CHAPTER VI

CONCLUSIONS

1. A square billet, when axially deformed by introducing a conical die constraint at one end of the die results with three geometries namely: a barrelled part, truncated part and an extruded part irrespective of the lubricating conditions and aspect ratios.

2. When square and rectangular billets are axially upset under differential lubricating condition (By applying lubricant at one end of the specimen and maintaining the other end in dry lubrication) results with two geometries namely: a barrelled part and a truncated part irrespective of geometries, aspect ratios and lubricants applied at one end face of the specimen.

3. The curvature of the barrelled part of the specimen, physically measured, follows the geometry of circular arc for all the experimented cases.

4. The stresses namely the axial stress, the hoop stress, the effective stress and the hydrostatic stress, which are calculated using simple theory of plasticity, are found to increase with increase in the level of deformation. It is observed that for any strain level, the increase in hoop stress is appreciably lower as compared with the axial stress for all the experimented cases.
5. The relationship between the new hoop strain and the axial strain confirms a straight-line behaviour irrespective of geometries; aspect ratios and lubricants used both in square and rectangular billets under all the experimented cases.

6. The calculated value of radius of curvature of the barrel is found to be in close proximity with the measured value of radius of the barrel. The radius of curvature of the barrel fits a circular arc for all the experimented cases.

7. New geometrical shape factor is derived for all the upsetting conditions. The ln-ln plots between the barrel radius and the new geometrical shape factor shows a straight-line behaviour in all the cases irrespective of geometries, aspect ratios and lubricating conditions. This straight-line relation suggests a power law relationship between them. The power law equation is in the following form:

\[ R = CS^{-m} \]

where \( R \) is the barrel radius, \( S \) is the new geometrical shape factor and \( C \) and \( m \) are empirically determined constants.

The rate of change of barrel radius with respect to the new geometrical shape factor does not vary much with different aspect ratios, lubricants and geometries.

8. The stress ratio parameter showed a direct effect on the barrel radius under all the upsetting conditions. The radius of curvature of the barrel decreases exponentially with increasing value of the stress ratio parameter irrespective of geometries, aspect ratios and lubricants used.

9. The ln-ln plot between the radius of curvature of the barrel and the stress ratio parameter establishes a straight line relationship with different slopes between them irrespective of geometries, aspect ratios and lubricants used for all the
upsetting conditions. The straight line behaviour between these two parameters suggests a power law relationship of the following form

\[ R = G_1 \left( \frac{\sigma_m}{\bar{\sigma}} \right) (h_0 - h_f)^{-m_0} \]

where \( R \) is the barrel radius, \( \sigma_m \) is the hydrostatic stress, \( \bar{\sigma} \) is the representative stress, \( h_0 \) is the height before deformation, \( h_f \) is the height after deformation, \( G_1 \) and \( m_0 \) are empirically determined constants.

10. The hydrostatic stress has a direct effect on the radius of curvature of the barrel. The radius of curvature of the barrel decreases exponentially with increasing value of the hydrostatic stress irrespective of the geometries, aspect ratios and lubricants used in all the upsetting cases. The behaviour of the hydrostatic stress is same as seen in the case of the stress ratio parameter.

11. The relationship between the friction factor ‘\( m \)’ and the new geometrical shape factor is found to be a straight line. This suggests that a power law relationship exists between the friction factor and the new geometrical shape factor, which is expressed as follows.

\[ m = G_2 \ln S + G_3 \]

where ‘\( m \)’ is the friction factor, ‘\( S \)’ is geometrical shape factor, and \( G_2 \) & \( G_3 \) are empirically determined constants.

12. The friction factor ‘\( m \)’ decreases linearly with increasing value of the natural logarithmic value of the stress ratio parameter. The logarithmic plot shows that the straight relationship between the friction factor and the logarithmic value of stress ratio parameter is the manifestation of the following expression

\[ m = G_4 \ln \left( \frac{\sigma_m}{\bar{\sigma}}(h_0 - h_f) \right) + G_5 \]
where $m$ is the friction factor, $\sigma_m$ is the hydrostatic stress, $\tilde{\sigma}$ is the representative stress, $h_0$ is the initial height of the billet, $h_f$ is the final height of the billet after deformation and $G_4 \& G_5$ are empirically determined constants.
SUGGESTED TOPICS FOR FURTHER INVESTIGATIONS

From the consideration of results of the present study, several additional areas may be worth for further investigations:

a) A study on barrelling of square and rectangular billets of ferrous metals can be studied.

b) A study on barrelling of different polygons can be studied.

c) A study on barrelling of elliptical specimens of non-ferrous metals can be carried out.

d) A study on the effect of die constraint at both ends on barrelling can be done.

e) Further work on cold work effect (Pre strain) on barrelling can be carried out.

f) A complete slip line solution for the effect of barrelling on various parameters can be carried out.

g) Research study on the effect of work hardening value and other mechanical properties on barrelling can also be carried out.

h) Research work on the effect of chemical composition and microstructure of steels and non-ferrous metals on barrelling can also be carried out.


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