AUTOMATED DESIGN AND FINITE ELEMENT SIMULATION OF REDUCER ROLLING TECHNOLOGY

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Summary

Reducer rolling is the technological operation that provides optimized shape of the billet for subsequent closed die forging to minimize the material loss. Meanwhile the material flow in reducer rolling process is quite complicated and requires many trials to provide adequate results. Design of the reducer rolls shape may be simplified using empiric rules but the best results can be obtained when the developed technology is verified by means of numerical simulation. The paper presents finite element model of reducer rolling and practical results obtained by this model for verification of the reducer rolling of the billet intended for forging of the crankshafts.

Keywords: reducer rolling, finite-element simulation, forging, QForm.

1. Introduction

In closed die forging of elongated parts like connecting rods, crankshafts, steering arms and some others the material loss can be minimized by means of using of the billet of profiled shape. The shape of the billet has to provide proper mass distribution along the axis of the forged part. Such shape of the billet can be obtained in different ways but the most productive one is reducer rolling technology. Meanwhile reducer rolling technology requires to develop the rolls of complicated shape that in practice means several trials to verify the correctness of the design. The rolls design can be automated by means of special program named VeraCAD[1] that is based on empiric rules derived from rolling practice. This program saves expenses and time by reducing manual work for design of the rolls profiles and creating the geometrical models of the rolls that are ready for the manufacturing on CNC mills. Meanwhile reducer rolling technology designed by VeraCAD cannot guarantee defect free process and in practice the rolls quite often require modification depending on the results of experimental trials. Simulation of reducer rolling allows to verify the technology *before* manufacturing of the rolls and without experimental trials. Reducer rolling model was developed within finite-element metal forming simulation program QForm that belongs to QuantorForm Ltd. QForm with

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[1] VeraCAD is developed by Dipl.-Eng. Hermann Eratz and belongs to Eratz-Ingenierbuero, Kirchhörder Str. 94, 44229 Dortmund, Germany

rolling module allows to analyze all stages of reducer rolling technology starting from analyzing the conditions of initial capturing of the billet by the rolls and simulating of several passes with rotation of the billet between them. The defects of material flow like laps or non-filled grooves can be detected. Furthermore the rolled billet within the same technological chain can be “placed” in the dies for subsequent simulation of closed die forging.

2. Material Flow Formulation

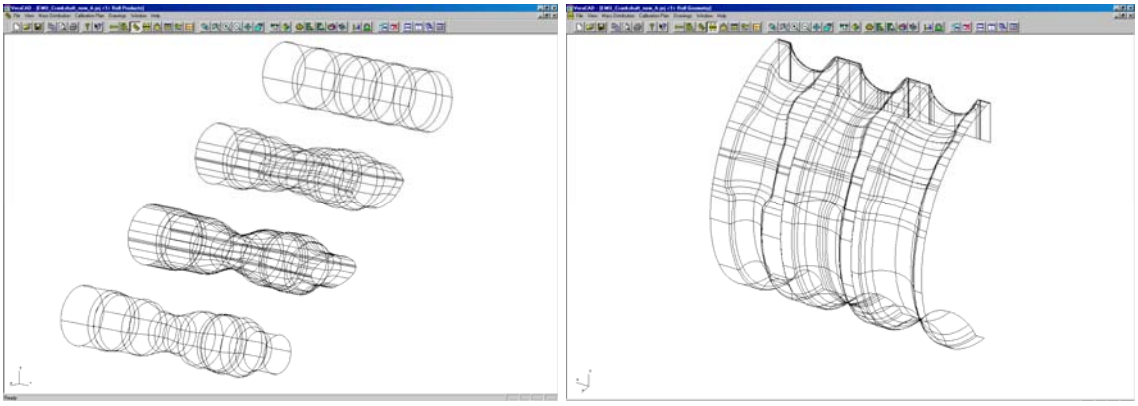
The numerical model of reducer rolling is based on flow formulation [1] where the material is considered as incompressible rigid-viscoplastic continua and elastic deformations are neglected. The rolls (tools) are treated as rigid bodies. The billet and die geometry data are imported from CAD system using STEP or IGES file formats. QForm uses the second order finite elements for approximation of the surfaces [2]. It allows frequent re-meshing without “undercut” of the workpiece surface and provides very good volume constancy. The program generates the mesh fully automatically without any users intervention. The adaptive self-controlled algorithm provides optimal mesh density distribution.

