# Analysis And Comparision Of Damage Models In The Cold Forging Of AA2014 Cylindrical Billets

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***Abstract—*** *In the present investigation, material AA2014 cylindrical billets having aspect ratios (height to diameter ratio (h/d)) h/d=1,h/d=0.75 & h/d=0.5 were considered for the analysis. AA2014 material has its own importance because the material used in automotive, aerospace and industrial applications without fracture. The cylindrical specimens were upset under cold working condition between two cylindrical flat die (H-13 steel) surfaces under different lubrication conditions namely UL/Grease, UL/MOS2 & Grease/MOS2. On sever plastic deformation the billets will fracture and failure occurs. The methods behind the failure of test specimens were analyzed and compared by utilizing damage models proposed by Cockroft and Latham, Freudenthal and Brozzo for different aspect ratios and lubrication conditions. Experimental, analytical and finite element simulation investigations were carried out to study the magnitude of critical damage value (ci). For formability of material at each and every stage of strain the critical damage value was examined and for particular material we imply the suitable damage model.*

***Keywords— Damage model; AA2014; Aspect ratio; Critical damage; Finite element modeling.***

## I. INTRODUCTION

In any metal forming process the wok piece achieves shape change by either plastic deformation or a combination of plastic deformation & cracking. Defects are common in the material due to extensive deformation. In forging process compressive forces may be provided by means power hammer, mechanical, manual and hydraulic press. Compare to all manufacturing process forging has more advantages because it give less wastage of material, production of complex parts with directional strength and grain orientation. For effective utilization of material and process, the fracture must be avoided in metals. Several authors made experiments and theoretical investigations on formability of material. Landre et al. [1] predicted when and where material is likely to fracture during cold forging, by utilization of ductile fracture criteria with finite element method. Altinbalik [2] conducted experiments on solid aluminium cylinders under axi-symmetric compression over different aspect ratio without any lubricant using. By using FEM program 3D bulging profile and effective strain distribution of billets were obtained. Li et al. [3] developed criteria for ductile fracture prediction in metal plastic deformation. Coupled damage criteria, uncoupled damage criteria are investigated to find reliability in ductile failure. Gouveia et al. [4] investigated accuracy for predicting and quantifying fracture initiation sites, and their chosen previous ductile fracture criteria. By utilising different test samples are ring, cylinder & tapered and predict the experimental values of the critical damage at fracture under several loading conditions.

In the present work grease, un lubricated & molybdenum disulphide (MOS2) taken as lubrication conditions and employed at the faces of billets. Under sever loading fracture will takes place on billet surface. To determine the damage values for different aspect ratios and lubrication conditions, several damage criteria's were implemented.

## II. EXPERIMENTAL METHOD

Solid cylinders machined to a height of 24 mm and diameter of 24 mm were compressed between H-13 steel dies by employing no lubricant on the top face and grease on the bottom face of the billet using a 100 ton capacity hydraulic press. After several deformations, a small crack initiates on surface of specimen. Fig: 1 represented before and after deformation of the cylindrical specimens having different aspect ratios. The machine was stopped after observing crack on surface. The point at which crack initiates on the billet surface is termed as critical damage.

To know the value of critical damage of material damage criteria's such as Normalised Cockroft Latham and Cockroft Latham [5], brozzo [6], Freudenthal [7] were utilised. The process is continued for remaining two lubrication conditions and for h/d=0.75 & h/d=0.5 test samples.

