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DÚPLEX STAINLESS STEEL WITH SILICON CARBIDE COATING TO AVOID STRESS CORROSION CRACKING IN GENERATORS OF TRANSFORMERS AND BESIDES RAISE THERMAL CONDUCTIVITY, EFFICIENCY

ACERO INOXIDABLE DÚPLEX CON RECUBRIMIENTO DE CARBURO DE SILICIO PARA EVITAR EL AGRIETAMIENTO POR CORROSIÓN BAJO TENSIÓN EN GENERADORES DE TRANSFORMADORES Y, ADEMÁS, AUMENTAR LA CONDUCTIVIDAD TÉRMICA Y LA EFICIENCIA

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Dúplex Stainless Steel with Silicon Carbide Coating to Avoid Stress Corrosion Cracking in Generators of Transformers and Besides Raise Thermal Conductivity, Efficiency

Acero inoxidable dúplex con recubrimiento de carburo de silicio para evitar el agrietamiento por corrosión bajo tensión en generadores de transformadores y, además, aumentar la conductividad térmica y la eficiencia

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ABSTRACT

The novel 18Cr-18Mn duplex steel arose from the need to prevent catastrophic failures caused by stress corrosion cracking in generator retaining rings. In this work, we propose using this material with a silicon carbide coating to prevent SCC failures in generators, which cause cracking in the materials. Since 18Cr-18Mn duplex steel is not susceptible to stress corrosion cracking, the SiC coating is expected to increase the steel's thermal conductivity and has also been used as a corrosion inhibitor. The steel will be developed, and its composition and microstructure will be characterized using SEM and X-ray diffraction equipment. Electrochemical tests of potentiodynamic polarization and electrochemical impedance will be performed to determine its corrosion behavior. Furthermore, its mechanical behavior will be characterized by performing hardness and/or microhardness tests and tensile tests to obtain its engineering properties. It is expected to develop a steel with excellent properties of high thermal conductivity and good resistance to cracking corrosion that is suitable for manufacturing Transformer Generators.

Keywords: duplex stainless steel, SiC coating, thermal conductivity, SCC

RESUMEN

El acero dúplex 18Cr-18Mn surgió de la necesidad de prevenir fallos catastróficos causados por el agrietamiento por corrosión bajo tensión (SCC, por sus siglas en inglés) en los anillos de retención de generadores. En este trabajo, se propone utilizar este material con un recubrimiento de carburo de silicio para evitar fallos por SCC en generadores, los cuales provocan grietas en los materiales. Dado que el acero dúplex 18Cr-18Mn no es susceptible al agrietamiento por corrosión bajo tensión, se espera que el recubrimiento de SiC aumente la conductividad térmica del acero, además de actuar como inhibidor de la corrosión. Se desarrollará el acero y se caracterizarán su composición y microestructura mediante equipos de microscopía electrónica de barrido (SEM) y difracción de rayos X. Se realizarán ensayos electroquímicos de polarización potenciodinámica e impedancia electroquímica para determinar su comportamiento frente a la corrosión. Asimismo, se caracterizará su comportamiento mecánico mediante ensayos de dureza y/o microdureza y ensayos de tracción para obtener sus propiedades de ingeniería. Se espera desarrollar un acero con excelentes propiedades de alta conductividad térmica y buena resistencia al agrietamiento por corrosión, adecuado para la fabricación de generadores.

Palabras clave: acero inoxidable dúplex, recubrimiento de SiC, conductividad térmica, SCC

INTRODUCTION

Transformers are versatile devices that can be used for various applications. They are used in climate control systems (heating and cooling), water purification, seawater desalination, pollutant collection (CO2, Si2O), and as electricity generators. Therefore, their applications are very important, as some address global environmental challenges such as seawater desalination and atmospheric pollutant capture.

They are highly efficient, generating more energy than they consume.

Failures due to stress corrosion cracking in the shell and tubes of generators have occurred, causing cracks.

