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# LUBRICATION CONDITIONS INFLUENCE ON THE FILLING PROCESS OF DIE IMPRESION IN COMPLEX FORGING EXTRUSION OF A95456 ALLOY

## 1. INTRODUCTION

At extrusion, just as in all processes of metal forming, surface friction exert huge influence on course of process. It cause shear stresses on the contact surfaces, which affect the pattern of stress state, increase inequality of strain and considerably increase the extrusion power. Except that friction increases significantly tool wear. In deforming process metal placed in container is under action of group of active and passive forces: punch pressure, forces of external friction and forces of reactions of immovable tool walls. One of those forces deformed metal, and second contrary, make difficult displace of metal molecules towards to another molecules as well to tool walls. As a rule, in the extrusion process in the zone of plastic deformation is present triaxial state of compressive stresses, which gives in established conditions the best plasticity of deformed metal. Metal flows influenced by compressive stresses in direction of biggest stress gradient [1].

Not always in extrusion in whole volume of deformed metal occurs compressive stresses, which are changing continuously from maximum values to zero. In fact, as a result of wide sections of container and matrix, action of friction forces and other external factors, the metal particles flow not only in the direction of highest strain, but also are moving laterally. Besides, in hot extrusion inevitably follows cooling of metal layers contacting with tool walls. The internal layers with higher temperature have highest plasticity and are moving faster than the outer layers, which leads to non-uniform deformation on the cross-section. Levelling of particles displace speed of deformed metal causes generation additional tensile stresses in external layers and compressive stresses in internal layers. Additional

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tensile stresses in external layers beside their considerably cooling may prove to be highest than the compressive stresses. Therefore, in these layers may occur hetero-nominal state of stresses. Result from this, that axial stresses in different points of cross-section of extructed metal can be miscellaneous not only as to the values but also to the mark, at the time when in center part occurs compressive stresses in external surface can work tensile stresses. This cause that on the surface of final product made from low plasticity alloys can occur transverse ring-shaped pulls [2, 3].

Proceeded unfavourably phenomenas reveal specially in complex extrusion processes of aluminium matrix alloys [3, 4, 5], therefore in this paper were analysed this problem on case of forging shown in Figure 1. Analysis were done based on numerical calculations, use various lubrication conditions on die impression surface.

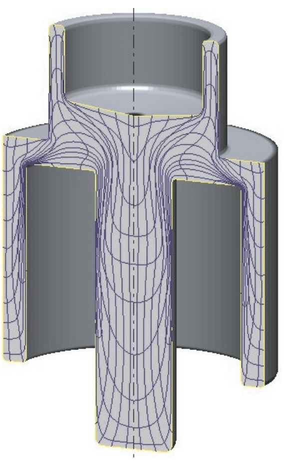


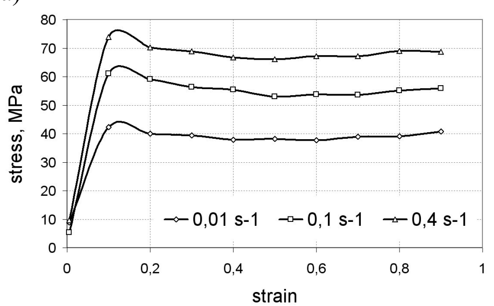
***Fig. 1.*** *Shape of model forging – numerical mesh*

## 2. NUMERICAL MODELLING

Numerical calculations of forging (Fig. 1) were performed for A95456 alloy. The characteristics of this alloy for the two temperatures and strain-rate is shown in Figure 2. For a numerical calculations the initial ingot temperature was equal 440$^{o}$C and tools temperature was equal 200$^{o}$C. Tools relative velocity 10 mm/s. Stock diameter was chosen so as to be equal to the width of the lower die (Fig. 3a). In practice this guarantee precise alignment of the stock. In first stage of calculations were accepted identically lubrication conditions on all tools surfaces. Results of numerical calculations of filling of die impression is shown in Figure 3c.

