1
Introduction

The electricity demand is increasing day by day, which has resulted in the development of more power plants to fulfil the growing electricity requirements. Coal plays an essential role in the power generation industry, due to which Pulverized Coal Combustion (PCC) power plants dominate the power industry (Nicole, 2013). Increasing PCC plant efficiency guarantees lower coal consumption, resulting in reduced fuel costs and helps to sustain valuable coal resources. Higher efficiency also lowers the amount of flue gas to be treated in the flue gas cleaning systems and lowers the carbon tax. An increase in the superheated steam temperature is an effective way to improve the efficiency of coal-based power plants (Nicole, 2013; 2014). Coal-based power plants are categorized into different types presented in Table 1.1.

Table 1.1: Types of coal-based power plants (Nicole, 2013; Chetal, 2015)

Type	Superheater parameters		Candidate materials	Efficiency %
	Temperature (°C)	Pressure (MPa)		
Subcritical	≤ 540	< 22.1	Ferritic steels (low alloy Cr-Mo steels)	< 35
Super critical (SC)	540-580	22.1-25	Ferritic and Martensitic steels (9-12% Cr)	35-40
Ultra-super critical (USC)	580-620	22-25	9-12% Cr steels	40-45
Advanced ultra-super critical (AUSC)	700-725	25-35	Advanced 10-12% Cr steels; Nickel alloys	45-52

It is reported that if the efficiency of fossil fuel power plants increases just by 1%, there is an approximate reduction of 2.5% CO_2 emission (Nicole, 2014). With the increase in operating temperature, there is a requirement for high-performance materials that can have better creep and high-temperature corrosion resistance properties for better service life in power plant applications (Table 1.1). Supercritical boilers consist of various components (like superheater, reheater, water wall tubes, and headers). For the construction of boiler components, different materials presented in Table 1.2 are used as per the required properties and operating conditions.

Table 1.2: Power plant boiler components and candidate materials

Component	**Operating conditions**	**Material requirement**	**Candidate materials**
Water wall tubes	450-600°C/250-300 bar	Creep strength, Fireside corrosion, Weldability	T12, T22, T23, T91, T92
Steam pipe	400-550°C/200-220 bar	Creep strength, Thermal expansion	Carbon steel, T22, T23, T91
Header	450-600°C/200-250 bar	Creep strength, Thermal expansion, Weldability	210-C, 106-C, T23, T91
Super heater/reheater	550-700°C/300-350 bar	Creep strength, Thermal expansion, Fireside corrosion/steamside oxidation, Weldability	T91, T92, SS304H, SS347, IN617

The various components need to be joined for boiler construction in thermal power plants. For the joining of these components, junctions are required, generally called headers, and welding processes are used to join these components. Various components require repair/maintenance of the cracks that may occur during fabrication, storage, transportation stages, or during service. The following types of welding processes are generally used for high-temperature steel.

- Shielded Metal Arc Welding (SMAW)
- Gas Tungsten Arc Welding (GTAW)
- Gas Metal Arc Welding (GMAW)
- Submerged Arc Welding (SAW)

SMAW process is a widespread and generally used process due to its simplicity, versatility, and ease of operation. SMAW setup usually consists of an electric power source, welding cable, electrode holder, welding electrode, and a workpiece to be welded. Flux coated electrode used in the SMAW process generally consists of the core wire and flux coating. The chemical composition of the core wire is selected on the basis of base materials to be welded and also on the required properties of the final welds. Core wire provides the required filler material to fabricate the weld joint and give the desired mechanical properties.

In contrast, the flux coating provides the protective shield to protect the molten weld pool from the atmosphere. It is also used to add the desired alloying elements to improve the final weld performance. The selection of the electrode coatings plays an essential role in deciding the weld quality. Electrode coatings perform several essential functions like improving the arc stability, promotes slag formation, improves alloying elements addition to weld and also removes harmful gases/impurities from the weld pool. Depending upon the type of electrode coating, these flux coatings are categorized as Cellulosic, rutile, and basic. These coatings are used according to the desired weld performance and location of the weld.

Power plant fabrication is a complex process due to the variety of service environments, which requires a range of different alloys in the boiler system. The application of alloy in different service conditions requires dissimilar metal welds (DMW). The fusion welds made between two different materials suffer from microstructure instability at the DMW interface. During the high-temperature service conditions, dissimilar welds undergo premature service failures. The following reasons contribute significantly to the dissimilar weld failures:

- Thermally-induced cyclic stress at the DMW interface due to the difference in coefficient of thermal expansion (CTE) between the base metal and weld metal.
- Migration of carbon from one material to another resulting in the formation of narrow carbon depleted zone with inferior mechanical properties
- Microstructural instabilities
- Oxidation at the weld metal/base metal interface resulting in the formation of oxide notches adjacent to the weld fusion line.
- Failures due to weld geometry, welding defects, type of weld metal, residual stresses, and operating conditions are also potentially important causes.

Dissimilar metal welding has been a very important aspect in the supercritical boiler design, repair and maintenance because it contains a number of dissimilar joints (Ferritic to martensitic steel; ferritic to austenitic steel). There are certain issues that need to be addressed during fabrication or repair the DMW due to the variation in properties of the two base materials and weld metal. These problems need to be resolved by selecting a suitable welding process along with adequate consumables.

This thesis contributes towards the broad research database to develop electrode coatings that are used to fabricate/repair ferritic to martensitic/austenitic steel welds used in power plant applications. For the design and development of electrode coatings, ternary phase diagram along with mixture design methodology was used. A comparison was also drawn between the weld characteristics of the welds fabricated using laboratory-developed electrodes and commercially available electrodes. High-temperature molten salt corrosion behavior of base metal and fabricated welds were also investigated in this work.

The organization of the content of this thesis is as follows:

Chapter 1 provides a brief introduction to the research work and the motivation for this investigation. This chapter also includes the organization of the thesis.

Chapter 2 provides a detailed literature review related to the various aspects of the current problem. This chapter contains the requirement of power plant boilers, selection of candidate materials, the need for dissimilar welding, the demand for electrode coatings to fabricate/repair dissimilar welds. It also reviews the state-of-the-art problem associated with the design and development of the welding electrodes, issues related to the dissimilar welding, and hot corrosion properties of base metal/weld metal under the molten salt attack.

Chapter 3 deals with the identification of the present problem and depicts it. It also highlights the objective of the present study along with the work plan.

Chapter 4 discusses the experimental design of the present investigations. It explains the design and development procedure of electrode coatings. It also describes the extreme vertices design approach to develop a design matrix for coating formulations. The welding electrode manufacturing for dissimilar joint P22/P91 and P91/SS304 has also been discussed. This chapter further discusses the weld fabrication procedure and different characterizations performed on the base metal and fabricated welds.

Chapter 5 consists of results and discussion of the experimentations performed in this work.

Chapter 6 consists of the conclusions drawn from the investigations and the future scope in the current area of investigation.