An influence of the material discontinuity on the die forging process – numerical simulation

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Abstract

In this paper a simulation of the defect (material discontinuity) influence on the die forging process has been presented. Two basic operations of the die forging process, i.e. upsetting and preparing, have been simulated. Numerical calculations have been made with the ADINA System using finite element methods. The results show changes in defect geometry as a result of plastic deformation. The defect influence on the plastic strain distribution in the forging and changes in its geometry has also been shown.

Keywords: Defects; Material discontinuity; Contact problems; Die forging; Numerical simulation; ADINA

1. Numerical model – guidelines

Numerical calculations were made with the ADINA System using finite element methods, described in Bathe [1] and Bathe et al. [2,3]. Figure 1 shows the numerical model of the upsetting process. For the sake of the axial symmetry of the problem, a 2D axial-symmetrical model of the process has been assumed. The numerical model had 19614 nodes and 4752 square 8-node elements. The finite element mesh was thickened in the area of the defect in order to obtain more accurate results.

The numerical analysis encompasses two cases: forging without and with a defect. In Fig. 1 a view of the element mesh for the analysed cases is shown. Figures 1(a) and 1(b) present the finite element mesh for the tools and forging with the defect before and after the forging process, while Figs 1(c) and 1(d) present the finite element mesh for the forging without any defects. An isothermal course of the process and a Coulomb frictional model of the contact surface between the forging and tool have been assumed. The friction coefficient was $\mu = 0.2$. The same frictional model and friction coefficient $\mu = 0.25$ were assumed for the contact zone of the defect surfaces. The chemical constitution of the forging and tool material is given in Table 1.

Upsetting of the slug forging to the height of h = 16 mm was the first operation of the analysed process. Next, the preparing operation was simulated.

Material discontinuity was simulated for the die forging process of the rolling bearing. The defect was shaped like a three-pointed star, as shown in Fig. 2. During this operation the defect closes. The individual defect surfaces make contact and empty spaces disappear.

Problems with the forging quality and identification of the forging defects are described in detail in Balendra et al. [4].

2. Calculation results

Calculation results are presented in Figs 1, 3 and 4. At the end of the die forging process there is an increase in stresses both in the die and the forging. Such stress increase can lead to the stable closure of the defect. There is no literature report giving the conditions when

Table 1
Chemical constitution of the materials

	Chemical constitution [%]					
	C	Mn	Si	Cr	Mo	V
Tool	0.4	0.4	1.0	5.0	1.3	0.3
Forging	0.95–1.1	0.25–0.45	0.15–0.35	1.3–1.65	–	–

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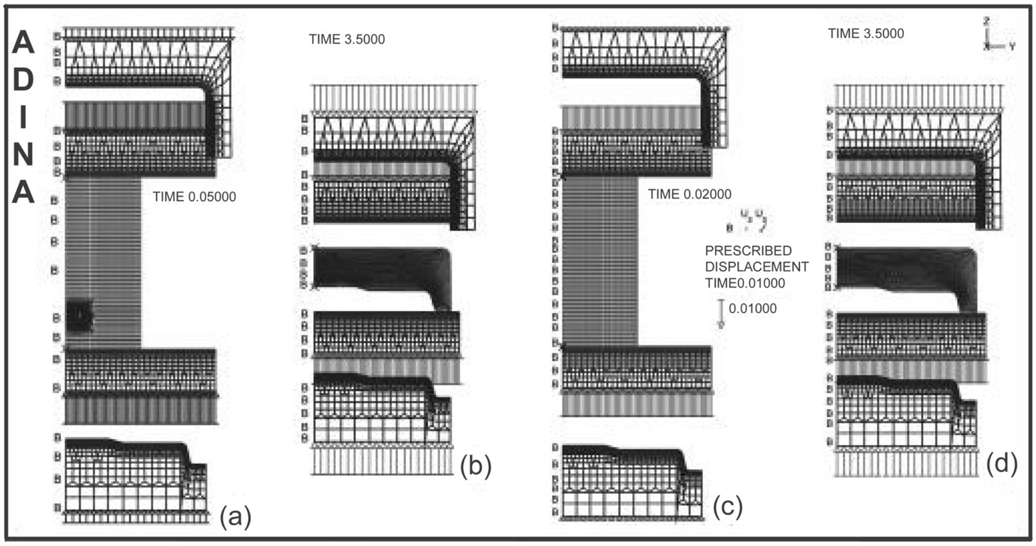

Fig. 1. MES numerical model: (a) the forging with a defect before deformation, (b) the forging with a defect after deformation, (c) the forging with no defect before deformation, (d) the forging with no defect after deformation.

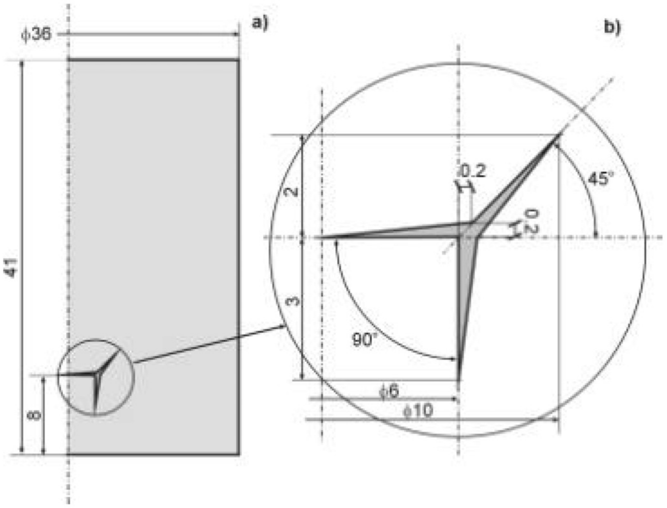

Fig. 2. Defect geometry: (a) a location of the defect in the slug forging, (b) defect dimensions [mm].

the stable closure of the defect occurs. In practice, it is known that closure of defects with oxidising surfaces is more difficult. In this paper it was assumed that the defect did not close and that the defect surfaces could shift along themselves.