The computer simulations were carried out with a use of commercial code QForm3D, based on the finite element method and rigid-viscoplastic model of body. Calculations were made for axisymmetric strain state.

a)




b)

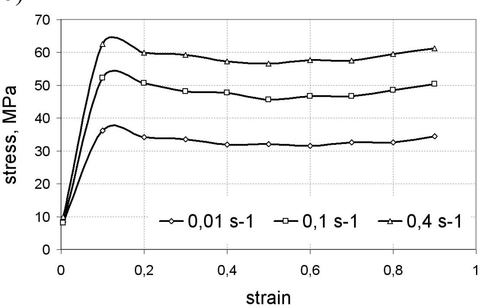



***Fig. 2.*** *Stress curves for A95456 alloy for temperatures: a) 430$^{o}$C; b) 450$^{o}$C*

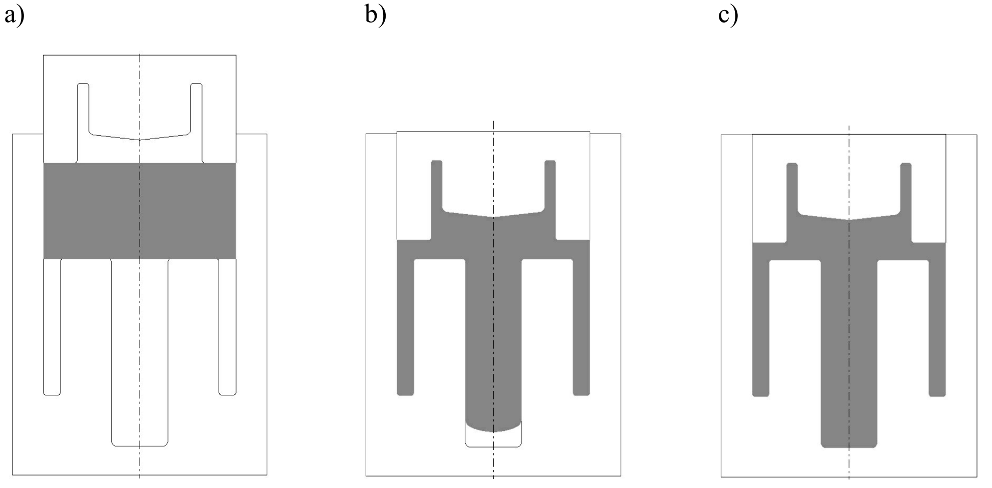



***Fig. 3.*** *Deformation process stages: a) start; b) fill punch area; c) end of extrusion process*

It was found non-uniform filling of die impression in final stage of tools displacement. Accepted forging shape for calculations showed considerable lubrication conditions influence on metal flow. Therefore, the next stage of research were adopted different lubrication conditions in order to obtain the most effect of fulfilling of die impression in final stage of process. In calculations were used 3 values of friction factor 0.14, 0.40 and 0.80 for upper and lower die, which gives 9 lubrication variants, Table 1.

**Table 1.** Lubrication conditions on upper and lower die

| Friction factor | | lower die | | |
|---|---|---|---|---|
| | | 0,14 | 0,40 | 0,80 |
| upper die | 0,14 | **1** | **4** | **5** |
| | 0,40 | **6** | **2** | **7** |
| | 0,80 | **8** | **9** | **3** |

In complex extrusion process of analysed forging important role in fulfilling of die impression acts friction on perpendicularly surfaces to the punch displacement direction. Friction also affects on strain distribution in a forging volume. An additional problem in uniform fulfilling of whole die impression space is different volume of displacement metal in the forward and backward direction of flow. Consequently in the extrusion process follows non-uniform deformation, which results the increase of stresses at the final stage of forging (Fig. 4). The least favourable lubrication conditions appears when the friction factor of the lower die is equal $m_1$ = 0.80 and for the punch $m_p$ = 0.40 (variant 7) or $m_1$ = 0.80 and $m_p$ = 0.80 (variant 3).

