CHAPTER 1

INTRODUCTION

1.1 GENERAL

The heat treatment of steels is one of the most important developments of the industrial era. The ability to attain high strength and toughness by conventional heat treatment process is a major benefit for alloy steels. As reported by George Krauss (2001), the addition of carbon to steel, helps in the heating and quenching of steel to make martensite had been mastered over 3000 years ago. Still, research effort continues in the process of producing steel components into a stronger and more wear-resistant than the earlier ones. In alloy steels, a low percentage of austenite is retained after the conventional heat treatment process. The retained austenite as a soft phase in steels could decrease the life of the component and can be transformed into martensite under certain working circumstances. This new martensite could cause some problems such as micro cracks thereby reducing the life of the component. It is found that this martensite causes microcracks and decreases the product life. Moreover, this type of martensitic transformation provides instability as reported in Mohanlal et al (2001). Concerning the problems stated above, the controlled transformation of the retained austenite into martensite is necessary to develop many types of durable component. For this controlled transformation of retained austenite to martensite, cryogenic treatment technique is adopted. This is a modern process used to manufacture highly durable components. It is an affordable supplement process to conventional heat treatment process of steel. As a result, the retained austenite is decreased and development of wear resistance is attained.

This thesis discusses the influence of conventional heat treatment (CHT), shallow cryogenic treatment (SCT) and deep cryogenic treatment (DCT) of En 19 alloy steel through various mechanical and characterization tests. It also discusses the optimization of deep cryogenic and heat treatment conditions to reduce wear loss of En 19 steel.

1.2 PROBLEM STATEMENT

It has been found that the wear and corrosion are the well-known problems in the heavy equipment of mineral processing industry owing to their significant impact on material loss and maintenance costs as pointed out by Dunn (1985). Tao et al (2006) and Tao et al (2007) discussed that, research efforts have been made for the past two decades with an aim to reduce the wear of mineral processing equipments namely cyclones, pumps, and heavy medium vessels and also to reduce the wear of automotive components namely crankshafts, connecting rods, axles, and gears. However, little research has been done to decrease the wear of screens, chains for conveyors, and piping where conventional wear resistance enhancement methods, (e.g. ceramic lining) are impractical.

Screening is a familiar process used in mineral processing. Screen is the most generally used device in the mineral processing industry to separate particles by size. Modern mineral processing is not possible without proficient screening. The different sizes of coal can be separated by passing through series of screens, each of a reducing size. The individual screen discharges are subsequently directed into different screen products for successive processing or trade. Mainly in vibrating screening equipment, dimension of the screen aperture enlarges as material wears which results in inappropriate aperture sizes and reducing screening efficiency. This creates non-ideal feed to downstream processes, further decreasing processing efficiency. Frequent replacement of these steel components increases the equipment down time and maintenance cost thereby reducing the process efficiency as explained by Tao et al (2006).

The screen section in vibrating screen equipment is vibrated during the operation. The vibrating screen equipment is shown in Figure 1.1. The screen section is shown in Figure 1.2, which is made of En 19 steel. This steel is equivalent to AISI 4140 steel and is also widely utilized for the manufacturing of equipments used in mineral processing industry and also for automotive industry.

Figure 1.1 Vibrating Screen Equipment

Figure 1.2 Screen Section Made of En 19 Steel (Tao et al (2007))

Wear has a severe deleterious effect as it causes a steel component to become entirely ineffective or prone to catastrophic failure, as indicated in Rao and Misra (1995). Laurila and Budge (2000) reported that up to 40% of the operating costs of a mineral processing plant are caused by equipment maintenance. Repeated breakdown of the equipments leads to the study of wear resistance improvement in mining and mineral processing industry besides automotive industry. In addition, the selection of treatment conditions for improving the wear resistance of steel components is also a major issue for the heat treatment processes. Generally, these conditions are selected from the metal’s handbook or standards, but the values are given only in some ranges. These values are not the optimal values. The improper selection of parameters will leads to inappropriate properties of steel. Hence, it is of a paramount importance to find the treatment conditions for minimizing wear of steels in the heat treatment industry.

1.3 SIGNIFICANCE OF THE RESEARCH

The present scenario of Mining Industry in India was reported by Sushilkumar Srivastava (2011). Currently in India, total number of functioning coal mines is around six hundred and there are several other seasonal or small mines. These small or seasonal mines are not submitting statutory returns to the Government of India. Around 2500 metalliferous mining industries are submitting statutory returns. Though, there are many additional small sized mines, seasonal in nature are not submitting the statutory returns. Therefore, the total numbers of metalliferous mining industries are around 6000. The whole workforce of the mining industry in India consists of more than one million employees. The total production of coal was 313.69 million tons and that of iron ore, was 80.59 million tons. For financial impact, the gross worth of mineral production in India was about Rs. 66,308 crores. This huge industry is scattered and wide spread over a large region of land and underground which includes many different kinds of jobs and processes. In search of larger production of minerals at the most feasible cost, which is needed to meet the requirements of developing industries, many sophisticated machineries and plants have been newly introduced. The research on tribology is very important for proper equipment design. Maintenance and up-keep of these equipments and systems is important for consistent and safe operation and thereby getting higher productivity. The improvement of wear resistance is essential for mining equipments and systems. Commonly, it can be considered as the heart of engineering. It is found that 70% of failures of the mechanical components are due to the tribological causes and as a rough estimate, one third of world’s energy resources appear as friction in one form and other end most of these appear as waste. This shows the significance of tribology, which would lead to considerable savings.

