COMPUTER SIMULATION OF THE AXISYMMETRIC COLD HEADING PROCESS

BY

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CERTIFICATE

This is to certify that the thesis entitled "COMPUTER SIMULATION OF THE AXISYMMETRIC COLD HEADING PROCESS" being submitted by Mr. Krishan Lal Arora to the Indian Institute of Technology, Delhi for the award of Degree of Doctor of Philosophy, is a record of bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of the thesis which, to our knowledge, has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any Degree or Diploma.

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SUMMARY OF REVISIONS INCORPORATED

The author is grateful to the examiners for their learned comments and suggestions for improvement of the thesis. He has carefully gone through the comments and has revised the original manuscript by incorporating the following alterations:

(i) The thesis has almost been completely rewritten.

(ii) Literature survey has been updated.

(iii) Finite Element Formulation has been changed from the less stable elasto-plastic to the more stable visco-plastic for the following reasons:

  (a) To tackle the problem of folding or dynamic contact at the work-tool interfaces

  (b) To solve the problem upto very high compression ratios

  (c) To deal with problems involving high aspect ratios

(iv) As mentioned above, theoretical results have also been obtained for larger compression ratios. It was, therefore, considered advisable to carry out experiments also upto corresponding larger compression ratios for verification purpose. This, however, necessitated mechanical tests on the new batch of steel specimens.

(v) The present work has been inspired by and built upon the contributions of other colleagues of the Computational Plasticity group of the Applied Mechanics Dept. at IIT, Delhi, especially, the two Ph.D. theses entitled :

(a) "Finite Uniaxial Compression under Static Loading" by Dr. K.S. Shishodia and (b) "Mechanics of Axisymmetric Closed-die Cold Forging Process", by Dr. P.C. Sharma. The present author has, however, made several improvements and additions to the earlier computer simulation procedures. For example, new expressions for element interfacial areas and incremental element rotations in the finite differences formulation. Also, variable smoothening technique has been used for lending greater stability to the solution procedure.

The visco-plastic formulation has been used in place of the elasto-plastic formulation for the finite element simulation approach. Mesh rezoning and variable interpolation have been used for tiding over numerical difficulties. The dynamic contact (folding) phenomenon has also been carefully tackled. Of course, as their titles suggest, the previous theses did not deal at all with the heading problem.

A finite differences computer program, in sharp contrast with a finite element program, suffers from the disadvantages that for a new problem, it has to be developed almost from scratch and debugged. The reason is that the new boundary conditions have to be incorporated and integrated within the basic equations. The author had to do the same.

Even the finite element program developed by the author, bears little resemblance with that of his predecessor Dr. P.C. Sharma owing to the use of the visco-plastic formulation (in place of the elasto-plastic formulation) and in incorporation of several new features mentioned in the foregoing paragraph. Computer listings based upon the present formulations are enclosed in a separate envelope attached herewith. The listings of Dr. Sharma's finite element and finite differences programs are also enclosed.

ABSTRACT

An important objective of the study of the mechanics of any metal-working process is to analyse the deformation pattern of the work-material. The deformation pattern in the case of the cold heading process is influenced by several factors, for example, the mechanical properties of the work-material, geometry of the blank, fixity conditions and severity of friction at the sliding interfaces. The deformation pattern governs both the state of stress and the forming load. Determination of the forming load is needed for the design and improvement of tools and equipment for production. Study of the mechanics of the production operation also helps in arriving at the range of process parameters for the manufacture of defect-free components and for real-time adaptive control of the given process.

A literature review on the cold heading process shows that most of the available analytical solutions are approximate or conventional. They are based upon simplifying assumptions on either the state of stress in the work material or mode of deformation or both. Exact solutions of cold heading operations on wire or rod are quite scarce. Probably, a major hurdle in the way of obtaining an exact solution to the problem of cold heading of a real work-material has been the mathematical complexity involved in solving the non-linear governing equations of the problem. Whilst several researchers have worked

in the field of axisymmetric compression or plain upsetting, only a few have worked on the problem of the cold heading process. The effect of different process parameters during the cold heading process has not been tackled adequately with the help of the powerful technique of computational plasticity.

The present study deals with the computer simulation of the cold heading process which is modelled as follows:

A cylindrical workpiece having a uniform cross section along its length is held in a long tight fitting cavity of a rigid die. A portion of the workpiece projects upwards from the die. A rigid flat die (platen) is brought into contact with the plane top end of the workpiece. The platen is slowly moved downwards in order to produce a "head" on the workpiece. The finite element (visco-plastic) and finite differences (elasto-plastic) techniques have been employed for simulating the process. The distinguishing features of the proposed elasto-plastic finite differences formulation include the use of simplified expressions for element interfacial areas and incremental rigid-body element rotations. Also the computed incremental radial displacements are smoothened in order to obtain better starting values for the next increment of deformation. Among the noteworthy features of the proposed visco-plastic finite element model are, automatic mesh rezoning, interpolation of effective strains and strain rates, and incorporation of an overall volume correction into the computational algorithm.

To verify the validity of results predicted by the above simulation procedures, experiments were conducted on specimens made of two materials, namely, low carbon steel and electrolytic copper. The computed heading loads and the bulge profiles were compared with those obtained experimentally on workpieces having different aspect ratios. A reasonable agreement was found between the predicted and experimental results.

The proposed simulation models were used to study the effect of the important process parameters of the heading process (namely the material constants and aspect ratio of the workpiece and the coefficient of friction at the work-tool interfaces). Main conclusions of the present study and computational results have been discussed.

C O N T E N T S