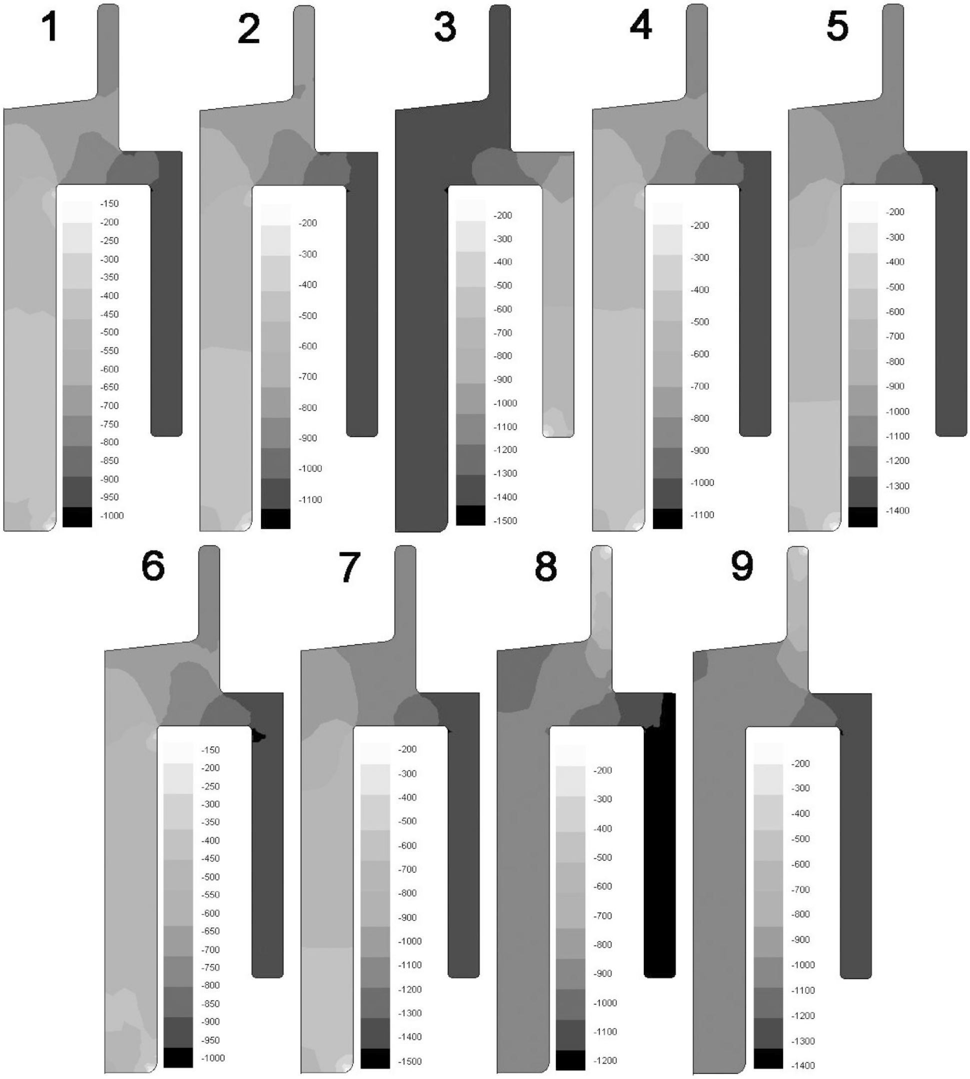



***Fig. 4.*** *Mean stress distribution dependence on lubrication conditions in vertical section of the forging for lubrication variants shown in Table 1*

## 3. ANALYSIS OF RESULTS

Numerical calculations was carried out for different and non-equally friction factors for upper and lower die, they shows that the most favourable lubrication effect will be obtained when friction factor of lubricant on the punch will be about twice lower then the friction factor of lubricant on the lower die. This effects a uniform strain distribution in intermediate stage (Fig. 5) and in final stage of process (Fig. 6).

