"EFFECT OF PERCENTAGE HYDROSTATIC PRESSURE AUTOFRETTAGE ON PROPERTIES OF ALUMINIUM CYLINDER"

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Abstract: The effects of different percentage of autofrettage on the radial compression strength in the aluminum cylinder of different thickness were investigated by experimental studies. The autofrettage Al cylinder 3 mm thicknesses were subjected to hydrostatic pressure and characterized for radial compression loading using the universal testing machine. The obtained results have been compared with different % of autofrettage. Some cracks were likely made in the thickness of materials; there was room for improvement if less expansion was desired. In conclusion, the result highlighted the importance of hydrostatic pressure property accounting for re-yielding and significance.

Index Terms **- Autofrettage, Radial Compression, Al Cylinder.**

I. INTRODUCTION

Recently, the autofrettage process gains significance importance to strengthen the thick walled cylinders, which partially yields by means of hydrostatic pressure. During hydrostatic pressure a larger residual strain is induced the inner surface of the metallic cylinder, which yields inner bore. The dimension of that of autofrettaged cylinder depends on the amount of yielding and plastically deformed inner surface the cylinder. Often unloading autofrettage pressure, the compressive residual stress is induced along the thickness of the cylinder, which are improving the fatigue life.

The general idea about autofrettage was initially proposed by St. Venant [1]. The revelation of the advantage of autofrettage process in the creation of firearm tube was found by specialists [2-4] by making extensive test studies on the overstrain of thick-walled chambers fundamentally amid the second war period. Amid this period, various explanatory methodologies and trial information were exhibited by numerous examiners on the elastic-plastic thick-walled chamber issue. By utilizing the suspicions of plane strain and constancy of volume and considering strain hardening, Noraziah [5] bloated an answer for overstraining of the thick-walled barrels. The above study demonstrates that the stress condition in the closed-end vessel is proportionate to pure shear superposed by hydrostatic tensile stress which brings about a way that the relativity of the maximum shear stress and the maximum shear strain is comparable in the tube as it is in a torsion test. The outcome got from a torsion test, i.e. shear stress-shear strain can be proximately used to conjecture the pressure-strain reaction of the tube having same material up to an ultimate pressure furthermore displayed by trial results for a mixed bag of comparable materials which were in great concurrence with the expository results. In light of Manning's methodology, Lviv et; al. [6] and Zhong et al. [7] advise that the diagnostic results got were in intently likeness with the broad exploratory information on diverse sort of materials. The aforementioned examinations and trial results on the autofrettage of different materials were taking into account the instance of low strength, strain hardening materials. In any case, the materials being utilized without further ado are for ultra-high weight vessels which generally display little strain hardening interest.

The effect of the re-autofrettage method on the residual stress distribution at the wall of a thick-walled vessel was studied [8-10]. For determining the behavior of the material under loading-unloading process, an improved Chaboche's hardening model, made of the high strength steel, DIN1.6959 is applied and also, finite element simulations are implemented to simulate the re-autofrettage method and to estimate the residual stresses. The numerical results show that the re-autofrettage method meliorates the residual stress distribution in high autofrettage percentage, and this method is not beneficial for low autofrettage percentage. The results from above method show that there is a vast difference in the residual stresses at various autofrettage pressures and the influence of the autofrettage's pressure quantity on residual stresses created in the thickness of the test cylinders can also be seen. The previous study was mainly concentrated on the cylinder made using steel, copper etc and in this work; the study is on aluminum cylinder having more industrial importance. Mainly, the effect of autofrettage on the strength was the concentration on previous work and there is no study on the dimensional change of the diameters at different stress levels. This project report describes the changes in the dimension of both autofrettaged and in autofrettaged aluminum cylinder. Load time graph and stress-strain graph between both autofrettaged and non-autofrettaged aluminum cylinder is also an essential study in the paper.

II. EXPERIMENTAL STUDY

Two distinct materials are used in hydraulic compression autofrettage process. First one is the material on which autofrettage is being carried out. Known as the cylindrical structure and the second one is the material being used as an oversized mandrill in the autofrettage process. In this report, Al 6061 alloy cylinder is used as one end closed tube structure and a mild steel rod is used as the mandrill material. An aluminum cylinder having outer diameter 40mm and internal diameter 25.5mm, and a gauge length of the cylinder is 85mm and 36mm outer diameter, the total length of the cylinder is 200mm and to carry the autofrettage process. To induce autofrettage, the pressure of oil inside the Al cylinder was increased using the pressure regulator until all four strain gauges showed a linear response. Now, the pointer of the pressure gauge was set to zero and the pressure of oil was increased in pressure cycles of 0-2-0, 0-4-0, and 0-6-0 and so on, till the required amount of deformation was obtained via the strain gauges. The pressure was then released and the deformation measured. The rate of autofrettage induced was computed by measuring the residual strain indicated by strain gauges after releasing the hydraulic load. The percentage of autofrettage in Al cylinder was obtained by trial and error.

