Analysis of Bi-Axial and Tri-Axial State of Stresses in Plastically Deformed Solid Cylindrical Specimens under Dry Lubrication

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Analysis of Bi-axial and Tri-axial State of stresses in Plastically Deformed Solid Cylindrical Specimens under Dry lubrication

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Abstract

This paper explains the type of stresses induced in the AA2014 solid cylindrical specimens when deformed plastically between a set of rigid dies. The solid cylindrical specimens machined to different height (h) to the diameter (d) ratios namely h/d=1, h/d=0.75 and h/d=0.5 were compressed between the two flat cylindrical dies using a 100 ton capacity UTM. These billets were deformed to different strain levels. At each and every stage of the incremental strain, the various elements of the geometry such as contact diameter at the die/billet interface, bulged diameter at the equatorial region and the height after deformation were noted down. The significance of measuring the various elements of the geometry is to predict the value of stresses namely axial stress, hoop stress, hydrostatic stress and effective stress which influence the ductility or formability of the material. The stresses induced in the billets were predicted using the empirical equations and a comparison has been made for uni-axial, bi-axial and tri-axial state of stresses for different aspect ratios. A notified behavior in the value of stresses has been observed for all the aspect ratios and for different state of stresses.

Introduction

A non uniform distribution of the material results in the plastic deformation of solid cylinders when the billet is compressed in between two rigid dies. This is because of the friction between die and the billet material which leads to the barreling of the specimen. Several authors [1-3] made experimental investigations on this phenomenon of cold upset forging processes by compressing the billets of same and different geometries and different processing conditions such as application of different lubricants at die faces. Because of the complexity of establishing the equations in upset forged cylindrical billets, Abdel-Rahman et al [4] assumed the state of stress as uniaxial and developed equations for axial, hoop, effective and hydrostatic stresses and also for axial and hoop strains. Narayanasamy et al [5-7] and Doraivelu et al [8] proposed a set equations for determining the stresses and strains by assuming the plane stress and triaxial stress conditions.

In the present investigation, several experiments have been carried out on solid cylinders of different aspect ratios for upsetting the billets. By considering the equations developed by several authors [4-8], the stresses developed in the billets were analyzed and compared for different aspect ratios.

Experimental Procedure & Results

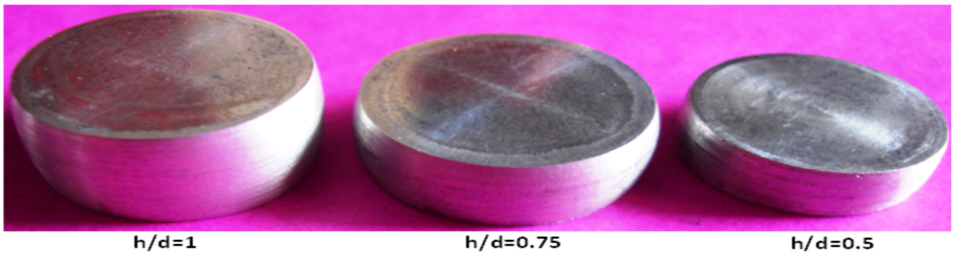

Fig.1 Deformed solid cylinders of different aspect ratios (h/d) subjected to same height reduction.