(a)

(b)

**Fig 1: Cylindrical specimens of different aspect ratios (a) before deformation (b) after deformation**

## III. DAMAGE MODELS

The Damage models usually based on combination of stress and strain rate rather than either of these two separately. Freudenthal [7] suggested workability criteria based on critical plastic work per unit volume.

$$\int_0^{\epsilon_{eff}} \bar{\sigma} \, \overline{d\epsilon} = C_1 \text{-------------} (1)$$

$\overline{d\varepsilon}$ is the effective strain increment

$\varepsilon_{eff}$ is the effective plastic strain

$\bar{\sigma}$ is the effective stress

In the view of importance of largest tensile stress, Cockroft and Latham [5] proposed alternative criteria based on critical value of the tensile strain energy per unit volume.

$$\int_0^{\varepsilon_f} \sigma_1 \overline{d\varepsilon} = C_2 \text{---------------} (2)$$

Where $\sigma 1$ is the largest (tensile) principal stress. The Normalized version of this criterion can be written as

$$\int_0^{\epsilon_{eff}} \frac{\sigma_1}{\bar{\sigma}} \overline{d\epsilon} = C_3 \text{------------} (3)$$

In the view of significance of both the largest (tensile) principal stress, $\sigma_1$, and the hydrostatic stress, $\sigma_m$, Brozzo [6] was proposed the criteria by combining these two stress and it is given as

$$\int_0^{\epsilon_{eff}} \frac{2\sigma_1}{3(\sigma_1 - \sigma_m)} \overline{d\epsilon} = C_4 \text{---------} (4)$$

Where $c_1$, $c_2$,$c_3$,..........$c_i$ are the critical damage values.

## IV. FINITE ELEMENT METHOD

Deform 2D software was used for finite element investigation and analysis of the axi- symmetrical open die forging process. The dies were treated as rigid and billet as plastic material. The load is applied on top of the die and billets were compressed in between two rigid dies and total set up modeled as axi- symmetric. The flow stress equation is

$$\sigma = 720 \, \varepsilon^{0.22} \text{---------------} (5)$$

By giving the flow stress equation as input to the finite element software, the total set up was modeled as axi-symmetric configuration as illustrated in Fig: 2.

b

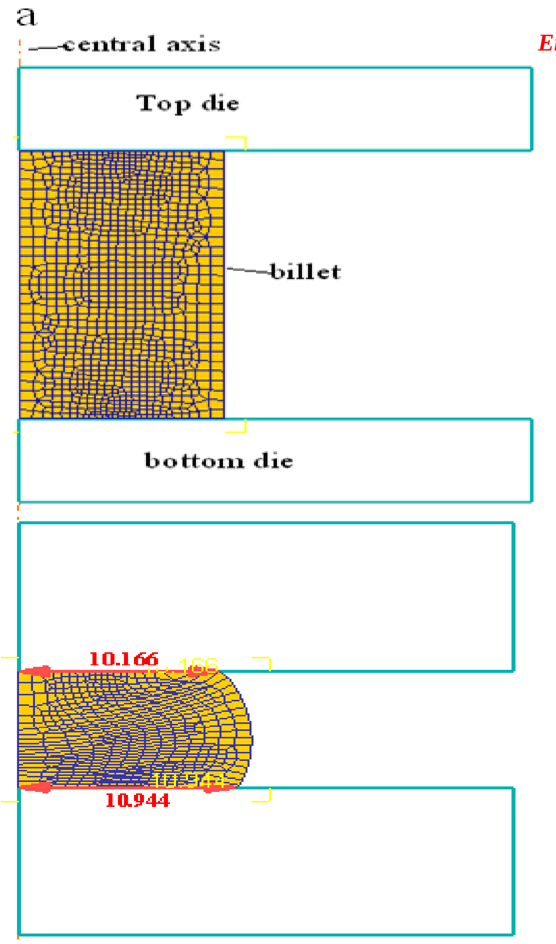


**Fig 2: Axi-symmetric modeling a) before deformation b) after deformation**

Fig 3: shows experimental crack initiated on the surface of the billet and simulated damage value of specimen.

