COMPARISON OF THE TORSION STRETCH FORGING OPERATION IN ASYMMETRIC ANVILS WITH THE STRETCH FORGING OPERATION IN COMBINED ANVILS

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The article analyzes results obtained from the numerical modeling of the torsion stretch forging operation carried out in asymmetric anvils, compared with the results obtained from the modeling of stretch forging in combined anvils. The analysis of the results has proved that the torsion stretch forging operation performed in asymmetric anvils yields a better quality forging compared to the forging obtained from the conventional forging operation carried out in combined anvils, which are now widely used in forges.

The analysis was performed using pressure distribution results obtained from computer simulations performed with the use of Forge 2007® [1], a finite element method-based computer program. The computations were made for a three-dimensional state of strain.

The use of flat, rhomboid or combined anvils for carrying out the stretch forging operation is now becoming increasingly rare in industrial practice. The quality requirements imposed by the purchasers of forged products entail the application of anvils with different geometrical shapes in industrial practice in order to meet those requirements.

However, the forging industry often relies only on the practical experience of using flat, rhomboid or combined anvils. In this situation, it would be purposeful to perform a theoretical analysis of the stretch forging operation in asymmetric anvils which, during the deformation of the stock, produce additional tangential stresses due to the asymmetry of their working surfaces [2]. This creates pairs of shearing forces causing the torsion of the forged metal between the anvil working surfaces. The change in the kinematics of metal flow between the working surfaces of asymmetric anvils results in a better homogenisation of strain and stress values within the whole forging volume. And this translates into the obtaining of similar mechanical properties and a homogeneous structure within the whole forging volume after the forging operation. This, in turn, assures the high quality of forgings and the satisfaction of quality requirements imposed by the designer, as the forgings will have similar mechanical properties within their entire volume [2]. The scatter of mechanical properties within the forging volume will not be as high as that resulted from forging in anvils presently used in forges.

Despite the fact that a number of studies devoted to stretch forging operations have been published so far [3-5], the stretch forging process has still been understood to an insufficient extent. This is particularly true to the problems of stress state determination. The existing data on the distribution of stresses within the forging being stretched are mainly limited to the case of simple stretch forging in flat, rhomboid or combined anvils [6-8]. Whereas, for the process of forging in asymmetric anvils there are no quantitative and qualitative relationships that would allow the local stress distribution to be determined as a function of the shape and geometry of asymmetric anvils and the basic technological parameters of this operation. It can be stated that the current state of knowledge on the stretch forging operation does not correspond to the possibilities offered by the contemporary mathematical and numerical methods, and the published results concerning the conducting of stretch forging operation in shape anvils are selective in character [6-8].

The data shown in Fig. 1 indicate that the values of compressive stresses in the axial forging zone are contained in the range of 80÷45 MPa, while in the outer zone in the range of 160÷116 MPa. Such a stress distribution is the most advisable, because, owing to the application of asymmetry with torsion in the core of the ingot being deformed, no excessive tensile stresses form, which, at large drafts, cause metal cracking in the axial forging zone. It is noteworthy that the tensile stresses exist only in the outer forging zone and are small, lying in the range of -60÷-38 MPa. The forging practice demands that the forging core should be adequately forged out and that it should develop an intensification of high-magnitude compressive stresses, not exceeding, however, the compressive stress values beyond the compressive strength limits of a given steel grade at the forging temperature. When analyzing the distribution of hydrostatic pressure (Fig. 1) it can be found that an inadequate forging-out of the forging core exists (the compressive stress values are too low), which is a very important problem in forging practice, as a forging core inadequately forged out prevents the forging from meeting the strength requirements in terms of construction in the future. Therefore, it was decided that in the second forging stage (Fig. 2) flat anvils would be used, which cause large compressive stress values of 138÷116 MPa to be obtained in the forging axial zone. Only when the two anvil assemblies discussed complement one another, will the intended and proper character of stress distribution in the deformed forging be obtained.

Such a strain intensity distribution indicates the homogenization of mechanical properties inside the forging after stretch forging operation. The deformation asymmetry introduced in the fist phase of stretch forging operation causes metal to flow in directions not restricted by the anvil working surface, but after tilting and making a subsequent pass, the metal is, in the same place, moved by the anvils in the direction, in which it freely flowed previously. This forging scheme will not be assured by anvils, where the deformation zone is symmetrical [1]. The application of deformation asymmetry in particular zones of the forging during deformation produces a different stress state that, during tilting, is varied alternately, which cannot be applied in symmetrical anvils. Moreover, torsion induced by the geometrical shaping of anvil working surfaces results in a uniform forging-out of the forging outer zones, which cannot be achieved by using asymmetric anvils with rounding radii opposite to one another [1].

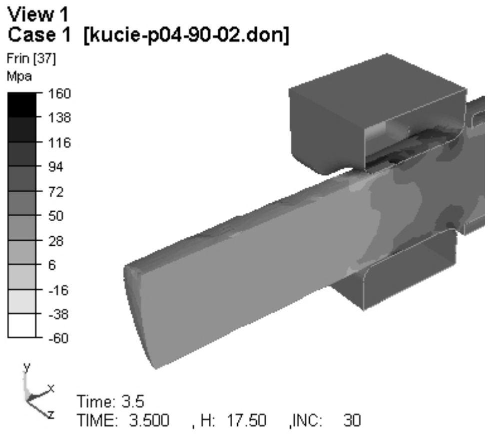

Figure 1 – Pressure distribution inside the forging after the first stage of forging process in asymmetric anvils

