

**BUSITEMA
UNIVERSITY**
Pursuing Excellence

**FACULTY OF ENGINEERING
DEPARTMENT OF POLYMER, TEXTILE AND INDUSTRIAL
ENGINEERING.**

FINAL YEAR PROJECT PROPOSAL

**MODELLING OF TENSILE STRENGTH OF STAINLESS-STEEL AT
HIGH TEMPERATURES USING ANN AND ANFIS**

BY

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**This final year project proposal is submitted to the department of Polymer,
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for the award of the degree of Bachelor of Science in Polymer, Textile and
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DEDICATION

We dedicate this project to our fellow enthusiasts in the field of polymer, textiles, materials and industrial engineering, our fellow classmates, family members and whoever has contributed their efforts throughout our Bachelors course.

DECLARATION


SSERWANGA EDIRISA and TUKAMUSHABA OLIVA, clearly declare that the contents in this report are original to the best of my knowledge and that the report has never been submitted to any institution or university for the award of any degree or diploma and am the true author of the report.

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APPROVAL

This is to certify that project research of Sserwanga Edirisa and Tukamushaba Oliva was under my supervision and it is ready for submission to the dean of faculty engineering of Busitema University with our approval.

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1. CHAPTER ONE: INTRODUCTION

BACKGROUND

Stainless steel has gained the world of material applications ever since its introduction to the material world in 1913. Harry Brearley introduced the first form of stainless steel which had the composition of 12.8% chromium and the rest being iron. Further research about stainless steel later led to discovery of more and more manufacturing processes and chemical composition (Iron: chromium: carbon: nickel: silicon: molybdenum) ratios that can be used to modify and manipulate properties of the material. This led to discovery of a series of stainless steels ranging from martensitic stainless steel to the present 410 stainless steel. Currently there are more than 100 grades of stainless steel falling in four general group i.e., austenitic, ferritic, austenitic and duplex stainless steel. Stainless steel has gained momentum in materials world because of its unique properties like, good recyclability, very high corrosion resistance, long service life, non-rusting character and many more. One of the main applications of stain steel is applications at high temperatures since it has a very low oxidation power, non-rusting, high thermo stability, high tensile strength and high melting point. (Of, 2003; Hosford, 2010).

High temperature materials are those that serve at temperatures above 540°C and are classified into authentic super alloys, refractory metals, ceramics, metal matrix composites and graphite composites. (Venables, 2010). Stainless steel is categorized under high temperature material under the authentic super alloys cause of their high thermo stability at very high temperatures. (Nicholls, 2014). Martensitic stainless steels contain the good composition ratios that give them suitable properties to be used at high temperatures above 500°C. Ferritic stainless steels have properties that make them applicable in applications bellow 500°C. Duplex stainless steels can be applied in high temperature applications of both austenite and ferritic stainless steels since it has a metallurgical structure with both phases. (Cobb, 1999). Stainless steel finds high temperature applications making aircraft jet engines, lighting devices, industrial gas turbines, furnaces, nuclear reactors and many more. (Marichamy and Babu, 2019). In all high temperature applications of stainless steel, the material is always subjected to stresses due to the work being done by the material. This effect brought scientists' attention to make more analysis of the mechanical properties of stainless steel at high temperature in order to optimize