Generators are critical components of transformers, within which fluids, often corrosive, flow at high velocities and temperatures, causing tensile stresses and tribocorrosion in the materials. These tensile stresses lead to cracks in the steel, which can result influid leaks and the mixing of reacting solutions, causing catastrophic damage. If the materials chosen for their design are unsuitable, if they are susceptible to stress corrosion cracking, then cracks will inevitably occur. 18Cr-18Mn steel was developed due to stress corrosion cracking problems in retaining rings during equipment operation (1), which led to several failures, some of them catastrophic. 18Cr-18Mn steel occurs in an austenitic or duplex phase. Duplex steel is characterized by its resistance to stress corrosion cracking, making it ideal for processes involving these types of stresses. Consequently, the steel has not exhibited cracking failures.

18Cr-18Mn steel also possesses high hardness and cold formability.

Figure 1. Generator in Heat Transformer

Source: own elaboration.

Figure 2. Heat generator

Source: own elaboration.

Silicon carbide is a ceramic material. It has high conductivity and low thermal expansion, low density, high wear resistance, good oxidation resistance, excellent chemical resistance, high thermal shock resistance, high resistance to elevated temperatures, and ultra-high hardness.

Silicon carbide (SiC), also known as carborundum, is a ceramic material with very high hardness and ultra-high thermal conductivity. Due to its structure, it is almost as hard as diamond and also has high mechanical strength. It withstands high temperatures because it is a refractory material.

Silicon carbide is obtained from carbon and silicon oxide:

$SiO_2 + 3\ C \rightarrow SiC + 2\ CO$

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Some of its properties are: a density of 3.21 g/cm3, a molecular weight of 40.11 g/mol, and a melting point of 2,730 °C.

METhODOLOGY

Twelve samples, each 1 cm x 1 cm x 0.3 cm thick, will be cut. Six of these samples will be coated with a layer of SiC using laser ablation.

The samples will be analyzed using SEM and X-rays to determine their composition and microstructure.

A GILL-AC potentiostat will be used to perform corrosion tests on the steels. The techniques employed will be potentiodynamic polarization, impedance, and electrochemical noise.

In addition, the steel will be mechanically characterized. Hardness and/or microhardness tests will be performed using a durometer or microhardness tester, and tensile tests will be conducted using a tensile testing machine.

All of this will be carried out following the scientific method at all times.

The results will be analyzed.

Each test will be performed three times to verify the consistency of the results obtained.

RESULTS AND DISCUSION

The most important factor in transformer generators is the thermal conductivity of the materials. Inside heat generators, constant heat exchanges occur between the working fluids and the equipment's construction materials; this is necessary for energy generation. Furthermore, these materials must be resistant to thermal shock, high working temperatures and pressures, and the corrosion suffered by equipment due to the transport of aggressive (corrosive) fluids. The material we are proposing is expected to have high strength and minimize the problems reported in Transformer Generators. A suitable material for generator construction is expected due to the non-susceptibility to SCC of 18Cr-18Mn steel and the anti-corrosive properties and ultra-high thermal conductivity of silicon carbide.

Figure 3. Crevice corrosion

Source: own elaboration.

Figure 4. Corrosion in generator

Source: own elaboration.

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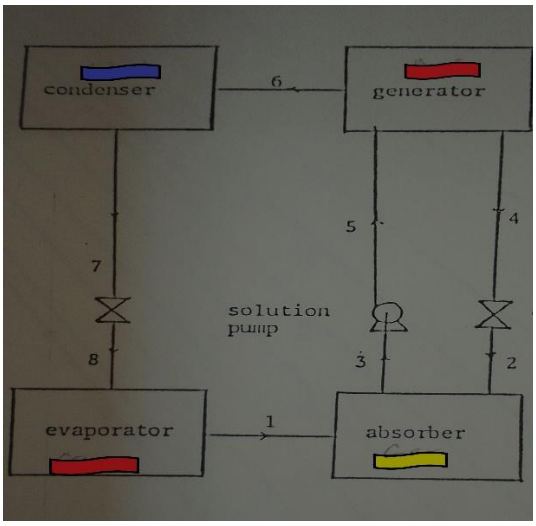
Figure 5. Corrosion on pipes

Source: own elaboration.

Figure 6. Corrosion on flange

Source: own elaboration.

Figure 7. Heat pump diagram



Source: own elaboration.

Figure 8. Silice Carbide

Source: own elaboration.

It is expected to obtain a suitable material for Transformer Generators that reduces the corrosion problem and also considerably increases the thermal conductivity in the working area of the Generator.