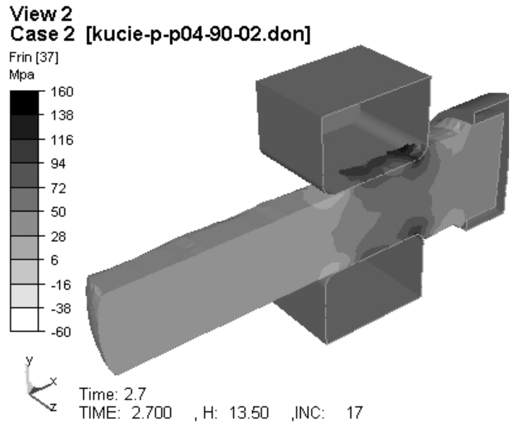

Figure 2 – Pressure distribution inside the forging after the second stage of forging process in flat anvils

The data shown in Fig. 3 indicate that the values of compressive stresses in the axial forging zone are contained in the range of 50÷16 MPa, while in the outer zone in the range of 160÷138 MPa. By analyzing the stress distributions for the model forging it can be found that such a method of forging does not assure regular distributions of values; they are scattered between the axial and the outer forging zones by one order of magnitudes. In addition, the forging core is not adequately forged out compared to the outer layers. The hardening that will occur in the outer forging zones, produced by the additional deformation made by the anvils, will prevent the metal from flowing in the forging axial zone in subsequent passes. The point is that the intensification of compressive stress values will never be brought about in the forging axis, despite the application of any further treatments. This forging method does not assure the homogenization of the mechanical properties of forgings. In order to achieve this, a decision was made to use flat anvils in the second stage of the stretch forging operation.

From the data shown in Fig. 4 it can be found that the values of compressive stresses in the axial forging zone are contained in the range of 60÷45 MPa. After the application of flat anvils in the second stretch forging stage, the forging-out of the forging axial zone was substantially improved; however, it turned out to be impossible to achieve such a forging-out as in the case of forging in asymmetrical anvils. What is more, the values of 60÷45 MPa disqualify the forging as a product nonconforming to the applicable forging practice, due to the poor forging-out of the axial zone.

During the stretch forging operation carried out in combined anvils, the upper anvil acts symmetrically on the stock causing the metal to flow in two directions along the metal and anvil contact surface, with the friction forces taking opposite directions. The boundary conditions are symmetric in relation to the plane of symmetry for the upper flat anvil. Whereas, the change in the direction of the friction forces takes place in the lower rhomboid anvil. The upper part of the deformed metal is under the action of the flat anvil; an unfavourable state of stress develops in the deformed metal in that case. The direct action of the anvil covers only part of the forging cross-section, which results in the formation of additional resistance to the longitudinal flow in the outer layers of the stock. As a consequence, tensile stresses develop in the middle part of the plastic zone, whose values are dependent on the relative draft value. The lower part of the forging is under the action of the rhomboid anvil that forces the metal flow in the space between the anvils and into the recess, inducing resistance oriented in the direction of the lower anvil recess, and this, in turn, produces the undesirable forging cross effect. It can be presumed that with increasing relative draft value, the values of compressive stresses in the forging cross zone will increase, as the result of which a faulty forging will be obtained.

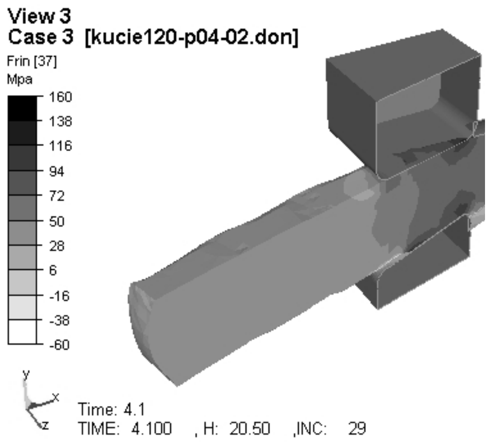

Figure 3 – Pressure distribution inside the forging after the first stage of the forging process in combined anvils

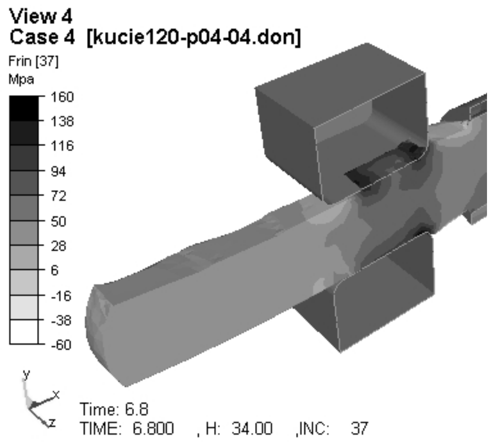

Figure 4 – Pressure distribution inside the forging after the second stage of the forging process in flat anvils

Conclusions

The theoretical analysis of the stretch forging operation carried out in asymmetric anvils with a helical line has confirmed the existence of such values of the shape-dimensional parameters of the anvil working surfaces and such values of the main technological parameters, for which the intended character of local stress distribution is obtained. This enables the rational shaping of a forging and obtaining the appropriate mechanical properties in specific forging regions, which cannot be obtained when using combined anvils. By conducting the asymmetric process of ingot stretch forging, a desired stress distribution in the forging axial zone can be introduced.

The introduction of the proper character of stress distribution within the forging volume is only successful by using several anvil assemblies in the stretch forging operation. Thanks to combining the advantages of different anvil types, the kinematics of metal flow during the initial stages of forming a forging can be substantially controlled.

In order to obtain a more favourable distribution of compressive stresses in axial forging zones, pairs of shearing forces should be introduced in the application of an external load, which can be successful owing to the use of asymmetric anvils producing additional non-dilatational strains.

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