Brief of Understanding Hydrogen Embrittlement

By

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Abstract:

Hydrogen embrittlement (HE) is a phenomenon that occurs when hydrogen atoms diffuse into the structure of metals and cause embrittlement, leading to cracking and failure of the material. This article explores the causes of HE, its effects on materials, and the measures that can be taken to prevent HE in industrial applications.

Introduction:

Hydrogen embrittlement (HE) is a complex and often poorly understood phenomenon that has significant implications for the mechanical properties and reliability of metals. The problem of HE arises in a wide range of industrial applications, including aerospace, energy, and automotive industries. Understanding the mechanisms of HE and the measures that can be taken to prevent it is critical to ensure the safe and reliable operation of these systems.

Causes and Effects

HE is caused by the interaction of hydrogen with metals, which can lead to the formation of hydrogen atoms that diffuse into the metal lattice. Once inside the metal, the hydrogen can cause a variety of changes to the material properties, including reducing its ductility and increasing its susceptibility to cracking and failure. The effects of HE can be particularly severe in high-strength steels and other metals that are commonly used in demanding applications.

Prevention

A range of measures can be taken to prevent HE in industrial applications, including careful material selection, surface treatments to reduce hydrogen uptake, and the use of coatings or barriers to prevent hydrogen diffusion into the material. Other strategies include the use of cathodic protection, the application of low-hydrogen welding techniques, and the careful control of the environment in which the material is used.

Conclusion

Hydrogen embrittlement is a complex phenomenon that poses a significant challenge to the safe and reliable operation of industrial systems. Understanding the mechanisms of HE and the measures that can be taken to prevent it is critical for ensuring the integrity of materials used in demanding applications. By carefully selecting materials, applying surface treatments, and controlling the environment in which materials are used, it is possible to prevent HE and ensure the long-term performance of industrial systems.

References

[1] M. Al Ali, A.Y. Sahib, M. Al Ali, Design Light Weight Emergency Cot With Enhanced Spinal Immobilization Capability, in: 6th Asian/Australian Rotorcr. Forum Heli Japan, 2017: pp. 1–11. https://vtol.org/store/product/design-light-weight-emergency-cot-with-enhanced-spinal-immobilization-capability-12410.cfm.

[2] M. Fujioka, M. Shimoda, M. Al Ali, Concurrent shape optimization of a multiscale structure for controlling macrostructural stiffness, Struct. Multidiscip. Optim. 65 (2022) 1–27. https://doi.org/10.1007/s00158-022-03304-y.

[3] P.M. Shimoda, M. Al Ali, C.A. Secondary, C. Author, M. Al Ali, M. Shimoda, M. Al Ali, Structural and Multidisciplinary Optimization Concurrent multiscale multiphysics topology optimization for porous composite structures under hygral loading, (n.d.).

[4] M.A. Al-Ali, M.A. Al-Ali, A. Takezawa, M. Kitamura, Topology optimization and fatigue analysis of temporomandibular joint prosthesis, World J. Mech. 7 (2017) 323–339.

[5] R.S. Abass, M. Al Ali, M. Al Ali, Shape And Topology Optimization Design For Total Hip Joint Implant, in: Proc. World Congr. Eng., 2019. http://www.iaeng.org/publication/WCE2019/WCE2019_pp559-564.pdf.

[6] M. Fujioka, M. Shimoda, M. Al Ali, Shape optimization of periodic-microstructures for stiffness maximization of a macrostructure, Compos. Struct. 268 (2021) 113873. https://doi.org/10.1016/j.compstruct.2021.113873.

[7] M.H. Faidh-Allah, M.A.M. Kadem, OPTIMAL DESIGN OF MODERATE THICK LAMINATED COMPOSITE PLATES UNDER STATIC CONSTRAINTS USING REAL CODING GENETIC ALGORITHM, J. Eng. 17 (2011).

