"EFFECT OF AUTOFRETTAGE ON MICROSTRUCTURE AND HARDNESS OF THE AL CYLINDRICAL STRUCTURE"

Neelkant Patil[1], Shivarudraiah[2], Amaresh Kumar D[3]
[1]Research Scholar, Department of Mechanical Engg. University Visvesvaraya College of Engineering, Bangalore, Karnataka.
[2]Professor, Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore, Karnataka.
[3] Assistant Professor, Department of Mechanical Engineering, Sri Venkateshwara College of Engineering, Bangalore, Karnataka.

Abstract: The objective of the research work was to investigate the effect of Autofrettage on the microstructural and hardness of the Al cylindrical structure, developed by hydraulic pressurization at 120MPa using UTM. It was obtained by inserting an oversized EN24 steel mandrill into the vessel which resulted in inducing the residual stresses after removal of the load. The strength of the vessel was determined along with the radial thickness of the cylinder by using Brinell's hardness. Autofrettage process on Al cylindrical structure changed the inner diameter from 25.5mm to 27.84 by the percentage of 9.1607. The Brinell hardness value of the aluminum cylinder was more an inner radial surface than that of outer surfaces. In conclusion, Autofrettage increased strength, durability and fatigue life cylindrical components.

Index Terms **– Autofrettage, Al cylinder, microstructure, hardness.**

I. INTRODUCTION

Modern industrial application cylindrical vessels are widely used in the transportation of chemicals and steam with a higher pressure. They are subjected to higher pressure and temperature during transportation [1]. Due to continuous operation, the cylindrical vessels are failed prematurely. Replacing these components is one of the expensive tasks. The many technologies already used to strengthen the pressure cylinder for longer life such as fiber winding on the cylinders, wire winding, metal lining, etc [2]. Recently the cold working process was used for improving the strength of the pressure cylinder effectively. Among cold working operation, the Autofrettage technique is a promising technology to enhance properties of cylindrical components [3]. Autofrettage is the recently developed technology in which Autofrettage pressure is applied at the one end of the cylinder (another end is closed) due high-pressure internal surface of the cylinder is deformed beyond the elastic limit, residual stresses are formed when a sudden release of working pressure [4]. Residual stresses at an inner portion of cylindrical cross-section but Bauschinger effect can decrease compressive residual hoop stresses near bore of cylinder hence components are widely used such that nuclear power plant, chemical industries, aerospace, and battle gun barrel many other applications [5-7].

Haghpanah et al [8] examined the residual stresses are induced by Autofrettage process in layered and functionally graded metal-ceramic composite cylindrical vessels. Salzar et al [9] to create hybrid gun barrels with an inner liner of traditional steel and an outer reinforcement of metal matrix composite material, to obtain the strength and fatigue resistance of steel gun barrels. Ale greet al [10] author presented an autofrettaged high pressure thick-walled cylindrical vessel for food industry working at an internal pressure is about 500 MPa, and material of vessel was 15-5PH stainless steel it shows a stronger Bauschinger effect due this fatigue life of the components are investigated by using ASME code. Hung-Wen Chen et al [11] in his paper analyzing the stress distribution in thick fiber-reinforced composite cylindrical tube structure integrate with shape memory alloy(SMA) under an internal 220 MPa, through-thickness stress distribution tendency and reduction in maximum stress by taking up of different SMA layer arrangement and temperature. Author [12] analyze the influence of material damage and Bauschinger effect on the autofrettaged of thick-walled cylindrical pressure vessels are solved by using finite element method Anup et al [13] studied the design and performance of hydraulic Autofrettage using universal testing machine compare the experimental result of hoop stress with the analytical and numerical result. No research work focuses Autofrettage by hydraulic compression using UTM and rotating Autofrettage technique used for enhancement of life of the cylindrical components. The objective of the work was to develop the Autofrettage setup, conduct autofrettaging of the Al cylinder, and conduct microstructural and hardness properties of the autofrettaged cylindrical structures.

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 work, Al6061 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.

