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Effect of Corrosion Attack on Pall Ring in Hydrocarbon Industry

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Abstract

This study investigates effect of corrosion attack on pall ring in hydrocarbon industry.Pall ring are widely used in hydracarbon industry for liquid contact in distillation, absorpation and chemical reactions.This research involved testing surface morpohlogy and elements analysis (Scanning Electron Microsopy and energy Dispray X-Ray), electrochemical testing and mechanical testing (tensile and hardness). A sodium chloride (3.5% NaCl) was used as the electrolyte due to its similarity to the ionic composition of seawater.SEM analysis showed there have corrosion in pall ring in three year process.Electrochemical test showed corrosion rate in the presence used 3.5% NaCL and mechanical properties show the impact material strength or hardness. The findings of this research, offer a comprehensive understanding of how prolonged industrial use influences the integrity, durability, and functional reliability of Pall rings in demanding operational settings.

1. Introduction

Pall rings are a type of random packing commonly employed in the chemical industry to improve mass transfer processes in distillation columns, absorption towers, and other chemical reactors [1]. The Pall rings are designed to decrease liquid channeling and holdup, resulting in a lower pressure drop across the packing bed. This leads into lower energy consumption during operation. Pall rings have both inner and outer surfaces, along with vertical tabs inside. These features increase the surface area where gas and liquid can come into contact. A larger surface area helps improve mass transfer between the two phases. This is important for processes like chemical reactions, absorption, and separation. Pall ring is widely used in industrial applications, particular in chemical processing where material degradation over time can impact performance, efficiency and safety. However, there is often limited information available regarding the changes in material composition and surface structure of pall rings after prolonged industries use. Industries may continue using compromised equipment, leading to process inefficiencies or potential failures. Pall ring also as vital components in mass transfer operations and also frequently used in corrosive environments such as chemical processing, that can cause corrosion long term exposure to such environments can lead to material degradation and loss of structural integrity. Pall ring is widely used in industrial processes for mass and heat transfer, so they are exposed to mechanical stresses and harsh operating conditions. Failure to understand the mechanical properties can lead to poor performance or premature failure. The first objective is to identify the microstructure of the surface and compare the elemental surface composition of pall ring samples. Secondly, the objective is to evaluate corrosion rate of pall ring. The lastly objective is to study structural integrity of pall ring overtime in corrosive environment.

2.0 Methodology

2.1 Visual Aids

There are two different sample were given and need to be testing. The one sample, is a new pall ring and the second pall rings there are used. As shown in Figure 1, the first picture show new pall ring appears to be in pristine condition, with a clean and smooth surface and no visible signs of corrosion or physical damage while the second picture show pall ring which shows clear signs of surface degradation. The surface exhibits corrosion marks, discoloration and potential pitting-indications of long-term exposure to harsh.

(a) (b)

Fig. 1 *Visual aids (a) New Pall Ring; (b) Pall Ring Used*

2.2 Characterization Testing

In this study, the test conducted to determine the results of surface morphology, microstructure, any microstructural and elemental composition of pall ring. There are two machines used to obtain the result which is scanning electron microscopy (SEM) and energy dispersive X-Ray (EDX).

2.2.1 Scanning Electron Microscopy (SEM)

The scanning electron microscope uses a focuses beam of high energy electron to generate a variety of signals at the surface of solid specimen. The signal from the scanned derives from electron detector [2]. The electron that interacts with the atoms that make up the sample produce a signal that contains information about the surface morphology, microstructure characterization of the samples. Figure 2 show scanning electron microscopy

Fig. 2 Scanning Electron Microscopy

2.2.2 Energy Dispersive X-Ray (EDX)

Energy dispersive X-Ray is an elemental analysis technique that generates distinctive X-Ray in specimen atoms using incident beams. Energy Dispersive X-Ray is used to identify the elemental composition of materials pall ring down a spot size for a few microns, and there to create elements composition maps over a much broader raster area. Section headings should be left justified, bold, with the first letter capitalized and numbered consecutively, starting with the Introduction.