6 REFERENCES

1. Aladejare, A.E. *et al.* (2022) ‘Soft Computing-Based Models for Predicting the Characteristic Impedance of Igneous Rock from Their Physico-mechanical Properties’, *Rock Mechanics and Rock Engineering* [Preprint], (0123456789). doi:10.1007/s00603-022-02836-5.
2. Alarifi, I.M. *et al.* (2019) ‘Feasibility of ANFIS-PSO and ANFIS-GA models in predicting thermophysical properties of Al₂O₃-MWCNT/Oil hybrid nanofluid’, *Materials*, 12(21). doi:10.3390/ma12213628.
3. Azeem, M.F., Hanmandlu, M. and Ahmad, N. (2000) ‘Generalization of adaptive neuro-fuzzy inference systems’, *IEEE Transactions on Neural Networks*, 11(6), pp. 1332–1346. doi:10.1109/72.883438.
4. Babajanzade Roshan, S. *et al.* (2013) ‘Optimization of friction stir welding process of AA7075 aluminum alloy to achieve desirable mechanical properties using ANFIS models and simulated annealing algorithm’, *International Journal of Advanced Manufacturing Technology*, 69(5–8), pp. 1803–1818. doi:10.1007/s00170-013-5131-6.
5. Burnwal, A.P. (2013) ‘On Soft Computing Techniques in Various Areas’, pp. 59–68.
6. Chandrasekaran, M. *et al.* (2010) ‘Application of soft computing techniques in machining performance prediction and optimization: a literature review’, *The International Journal of Advanced Manufacturing Technology*, 46(5), pp. 445–464. doi:10.1007/s00170-009-2104-x.
7. Chandwani, V., Agrawal, V. and Nagar, R. (2013) ‘Applications of Soft Computing in Civil Engineering: A Review’, *International Journal of Computer Applications*, 81(10), pp. 13–20. doi:10.5120/14047-2210.
8. Cobb, H.M. (1999) ‘Steel Products Manual: Stainless Steels’, *Iron & Steel Society*, p. 116.
9. Dobrota, A.S. and Pašti, I.A. (2020) ‘conversion title in Press Article in Press’, 10(0), pp. 1–12.
10. Fan, S.G. *et al.* (2017) ‘S30408奥氏体不锈钢高温力学性能试验研究’, *工程力学*, 2017, Vol. 34, Issue 4, Pages: 167-176, 186, 34(4), pp. 167–176, 186. doi:10.6052/J.ISSN.1000-4750.2015.11.0889.

10. Get Ready for AI with MATLAB and Simulink - MATLAB & Simulink (no date).
11. Girinath, B., Siva Shanmugam, N. and Sankaranarayanan, K. (2019) 'Weld bead graphical prediction of cold metal transfer weldment using ANFIS and MRA model on Matlab platform', *Simulation*, 95(8), pp. 725–736. doi:10.1177/0037549718809162.
12. Hosford, W.F. (2010) Iron Willed , Iron Fisted , Iron Clad , Iron Curtain ,.
13. Hybrid Systems in Soft Computing - CSVeda (no date).
14. Ibrahim, D. (2016) 'An Overview of Soft Computing', *Procedia Computer Science*, 102(August), pp. 34–38. doi:10.1016/j.procs.2016.09.366.
15. Introduction to ANN (Artificial Neural Networks) | Set 3 (Hybrid Systems) - GeeksforGeeks (no date).
16. Kee, J. *et al.* (2013) 'Test database of the mechanical properties of mild , high- tensile and stainless steel and aluminium alloy associated with cold temperatures and strain rates', pp. 1–34.
17. Kim, J. and Kasabov, N. (1999) 'HyFIS: Adaptive neuro-fuzzy inference systems and their application to nonlinear dynamical systems', *Neural Networks*, 12(9), pp. 1301–1319. doi:10.1016/S0893-6080(99)00067-2.
18. Lasheen, M. and Abdel-Salam, M. (2018) 'Maximum power point tracking using Hill Climbing and ANFIS techniques for PV applications: A review and a novel hybrid approach', *Energy Conversion and Management*, 171(March), pp. 1002–1019. doi:10.1016/j.enconman.2018.06.003.
19. Lee, J. *et al.* (2007) 'Non-contact measurement of creep resistance of ultra-high-temperature materials', *Materials Science and Engineering A*, 463(1–2), pp. 185–196. doi:10.1016/j.msea.2006.07.160.
20. Machine Learning with MATLAB - MATLAB & Simulink (no date).
21. Malami, S.I. *et al.* (2021) 'Implementation of hybrid neuro-fuzzy and self-turning predictive model for the prediction of concrete carbonation depth: A soft computing technique', *Results in Engineering*, 10, p. 100228. doi:10.1016/J.RINENG.2021.100228.
22. Marichamy, M. and Babu, S. (2019) 'Mechanical Properties of High Temperature Materials : A Review', 13(1), pp. 48–52. doi:10.3968/11347.

