CHAPTER 1

INTRODUCTION

1.1 WELD HARDFACING

Weld hardfacing is a process of depositing a filler material on the surface of carbon and low alloy steel base metal in order to improve the wear resistance. Gate Valve used in Oil and Natural Gas Corporation (ONGC) Ltd. India, are subjected to heavy wear and tear, resulting in reduced service life requiring frequent replacement. The replacement could be either through the whole material removal or coating the existing with superior wear resistant material. The latter is cheap and cost effective but useful only when service conditions demand the surface properties of the material playing major role in controlling the overall performance (Modi et al 2004). Therefore an extension of service life through coatings by a process called hardfacing (D’Oliveira et al 2006), has significant cost savings.

Weld hardfacing is mainly employed for surface modification of the existing valves, valve seats, turbines, steam generators, pumps etc.

1.2 PROBLEM IDENTIFICATION

The low alloy steel gate valves are made by casting process in Bharat Heavy Electricals Limited (BHEL), Tiruchirapalli, TamilNadu, India. They produce 6.0 lakhs valves per year and supply it to ONGC Ltd India. In ONGC, the gate valves are operating under high pressure at an elevated temperature and a high load sliding condition causing oil leakage on the
surfaces resulting in reduced service life of the gate valve. Subsequently it has been given to BHEL seeking solution to improve service life of the gate valves through the arrest of oil leakage. In this connection, this study attempts to analyse some performance related research which would eventually improve the service life of the gate valves and outcomes are highlighted in the following sections.

1.2.1 Bead Geometry and Dilution

In determining the quality of hardfaced components, the bead geometry and dilution play a vital role by critically affecting the mechanical and metallurgical properties of the overlays (Gourd 1998, Palani and Murugan 2006a, Benyounis and Olabi 2008, Siva et al 2008). Several welding parameters seem to affect the overlay bead geometry (Nagesh and Datta 2002) and dilution. Therefore, overlay bead geometry and dilution has to be effectively controlled by selecting proper welding process parameters.

1.2.2 Wear Resistance

Wear is the major problem that occurs wherever there is a load and relative motion between surfaces. It takes place due to a combination of several factors, such as, chemical and mechanical effects, the kind of contact, etc. and it depends critically on the environmental conditions (Vite et al 2005). Moreover, it has got important technological and economic significances because the worn mechanical component affects the product quality, profitability of the manufacturing operations (Yang and Loh 1995) and simultaneously reducing the effectiveness of mechanical components (Jeng et al 1991). In ONGC applications, the damage due to sliding wear of metal-to-metal contact of gate valve is a major problem. It is expected that the high load sliding contacts at an elevated temperature degrades the material and therefore it opposes wear resistance. Parameters such as chemical
composition, topography, hardness and microstructure play an important role in abrasive wear (Vite et al 2005). But still, the actual control of wear starts with the choice of the correct deposition technique and its variables. The deposition techniques include hardfacing with wear resistant alloys, plasma nitriding, laser hardening and other case hardening methods (Yang and Loh 1995). Variables controlling wear are high work load, high relative speed or the abrasive nature.

1.2.3 Residual Stresses

Residual stresses are formed in the components during welding. The welding residual stresses formed may be tensile or compressive which significantly influence the weld cracking, strength and inservice behaviour of welded structures (Wang et al 1991). Tensile residual stresses can lead to stress corrosion cracking, distortion, fatigue cracking and premature failures in components (Molzen and Hornbach 2001), while compressive residual stresses tend to reduce the buckling strength of a component (Odar et al 1961). The tensile residual stresses measured through thickness in the component may cause lamellar tearing in thick section weldments (Hong et al 1993). Their effects are inevitable until the components are subjected to external load or exposed to adverse conditions. Thus, it is essential to measure the residual stresses in hardfaced overlays, as residual stresses influence the service life of overlays.

1.3 Selection of Materials

Cobalt based super alloys are premier wear resistance alloys generally used under elevated temperature (Menon 1996) and high load sliding conditions (Hayness and Farmer 1992), where corrosion resistance is required at the same time (Raghu and Wu 1997, Vite et al 2005). These alloys are hard and ductile having high resistance against abrasive wears (Vite et al
Their hardness may be obtained by adding tungsten carbides, chromium carbides and cobalt carbides (Burwell 1957, Arnell et al 1991).

Stellite 6 (Co-Cr-A) is one of the families of cobalt-based materials and is composed primarily of interdendritic carbides in a Co-Cr-W-C matrix (Shiels et al 1994). This alloy is widely selected for different wear applications and exhibits good wear and corrosion resistance even upto 750°C (Hayness and Farmer 1992, Yang and Loh 1995, Aoh et al 1999, Marimuthu 2006). It is available in the form of cast rod or as a hardfacing material (Deuis et al 1998) and it could be deposited by conventional welding material (Deuis et al 1998) and more advanced processes such as Plasma Transferred Arc (PTA) hardfacing and laser cladding (D’Oliveira et al 2002a).

In the present investigation, Low alloy steel (AISI 4140) has been chosen as the substrate material and stellite 6 as the hardfacing material. The former is extensively used as a construction material of Gate Valve in ONGC, India.