2.3 Corrosion Mechanism

In this research, the sample preparation is precise to ensure that all planning processes to methodology can be put into practice. The preparation process includes several stages such as soldering, mounting, grinding and polishing. There are two different sample and each sample was cut to a size 1cm x 1cm.After cut the sample, the sample will through the process soldering, where a wire is attached to sample. The purpose of the wire is to enable current flow when the sample is connected to a potentiostat or Galvano stat. Then, it will through cold mounting process which is to protect and preserve the side surface and extreme edges from detection and to focus only on the desired surface area to be tested. The epoxy such as resin and hardener were mixed in a 2:1 ratio for cold mounting. After the cold mounting, the sample undergoes grinding stage. Grinding process to removed defects, imperfections and any contaminates present. The sample ground manually using hand grinding machine by using emery paper varying grit size which is 240, 320, 400 and 600.The final step is the preparation is polishing which eliminates fine scratches, swirl marks and the other miner imperfections. Polishing ensures a clean and even surface for allowing accurate analysis. Figure 3 show the sample mounting.

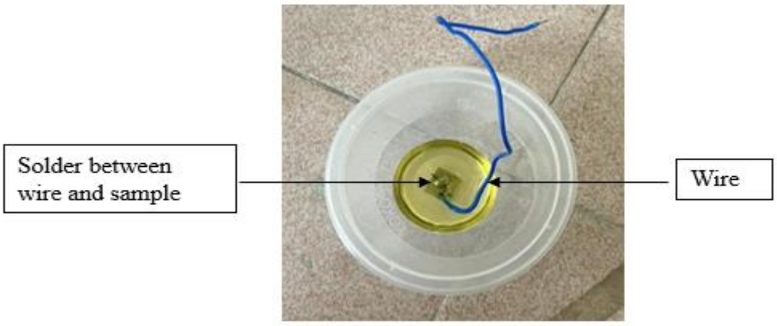
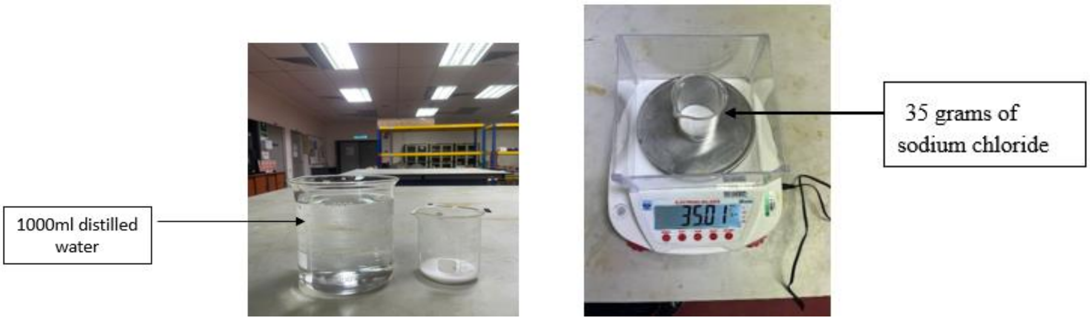


Fig. 3 Sample Mounting

2.3.1 Electrolyte

An electrolyte is a conductive liquid solution that contains free ions, enabling the flow of electric current. In this research, a sodium chloride (NaCl) was used as the electrolyte due to its similarity to the ionic composition of seawater. A 3.5% NaCl solution was prepared, which mimics the corrosive environment found in marine and industrial settings as shown in Figure 4. The solution contains equal concentrations of Na^+ and Cl^- ions, which facilitate electrochemical reactions on metal surfaces. To prepare the solution, 35 grams of sodium chloride was dissolved in 1000 milliliters (1 liter) of distilled water and stirred thoroughly until fully dissolved. Distilled water is used in electrolyte preparation to ensure purity, eliminate external ion interference, and maintain the accuracy and reproducibility of corrosion testing results.



(a) (b)

Fig. 4 3.5 NaCL a)1000ml distilled water b) 35 grams sodium chloride

2.4 Mechanical Properties

The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and loads. There are use hardness and tensile machine.