3. Automated design of reducer rolls

Reducer rolling simulation model was tested on practical example of a crankshaft manufacturing. Total weght of the forged part is about 40 kg, the material is steel DIN C43. To reduce the material loss and to desrease the load during closed forging the profiled rolled billet is used. Only experienced forgers have the knowledge for developing reducer roller tools. Thus to save development time and cost the special program VeraCAD was used. It is built using empirically based forging rules. A 3D geometry of the forged part is cut into many panes, and their volumes distributed over the central axis yield the mass distribution diagram. For bent parts the curved spine line is first entered interactively. If the geometry data set contains no flash area, the special function of the VeraCAD adds the necessary flash material amount. This function calculates the flash using empirical coefficients. Usually the resulting mass distribution is too complex for direct derivation of the final roller piece. Equalizing the local volume balance at all times supports the design of an ideal roller blank.

Than VeraCAD calculates suitable calibration sequences as well as the size of raw material and number of necessary passes. Therefore a variety of shapes are offered: circle, oval, lens, diamond, square, rhombus and rectangle. Standard rolling algorithms like "linked reduction rates"; "limit reduction", "cross-section spreading" or "priority calibration sequences" are automatically applied.

For the considered case the technology automatically designed by the program includes 3 rolling passes using the scheme “round-oval-oval-round”. The initial diameter of the billet is 125 mm and its length is 421.7 mm. The designed intermediate and final billet shapes after each pass are shown on Fig. 1a. The geometrical model of the roll with three grooves is shown on Fig. 1.b. The geometrical model of the roll is principal source data for simulation of reducer rolling process.

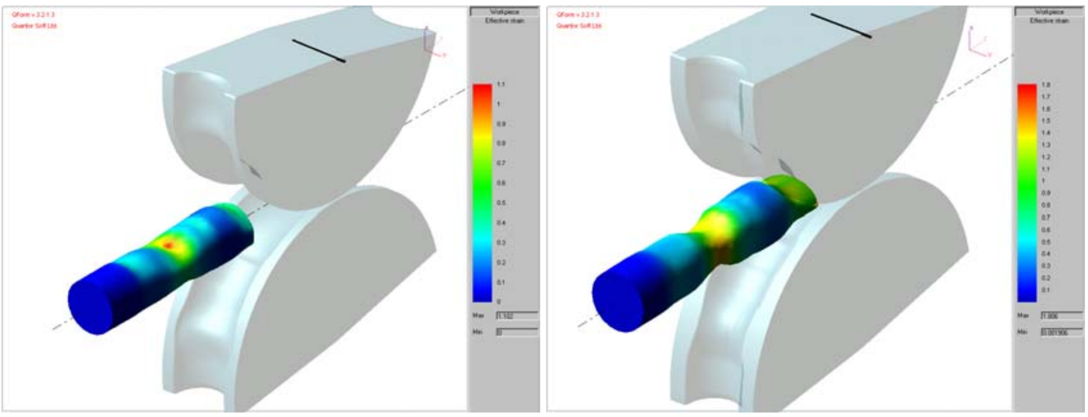


a. b.

Figure 1. Automatically designed sequence of billet shapes (a) and respective model of the working surface of the roll with three grooves (b).

4. Reducer rolling simulation

The simulation allows to “test” proposed reducer rolling technology starting from the critical point of determination of proper billet position at initial contact with the rolls and then analyzing the material flow in every pass. On Fig. 2 are shown results of simulation of two passes of rolling with distribution of effective strain on the billet surface. After simulation of each pass we get the shape of the billet that is effected by elongation and cross spreading that in turn depends on roll grooves shape, friction conditions and material properties. Usually the shape of the billet obtained after simulation does not coincide with its preliminary designed shape but is much closer to the shape obtained in real rolling. The discrepancy between designed shape of the rolls and the billet shape obtained in reality in previous pass may cause the defects in the next pass.



a. b.

Figure 2. The billet after simulation of the first (a) and second (b) passes of reducer rolling.

Here in the last pass final round shape with proper distribution of mass has to be obtained from intermediate oval shape. When the billet was positioned according to initial design at distance 40 mm to the center line of the rolls the groove is overfilled with the material. It results in appearing of the lugs (flash) on both sides of the rolled billet (Fig. 3). It means that cross spreading is bigger than was supposed to be in design. Such billet cannot be used for further closed die forging.