Duplex 18Cr-18Mn steel is expected to reduce the problem of stress corrosion cracking due to its non-susceptibility to this type of corrosion.

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SiC also generally increases the corrosion resistance of materials.

It is expected that the developed material will have ultra-high thermal conductivity, due to the addition of SiC which has excellent thermal conductivity, above 110 W/mK, thus improving the thermal conductivity of steel which is between 15 and 25 W/mK.

18Cr-18Mn steel has high formability, even when cold.

SiC has a very high hardness.

CONCLUSIONS

The aim is to develop a material suitable for Transformer Generators that supports continuous manufacturing improvement for this industry and serves as a basis for the manufacture of these heat exchange equipment, reducing problems and incidents caused by corrosion and increasing the efficiency of the equipment.

REFERENCES

Allam, T., Guo, X., Sevsek, S., Lipińska-Chwałek, M., Hamada, A., Ahmed, E., & Bleck, W. (2019). Development of a Cr-Ni-VN medium manganese steel with balanced mechanical and corrosion properties. Metals, 9(6), 705.

Chen, J., Zhou, Q., Liu, Y., Ma, Y., Yin, J., Hu, T., & Li, Y. (2022). Influence of Temperature on the Corrosion Behavior of 18Mn–18Cr Austenitic Stainless Steel in 3.5 wt. % NaCl Solution. International Journal of Electrochemical Science, 17(10), 22105.

Chen, X., Jiang, N., Zhan, Y., Luo, Y., Ye, N., Tang, J., & Zhuo, H. (2024). Preparation and tribological performance of Ni-SiC composite coating on 304 stainless steel through brush plating. Surface and Coatings Technology, 494, 131491.

Kanyane, L. R., Malepe, T. J., Malatji, N., & Popoola, A. P. I. (2021). Synthesis and characterization of Al–SiC composite coatings on 316L stainless steel fabricated via laser cladding technique. Metallography, Microstructure, and Analysis, 10(5), 601-609.

doi 10.65011

ISSN 3072-8452

Kilic, M., Imak, A., & Kirik, I. (2021). Surface modification of AISI 304 stainless steel with NiBSi-SiC composite by TIG method. Journal of Materials Engineering and Performance, 30(2), 1411-1419.

Lailatul, P. H., & Abd Maleque, M. (2018). Tribological properties of surface coated duplex stainless steel containing SiC ceramic particles. Jurnal Tribologi, 18, 136-148.

Liu, J., Liu, J., Wang, H., Jiang, C., & Huang, W. (2022). Research on adding nano-SiC reinforced wire arc additive manufacturing stainless steel. Journal of Materials Engineering and Performance, 31(6), 4945-4954.

Reyes-Hernández, R., Torres-Islas, A., Serna, S., Molina-Ocampo, A., Coli, J., & Bedolla, A. (2017). Austenite and forging effects on 18Cr-18Mn stainless steel impedance. South African Journal of Chemistry, 70, 108-112.

Yang, L., Sun, W., Xu, J., Xiong, X., Wang, L., Zuo, J., & Yang, B. (2024). Ablation behavior of a SiC/ZrC–SiC coating on C/CA composite for high-temperature thermal protection. Ceramics International, 50(11), 20447-20459.

Yun, D. B., Park, J. S., Lee, S. C., Choi, J. K., & Kim, S. J. (2023). Effect of Cr addition on the corrosion-wear behaviors of 18Mn (V, Mo) steel in a seawater environment. Korean Journal of Metals and Materials, 61(9), 633-641.

Zhang, L. M., Zhang, S. D., Ma, A. L., Daniel, E. F., Wang, J. Q., & Zheng, Y. G. (2024). Superior resistance to cavitation erosion and corrosion of a novel SiC-reinforced superaustenitic stainless steel coating fabricated by high-velocity air fuel spraying. Materials Characterization, 208, 113651.

Zhuan, L. I., Peng, X. I. A. O., Jun-jie, D. U. A. N., Yang-jie, L. I., Liang, P. A. N. G., Zong-long, G. A. O., ... & Yang, L. I. (2024). Research progress on silicon carbide and its modified coatings in C/SiC composites. Transactions of Nonferrous Metals Society of China, 34(12), 3822-3845.

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