[8] M. Fujioka, M. Shimoda, M. Al Ali, Concurrent Shape Optimization for Multiscale Structure with Desired Static Deformation, Proc. Comput. Mech. Conf. 2021.34 (2021) 3. https://doi.org/10.1299/jsmecmd.2021.34.003 (in Japanese).

[9] M. Al Ali, Toward fully autonomous structure design based on topology optimization and image processing, in: Proc. 6th IIAE Int. Conf. Intell. Syst. Image Process., The Institute of Industrial Applications Engineers, 2018.

[10] M. Torisaki, M. Shimoda, M. Al Ali, Shape optimization method for strength design problem of microstructures in a multiscale structure, Int. J. Numer. Methods Eng. 124 (2023) 1748–1772. https://doi.org/10.1002/nme.7186.

[11] M. Shimoda, M. Umemura, M. Al Ali, R. Tsukihara, Shape and topology optimization method for fiber placement design of CFRP plate and shell structures, Compos. Struct. 309 (2023) 116729. https://doi.org/10.1016/j.compstruct.2023.116729.

[12] M. Al Ali, M. Shimoda, B. Benaissa, M. Kobayashi, Concurrent Multiscale Hybrid Topology Optimization for Light Weight Porous Soft Robotic Hand with High Cellular Stiffness, in: Proc. Int. Conf. Steel Compos. Eng. Struct. ICSCES 2022, 2023: pp. 265–278. https://doi.org/10.1007/978-3-031-24041-6_22.

[13] N. Amoura, B. Benaissa, M. Al Ali, S. Khatir, Deep Neural Network and YUKI Algorithm for Inner Damage Characterization Based on Elastic Boundary Displacement, in: Proc. Int. Conf. Steel Compos. Eng. Struct. ICSCES 2022, 2023: pp. 220–233.

[14] M.S. Musaddiq Al Ali, Toward Concurrent Multiscale Topology Optimization for High Heat Conductive and Light Weight Structure, in: 15th World Congr. Comput. Mech. 8th Asian Pacific Congr. Comput. Mech., 2022: pp. 1–12. https://doi.org/10.23967/wccm-apcom.2022.118.

[15] M.S. Musaddiq Al Ali, Concurrent Multiscale Topology Optimization for Designing Displacement Inverter, in: 15th World Congr. Comput. Mech. 8th Asian Pacific Congr. Comput. Mech., 2022: pp. 1–10. https://doi.org/10.23967/wccm-apcom.2022.027.

[16] M. Al Ali, M. Shimoda, Toward multiphysics multiscale concurrent topology optimization for lightweight structures with high heat conductivity and high stiffness using MATLAB, Struct. Multidiscip. Optim. 65 (2022) 1–26. https://doi.org/10.1007/s00158-022-03291-0.

[17] M. Al Ali, M. Shimoda, Toward Concurrent Multiscale Topology Optimization for High Heat Conductive and Light Weight Structure, in: S. Koshizuka (Ed.), 15th World Congr. Comput. Mech. 8th Asian Pacific Congr. Comput. Mech., CIMNE, 2022: p. 12. https://doi.org/10.23967/wccm-apcom.2022.118.

[18] Musaddiq Al Ali, Toward fully autonomous structure design based on topology optimization and image processing, in: Proc. 6th IIAE Int. Conf. Intell. Syst. Image Process. 2018, 2018: pp. 1–7.

[19] M. Al Ali, A. Takezawa, M. Kitamura, Comparative study of stress minimization using topology optimization and morphing based shape optimization comparative study of stress minimization using topology optimization and morphing based shape optimization, in: Asian Congr. Struct. Multidiscip. Optim., 2018. https://www.researchgate.net/profile/Musaddiq-Al-Ali-2/publication/324559492_Comparative_Study_of_Stress_Minimization_Using_Topology_Optimization_and_Morphing_Based_Shape_Optimization/links/5d6467ac92851c619d781329/Comparative-Study-of-Stress-Minimization.