23. Materials, H. (2006) 'High-Temperature Materials and Mechanisms: Applications and Challenges', pp. 499–512.
24. Mohammed, A. *et al.* (2021) 'Soft computing techniques: Systematic multiscale models to predict the compressive strength of HVFA concrete based on mix proportions and curing times', *Journal of Building Engineering*, 33, p. 101851. doi:10.1016/j.jobbe.2020.101851.
25. MURRAY SF (1969) 'Research and Development of High Temperature Gas Bearings-2', *NASA Contractor Reports* [Preprint].
26. Nicholls, J.R. (2014) 'Editorial: A new era for materials at high temperatures', *Materials at High Temperatures*, 31(1), p. 1. doi:10.1179/0960340913Z.00000000014.
27. Nikulin, I., Kipelova, A. and Kaibyshev, R. (2012) 'Effect of high-temperature exposure on the mechanical properties of 18Cr – 8Ni – W – Nb – V – N stainless steel', *Materials Science & Engineering A*, 554, pp. 61–66. doi:10.1016/j.msea.2012.06.011.
28. Odejebi, O.A. and Umoru, L.E. (2009) 'Applications of soft computing techniques in materials engineering: A review', *African Journal of Mathematics and Computer Science Research*, 2(7), pp. 104–131. Available at: <http://www.academicjournals.org/AJMCSR>.
29. Of, E. (2003) 'Mechanical Engineering Theory and Applications Stainless Steel Microstructure, Mechanical Properties and Methods of Application'.
30. Sharma, N. *et al.* (2021) 'Optimal deflection and stacking sequence prediction of curved composite structure using hybrid (FEM and soft computing) technique', *Engineering with Computers*, 37(1), pp. 477–487. doi:10.1007/s00366-019-00836-8.
31. Singh, R., Kainthola, A. and Singh, T.N. (2012) 'Estimation of elastic constant of rocks using an ANFIS approach', *Applied Soft Computing Journal*, 12(1), pp. 40–45. doi:10.1016/j.asoc.2011.09.010.
32. Singh, T.N., Sinha, S. and Singh, V.K. (2007) 'Prediction of thermal conductivity of rock through physico-mechanical properties', 42, pp. 146–155. doi:10.1016/j.buildenv.2005.08.022.
33. Sirdesai, N.N. *et al.* (2019) 'Development of novel methods to predict the strength properties of thermally treated sandstone using statistical and soft-computing approach', *Neural Computing and Applications*, 31(7). doi:10.1007/s00521-017-3233-z.

34. Sobhani, J. *et al.* (2010) ‘Prediction of the compressive strength of no-slump concrete: A comparative study of regression, neural network and ANFIS models’, *Construction and Building Materials*, 24(5), pp. 709–718. doi:10.1016/j.conbuildmat.2009.10.037.
35. Soto B., R. *et al.* (2001) ‘Permeability Prediction Using Hydraulic Flow Units And Hybrid Soft Computing Systems’, *SPE Annual Technical Conference and Exhibition*, p. SPE-71455-MS. doi:10.2118/71455-MS.
36. *Steady state test results for the steel 4016-1. | Download Table* (2013). Available at: https://www.researchgate.net/figure/Steady-state-test-results-for-the-steel-4016-1_tbl6_296484347 (Accessed: 26 July 2022).
37. Sultana, N. *et al.* (2020) ‘Soft computing approaches for comparative prediction of the mechanical properties of jute fiber reinforced concrete’, *Advances in Engineering Software*, 149, p. 102887. doi:10.1016/J.ADVENGSOFT.2020.102887.
38. Syed Nouman, N.S.K.C.K. (2022) ‘IRJET- Application of ANFIS in Civil Engineering- A Critical Review’, *Irjet*, 9(1).
39. Tenner, J. *et al.* (2001) ‘Prediction of mechanical properties in steel heat treatment process using neural networks’, 28(1), pp. 15–22.
40. *UNS S31803, Duplex S31803 material price, properties and composition* (2018). Available at: <https://www.duplexplates.com/uns-s31803-material-supplier.html> (Accessed: 26 July 2022).
41. Venables, J.D. (no date) ‘HIGH TEMPERATURE STRUCTURAL MATERIALS M E S P L C E O – P L C E O –’.
42. Victor, A.C. and Douglas, T.B. (1960) ‘Physical Properties of high temperature materials.pdf’, pp. 57–374.
43. Voorde, M. H. (1991) ‘High Temperature Materials and Industrial Applications’, *Butlletí de les Societats Catalanes de Física, Química, Matemàtiques i Tecnologia*, XI, pp. 199–226.
44. Wang, J.S. and Lee, C.S.G. (2002) ‘Self-adaptive neuro-fuzzy inference systems for classification applications’, *IEEE Transactions on Fuzzy Systems*, 10(6), pp. 790–802. doi:10.1109/TFUZZ.2002.805880.

45. Wang, S.L. *et al.* (2004) 'A study on the mechanical properties of Ti(C, N) based ceramic tool material', *Materials Science Forum*, 471–472, pp. 369–373. doi:10.4028/www.scientific.net/msf.471-472.369.
46. Zahra, K. and Torkian, H. (2020) 'Application of ANN and ANFIS models in determining compressive strength of concrete'.