

Declaration

I hereby declare that the work presented in this thesis titled “**Experimental investigations on dissimilar metal welds fabricated using nickel based welding consumables**”, submitted to the Indian Institute of Technology Jodhpur in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work carried out under the supervision of Prof. Rahul Chhibber. The contents of this thesis in full or in parts have not been submitted to and will not be submitted by me to any other Institute or University in India or abroad for the award of any degree or diploma.

Vijay Kumar
P19ME001

Certificate

This is to certify that the thesis titled “**Experimental investigations on dissimilar metal welds fabricated using nickel based welding consumables**”, submitted by Vijay Kumar (P19ME001) to the Indian Institute of Technology Jodhpur for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work done by him under my supervision. To the best of my knowledge, the contents of this report, in full or in parts, have not been submitted to any other Institute or University in India or abroad for the award of any degree or diploma.

Prof. Rahul Chhibber

Professor

Indian Institute of Technology Jodhpur

Abstract

In the current context of industrial advancement, there is a rapid surge in electricity demands. Meeting this escalating need involves either enhancing the efficiency of existing power plants or establishing new ones. Pulverized coal stands out as the cost-effective fuel choice predominantly utilized in power industries. However, the expansion of power plants contributes to increased emissions of gases like CH_4 and CO_2 . The efficiency of power plants hinges largely on their operational steam parameters, particularly temperature and pressure. Supercritical power plants offer a solution by boosting efficiency through elevated operating conditions, resulting in reduced coal consumption and lower CO_2 emissions. Fabricating and maintaining power plants pose significant challenges due to the demanding working conditions. Utilizing cutting-edge high-temperature materials has become imperative in the power plant sector. Different components and structural elements necessitate dissimilar metal welds to enhance structural integrity and performance. This research endeavors to develop Shielded Metal Arc Welding (SMAW) electrode coatings aimed at enhancing performance and mitigating issues associated with high-temperature failures. SMAW is widely employed for welding, repairs, and maintenance in this context. However, detailed information on the welding consumables currently in use remains classified and limited in the public domain.

This research aims to develop coated electrode for producing Inconel 617/SS304H dissimilar joints, particularly for power plant applications. Utilizing the extreme vertices methodology, the coating compositions were formulated from mineral systems like $\text{CaO-TiO}_2\text{-SiO}_2\text{-Na}_3\text{AlF}_6$ and $\text{CaO-CaF}_2\text{-SiO}_2\text{-SrO}$. The experimental characterization focused on thermophysical, physicochemical, and wettability properties of the coatings. A regression model was employed to analyze the impact of coating constituents. Subsequent multipass bead-on-plate experiments using these coatings were used to evaluate their performance. Qualitative and quantitative assessments of the resulting beads determined electrode suitability. The most effective coating was then applied to fabricate dissimilar IN617/SS304H welds using extruded IN-617 core wire. Mechanical, microstructural, and hot corrosion properties of the welds were thoroughly examined. Additionally, a comparative analysis between our laboratory-developed electrodes and commercially available ones was conducted. Overall, the study demonstrates successful development of SMAW electrode coatings tailored for welding IN617/SS304H, specifically for A-USC power plant applications. These developed electrodes exhibit superior mechanical properties, high-temperature corrosion resistance, and satisfactory microstructural stability compared to their commercially available alternatives.

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Vijay Kumar
Ph.D. Student

Dedicated to

This thesis is dedicated to my family who has always been incredibly supportive of my educational pursuits. Thank you for believing in me and pushing me to succeed in all my endeavours.

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List of Symbols

Symbol	Description	Units
δ_{LG}	Interfacial tensions at the liquid-gas interface	(N/m)
δ_{SG}	Interfacial tensions at the solid-gas interfaces	(N/m)
δ_{SL}	Molten slag surface tension	(N/m)
W_a	Adhesion energy (specific surface energy)	(J/m ²)
θ	Contact angle	Degree (°)
n	No of experiments	-
k	No of regression variables	-
T_c	Thermal conductivity	W/mK
T_D	Thermal diffusivity	mm ² /s
ΔH	Change in enthalpy	J/g
SH	Specific heat	MJ/m ³ K
D	Density	g/cm ³
$\Delta W \%$	Percentage weight loss	%
Hv	Microhardness	-
K_p	Parabolic rate constant	mg ² /cm ⁴ s
t	Oxidation time	s
T	Temperature	°C
$\Delta W/A$	Weight gain/unit area	mg/cm ²

List of Abbreviations

Abbreviation	Full form
SC	Super critical
AUSC	Advanced ultra-super critical
IGCC	Integrated gasification combined cycle
RH/SH	Reheater/ superheater
SMAW	Shielded metal arc welding
GTAW	Gas tungsten arc welding
GMAW	Gas metal arc welding
MMA	Manual metal arc
TIG	Tungsten inert gas
A-TIG	Activated Tungsten inert gas
DMW	Dissimilar metal weld
DWJ	Dissimilar weld joints
AC	Alternative current
DC	Direct current
DCEP	Direct current electrode positive
PCGTAW	Pulsed current gas tungsten arc welding
CCGTAW	Continuous current gas tungsten arc welding
CaO	Calcium oxide source
CaF ₂	Calcium fluoride
SiO ₂	Silica
Al ₂ O ₃	Aluminium oxide
TiO ₂	Rutile
Na ₃ AlF ₆	Cryolite
SrO	Strontium oxide
P	Phosphorous
Mg	Magnesium
Fe	Iron
S	Sulphur
Nb	Niobium
Al	Aluminium
Ni	Nickel
Mo	Molybdenum
Ti	Titanium
C	Carbon
BI	Basicity Index
IIW	International Institute of welding
ASTM	American Society for Testing and Materials
BM	Base metal
FM	Filler metal
WM	Weld metal
HAZ	Heat affected zone
SGBs	Solidified grain boundaries
MGBs	Mitigated grain boundaries
FGHAZ	Fine grain heat affected zone
XRF	X-ray fluorescence
TGA	Thermogravimetric analysis
FTIR	Fourier Transform Infrared Spectroscopy

XRD	X-ray diffraction
SEM	Scanning electron microscopy
EDS	Energy dispersive spectrometry
ANOVA	Analysis of variance