2.4.1 Tensile Test

Tensile Testing machine are designed to apply a tensile (pulling) force a material sample until it fails. In this research, ASTM E8/E8M standard is used to measure tensile test of the pall ring specimen [4-6]. The standard ASTM E8/E8M specifies the use of machined round or flat specimens with precise dimensional tolerances, the adapted procedure aimed to maintain the core principles of uniaxial tensile loading, controlled strain rate, and failure observation. The tests were carried out using a universal testing machine (UTM), and data such as yield strength, ultimate tensile strength, elongation at break, and Young's modulus were obtained from the resulting stress-strain curves. There are two different specimen which is one sample, is a new pall ring and the second sample pall rings that have that have undergone processing for three years. To prepare the specimens, the cylindrical pall rings were initially flattened using a hammer to achieve a uniform sheet profile. Figure 5 show sample shape during tensile test,

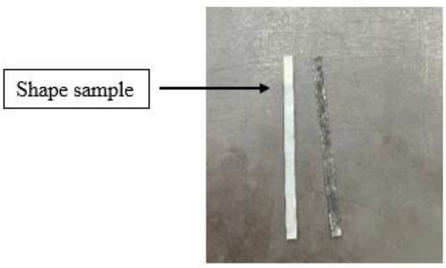


Fig. 5 Shape Sample

2.4.2 Micro Vickers Hardness

Micro Vickers hardness test is the standard method for measuring the hardness for the metal. It is widely used method to measure hardness of materials, particularly thin sections and small parts. During preparation and testing, the sample is first embedded in a mounting resin to hold and stabilize. The mounted surface is then ground and polished until it becomes perfectly flat and smooth.

3. Result/Discussion

This section presents the findings of the study, focusing on characterization The results from scanning Electron Microscopy (SEM), Energy-Dispery X-Ray analyses are discussed to highlight the microstructure and elemental composition. The result for electrochemical is highlight about corrosion rate of pall ring and mechanical properties such as tensile and hardness are to show the impact material strength or hardness of pall ring.

3.1 SEM Analysis

Figure 6 show the new pall ring's which appears smooth with clearly defined machining or rolling lines. There surface was smooth and clean, indicating no signs of corrosion or mechanical wear. In contrast, the pall ring that used showed considerable surface roughness with multiple dark spots that suggest the presence of localized corrosion such as pitting corrosion.

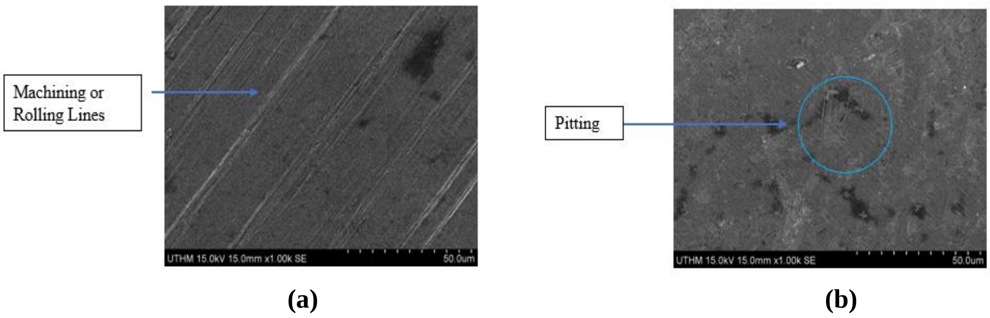


Fig. 6 SEM analysis (a) New Pall Ring; (b) Pall Ring Used

3.2 EDX Analysis

Based on the Table 1, chromium (Cr) in pall ring used is higher than new pall ring because indicates Cr surface enrichment, likely due to formation of a passive oxide layer. Nickel (Ni) in pall ring have been in the process for three years is absent but new pall ring result are present. Iron (Fe) in pall ring have been in the process for three years higher than new pall ring and it is relative increase due to loss of Ni content. The elemental composition of the new pall ring clearly corresponds to that of Stainless Steel 310, which is known for its high Cr and Ni content. However, the surface composition of the pall ring used does not clearly indicate Stainless Steel 310, likely due to material degradation from prolonged environmental exposure, corrosion, and oxidation.