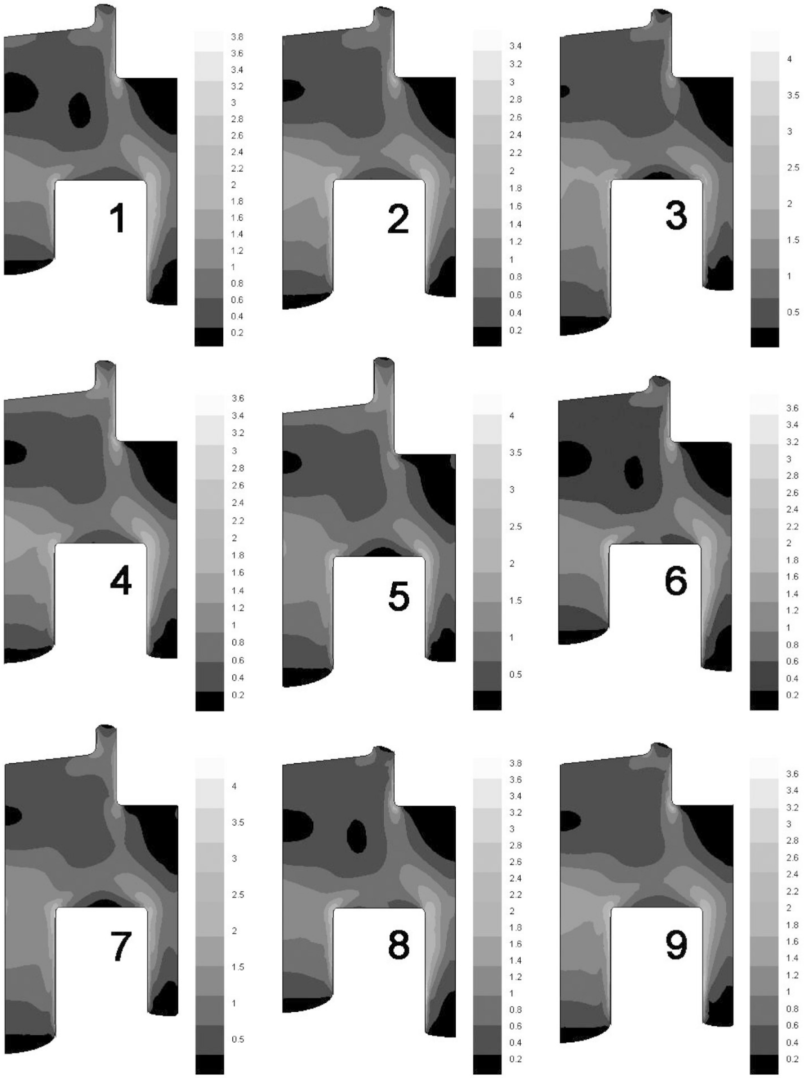



***Fig. 5.*** *Effective strain distribution dependence on lubrication conditions in intermediate stage of extrusion process for lubrication variants shown in Table 1*

The most favourable lubrication variant is in case, when the friction factor of punch lubricant is equal 0.14 and friction factor of lower die is equal 0.80. For this variant filling of die impression is uniform in whole deformation cycle, as illustrated by the distribution of vectors of metal displacement in the last stage of process (Fig. 7 and 8). In case when vectors of metal displacement shows non-uniform metal displacement for example after fulfilling of punch impression and deformed material moves only in lower die, this effects increase of load in final stage of process (Fig. 9 and 10).

