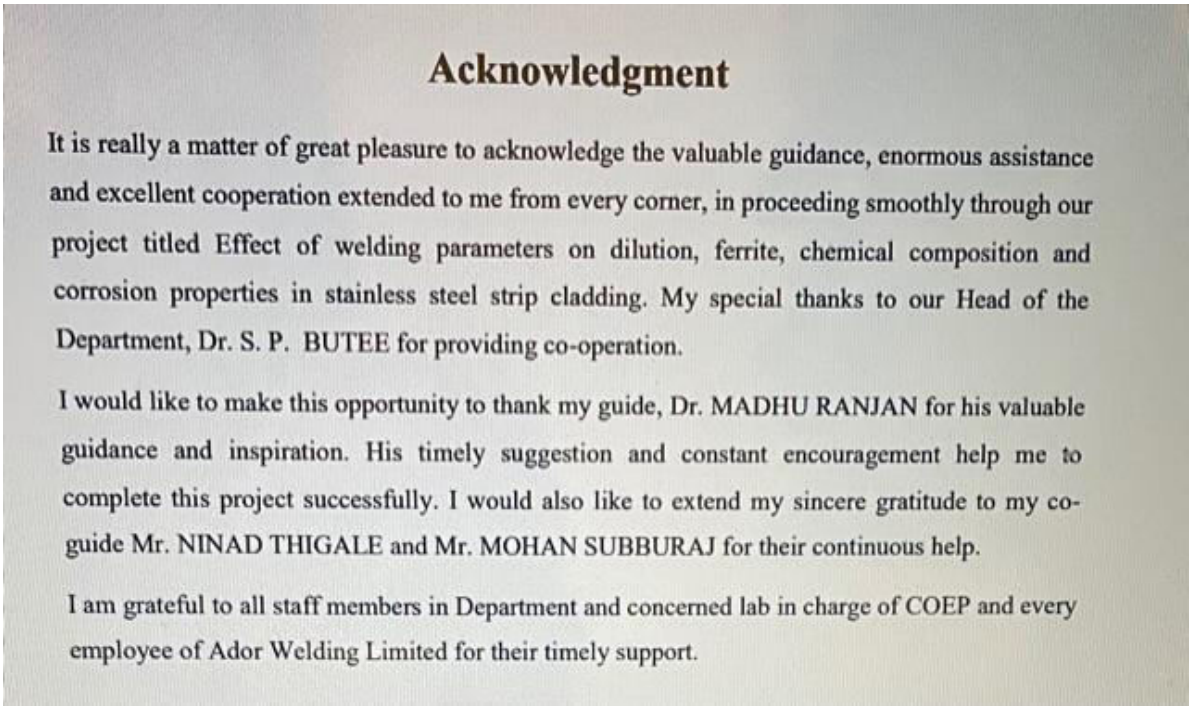
Akshay Shitole Tatyasahab :

'EFFECT OF WELDING PARAMETERS ON DILUTION, FERRITE, CHEMICAL COMPOSITION AND CORROSION PROPERTIES OF STAINLESS STEEL IN ELECTRO SLAG STRIP CLADDING'. The project was carried out at Ador Welding, Pune



Acknowledgment

It is really a matter of great pleasure to acknowledge the valuable guidance, enormous assistance and excellent cooperation extended to me from every corner, in proceeding smoothly through our project titled Effect of welding parameters on dilution, ferrite, chemical composition and corrosion properties in stainless steel strip cladding. My special thanks to our Head of the Department, Dr. S. P. BUTEE for providing co-operation.

I would like to make this opportunity to thank my guide, Dr. MADHU RANJAN for his valuable guidance and inspiration. His timely suggestion and constant encouragement help me to complete this project successfully. I would also like to extend my sincere gratitude to my co-guide Mr. NINAD THIGALE and Mr. MOHAN SUBBURAJ for their continuous help.

I am grateful to all staff members in Department and concerned lab in charge of COEP and every employee of Ador Welding Limited for their timely support.

(Madhu Ranjan)

Professor Emeritus

ABSTRACT

Precipitation hardening ferritic pearlitic (PHFP) steels form a group of alloy steels containing 0.2 - 0.9 wt % carbon apart from the addition of either of carbide forming elements such as Cr, Mo, Ti, V, and Nb. In the recent past, the PHFP steels were primarily investigated as a forging grade automotive material towards the attainment of better mechanical properties than quenched and tempered (Q&T) steels. These required properties are achieved directly by controlled cooling after hot forging, which eliminates the additional heat treatment steps involving a hardening, tempering and stress relieving cycle, thereby saving production time, capacities and lowering the manufacturing cost to 90% vis-à-vis quenched and tempered steels. The medium carbon PHFP steels so developed mainly finds application in the automotive components like crankshaft, diesel engine connecting rod, gear wheel, pinion shaft and rotating parts of trucks. They also find applications in aerospace structural components like the undercarriage system and load-bearing members substituting Q&T steels. The obvious cause being their cost effective production and achievement of a ferrite - pearlite microstructure imparting good strength as well as toughness. We selected the PHFP steels for this study with an aim to enhance the bandwidth of their applications by way of achieving other phases/phase mixtures in this steel by incorporating a suitable thermomechanical processing (TMP) treatment. The focus of our research work was primarily on microstructure, simulation and mechanical properties of medium carbon PHFP steels of type 34CrMo4, 42CrMo4 and 50CrMo4.