Samples of FML cylinders were autofrettaged to 0.5, 1, 1.5 and 2% Al cylinders without and with autofrettage were subjected to external hydrostatic pressure loading. The enhancement in strength of autofrettaged cylinders concerning their failure pressure and rate of buckling deformation was investigated. The external hydrostatic pressure loading of non-autofrettaged and autofrettaged Al cylinders was carried out. The strains corresponding to the applied hydrostatic pressures were recorded via strain indicator for each Al cylinder. Al cylinders without autofrettage and cylinders autofrettaged to 0.5% and1% were subjected to radial compression loading, to study the enhancement in strength of autofrettaged cylinders when compared to non-autofrettaged cylinders. The compression loading of non-autofrettaged and autofrettaged cylinders was carried out for the applied load, the changes in major and minor axis concerning its original dimensions were recorded and the aspect ratio was calculated.

III. RESULTS AND DISCUSSION

Al cylinders of thickness 1mm, autofrettaged to 0.5%and 1% were subjected to compression (radial) loading. For the applied load, the changes in the major and minor axis concerning its original dimensions were recorded and the aspect ratio was computed.

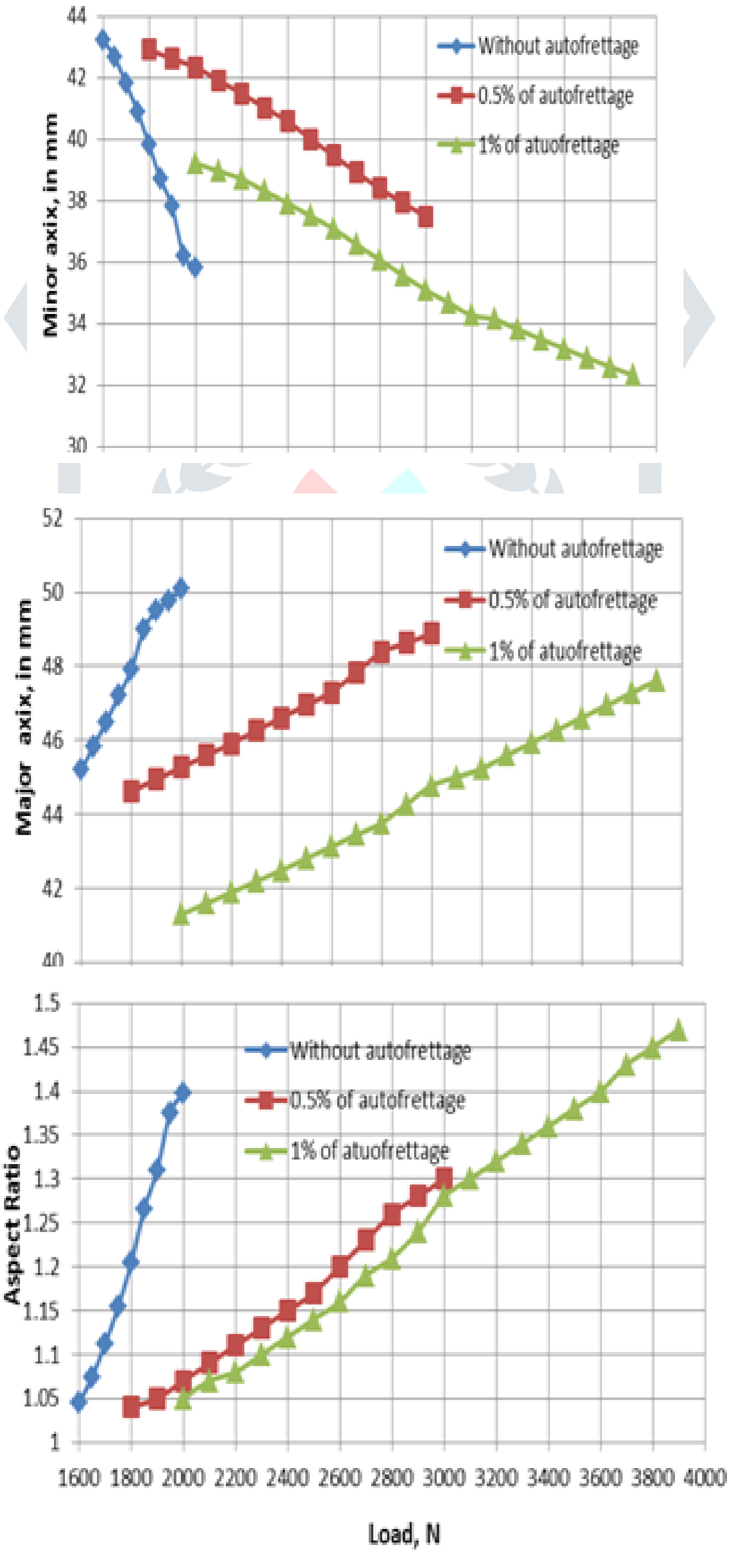

Fig.3. 1 effect of % of autofrettage on major, minor and aspect ratio of Al

The results are recorded and tabulated. These are given in Fig. 1 respectively. The radial loading on the FML cylinder creates two axes namely major axis and the minor axis along the loading direction and perpendicular to the loading direction respectively.