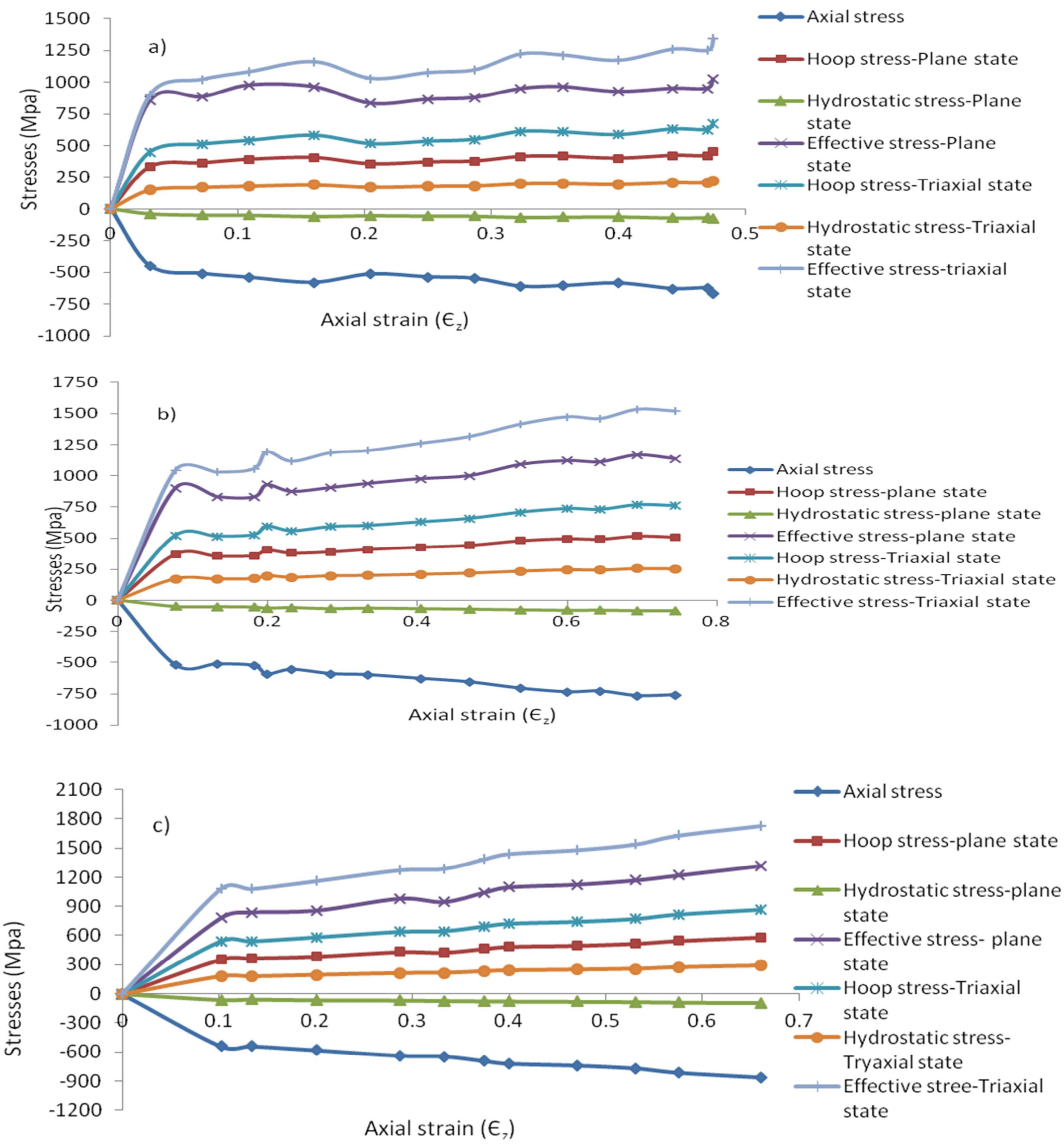

Fig.2 Variation of different stresses with respect to Axial strain for a) h/d=1 b) h/d=0.75 c) h/d=0.5.

A series of experiments were conducted by considering different aspect ratios namely h/d=1, h/d=0.75, h/d=0.5 under cold working condition. Fig.1 illustrates that the cylinders are compressed between two rigid dies to the same level of deformation. Fig. 2 illustrates the variation of stresses versus axial strain for different aspect ratios. After each and every successive stage of the process, the geometrical parameters namely contact diameter, bulged diameter at the middle of the specimen were measured and their corresponding values of axial strains and hoop strains were calculated. The equations developed by several authors [4-8] were used to predict the stresses namely axial, hoop, hydrostatic and effective stresses under uniaxial, biaxial and triaxial state of stresses. Each and every type of stress determined has a specific importance. The axial stress is useful in compressing the billet but when the specimen is deformed beyond the fracture limit, the nature of the stress will be tensile and promotes fracture. As shown in Fig. 3, the value of uniaxial stress at the beginning is lower and then starts increasing because of the initial strain hardening. The rate of increase of uniaixal stress is more in case of h/d=0.5 than h/d=0.75 and h/d=1.

An increase in the amount of axial strain increases the magnitude of stresses with the deformation load. With the increase in the level of deformation the hoop stresses, hydrostatic stresses and effective stresses were increasing for both plane and triaxial state of stresses. This behavior is same irrespective of any aspect ratio of the billets considered for the investigation. The decrease in the aspect ratio requires more load for deformation. This is because the shorter billets require higher loads for deformation compared to longer billets to reduce them to the same strain level.