1.4 SELECTION OF PROCESS

Hardfacing alloys are deposited by any number of welding processes, because welding is a fusion process which leads to sound metallurgical bond between the hardfacing alloy and substrate. The weld hardfacing are generally done by traditional welding processes such as Oxy-Fuel gas welding (OFW), Gas Tungsten Arc welding (GTAW), Manual Metal Arc Welding (MMAW), Gas Metal Arc Welding (GMAW) and Submerged Arc Welding (SAW) (Deuis et al 1998, Garg 2002). Compared to these processes, PTA surfacing provides a higher deposition rate (Hallen et al 1992), higher deposition efficiency (approx 85%), homogenous refined microstructure (Davis 1993, D’Oliveira et al 2006) and especially its wide range of selection of material (Hallen et al 1992) have resulted in the
possibility of producing sound metallurgical bonding between the hardfacing layer and substrate with very low dilution and distortion (Budinski 1988, Davis 1993, Garg 2002, Shin et al 2003). Moreover, it permits precise control of important welding process parameters (Marimuthu and Murugan 2003) to obtain the desired weld bead geometry. Because of these reasons, PTAW is selected for deposition of stellite 6 on low alloy steel gate valves.

1.5 NEED AND OBJECTIVES OF THE RESEARCH

The present investigation aims to find a suitable welding procedure to overcome the problems mentioned above and the detailed objectives are discussed hereunder.

1.5.1 Regression Modelling of Bead Geometry

It is essential to obtain desirable mechanical properties that are influenced by the overlay bead shape. Therefore it is clear that precise selection of the welding process parameters is necessary to control the overlay bead shape. Mathematical models may help to study the main and interaction effects of the various process parameters affecting the dimensions of the overlay beads. In addition, the automatic and robotised weld hardfacing is being employed increasingly in the process industries for improved quality and productivity. This will lead to an increased dependence on the use of equations to predict the dimensions of the overlay bead.

Hence, the first objective of the investigation is to develop the regression models using Response Surface Methodology (RSM) for the prediction of overlay bead geometry like bead width, depth of penetration, height of reinforcement and percentage dilution.
1.5.2 Regression Modelling of Macrophase hardness

It is known that there is a significant effect of carbides in an alloy determining the deposit hardness and resulting wear resistance. Presence of carbides/complex carbides in the hardfaced overlay is the best indicator of wear resistance. An increase in surface hardness almost certainly leads to increased wear resistance. The literature available indicated that mathematical models have not yet been developed to quantify the effects of PTA process parameters on macrohardness.

Therefore, the second objective is to develop mathematical models to study the main and interaction effects of PTA process parameters on macrohardness of hardfaced overlay.

1.5.3 Effects of Heat Input on Microstructure and Microhardness Survey

The heat input has significant effect on mechanical and metallurgical properties of the hardfaced layer. Information about factors affecting microstructure and microhardness of the PTA hardfaced layer is scarce. Hence, the third objective of the investigation is to find out the effects of the heat input on the microstructure and microhardness of the hardfaced components.

1.5.4 Regression Modelling of Wear Rate

Earlier researchers obtained significant results from studies on wear performance of the PTA hardfaced layer with respect to applied load, sliding speed, counterface, track radius, lubrication and atmosphere. But very few investigators have studied the effects of wear testing parameters on wear rate of PTA hardfaced layer by developing mathematical models. Hence, an
indepth investigation is necessary to study the direct and interaction effect of wear testing parameters on the wear rate of the hardfaced specimens.

Therefore, the fourth objective is to study the direct and interaction effects of wear testing parameters (applied load and sliding velocity) and PTA heat input on wear rate by developing mathematical model.

1.5.5 Measurement of Residual Stresses

It is prime important to calculate the residual stresses in welded components during welding. Because, the residual stresses are essential to assess the strength of the welded structure. The residual stresses in actual welding structures are much more complicated, changing with the thickness of components, the amount of welding heat input and the effect of phase transformation (Wang et al 1991). The possible method to find residual stresses is by simulating the welding and cooling to room temperature through Finite Element Method (FEM) software. Although, it is interesting to predict residual stresses on thick section weldments through FEM software, it may cause lamellar tearing. Previous researchers have not yet referred the measurement of residual stresses on 2” stellite 6 hardfaced gate valve using contour method.

Therefore, the fifth objective is to measure the residual stresses on stellite 6 hardfaced gate valve using contour method and compared the result with X-Ray Diffraction (XRD) technique.

1.6 PLAN AND SEQUENCE OF RESEARCH WORK

The plan and sequence of activities in which the research work was carried out is depicted in Figure 1.1.
Figure 1.1 Plan and Sequence of Research Work
1.7 OUTLINE OF THE THESIS

This thesis comprises of seven chapters and the outline of each chapter is described below.

Chapter 2 presents a detailed survey on the investigations carried out by various researchers in the selected fields of interest.

Chapter 3 discusses the selection of equipment for conducting the experiments, process variables identified for the investigation and the experiment conducted. Experimental results are presented in this chapter and the development of mathematical models for the prediction of bead geometry and percentage dilution of linear overlay bead is discussed.

In chapter 4, the main and interaction effects of process parameters on bead geometry and percentage of dilution of circular overlay bead are discussed with the help of development of mathematical models.

In chapter 5, the mathematical modelling of the macrohardness of the hardfaced overlay is elucidated. The effects of PTA process parameters on the macrohardness are discussed. This chapter includes a study on microstructures along with microhardness survey of stellite 6 hardfaced gate specimens.

Chapter 6 deals with the detailed wear behaviour analysis of the hardfaced layer. The main and interaction effects of wear testing parameters (applied load and sliding velocity) and PTA heat input on wear rate of the hardfaced overlay are also presented. This chapter presents the measurement of residual stresses on stellite 6 hardfaced gate valve using contour method and the results are compared with the XRD technique.

Chapter 7 brings out the summary of results along with the recommendations for future scope of research in this specific field of study.