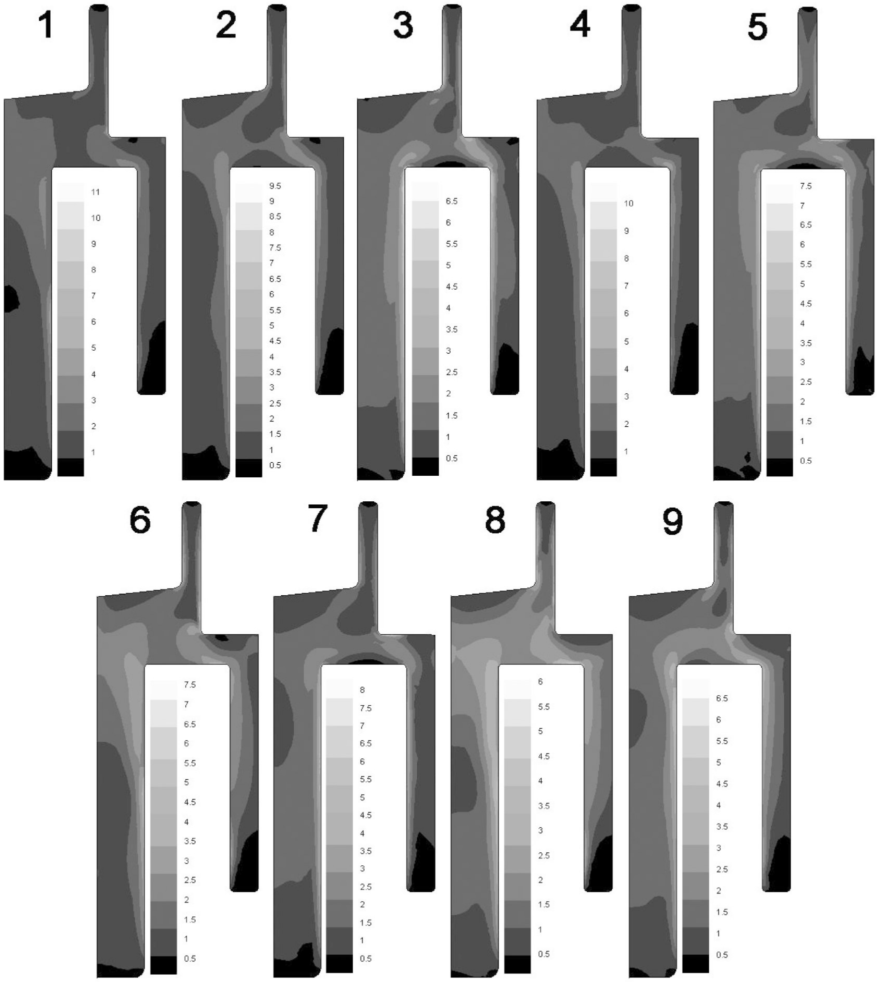



***Fig. 6.*** *Effective strain distribution distribution dependence on lubrication conditions in final stage of extrusion process for lubrication variants shown in Table 1*

Forging in closed dies without compensation of metal excess causes in final stage of process hydrostatic state of stress which are very unfavourable for the tools load independently from lubrication conditions. Practically, the minimum displacement of the tools causes hydrostatic state of stress manifested as a sharp increase in load (Fig. 9a and 10a). Control of lubrication conditions provides significant effects, if space is provided for compensation of metal excess or process of punch displacement is interruption of the process prior to the time stamp on the state of hydrostatic stress (Fig. 9b and 10b). At the same time, a significant effect of regulated lubrication of die impression surface provides favourable effects beside precision dose of lubricant, which come from load curves (for lubrication variants 5 and 7).

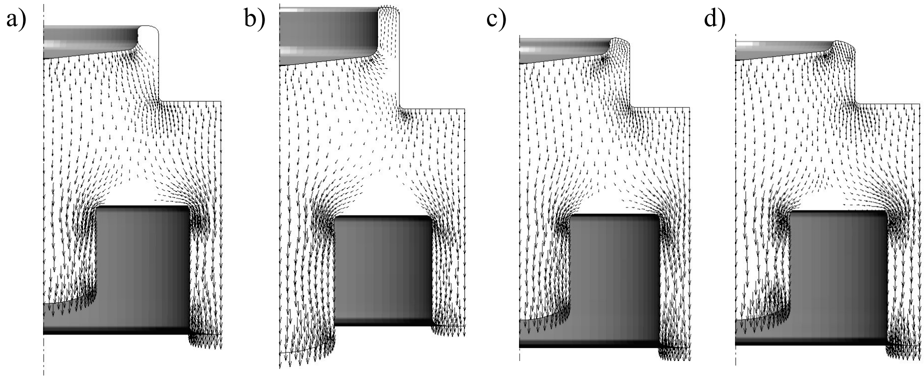



*__Fig. 7.__ Vectors of the metal displacement in intermediate stage of extrusion process for lubrication variants: a) 1, 4 i 7; b) 5; c) 2, 3, 6 i 9; d) 8*