To check the dependability of the aspect ratios on the state of stresses namely bi-axial and triaxial, Fig. 4 and Fig. 5 were plotted. An increase in the load increases the magnitude of stresses for plane and triaxial stress state conditions. The analysis of axial stress and hoop stress is needed as the biaxial stress state condition promotes barreling near the equatorial region. The increased value of hoop stresses increases bulging at the center and further deformation leads to the crack formation at the center. The indifference in the amount of axial strains for all the h/d ratios indicates the inability to form to the higher strain limits. Greater h/d ratios lead to problems such as buckling and this severity decreases with the decreasing tendency of the h/d ratios. Because of this problem, when billets of

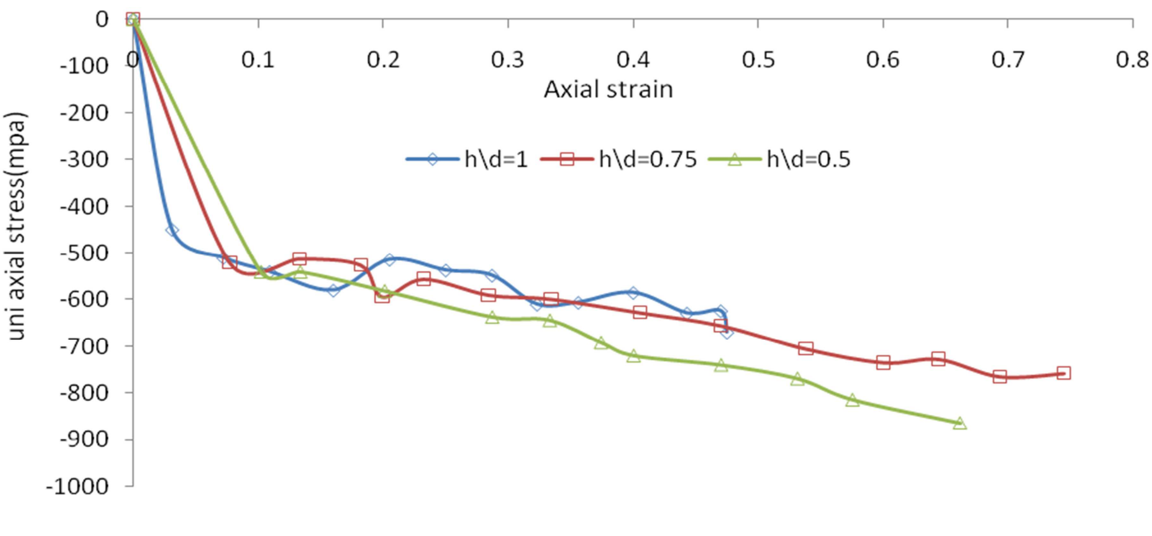

Fig. 3 Uni axial stress vs axial strain for different aspect ratios (h/d).