[20] M. Al Ali, A.Y. Sahib, M. Al Ali, Teeth implant design using weighted sum multi-objective function for topology optimization and real coding genetic algorithm, in: 6th IIAE Int. Conf. Ind. Appl. Eng. 2018, The Institute of Industrial Applications Engineers, Japan, 2018: pp. 182–188. https://doi.org/10.12792/iciae2018.037.

[21] M. Al Ali, M. Al Ali, A.Y. Sahib, R.S. Abbas, Design Micro-piezoelectric Actuated Gripper for Medical Applications, in: Proc. 6th IIAE Int. Conf. Ind. Appl. Eng. 2018, The Institute of Industrial Application Engineers, 2018: pp. 175–180. https://doi.org/10.12792/iciae2018.036.

[22] M. Torisaki, M. Shimoda, M. Al Ali, Shape optimization method for strength design problem of microstructures in a multiscale structure, Int. J. Numer. Methods Eng. 124 (2023) 1748–1772. https://doi.org/10.1002/nme.7186.

[23] M. Fujioka, M. Shimoda, M. Al Ali, Concurrent shape optimization of a multiscale structure for controlling macrostructural stiffness, Struct. Multidiscip. Optim. 65 (2022) 211. https://doi.org/10.1007/s00158-022-03304-y.

[24] M. Al Ali, Design offshore spherical tank support using shape optimization, in: Proc. 6th IIAE Int. Conf. Intell. Syst. Image Process., 2018. doi: 10.12792/icisip2018.051.

[25] R.S. Abass, M. Al Ali, M. Al Ali, Shape And Topology Optimization Design For Total Hip Joint Implant, in: World Congr. Eng. 2019, 2019.

[26] M. Al Ali, A. Takezawa, M. Kitamura, Comparative study of stress minimization using topology optimization and morphing based shape optimization comparative study of stress minimization using topology optimization and morphing based shape optimization, (2019).

[27] 藤岡みなみ, 下田昌利, A.L.I. Musaddiq Al, 所望変形を実現するマルチスケール構造の同時形状最適化, 計算力学講演会講演論文集. 2021.34 (2021) 3. https://doi.org/10.1299/jsmecmd.2021.34.003.

[28] M. Al Ali, M. Al Ali, R.S. Saleh, A.Y. Sahib, Fatigue Life Extending For Temporomandibular Plate Using Non Parametric Cascade Optimization, in: Proc. World Congr. Eng. 2019, 2019: pp. 547–553. http://www.iaeng.org/publication/WCE2019/WCE2019_pp547-553.pdf.

[29] M. Torisaki, M. Shimoda, M. Al Ali, Shape optimization method for strength design problem of microstructures in a multiscale structure, Int. J. Numer. Methods Eng. (2022).

[30] M. Al Ali, M. Shimoda, Investigation of concurrent multiscale topology optimization for designing lightweight macrostructure with high thermal conductivity, Int. J. Therm. Sci. 179 (2022) 107653. https://doi.org/10.1016/j.ijthermalsci.2022.107653.

[31] B. Benaissa, N.A. Hocine, S. Khatir, M.K. Riahi, S. Mirjalili, YUKI Algorithm and POD-RBF for Elastostatic and dynamic crack identification, J. Comput. Sci. 55 (2021) 101451. https://doi.org/10.1016/j.jocs.2021.101451.

[32] M.I. Shirazi, S. Khatir, B. Benaissa, S. Mirjalili, M.A. Wahab, Damage assessment in laminated composite plates using modal Strain Energy and YUKI-ANN algorithm, Compos. Struct. 303 (2023) 116272.

[33] M. Irfan Shirazi, S. Khatir, B. Benaissa, S. Mirjalili, M. Abdel Wahab, Damage assessment in laminated composite plates using Modal Strain Energy and YUKI-ANN algorithm, Compos. Struct. (2022) 116272. https://doi.org/https://doi.org/10.1016/j.compstruct.2022.116272.