(a)

(b)

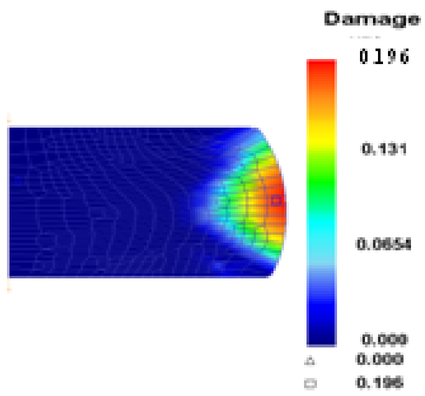


**Fig 3: Cracked billet (a) experimental (b) simulation**

## V. Result And Discussion

Fig 4: illustrated that damage models comparison for different aspect ratios such as h/d=1, h/d=0.75, h/d=0.5. The critical damage value (ci) was evaluated for all damage criteria and the average critical damage value (cavg) at fracture for different lubrication conditions was determined. In order to compare the damage models the value of (ci/cavg) was taken for consideration. In fig:4, for the same aspect ratio the deviation in damage value for all criteria's is less.

Fig 5: represented that damage models comparison for different lubrication conditions, fig (4) & fig (5) shows that deviations were approximately with in range of ± 30%. It shows different aspect ratios and different lubrication conditions do not have much impact on value of critical damage.

By conducting experiments on flanged specimen, tapered specimen and cylindrical specimens, (O. Koack [8], J. Landrea et al [1] and B.P.P.A. Gouveia et al [4]) concluded that only Freudenthal model was deviating much compared other damage criteria for flanged and tapered specimens. The accuracy of the damage model depends on the type of geometry considered for the investigation. Since in the present study, the billets deformed to the fracture level are solid cylinders, all the four damage criteria could validate the condition that critical damage is a material constant.

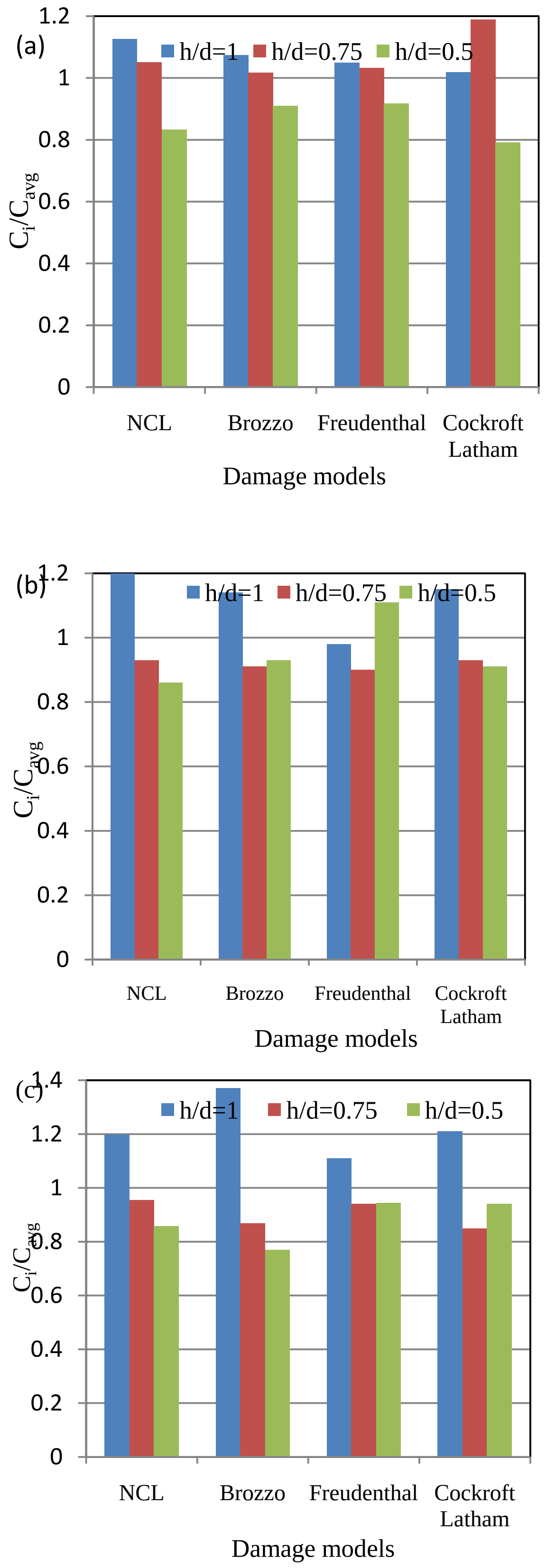


**Fig 4: $C_i/C_{avg}$ value predicted based on four fracture criteria for different aspect ratios (a) h/d=1 (b) h/d=0.75 (c) h/d=0.5**

