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PARAMETERS CONTROL FOR RE-AUTOFRETTAGE OF THICK WALLED HYDRAULIC CYLINDERS FOR HEAVY ENGINEERING APPLICATIONS

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Abstract:
Autofrettage is the process used for thick cylinders, in which one can apply above elastic stress equivalent pressure to a hydraulic cylinder and then such cylinder will give reduced stress pattern as compared to earlier stress which was generated in same cylinders. Further to it in Re-Autofrettage heat soak treatment is proposed, where Heat treatment process is introduced in 1st Autofrettage and second 2nd Autofretage to get uniform stress distribution as compared to earlier Autofrettage treatment. For both the processes i.e. Autofrettage and Re-Autofrettage controlling parameters like Hydraulic Pressure, Time, Heating time, Heat Treatment process etc. are crucial parameters which one can control for exact results.

Keywords: Autofrettage, Re-Autofrettage, Heat Soak Treatment etc.

1.0 INTRODUCTION:

Pressure vessels that are thick and cylindrical, like those used in chemical and artillery industries, Heavy equipment industry are designed to withstand very high pressure. Before normal use, many engineering components and structures are subjected to overloads that exceed their design operating level. Autofrettage is the process used for thick cylinders, in which one can apply above elastic stress equivanant pressure to a hydraulic cylinder and then such cylinder will give reduced stress pattern as compared to earlier stress which was generated in same cylinders. Further to it in Re-Autofrettage heat soak treatment is proposed, where Heat treatment process is introduced in 1st Autofrettage and second 2nd Autofretage to get uniform stress distribution as compared to earlier Autofrettage treatment as shown in figure-1. However Wire winding is the safest method in Autofrettage as compared to other one [6]

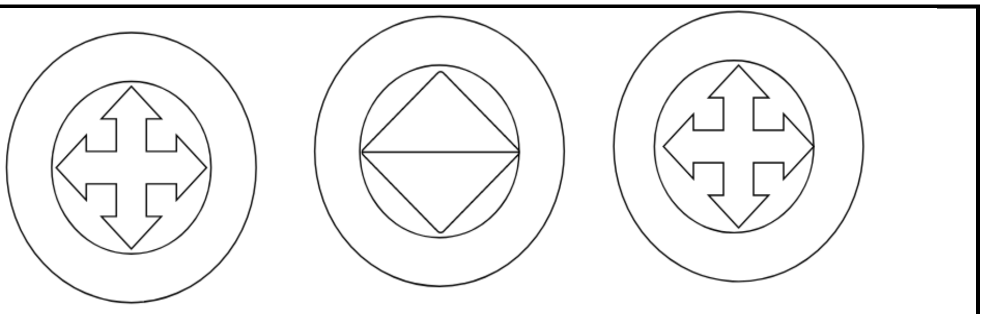

Figure-1: Processes in Re-Autofrettage

Furthermore, the effect of autofrettage on the shakedown behaviour of thick cylinders subjected to constant internal pressure and cyclic thermal loading is discussed. The results show that the thermal limit load depends on the thickness ratio and the operating pressure and that the optimum autofrettage pressure depends on the thickness ratio, the operating pressure, the strain hardening exponent and the thermal load. The proposed solution for the optimum autofrettage pressure agrees very well with the FEM.[5]

1.1 Importance of Parameter Control of Hydraulic Cylinder

Following steel made cylinder is considered for deciding parameters as per Table-1 for Autofrettage & Re-Autofrettage.

Mechanical Properties of Steel made Hydraulic Cylinder	Value
Gauge Length of selected Cylinder	50 mm
Specimen shape	Round
Yield Load	30.03 KN
Ultimate Load	50.08 KN
Yield Stress	383.87 N/mm^2
Ultimate Stress	640.16 N/mm^2
Percentage Elongation	24.80 %

Table- 1: Major Mechanical Properties of Hydraulic Cylinder

Steel made Cylinder with following input parameters as per Table-2 are considered for the study.