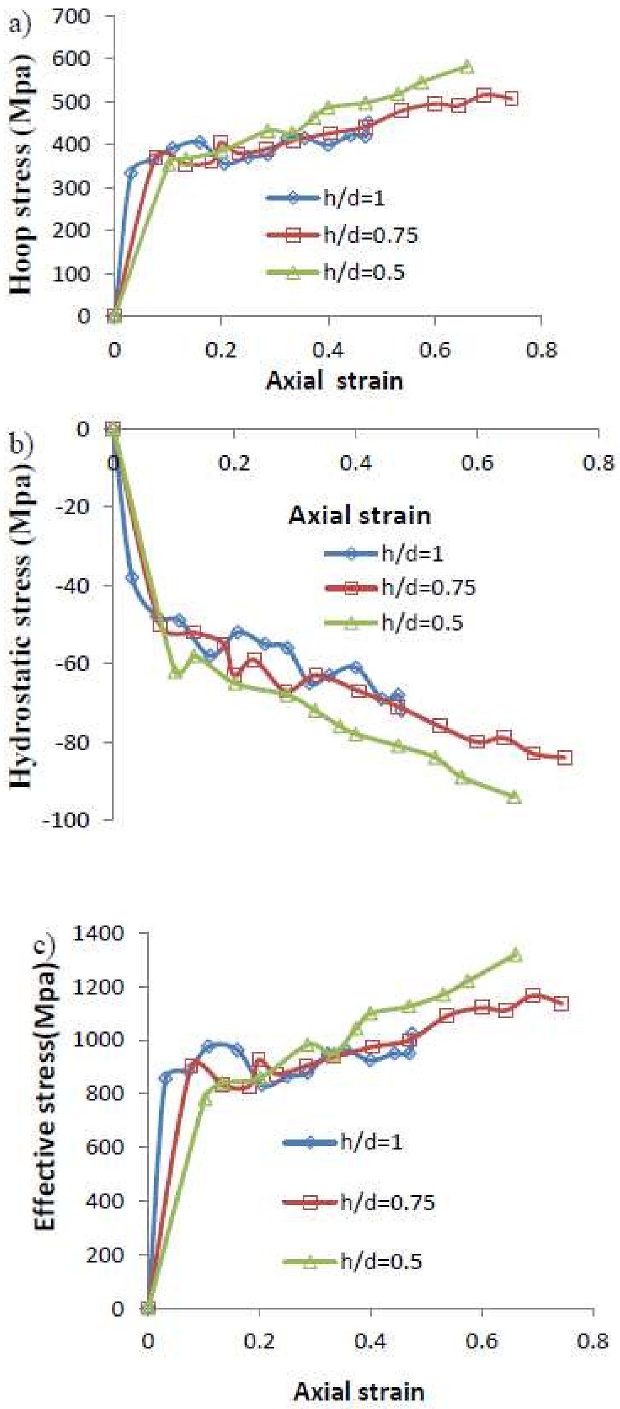

Fig. 4 Biaxial stress vs axial strain for different aspect ratios (h/d).

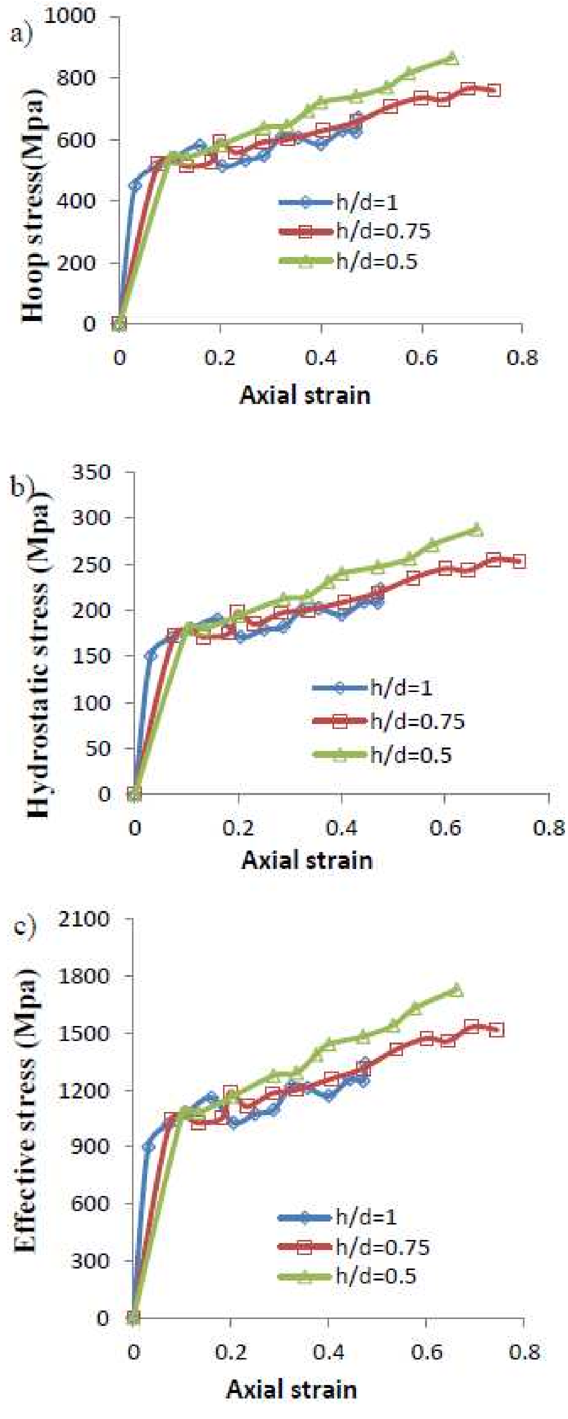

Fig. 5 Triaxial stress vs axial strain for different aspect ratios (h/d).