Table 1 Comparison Element Different Sample with Stainless steel 310

	Element		
	CR	FE	NI
New Pall Ring	28.26	51.65	20.08
Pall Ring used	34.40	63.97	-
Stainless steel	24-26	Balance	19-22

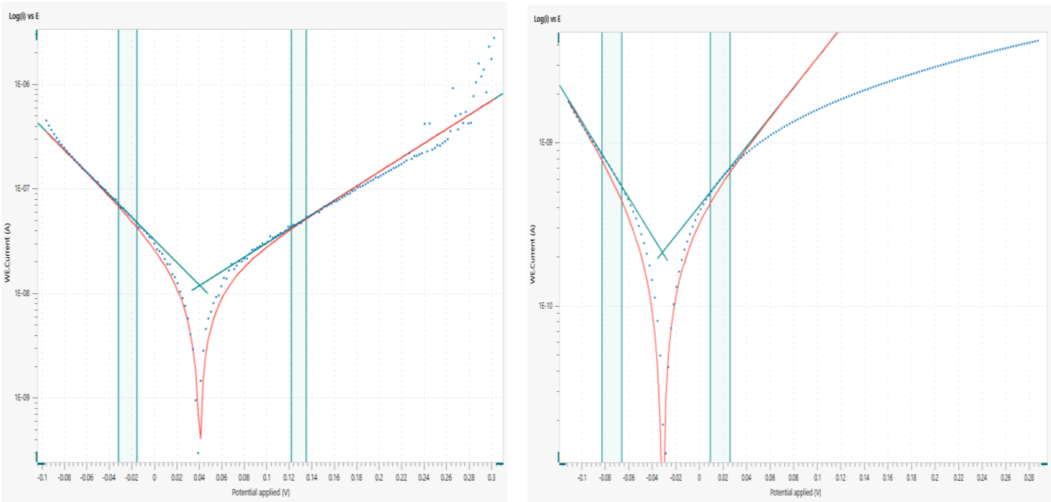
3.4 Tefal Analysis

Tefal test is conducted using a three-electrode setup to measure the electrochemical behavior of SS310 pall ring in a chloride-rich environment. The test solution consists of 3.5% sodium chloride (NaCL),) as the electrolyte due to its similarity to the ionic composition of seawater. The test followed the procedures outlined in ASTM G5, ASTM G59, and the corrosion rate calculation was based on ASTM G102.The data corrosion rate are presented in Table 2 were analyzed in Met Rohm Auto lab Software.

Table 2 Data Corrosion Rate

	NEW PALL RING	PALL RING USED (3 YEAR-PROCESS)
Corrosion rate	1.3853 x 10^-4mm/y	2.1442x10^-6mm/y
Polarization	2.0731x10^6 Ω	2.0346x10^8 Ω
[ba]	147.01mV/dec	204.96mV/dec
[bc]	92.911mV/dec	149.61mV/dec
Ecorr,	0.03911VREF	0.0073216 VREF
Ecorr	0.040545Vref	0.027858 Vref
icorr	1.1924x10^-8 A	1.8457x10^-10 A
icorr	1.1924x10^-08 A/cm^2	1.8457x10^-10 A/cm^2

Based on Table 2, it can observe the corrosion rate of the new pall ring was determined to be 1.3853 x 10^-4 mm/year, whereas the three-year processed pall ring showed a much lower rate of 2.1442×10^{-6} mm/year. This data clearly demonstrates that the three-year processed pall ring is more resistant to corrosion. The lower corrosion rate is attributed to the formation of a passive oxide film over time during its use in an industrial environment. This passive layer reduces the rate of metal dissolution, thereby lowering the corrosion current (icorr) and increasing polarization resistance. In contrast, the new pall ring, which lacks such protective surface conditioning, has a more reactive surface when first exposed to the chloride solution, resulting in a higher corrosion rate and higher electrochemical activity. Figure 7 a tefal curve for two different pall rings.



(a) (b)

Fig. 7 Tefal Analysis a) New Pall Ring b)Pall Ring Used

3.4 Result Tensile Test

Pall ring sample was tested using a tensile test. The purpose of tensile test is to analysis tensile strength, yield strength and modulus young. Figure 8 shows the bar chart comparison of ultimate stress for pall ring.