Available Cylinder Parameter	Value
Internal Diameter of Hydraulic cylinder	50 mm
Outside diameter of Hydraulic cylinder	60 mm
Length of Hydraulic Cylinder	62 mm
Thickness of Hydraulic cylinder	5 mm
Poisson's ratio of hydraulic cylinder	0.3

Table -2: Available Input Parameters for hydraulic cylinders

The residual stress in cylinders reduces the carrying ability of the component and the resisting area, thereby reducing cylinders stiffness and stability. [7] In steel made Hydraulic Cylinders following important parameters need to be controlled. Hydraulic Internal Pressure during Autofrettage.

- Temperature control during Heat treatment
- Hydraulic Internal Pressure during Re-Autofrettage
- Controlled Heating and cooling rate during Autofrettage and Re-Autofrettage.
- Appropriate Soaking time.

1.1.1 Internal Hydraulic Pressure during Autofrettage.

Hydraulic internal pressure during Autofrettage can be the crucial parameter by which one can know the minimum pressure for Autofrettage and for start of Plastic deformation as well. According to Clavarino's equation and Table 1 & Table 2 Values, one can find 74.40 MPa as a Minimum hydraulic pressure for above said cylinder.

1.1.2 Temperature control during Heat Treatment

In heat soak it can be treat the cylinder similar to Annealing. Annealing consists of heating the steel to above the recrystallization temperature, soaking at the same temperature, and then cooling it up to normal temperature. Heating of the steel during annealing allow the movement of iron items, resulting in the absence of dislocations and formation and growth of newly formed grains of different sizes. Annealing of a heavily cold worked steel sheet can be divided into three physically distinct but normally overlapping stages, namely recovery, recrystallization, and grain growth. [2]

Figure-2 shows heating and cooling of cycles with hot and cold points during annealing process. Hot points were seen at outer periphery. Cold points were observed at meddle of cylinder walls.