different aspect ratios were deformed to the same level, the tensile hoop stress which is responsible for the barreling will be more for h/d=1 compared to the h/d=0.75 and h/d=0.5. This behavior is similar for both the biaxial and triaxial stress states. The hydrostatic stress which is responsible for the formability of the material is found to be compressive in case of plane stress condition and tensile incase of tri axial stress state condition This is because; the radial stress near the free surface is zero in case of plane stress condition making the hydrostatic stress compressive. The compressive nature of the hydrostatic stresses improves the formability of the material by suppressing the internal voids of the billet. The radial stress for tri axial stress state condition is assumed to be equal to the hoop stress which results in the tensile nature of hydrostatic stress. The tensile nature of the hydrostatic stress promotes severe barreling leading to the failure of the billet. The value of the effective stress is more for triaxial stress state condition than the plane stress condition when the billet is subjected to the same amount of axial strain. This is because the biaxial stress state doesn't comprise of the radial stress.

Conclusions

The stresses namely hoop stress, hydrostatic stress and effective stress under plane and triaxial stress state conditions are increasing with the increasing axial strain. The tensile nature of the hoop stress and hydrostatic stress will have greater influence on the formability of the material. For the same amount of axial strain, there is an increase in the stress with the decrease in the aspect ratios. The hydrostatic stress is compressive in plane stress condition and tensile incase of tri axial stress state condition. The effective stress under triaxial stress state is high compared to plane stress state condition for all the aspect ratios.

References

[1] D. Y. Yang, Y. Choi, J. H. Kim, Analysis of upset forging of cylindrical billets considering the dissimilar frictional conditions at two flat die surfaces, Int. J. Mach. Tools Manuf. 31 (1991) 397-404.

[2] F. K. Chen, C. J. Chen, On the non-uniform deformation of the cylinder compression test, J. Eng. Mater. Technol. (Trans. ASME) 122 (2000) 192-197.

[3] M.I. Gokler, H. Darendeliler, N. Elmaskay, Analysis of tapered preforms in cold upsetting, Int. j. Mach. Tools manuf. 39 (1999) 1-16.

[4] M. Abdel-Rahman, EI-Sheikh, Workability in forging of powder metallurgy compacts, J. Mat. Process. Technol. 54 (1995) 97-102

[5] R. Narayanasamy, K.S. Pandey, Phenomenon of barreling in aluminium solid cylinders during cold upset forging, J. Master. Process. Technol. 70(1997) 17-21.

[6] R. Narayanasamy, R. Ponalagusamy, Unpublished report on P/M forging part-1, National Institute of Technology, Tiruchirapally 620015, Tamilnadu, India, 2005.

[7] R. Narayanasamy, Unpublished report on P/M forging part-II, National Institute of Technology, Tiruchirapally 620015, Tamilnadu, India, 2005.

[8] S.M. Doraivelu, H.L. Gegel, J.S. Gunasekara, J.C. Malas, J.T. Morgan, A new yield function for compressed P/M materials, Int. J. Mech. Sci. 26(1984) 527-535.

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DOI References

[1] D. Y. Yang, Y. Choi, J. H. Kim, Analysis of upset forging of cylindrical billets considering the dissimilar frictional conditions at two flat die surfaces, Int. J. Mach. Tools Manuf. 31 (1991) 397- 404.
http://dx.doi.org/10.1016/0890-6955(91)90084-G
[2] F. K. Chen, C. J. Chen, On the non-uniform deformation of the cylinder compression test, J. Eng. Mater. Technol. (Trans. ASME) 122 (2000) 192-197.
http://dx.doi.org/10.1115/1.482786
[3] M.I. Gokler, H. Darendeliler, N. Elmaskay, Analysis of tapered preforms in cold upsetting, Int. j. Mach. Tools manuf. 39 (1999) 1-16.
http://dx.doi.org/10.1016/S0890-6955(98)00021-2
[4] M. Abdel-Rahman, EI-Sheikh, Workability in forging of powder metallurgy compacts, J. Mat. Process. Technol. 54 (1995) 97-102.
http://dx.doi.org/10.1016/0924-0136(95)01926-X
[8] S.M. Doraivelu, H.L. Gegel, J.S. Gunasekara, J.C. Malas, J.T. Morgan, A new yield function for compressed P/M materials, Int. J. Mech. Sci. 26(1984) 527-535.
http://dx.doi.org/10.1016/0020-7403(84)90006-7