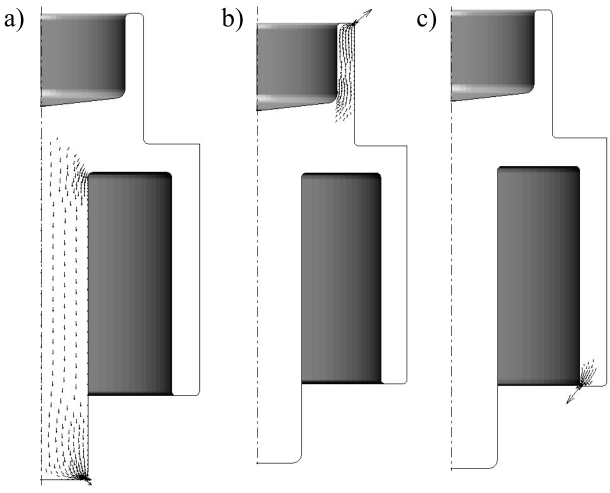



*__Fig. 8.__ Vectors of the metal displacement in final stage of extrusion process for lubrication variants: a) 1, 2, 4÷7; b) 8 i 9; c) 3*

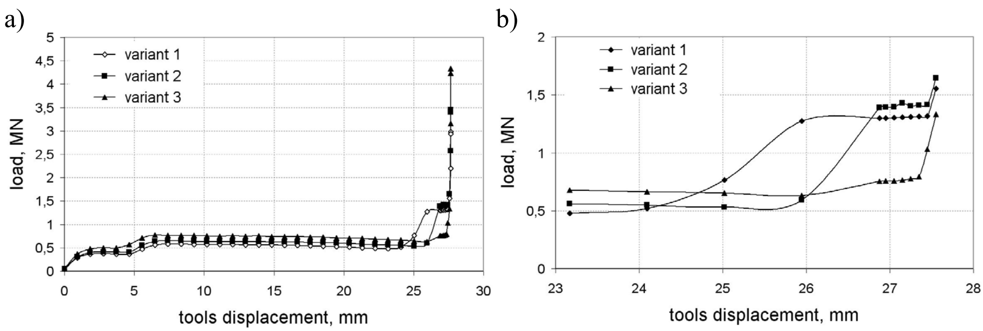



*__Fig. 9.__ Load in extrusion process with uniform lubrication dependence on punch displacement: a) 100%; b) 99.6%*

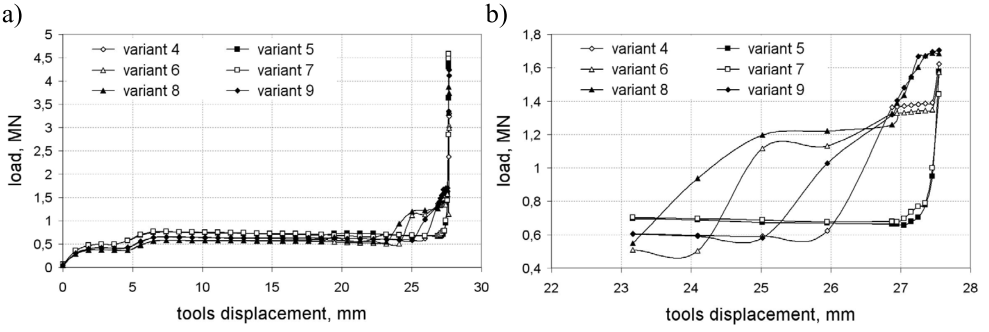



*Fig. 10. Load in extrusion process with regulate lubrication dependence on punch displacement: a) 100%, b) 99.6%*

## 4. CONCLUSIONS

For die impressions with a high degree of complexity, especially when the die impression is filled with metal in the extrusion process, it is advisable to analyse the metal flow based on numerical calculations. This allows to apply the modification of forging process, e.g. for in range of regulated lubrication, which allows the numerical calculations performed for several variants of boundary conditions taking into account the technological characteristics of lubricants.

Forging maded in complex extrusion process require specially penetrating analysis of lubrication process. Numerical calculations of forging process of chosen forging, takes into account different variants of friction conditions, indicates on favourable effect of regulated lubrication on indicated surfaces of the die impression.

**Acknowledgment**

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