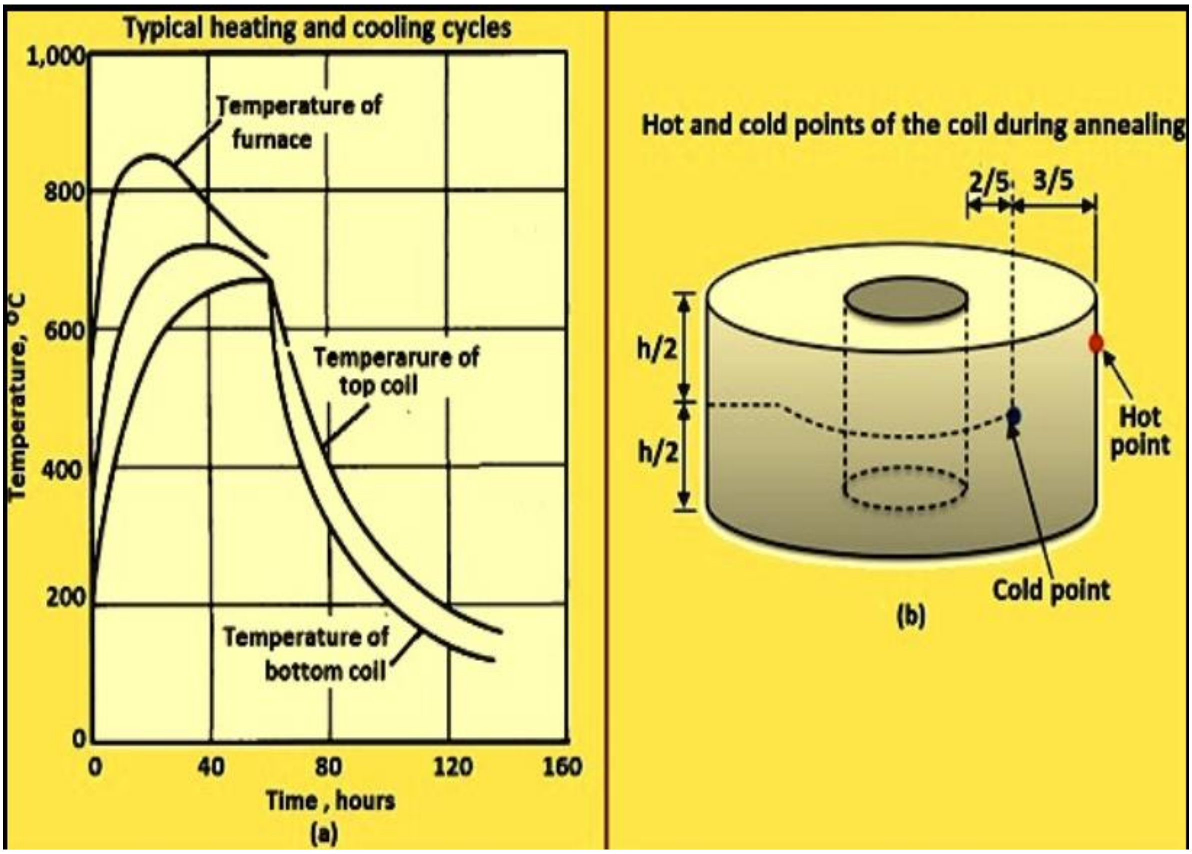

Figure -2: Heating and cooling cycles with hot and cold points during annealing

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Figure-3 shows the variation of hardness value w.r.t. carbon contents of steel. It can be clearly visible that Hardness value of steel for 700^0 C is increased when % carbon in steel is increased from 0.22% to 0.24%. For carbon percentage 0.24 to 0.36 % similar trend is observed.