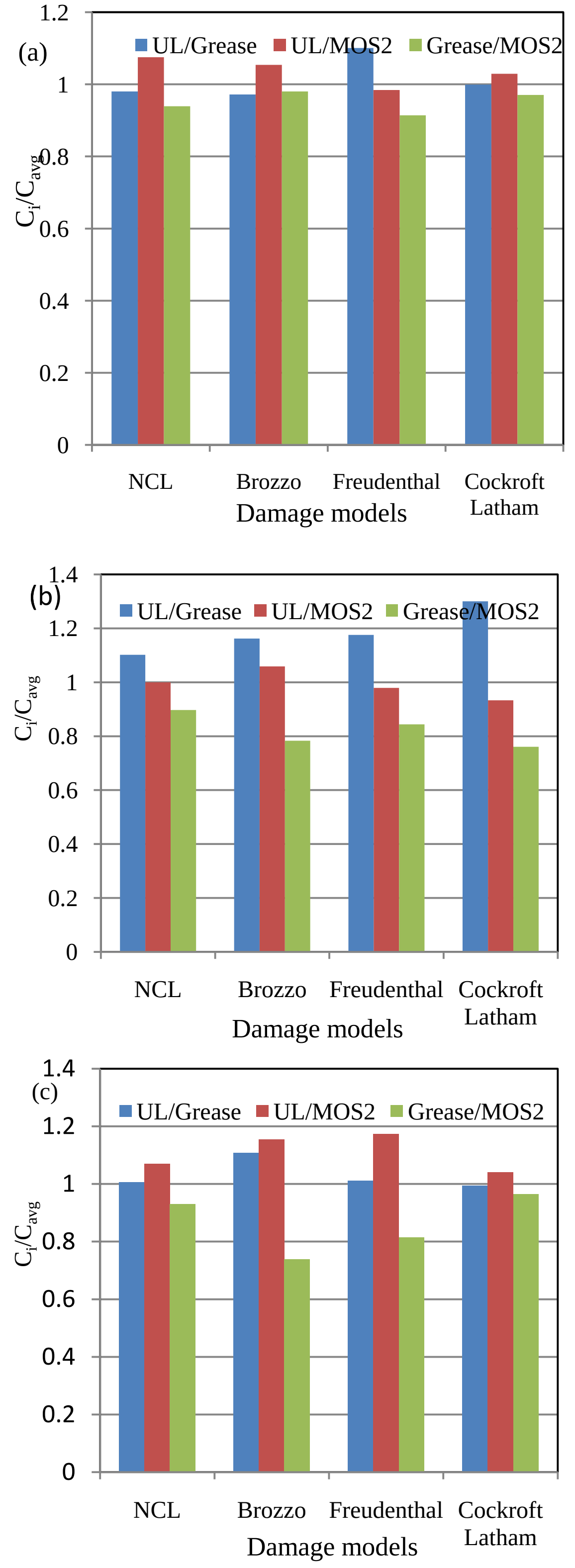


**Fig: 5 $C_i/C_{avg}$ value predicted based on four fracture criteria for different lubrication conditions (a) UL/Grease (b) UL/$MOS_2$ (c) Grease/$MOS_2$**

## VI. Conclusions

- The value of the critical damage doesn't depend on the type of lubricant applied at the die/billet interface.
- Predicting the ductile fracture made effective utilization of the material and process.
- Higher aspect ratio increases the tendency of initiation of fracture.
- Lower aspect ratios gives better formability of a material since it had lesser critical damage value.
- The accuracy in predicting the critical fracture depends on the type of geometry considered.

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