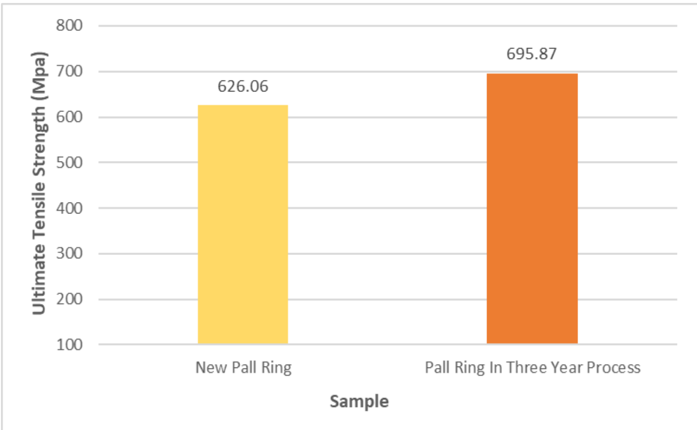


Fig. 8 Comparison Ultimate Stress

From Figure 8, it can be seen ultimate tensile strength pall ring in three-year process is higher than new pall ring. This indicates that the pall ring used underwent a strain hardening process, where prolonged exposure to mechanical stress and elevated temperatures caused microstructural changes that made the material harder and stronger. The new pall ring indicates the value UTS IS 626.06Mpa and this value is consistent with the expected performance of stainless-steel materials like Stainless Steel 310, which is widely used in industrial applications due to its strong resistance to heat and corrosion. The comparison of Ultimate Tensile Strength (UTS) values between the two Pall Rings indicates that the material not only retains its original strength but may actually become stronger due to strain hardening. This demonstrates the material's long-term reliability, making it well-suited for continuous use in demanding industrial environments.

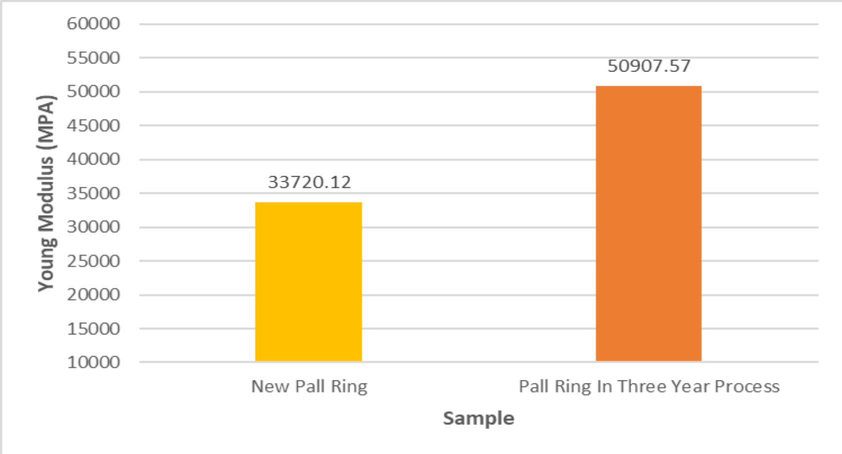


Fig. 9 Comparison Young Modulus

Figure 9 shows a bar chart indicating that the Pall Ring in three years has a higher Young's Modulus than the new Pall Ring. This is because the 3-year-used Pall Ring has undergone prolonged exposure to mechanical stress and high temperatures, leading to microstructural changes that make the material stiffer and harder. While the new pall ring shows a lower Young's Modulus as it is still in the annealed condition, having not yet been subjected to operational stresses or heat. As a result, the new Pall Ring remains more ductile and less stiff. Figure 10 below shows a bar chart comparison of yield strength pall ring.

