperature distribution in the sample is more uniform in the conventional process.

Table1. Process parameters

Parameter	Value
Material	steel 40H
Initial dimensions of the sample	ϕ30x30
Press velocity	2mm/s
Angular velocity of the die	400rpm
Initial temperature	650^{O}C

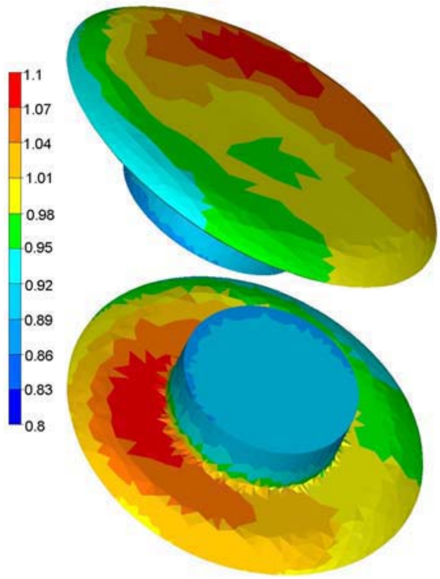

Figure 3. Strain distribution in 3D obtained at the end of deformation in the orbital press.

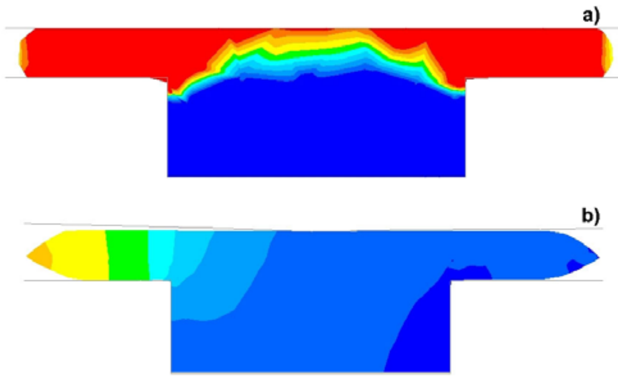

Figure 4. Strain distribution at the end of deformation in the conventional forging (a) and in the orbital press (b), scale as in Figure 3.

Tendency to crack initiation in the two considered processes was investigated next. Calculated distributions of the Latham-Cockcroft failure coefficient [9] are presented in Figure 7. The 3D distribution of the failure coefficient is presented in Figure 8.

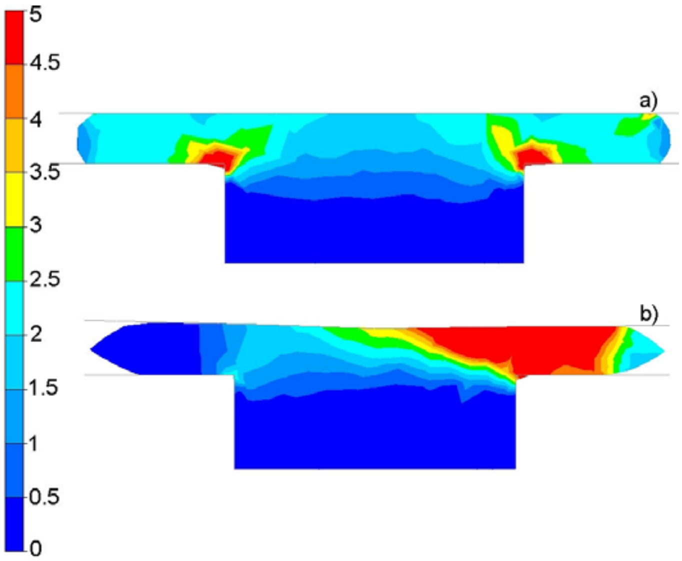

Figure 5. Strain rate distribution before the end of deformation in the conventional forging (a) and in the orbital press (b).

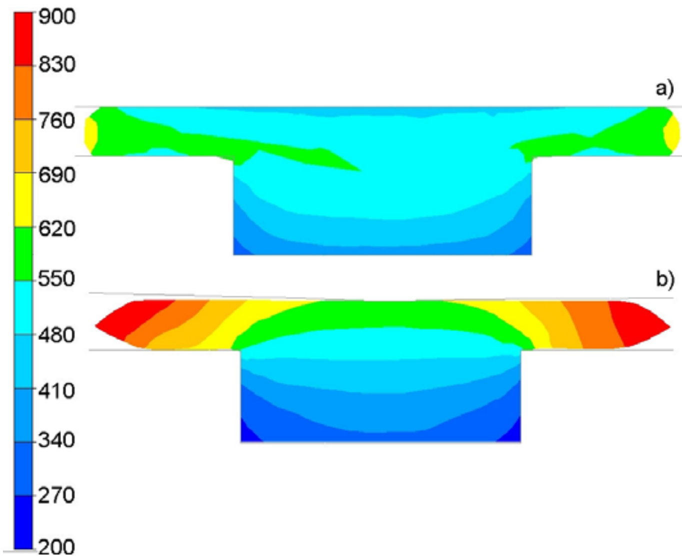

Figure 6. Temperature field obtained at the end of deformation in the conventional forging (a) and in the orbital press (b).