Maximum load is applied on the minor axis and minimum load acts on the major axis. The minor axis decreases with an increase in load and an opposite behavior could be seen for the major axis. The aspect ratio also increased with an increase in radial compression during testing for both Al cylinders and autofrettaged Al cylinders.

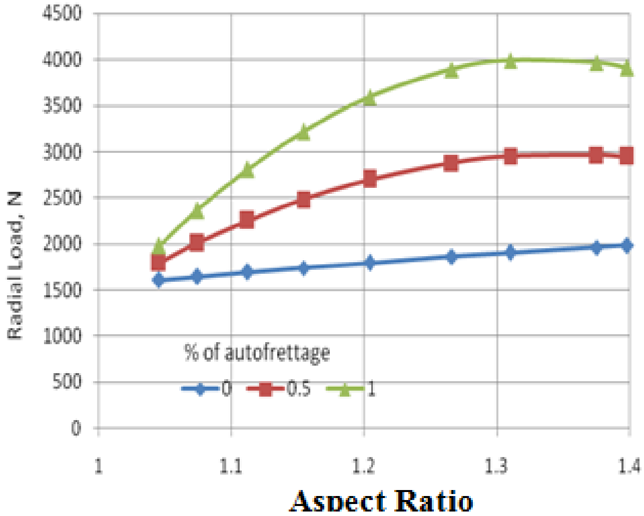

Fig. 3.2 Effect of autofrettage on radial compressive strength of Al cylinders

Fig. 2 shows the effect of radial compressive cylinders without autofrettage and strength as a function of aspect ratio for Al autofrettaged to 0.5% and 1.0%. The effect of aspect ratio in non-autofrettaged Al cylinders indicated almost linear variation (straight line) and it follows the governing equation represented by

Y = 1053.x + 519.2 (Y is radial Loading and x is aspect ratio). --- (1)

The effect of aspect ratio in Al cylinders autofrettaged to 0.5% was parabolic and it followed the equation:

$Y = -12386x^2 + 33522x - 19708$. --- (2)

In FML cylinders autofrettaged to 1% the curve followed the governing equation:

Y = -24198x2 + 64585x – 39085. --- (3)

The initial points of aspect ratio for all the Al cylinders start within a closed range and they tend to diverge at higher aspect ratio. This indicated that at initial values of loading, the effect of residual stresses was less on the strength of the Al cylinders. As the loading increased, the effect of residual stresses was evident towards the higher aspect ratio. The residual stresses strengthen the FML cylinders against deformation. Hence the strength of Al cylinders enhanced with increase in the percentage of autofrettage when subjected to radial compression loading.

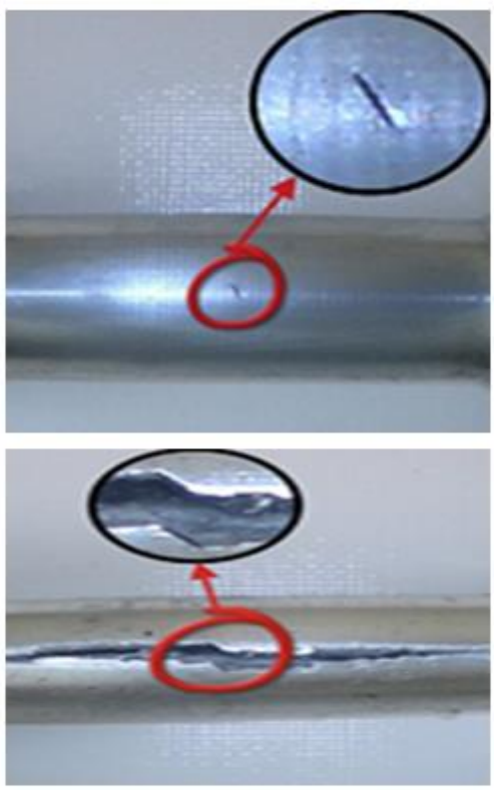

Fig. 3.3 Radial compression leads to crack development in the specimens

The cracked cylinders were connected to the pump then the pressure was supplied slowly and continuously until the cylinders cracks. Crack creation on aluminum cylinder for different orientation 30, 60 and 90 degrees in this manner characterize the bursting pressure for the aluminum thick-walled cylinder as shown in Fig 3.

IV. CONCLUSION

a) In Al cylinders with different thickness of Al were autofrettaged to 0.5% and 1%, subjected to radial compression loading, the following conclusion was drawn.

b) The aspect ratio increased with increase in the percentage of autofrettage.
c) The initial points of aspect ratio for all the Al cylinders lie within a closed range indicating a reduced effect of residual stresses.
d) The effect of residual stresses was evident towards the higher aspect ratio.

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