In the first part, all three medium carbon steels were preheated at 1100 °C, held there for 60 min and forged horizontally at 1050 °C for e = 0.2 to 0.6, followed by a furnace-, natural air- and forced air- cooling. The optical microscopy and scanning electron microscopy (SEM)

results revealed the initial ferrite - pearlite microstructure transformation into nearly equiaxed and coarse grained ferrite - pearlite microstructure on furnace cooling and further into fine ferrite - bainite microstructure after natural and forced air cooling respectively. For all strain conditions (e = 0.0 to e = 0.6), fine ferrite along with distorted fine colonies of bainite being formed with an increase in both strain and cooling rate. For 34CrMo4 steels, the highest toughness of 54 J was observed for e = 0.4 with furnace cooling, whereas, for 42CrMo4 and 50CrMo4 steel, a higher value of toughness (24.8 J and 18 J respectively) was noted for e = 0.2 with furnace cooling. These toughness values were almost 10%, 75% and 2.3 times more than as-received samples of the respective grades. The maximum YS and UTS achieved was, YS = 700 and UTS = 790 MPa for 34CrMo4 steel, YS = 979 and UTS = 1147 MPa for 42CrMo4 steel and YS = 1240 and UTS = 1395 MPa for 50CrMo4 steels at e = 0.6 with forced air cooling. These properties were almost two to three times better than as-received samples. The wear behavior of only continuous cooled 34CrMo4 steels was studied using a 60 – 100N load and a sliding distance of 3000 m. Both calculated wear rate and wear track SEM images demonstrated a decrease in wear rate with an increase of both strain and cooling rate, thereby meaning that forced air cooling treatment enhanced the wear performance of 34CrMo4 steel samples.

In the second part, as received and annealed 42CrMo4 round steel bar was subjected to similar forging conditions, but now held isothermally for 45 minutes in a salt bath at four different temperatures (350 °C - 650 °C) followed by air cooling. Here, the optical microscopy performed along with SEM and simulation results using forge NxT 3.0 est disponible simulation software revealed a transformation from initial ferrite - pearlite microstructure to a ferrite - bainite microstructure for lower holding temperatures, revealing different

morphologies of these phases/phase mixtures, apart from a monotonic reduction in phase/phase mixtures, grain and carbides precipitate size. A simple 2-step TMP treatment demonstrated an improvement in UTS by 20% and elongation by 10% vis-à-vis same grade conventional hardened and tempered steels involving a large number of manufacturing steps. YS and impact toughness recorded a significant improvement by almost 82% and 70% vis-à-vis as received annealed samples.

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I am highly honored that I have been allowed to complete my Ph.D. degree in the prestigious College of Engineering, Pune. I would like to express my sincere and heartiest thanks to Director, Dr. B. B. Ahuja and the Department of Metallurgy and Materials Science, College of Engineering, Pune, for giving me the chance of using my engineering and communication skills through this project.

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I would like to thanks M/s Kalyani Carpenter Special Steel Ltd., mundhwa, Pune, for providing furnace and hydraulic press for hot deformation of my steel samples. I would also like to thanks M/s Automotive Research Association of India (ARAI), Paud road, Kothrud, Pune for conducting forge simulation.

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Date: 28|07|2020

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APPROVAL CERTIFICATE

I hereby forward the thesis entitled "**EFFECT OF THERMO-MECHANICAL PROCESSING ON MECHANICAL PROPERTIES OF PRECIPITATION HARDENING FERRITIC PEARLITIC (PHFP) STEELS**" prepared by **Mr. Arun Shivaji Thakare** (MIS No.:131511002) in the fulfillment of the requirement for the award of **Doctor of Philosophy in Metallurgy and Materials Science Engineering** of Savitribai Phule Pune University, Pune.

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INSTITUTE CERTIFICATE

This is to certify that **Mr. Arun Shivaji Thakare** (MIS No.:131511002) has been working for his Doctor of Philosophy degree in Metallurgy and Materials Science Engineering under the guidance of **Prof. S. P. Butee,** Professor in Metallurgy and Materials Science Engineering Department. We had provided all the related facilities for carrying out his research work in the Department of Metallurgy and Materials Science of this institute.