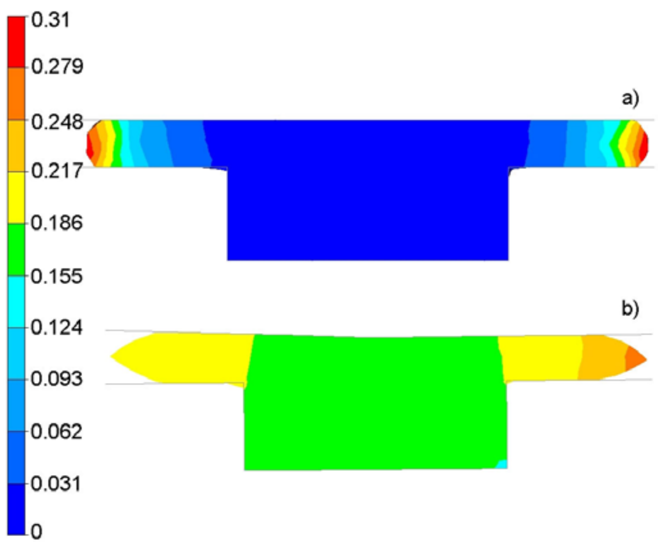

Figure 7. Latham-Cockcroft failure coefficient just before the end of deformation in the conventional forging (a) and in the orbital press (b).

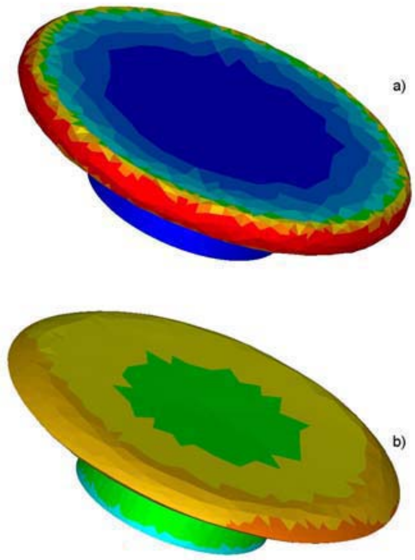

Figure 8. 3D view of the Latham Cockcroft failure coefficient just before the end of deformation in the conventional forging (a) and in the orbital press (b), scale as in Figure 7.

It is seen in Figure 8a that large values of failure coefficient are observed at the circumference in the conventional forging. That indicates high probability of failure in this region in this method. This is a limiting factor to obtain large deformations. The Marciniak method, as seen in Figure 8b, is free of such behaviour. Failure coefficients are lower that is one of the advantages of this incremental forging technology. Reduction of loads needed to obtain the same level of deformation, what is seen in Figure 9, is another advantage.

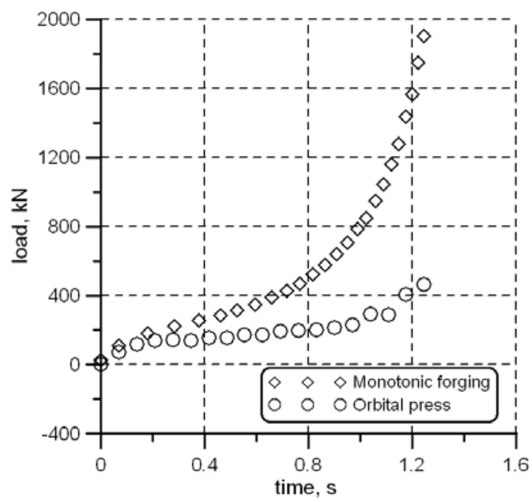

Figure 9. Comparison of the loads obtained from the conventional forging and the orbital press.

The orbital process was designed in the Institute for Metal Forming (INOP) in Poznan and the tests were performed, see macrographs in Figure 10. Experimental analysis confirmed results presented in Figure 9. This process is successfully introduced in the industrial practice now.