Autofrettage process is done by using Universal Testing Machine, steel rod of length 130mm is connected to the tapered rubber cork material that is used as a mandrill. The cylindrical structure is filled with 1/3rd of SAE-40 Grade oil, inserting the steel mandrill for the open end of the cylindrical structure. Gradually load increased vertical direction means that radial hydraulic compression along with the thickness of the cylinder, the load increased up to the inner layer of the cylinder deformed beyond the elastic limit. To prevention of the outer diameter expansion to make wire winding on the cylindrical structure. This constraint was given to avoid the deformation of the outside diameter of the cylinder which will prevent the plastic deformation as shown in the figure. The tapered end of the steel-EN24 rod is inserting into the cylinder

Autofrettage process Al6061 cylindrical structure which will produce radial expansion. Hydraulic compression by UTM as shown in the above figure provides the required load to move the mandrill into the Al cylinder operating directly on the rear end of the steel rod (mandrill) which forms an autofrettaged aluminum cylinder**.** Before the Autofrettage process, the interference between the maximum diameter of the mandrill (steel rod) and the cylinder was calculated. The radial displacement of the bore and the maximum internal pressure was also calculated which will produce desired overstrain. The initial interference can be easily calculated by the sum of the radial displacement of the tube and the elastic radial contraction of steel mandrill due to its pressure observing the grain size change in the vicinity of the thickness is an important part of the study. Scanning Electron Microscope was used to observe the grain size. Specimen for SEM images was prepared by cutting the specimen to small size near to the hole surfaces. The specimen after cutting, the surface for which the SEM images are polished on the sandpaper of 60, 80, 100, 200, 400, 800,1000 and 1200 in the same order where every time the specimen was polished in next abrasive size the perpendicular direction of polishing to eliminate the lines formed due to sandpaper. The polished specimen was later undergone etching process by the usage of an etchant which is Hydrofluoric acid (HF-60% dilution). Hardness testing measurement conducting on autofrettaged aluminum cylindrical structure, using Brinell hardness testing to find the hardness value along radial (thickness) direction of the cylinder.

III. RESULTS AND DISCUSSION

Fig. 1 shows the microstructure of the effect of cold hole expansion holes on grain boundaries of a) without cold hole expansion and b) 2% cold hole expansion. Fig. 1 (a) shows the clear grain structure, but no compression zone, no plastic deformation and no elastic deformation between the grain boundaries. On the other hand, Fig. 1(b) shows no clear grain boundaries due to the domination of layer by layer compression zone, plastic deformation and elastic deformation. It shows plastic and elastically deformed microstructure of cold hole expanded holes. Both plastic and elastic deformations zones are seen layer by layers and Forms Island with irregular shapes, white color batches are plastic.