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CERTIFICATE OF THE GUIDE

This is to certify that this work on the subject **"Effect of thermo-mechanical processing on mechanical properties of precipitation hardening ferritic pearlitic (PHFP) steels"** is the bonafide work of **Mr. Arun Shivaji Thakare** (MIS No.:131511002)**.** The work is carried out under my supervision for the fulfillment of the requirement for the award of the degree of **Ph.D. in Metallurgy and Materials Science Engineering.** He has worked on the thesis since May 2016 and the thesis in my opinion is worthy for the award of the **Doctor of Philosophy in Metallurgy and Materials Science Engineering**. In accordance of the rules and regulations of the **Savitribai Phule Pune University** the results embodied in the thesis have not been submitted to any other University or Institute for the award of any other degree or diploma.

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Acknowledgement

This acknowledgment is not mere formality, but it is penned to express my sincere gratitude towards everyone who has contributed towards making my project work a memorable experience.

Firstly, I would like to express my sincere gratitude to my guide Dr. S. B. Sarkar, Emeritus professor for selecting this project topic having immense industrial importance, sourcing the valuable samples from the steel plant, designing the experiments, analysing and interpreting the results and guiding me with proper information even in the lockdown period. Without his support I could not have completed this project. His guidance helped me all the time in research and writing of dissertation report.

I am highly honoured and express my thanks to Dr. S. P. Butee for giving me an opportunity to complete my M.Tech degree in the prestigious College of Engineering, Pune. I would like to express my sincere and heartiest thanks to the Department of Metallurgy and Materials Science, College of Engineering, Pune, for giving me the chance of using the well equipped labs and my engineering skills throughout this project. I am thankful to all teaching and non-teaching staff for helping me in carrying out this project.

CERTIFICATE

This is to certify that the report entitled '**A Study on the Physico-chemical Characteristics of inclusions in steel and their role in Bearing and Gear Failure**' submitted by **METKARI AKSHAY CHANDRAKANT** (MIS NO-121927004) in the partial fulfilment of the requirement for the award of degree of Master of Technology under department of Metallurgy and Materials science with specialization in Materials Engineering of College of Engineering Pune, affiliated to the Savitribai Phule Pune University, is a record of his own work.

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Acknowledgement

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I would also like to thank Arihant Steels Ltd Ltd for providing the required material for my project and sharing the required technical information.

CERTIFICATE

This is to certify that the dissertation entitled **'Effect of Segregation & Banding AND Microstructure on Carburization of Steel'** submitted by **Chougule Nilesh Balasaheb** (MIS NO-121946003), in the partial fulfillment of the requirement for award of degree of Master of Technology under department of Metallurgy and Materials science with specialization in Materials Engineering of College of Engineering Pune, affiliated to the Savitribai Phule Pune University, is a record of his own work.

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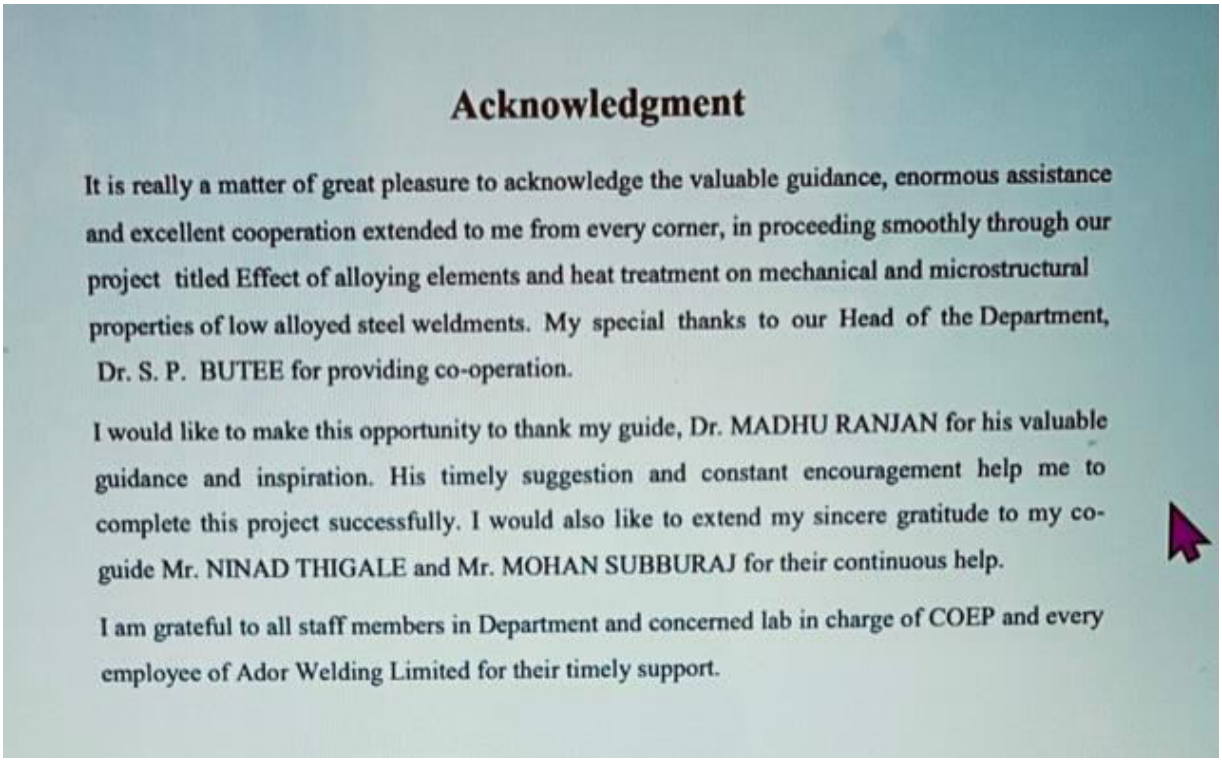
PARASNIS KEDAR PRASHANT :
'EFFECT OF ALLOYING ELEMENTS AND HEAT TREATMENT ON MECHANICAL AND MICROSTRUCTURAL PROPERTIES OF LOW ALLOYED STEELWELDMENTS'. The project was carried out at Ador Welding, Pune



