Improvements in the process of boss bar upset forging into a horizontal forging machine with the aim of joint knuckle forging quality improvement

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Abstract. A new technique for tapered composing transition shaping has been put forward in the process of upset forging with the use of an experimental tool. The results of the upset forging process with the use of a new composing transition has been computer simulated.

In the process of group 1 subgroup 1 (boss bar forged pieces) upset forging into a horizontal forging machine we recognize upset forging with no bending and with the restricted bending of an upset blank. The upset blank stability is determined by upset length ratio \(\psi = \frac{l_{\text{upset forging}}}{d}\). The value for upset forging with no bending equals \(\psi \leq 2,7\). Under the circumstances of this ratio overriding the upset boss bar forming is going on with the restricted bending [1]. In the process of high-carbon and alloyed steel upset blanks forging their tapered punches have critical upset length ratio being matched by spatial bending equal to \(\psi_{\text{space curvature}} \leq 5,0 \pm 5,1\), but in case of \(\psi \geq 6,8 \div 7,3\) spatial concavity does not go under smoothing that in its turn hardens the process of cavity filling (fig. 1, a) and results in one-sided lateral burrs (fig. 1, b).

Fig.1. Shape deflection while upset forging in case of \(\psi \geq \psi_{\text{space curvature}}\)
It is suggested to use a selector punch with a cylindrical part along the full length of an upset blank running over 10d, if \( \psi \geq 10 \) (fig. 2) [1].

![Fig. 2. Limiting values of boss dimensions and upset forging process in a tapered composing pass, if \( \psi \geq 10 \).](image)

Generally, if \( \psi \geq \psi_{\text{d}} \) (allowable upset length ratio) at a bending phase on arbitrary plane XOY, point data of 0.25\( l_x \) and 0.75\( l_x \) are bending points, while point data of 0.2\( \pi l_x \) (≈0.63\( l_x \)) correlate with initial contact of the upset blank convex surface and tapered cavity wall. An upset blank is being deformed after coming into contact with a face of fill under side upthrust from fill wall conditions (fig.3) [1].

![Fig. 3. Bending in a plane.](image)

From this viewpoint the example described by A.N. Bryukhanov is interesting [3]. There is a cone generatrices slope of less than 2° to upset blank axis in the first composing transitions. Being so minor the tapering can’t eliminate one-side burr in a slot. That’s why such slot transitions contemplate extended tapering along the section 10mm long. Thus, taking into account bending in a plane (fig.3) we can reason that grade reduction of a cone major section involves earlier upthrusting from a pass wall. However it can extend blank base diameter under the circumstances of volume conservation in transitions, that in actual practice results in increasing dimensions of forging devices, but it may be unacceptable in case of equipment dimensions limitation.

Production process of joint cam forging at Open Joint Stock Company “KAMAZ” Forging plant comprises 3 composing upsetting and the fourth final transition on the basis of the blank made of steel 20X2H4A Ø50. In practice the technology under discussion has an essential drawback – repeatable defects of unfilled die bed contour and burr punching in the detailed section (fig.4). These drawbacks are reflected in a completed part. One solution of the infilling problem proposes to change the 2nd and the 3rd composing transition geometry. In the study by I.V. Grezina [2], a cylindrical section in tapered punches while composing upset forging with the result of approximately correct geometry is reported.
Fig. 4. Composing transition forming technique with a circular section on the 2\textsuperscript{nd} and the 3\textsuperscript{rd} transitions and variable cone on the 3\textsuperscript{rd} one.
As far as strength of materials is concerned the upset blank stability in the process of upset forging into a horizontal forging machine can be thought of as the problem of the bar stability with an overhung end and a joint one [4], whereas critical value of a compressive axial force is inversely as the bar length up to a joint end $P_{kp} = \frac{\pi^2 E}{(\mu)^2}$ (fig.5, a, b). The usage of a circular section allows to displace a joint holdfast as much as a land portion, according to it the bar system stability increases and bending shape changes in the process of deforming — bending point data of $I_x$ displaces (fig.3). A detailed solution to the problem of upset blank stability in a composing transition while the process of alike upset forging is given in the studies by O.S. Zhelezkov [6] and F.F. Gatin [7].

![Fig.5. Compressed bars stability](image)

Considering the equality of transition volume with the existing and pilot processes, actual values of circular sections on the 2nd and the 3rd transitions equal to ~ 8.35% and about 4.5% of the upset length respectively. The configuration of the final composing transition with a variable forming cone should be determined by the volume equality with the current technology, and a priority of metal setting in a hard-to-infill part (typically, it is a forged piece cross-section with a maximum area). In contrast to the technique by A.N. Bryukhanov [3] composing transition base slope is reduced to $1^\circ$ and the main section slope is increased to $6^\circ 35'$. This technique allows reducing the overall length of composing transition without changing the base diameter, which in its turn causes upsetting stability of a subsequent final transition to increase, i.e. coefficient $\psi$ reduction. In the process of a forged piece upsetting, due to the originally used technology we make use of the technique by A.S. Somkina [5], which involves a clamping portion and a matrix-profiling radius changing on the transitions following the first one.

The computer simulation in the software package QForm3DV 8.0.4 for a new pilot technology of upsetting has showed the forming of the 2nd and the 3rd composing transitions’ configuration required for the subsequent punching and has helped to confirm the predicted result of the uniform metal distribution increasing while the final transition upsetting (fig.6) [8].
The comparison of the 2nd composing transition computer simulation has shown that circular section insertion with relative height of 8.35% from upset length ratio allows to reduce relative height.
h of recessed undercut formation for ~17% and bending of the axis Λ for ~39% (fig.6). The final transition upsetting confirms risk minimization of such drawbacks as lack of infilling, burr punching and chuck in a completed part.

Conclusions.
The usage of final composing transition pilot technology with a variable forming cone of an element of cone along with a cylindrical section on the top of the 2nd and the 3rd composing transitions has allowed to improve uniformity of forming while upsetting and to increase completed part quality. The given solution can be used for devices engineering in the process of forged pieces upsetting group I – boss bar type.

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