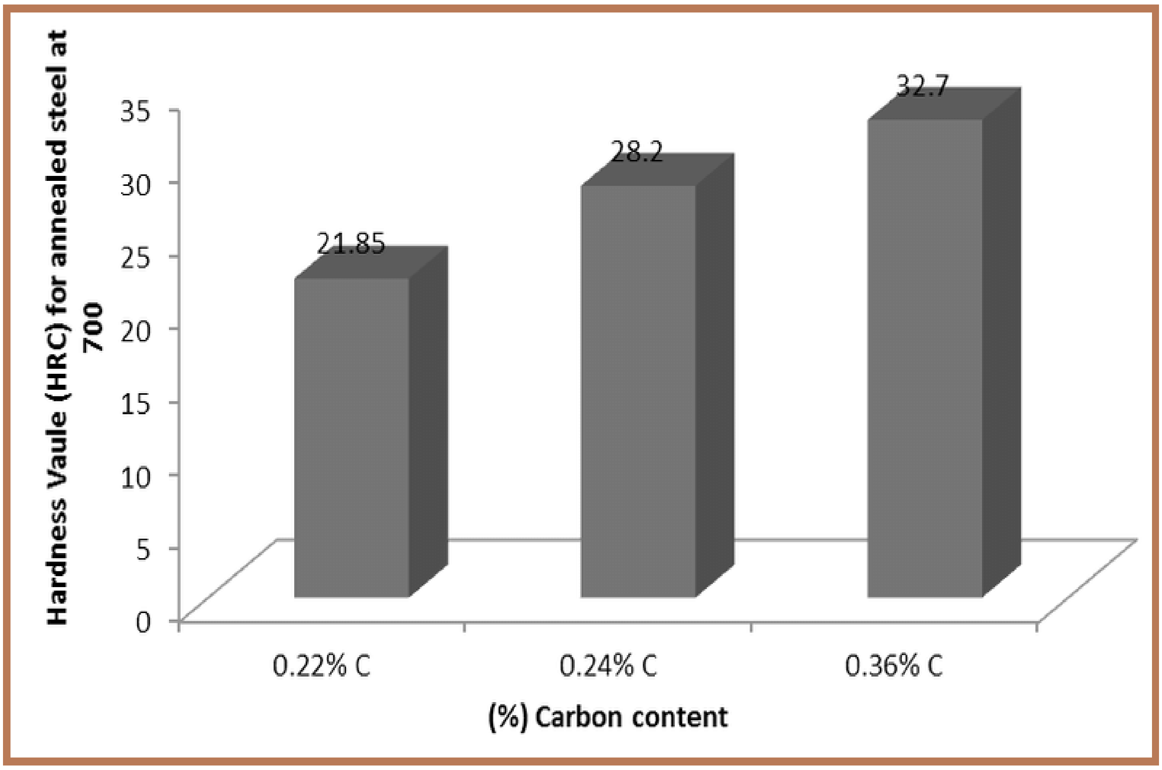

Figure-3: Variation of hardness value as per carbon contents

For steel made hydraulic cylinder, during heat treatment annealing can be done for heat soak treatment with 20^0 per hour Heating rate up to 761^0 C. Annealing is expected to refine grains, form new microstructure from it, soften and restore ductility of material and improve work ability of deformed materials [1]

1.1.3 Hydraulic Internal Pressure during Re-Autofrettage

Re-Autorettage and Autofrettage both are similar processes but Re-Autofrettage is mostly done after Autofrettage and Heat treatments (Heat soak). Normally one can keep the same pressure otherwise in exceptional cases it can be increased by 10-15 %. However Autofrettage pressure can be decided as per the Clavarino's equation which is used for Closed Thick cylinders.

1.1.4 Controlled Heating and cooling rate during Autofrettage and Re-Autofrettage

Heat treatment has the effect of reducing or eliminating microscopic dislocations, while macroscopic residual stresses remain due to the previous overload. Assuming that the material actually reacts like a new material with a pre-existing residual stress field at the next overload, the plastic strain and thus the Bauschinger effect is drastically reduced during the second and subsequent Autofrettage. This behaviour is comparable to the Autofrettage of pre-shrunk pipes, where there has been no earlier plastic deformation [2].

Normal heating and cooling rate can be considered as 20^0 per hour to 25^0 per hour.

1.1.5 Appropriate Soaking time post heat soak treatment.

As we know there are three stages of heat treatment:

- Heat the metal slowly to ensure that the metal maintains a uniform temperature
- Soak, or hold, the metal at a specific temperature for an allotted period of time
- Cool the metal to room temperature

The results showed that the microstructure of the ferrite matrix with mass dispersed cementite particles was formed by the decomposition of martensite in medium carbon martensitic steel after hot rolling.[6] Pure kinematic hardening analysis is also not precise for estimating residual hoop stress induced in Hydraulic cylinders by Autofrettage.[9]

The cold-drawn steel with a low carbon content and a deformation of 40% was annealed at 900 degrees Celsius for 10, 20, 30, 40, 50 and 60 minutes. Tensile, Charpy and Brinnel hardness tests were performed to determine the yield strength, tensile strength, notched impact strength, ductility and hardness of the annealed steel with increasing soaking time. The yield strength, tensile strength, hardness and impact toughness of the steel showed a continuous decrease in values with increasing soaking time up to 60 minutes.[3]

Normally 30-45 Minutes is standard soaking time for Thick cylinders up to 25 mm thickness. After that impact of hole drilling is also a very important parameter for effectiveness checking. Residual stresses in a welded component can lead to deformations and dimensional fluctuations, which in turn affect the reliability and service life of the component. Detailed knowledge of residual stresses would be helpful in assessing the functional requirements of the component.[4]

2.0 CONCLUSION:

As per above points controlling the said parameters are very important aspects of Autofrettage & Re-Autofrettage. Further to this impact of the variations in parameters can be checked by Residual Stress Analysis in further study.

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