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It is really a matter of great pleasure to acknowledge the valuable guidance, enormous assistance and excellent cooperation extended to me from every corner, in proceeding smoothly through our project titled Effect of alloying elements and heat treatment on mechanical and microstructural properties of low alloyed steel weldments. My special thanks to our Head of the Department, Dr. S. P. BUTEE for providing co-operation.

I would like to make this opportunity to thank my guide, Dr. MADHU RANJAN for his valuable guidance and inspiration. His timely suggestion and constant encouragement help me to complete this project successfully. I would also like to extend my sincere gratitude to my co-guide Mr. NINAD THIGALE and Mr. MOHAN SUBBURAJ for their continuous help.

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(Madhu Ranjan)

Professor Emeritus

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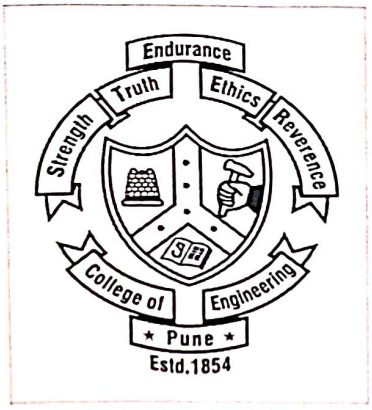

This is to certify that the report entitled "**FABRICATION & CHARACTERIZATION OF LITHIUM DISILICATE GLASS CERAMIC WITH PRESSABLE DENTAL PROSTHESIS**" submitted by **SHUBHAM SARJERAO SAWANT (MIS No. 121927009)**, in the partial fulfillment of the requirement for the award of degree of Master of Technology with specialization in Process Metallurgy of College of Engineering Pune, affiliated to the Savitribai Phule Pune University, is a record of his own work.

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ABSTRACT

Lithium Disilicate Glass Ceramic is primarily used for dental applications. The SiO_2-Li_2O-Al_2O_3-ZrO_2-P_2O_5 based dental glass ceramic with additives were synthesized by glass ceramic route. SiO_2 & Li_2O were the main components of the system. The additives comprised of P_2O_5 as nucleating agent, CeO_2 as glass coloring oxide, ZrO_2 as coloring body, La_2O_3 and Al_2O_3 both used to avoid reaction with the investment material. The other additives used were K_2O to lower the viscosity and reduce the processing temperature) & MgO for better pressing ability. The route comprised of milling, glass melting and followed by quenching to get glass frit, regrinding of frit to form fine powder of size ~2μm and compaction. The pellets so formed were subsequently annealed at 500°C/1hr followed by first heating at 530°C and second heating at 720°C-920°C/ 2 hours. Density ranged from 2.34-2.43 g/cc. Characterization for XRD revealed Li-Metasilicate glass formation after first heating and Li-Disilicate glass ceramic formed during second heating. SEM of Li-Metasilicate revealed the microstructure comprising of small spherical crystals, whereas Li-Disilicate showed needle / plate like crystals of length 1μm-4μm. Wear rate ranged from 0.0101 - 0.01467 mm^3/m for 5N & 0.01274 – 0.02113 mm^3/m for 25N. Microhardness ranged from 380 – 470 HV & the pellets passed the standard chemical solubility test with the values ranging from 130 – 250 $\mu g/cm^2$.

KEYWORDS: - Glass Ceramics, Lithium Disilicate, Lithium Metasilicate, Heat Treatment, Microstructure, Wear Rate

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