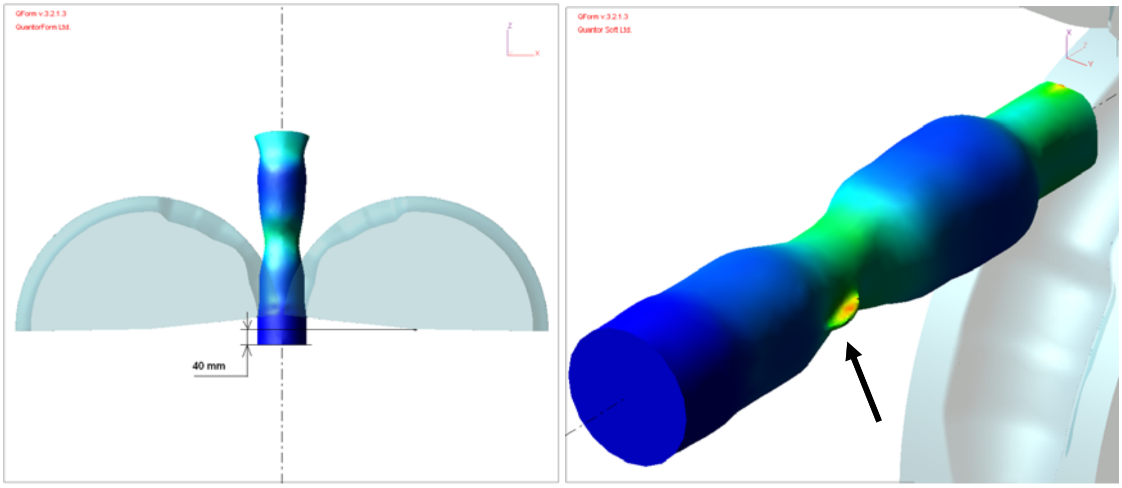


Figure 3. Improper initial positioning of the billet with respect to center line of the rolls (a) and the shape of the rolled billet with the defect pointed by arrow (b)

Changing the initial position it is possible to influence the material flow by means of distributing the material between elongation and cross spreading. After several computer trials it was found that initial distance 35 mm is the most optimal. Cross spreading is exactly as supposed to be to fill the groove and the shape of the billet after finish pass is as required (Fig. 4).

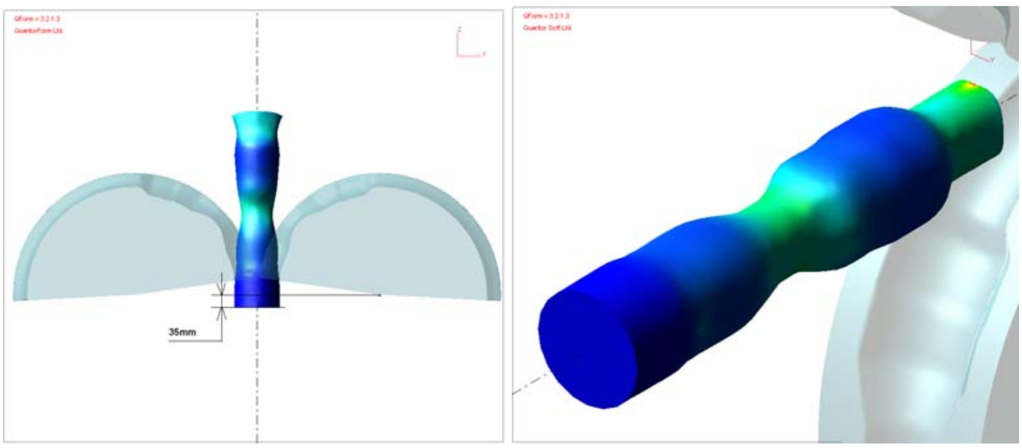
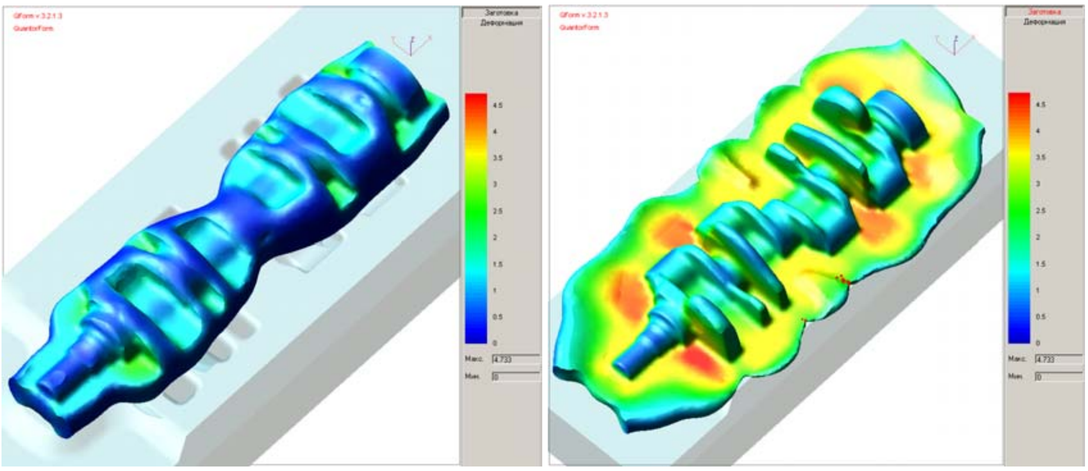