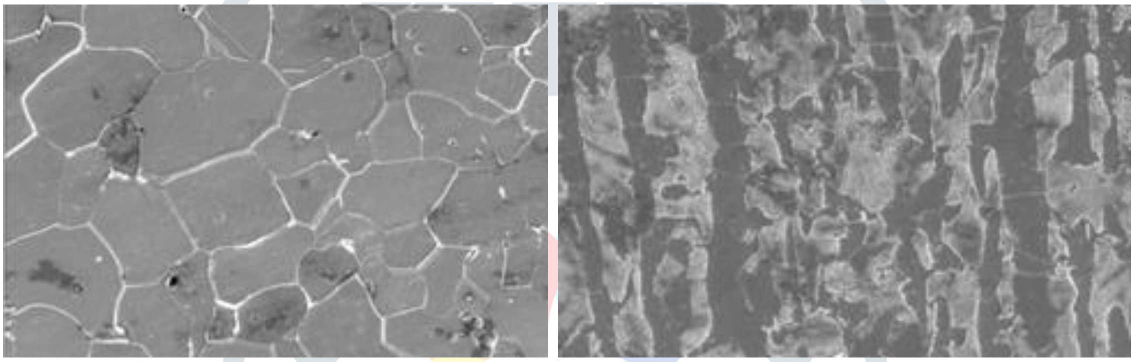

Fig.3. 1 Comparative studies between a) without and b) Autofrettage cylinder

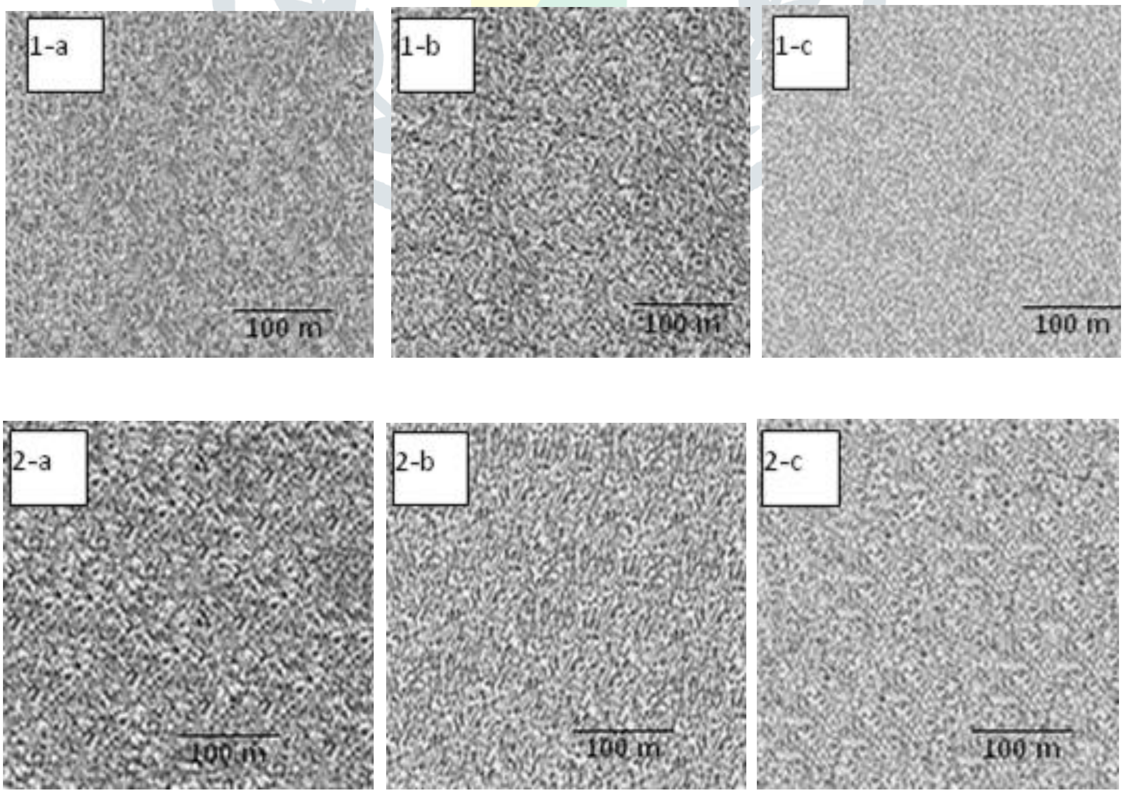

Fig. 3.2Microstructure of Autofrettage specimens 1) as cast, 2) 0.5 % autofrettaged and 3) 1% autofrettaged (a- Entrance, b- middle and c-end of the specimens)

The microstructure of Autofrettage for different process parameters as shown in Fig.2. The changes in grain size and grain orientation were due to the Autofrettage. The microstructure of the hole surface at three different locations, starting, middle and ending were obtained. The location showed the effect of the first point in the process. The micrograph presents the orientation and texturing of the grains along the forming direction. Also, fragmentation of the relatively larger sized particles present in the raw material presented elongated streaks. Observation of the microstructure shows the presence of undissolved large and fine grain particles without grain orientation.

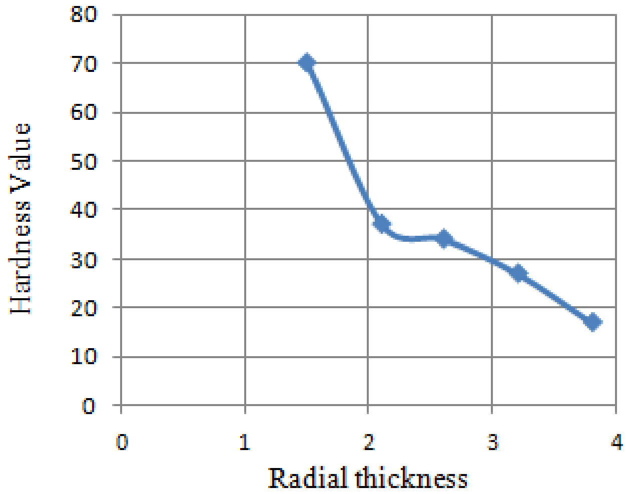

Fig. 3.3 Plot between hardness value and radial thickness

Hardness testing measurement conducting on autofrettaged aluminum cylindrical structure, using Brinell hardness testing to find the hardness value along radial (thickness) direction of the cylinder as shown in the given **Fig. 3.** Fig. shows that graph Plot between hardness value and the radial thickness of autofrettaged aluminum cylindrical structure. From the graph, it can easily infer that hardness value nearer to the inner layer of the cylindrical structure higher than the outer radius of the cylinder hence it and indication of after Autofrettage the inner surface is highly strengthening than the outer surface of the cylinder.

IV. CONCLUSION

a) Experimental studies of the hydraulic compression test for the aluminium cylindrical structure using UTM machine were undertaken
b) After hydraulic compression thickness of the cylindrical structure reduced along the circumferential direction, and residual hoop stresses increases of the same radial thickness direction
c) The grain size had become finer near the hole and coarse as moved away from the hole which increases the strength near the hole.
d) Brinell hardness testing conducting along the thickness direction of autofrettaged aluminium cylindrical structure, finally concluding as hardness value at nearer inner surface greater than the outer surface of the cylindrical structure.

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