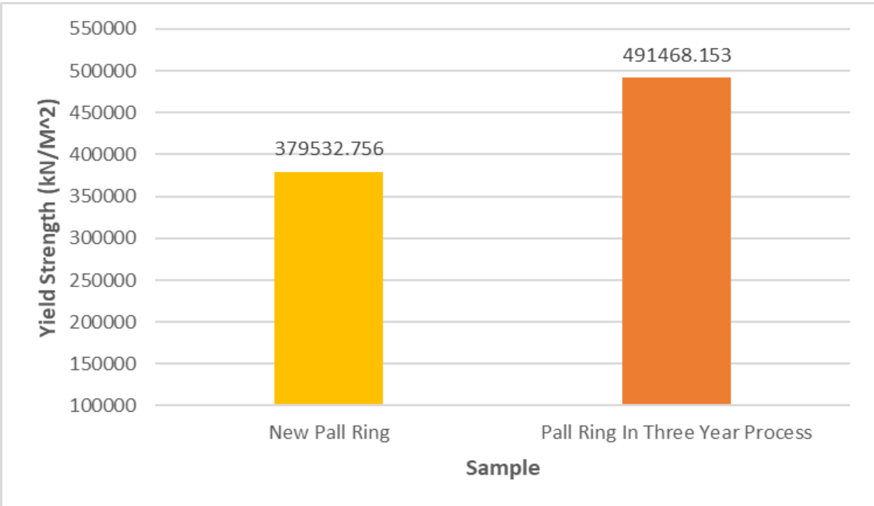


Fig. 10 Yield Strength

Figure 10, it can be observed pall ring in three-year process are highest yield strength than new pall ring. Pall ring in three-year has strengthened and become more resistant to plastic deformation. This is more likely due to the impacts of strain hardening and microstructural changes caused by continuous operating exposure. While the new pall ring remains annealed and it is with minimal internal stress, contributing to its lower yield strength.

3.4 Result Tensile Test

Figure 11, the graph below shows a comparison of hardness values between the two samples. Each sample was tested at four different points to obtain hardness value for comparison.

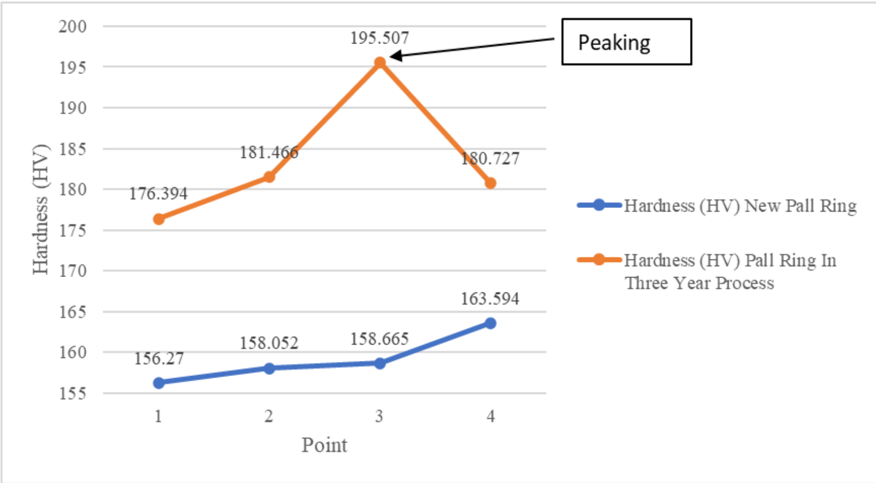


Fig. 11 Comparison Hardness Test

The New Pall Ring maintains consistent stable and moderate hardness across all four points, between 156.27 HV and 163.59 HV. The Pall Ring three year in process shows a significant increase in hardness, peaking at 195.51 HV at Point 3 and followed by a slight decrease at Point 4. The new pall ring has a steady rise since it has not aged and has not seen any microstructural changes as a result of mechanical load or high temperatures. The pall ring used increase from Point 1 to Point 3 it is due effects of mechanical and thermal stress while drop at point 4 could be due to reduced exposure, early-stage surface degradation, which slightly lowered the surface hardness.

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4.0 Conclusion

In short, the investigation effect of corrosion attack on pall ring in hydrocarbon industry has to come end. There are three main objectives in this study which have accomplished at the end of study. The first objective was to identify the microstructure of the surface and compare the elemental surface composition of Pall ring samples. For SEM analysis show new pall ring had a clean, smooth surface with no signs of corrosion and pall ring in three-year process exhibited significant surface roughness, micro pit and degradation. EDX result indicated compositional changes with the pall ring in three-year process showing increased chromium and iron content but the absence of nickel, suggesting material degradation and surface oxidation over time Furthermore, EDX can determine whether the material of the pall ring is stainless steel 310.The second objective is to corrosion rate of pall ring under various environmental. Corrosion testing by using electro indicated that the pall ring in three-year process had a much lower rate attributed to the formation of a passive oxide film that enhanced corrosion resistance. Lastly, the objective is to identify mechanical properties of pall ring such as tensile and hardness. Tensile analysis showed that pall ring in three years had higher ultimate tensile strength, yield strength and young modulus than new pall ring. This demonstrates strain hardening due to prolonged exposure to mechanical stress and high temperatures during industrial use. While, hardness testing, the pall ring in three-year average hardness is much better than new pall ring. Overall, this study demonstrates the long-term durability and reliability of stainless steel 310 pall rings in harsh industrial environments.

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