Figure 4. Proper initial positioning of the billet with respect to center line of the rolls (a) and the ideal shape of the rolled billet (b)

Thus making several computer trials it is possible to modify the reducer rolling technology by altering its initial design and to provide adequate material flow.

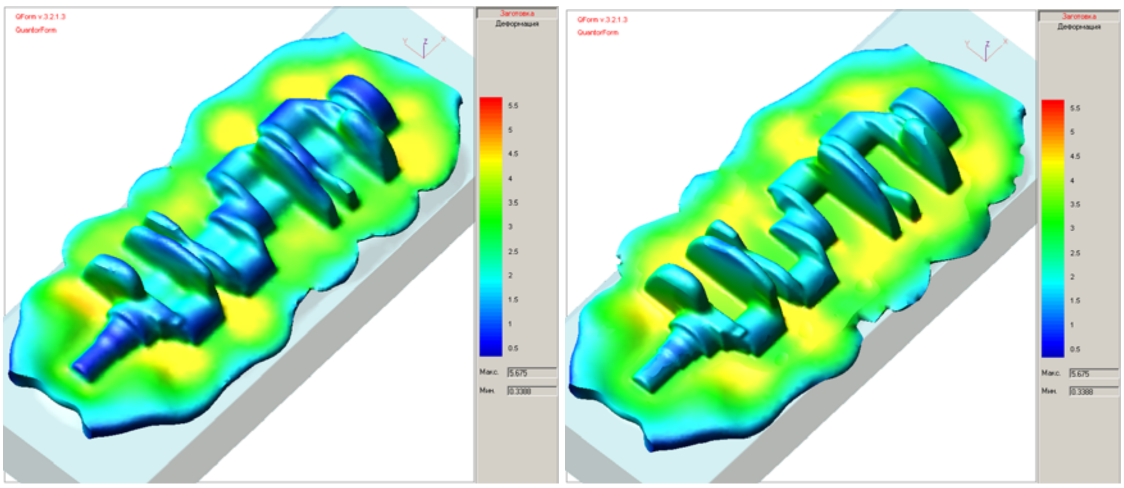
5. Using of the rolled billet for simulation of closed die forging

Within the same technological chain it is possible in QForm to transfer the rolled billet to the next operation that is closed die forging and then to simulate it. Forging is performed in two blows on mechanical press at the temperature 1200 C. The length of the billet after rolling is about 550 mm that is approximately the length of the crankshaft. Figs. 5 and 6 show the results of simulation of closed die forging.



a. b.

Figure 5. Simulation of the first blow of crankshaft forging using rolled billet: (a) intermediate shape; (b) final shape. Effective strain is shown.



a. b.

Figure 6 . Simulation of the second blow of crankshaft forging using rolled billet: (a) shape before blow; (b) final shape. Effective strain is shown.

Summary

Finite-element model of reducer rolling was developed and included into metal forming simulation program QForm. The model was tested for the technology of manufacturing of the profiled billet for crankshaft forging. The reducer rolling technology was automatically designed using program VeraCAD. The simulation has shown that material flow in longitudinal and transversal directions in rolling depends also on proper positioning of the billet between passes. After several computer trials optimal position of the billet was found and required shape of the billet was obtained. Obtained shape of the billet was used for subsequent simulation of closed die forging of the crankshaft in two blows.

References

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