Not only does material discontinuity cause local changes in strain distribution but also changes plastic strain in the whole forging volume. Figures 3 and 4 present plastic strain distribution in a forging section and the geometry of the contact surface between the tool and forging after the second forging cycle. Material discontinuity, which is visible in Fig. 3 in comparison with the forging without any defect, causes a decrease in strain in the area between the lower die and the line of the defect closure. The maximum strain value in the forging without any defect is $\varepsilon_{\max} = 2.68$. Material discontinuity causes an increase in the maximum strain value of about 30%, which localises in the area of a concave radius of the forging. The defect affects changes in location of the maximum strain value. During deformation of the material without any defects, the maximum strain value localises a certain distance from

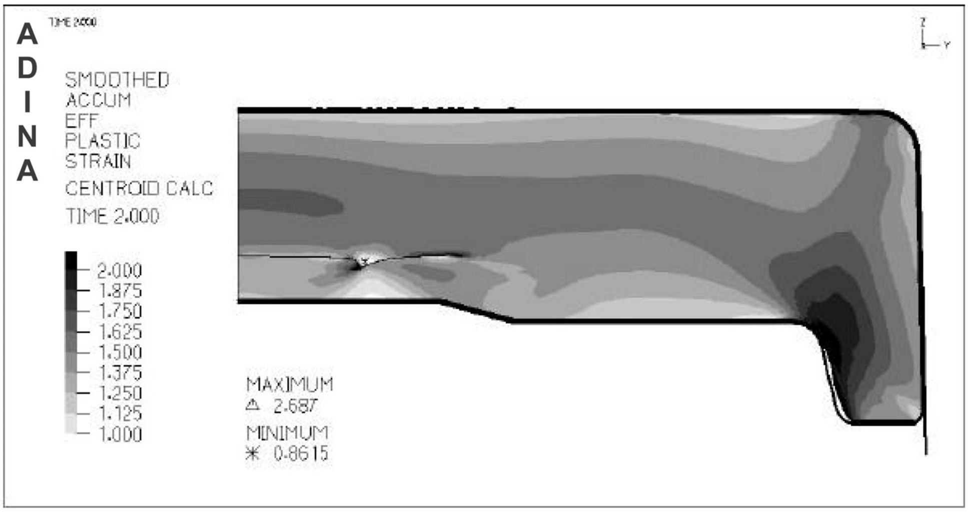

Fig. 3. Plastic strain distribution in the forging with the defect after the second forging cycle.

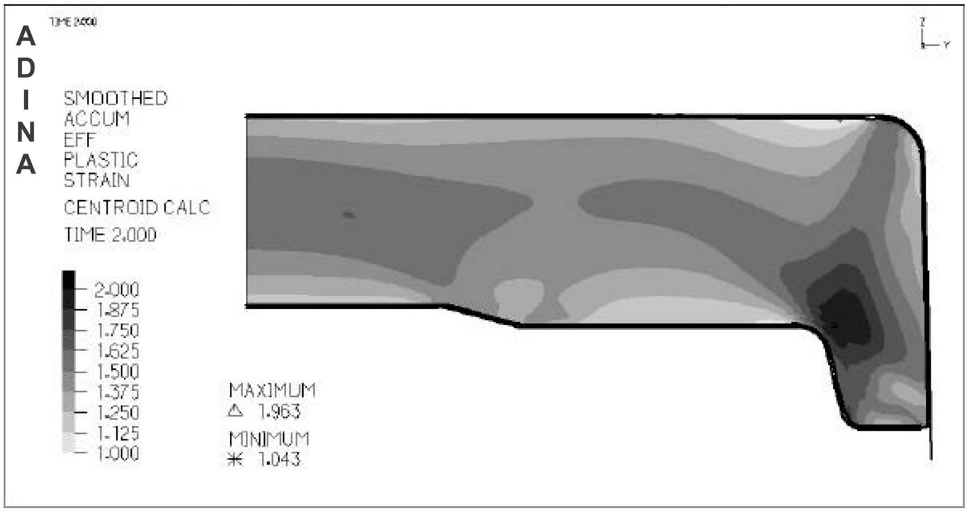

Fig. 4. Plastic strain distribution in the forging without any defects after the second forging cycle.

the concave forging radius. The defect affects the dislocation of the maximum strains towards the surface. High strain values occur along the generating line of the concavity.

The outer dimensions of the slug forging were the same for the case with and without the defect. A difference in volume caused by the material discontinuity affects the underfill of the die, which is seen in Fig. 3.

More details on modelling of the metal forming processes have been given in Gierzyńska-Dolna et al. [5] and Lacki [6].

3. Conclusions

The calculations allow assessment of the effects of material discontinuity in the forging. According to the numerical simulation analysis of the die forging process it is possible to draw the following conclusions:

1. Material discontinuity, depending on the deformation conditions, can close and open again during the forging process.
2. In the defect area a relative extreme of plastic strain appears. High strain values in the zone of a sharp defect edge can be extremely dangerous, and can lead to further development of the defect.

3. Numerical simulations allow technological processes to be explored and analysed. The proper technology allows products of better quality to be obtained.

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