However, despite important advantages of the orbital press in comparison with the conventional forging, the probability of failure initiation at the sample circumference at certain conditions still exists. It is due mainly to friction between rotating die and the workpiece. Thus, researchers have recently focused on further minimisation of this probability. That should results in a possibility to obtain larger deformation of the sample.

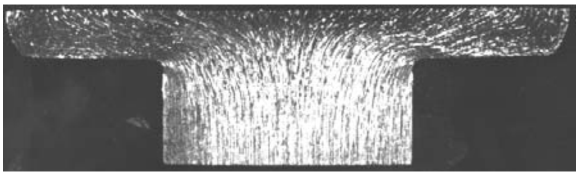

Figure 10. Macrograph of the cross section of the sample forged at the Marciniak press.

3 POSSIBLE MODIFICATIONS

Possibilities of modification of the classical Marciniak orbital forging technology to obtain more effective process are investigated to solve the problem with crack initiation. The idea of the modification of the orbital press is towards creation of the process that is strictly based on small incremental deformations. To reach this goal the shaped lower die is replaced by the flat one that pushes the sample up towards a series of small anvils. The motion of these anvils is constrained by an orbital movement of the upper die. Schematic idea of this process is presented in Figure 11.

The preliminary tests have shown that loads necessary to forge the material are smaller in comparison with the traditional orbital forging. Beyond this, the workpiece do not contact with the orbital die, therefore, it is expected that tendency to crack initiation should decrease. This process will be a subject of further experimental investigation and numerical modelling.

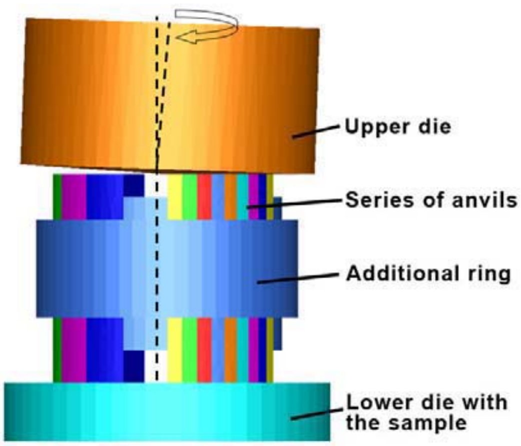

Figure 11. Schematic idea of the modification of the classical orbital forging technology.

4 CONCLUSION

This work is part of the larger project leading to create orbital forging technology that is capable to obtain large deformations without danger of material failure. Firstly, the classical Marciniak orbital forging process was compared with the monotonic forging. This comparison provided information regarding advantages and limitations of the orbital forging. Despite minimisation of the probability of failure in comparison with the monotonic forging, the danger still exists. Thus a possible modification to the Marciniak press was proposed. Elimination of the sliding of the die with respect to the deformed material is the main advantage of this process. Investigation of the material flow during deformation in the modified method will be a subject of further research.

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REFERENCES

1. GROCHE P., FRITSCHE D., TEKKAYA E.A., ALLWOOD J.M., HIRT G., NEUGEBAUER R., Incremental bulk metal forming, Annals of the CIRP, 56, 2007, 635-656.
2. LI G., JINN J.T., WU W.T., OH S.I., Recent development and applications of three-dimensional finite element modelling in bulk forming process, J. Mat Proc. Tech., 113, 2001, 40-45.
3. LIU G., YUAN S.J., WANG Z.R., ZHOU D.C., Explanation of the mushroom effect in the rotary forging of the cylinder, J. Mat Proc. Tech., 151, 2004, 178-182.
4. HIRT G., KOPP R., HOFMANN O., FRANZKE M. BARTON G., Implementing a high accuracy multi-mesh method for incremental bulk metal forming, Annals of the CIRP, 56, 2007, 313-316.
5. BRUSCHI S., CASOTTO S., DAL NEGRO T., ICARELLI R., Modelling material behaviour in incremental bulk forming processes, Proc. ICTP 2005, Verona, CD ROM.
6. GROCHE P., FRITSCHE D., Efficient algorithms for the simulation of incremental bulk metal forming, Proc. ICTP 2005, Verona, CD ROM.
7. MUNSHI M., SHAH K., CHO H., ALTAN T., Finite element analysis of orbital forming used in spindle/inner ring assembly, Proc. ICTP 2005, Verona, CD ROM.
8. MARCINIAK Z., A Rocking-Die technique for cold-forming operations, Mech. Prod. Eng., 117, 792-797, 1970.
9. COCKCROFT M.G., LATHAM D.J., Ductility and the workability of metals, J. Inst. Metals, 96, 33–39, 1968.