The improved attention to wear and friction would save developed countries upto 1.6% of their gross national product, or over $100 billion annually in the USA alone as mentioned in Jost HP (1990). The level of the financial loss related with friction and wear arises from the fact that whole mechanical systems, be they automobiles, are frequently scrapped whenever only a few of their parts are badly worn. In the case of an automobile, the energy consumed in its manufacture is equivalent to that consumed in 100000 miles of operation, has been pointed out by Ludema (1996).

Knowledge of residual stress in steels is also significant in the component design field. It is extremely important that the researcher understands the mechanism for the inducement of the residual stress field of concern. When manufacturing processes or some times repair procedures are judged the most likely source of the residual stress, it is often possible to predict the magnitude and distribution of residual stress. Such information can be obtained consulting the literature.

Thus the technological demand for enhancing the life of the mechanical components has led to the development of the properties of steel components. To achieve this tough task, researchers are involved in the development of the mechanical properties of steels by means of various techniques. The cryogenic treatment is one of the modern techniques used to improve the mechanical properties of steel components. In recent years material scientists and engineers devote their efforts in enhancing the fatigue and impact properties of metals by deliberately producing compressive residual stresses in to the surface of engineering materials. Numerous critical or highly stressed steel components such as gears, crankshafts, axles, connecting rods etc. are manufactured from En 19 steels that are subjected to conventional heat treatment to achieve a combination of high strength and toughness, as indicated by

Ferguson et al (2005). The problem of retained austenite still exists after conventional treatment of steels. However, the cryogenic treatment is one of a modern process, which can convert the retained austenite to martensite along with the fine carbide precipitations thereby improving the tribological behaviour of steel. It plays an important role in developing the wear resistance of steels. In recent years, researchers have also tried to evaluate the process to optimize the cryogenic treatment parameters. The scientific literature available in this area is also limited. Hence, it is of great value to optimize the parameters used in the deep cryogenic and heat treatment processes with respect to En 19 steel. The purpose of this optimization study is to provide a guide for the automotive and heat treating engineers so that they know the treatment conditions for the part to be produced. Besides, this research work will also assist the engineers to save time, energy and cost.

1.4 APPROACH OF THE RESEARCH

Cryogenic treatment plays an important role in developing the tribological properties of steels. One of the most common claims in cryogenic treatment is an increase in wear resistance of steels as investigated by Barron (1973). Adding cryogenic treatment to conventional heat treatment process will aid the manufacturers to attain better wear resistance of steel components. Mohanlal et al (2001) pointed out that the cryogenic treatment is an affordable one-time permanent treatment process that affects the entire cross section of the steel component. Collins and Dormer (1997) found that the cryogenic treatment promotes the transformation of the retained austenite into martensite at cryogenic temperatures and facilitates the formation of fine carbides in the martensite, thus improving the wear resistance. It has lot of benefits and it gives dimensional stability to the material by improving wear resistance, strength and hardness of the materials as stated by Molinari et al (2001). However, scientific research on cryogenic treatment has been very few and only less number of research papers have been published on medium carbon steels as indicated by Zhirafar et al (2007). The alloy considered in the current study is En 19 Chromium Molybdenum steel. This material is widely used in the fabrication of the equipments used in mineral processing industries as pointed out by Tao et al (2006). It also has a wide usage in the manufacture of automotive components such as crankshafts, axle shafts, connecting rods, gears, propeller shafts joints, etc, where mechanical properties are significant one. On this basis, development of mechanical properties of En 19 steel is mandatory for the mineral processing and coal preparation industry, besides automotive industry. Therefore, in the present study, the influence of shallow cryogenic treatment and deep cryogenic treatment on behaviour of En 19 steel is considered.

The metallurgical transformations produced by deep cryogenic treatment to enhance the wear resistance are

- The transformation of retained austenite into martensite
- The carbon redistribution (segregation and clustering) responsible for low temperature conditioning of martensite can occur for relatively long soaking time only

Apart from the requirement of development on tribological behaviour, the optimization of Deep cryogenic and heat treatment conditions namely hardening temperature, soaking period, tempering temperature and tempering period, is also considered in this research work.

1.5 AIM AND SCOPE – OF THE PRESENT WORK

AIM

The main objectives of this research work are to evaluate the influence of both shallow cryogenic treatment (SCT) (at -80ºC for 5 hours) and deep cryogenic treatment (DCT) (at -196ºC for 24 hours) on behaviour of En 19 chromium molybdenum steel, with respect to conventional heat treatment (CHT) and also to optimize the Deep Cryogenic and heat treatment parameters for minimizing the wear loss.

SCOPE

- The scope of the research is to evaluate the influence of cryogenic treatment on hardness, wear resistance, tensile strength, impact strength, residual state of stress, corrosion resistance and damping capacity
- To quantify the influence of cryogenic treatment on microstructure (Retained austenite content)
- To find whether there is any change in steel microstructure due to conventional and cryogenic treatments (before and after tempering) using scanning electron microscope
- To arrive at the best treatment among CHT, SCT and DCT for the maximum benefits pertaining to En 19 steel
- To optimize the parameters affecting deep cryogenic and heat treatment to reduce wear loss of En 19 steel using Taguchi technique

1.6 OUTLINE OF THE THESIS

The outline of the remaining chapters of this thesis is shown in Figure 1.3.

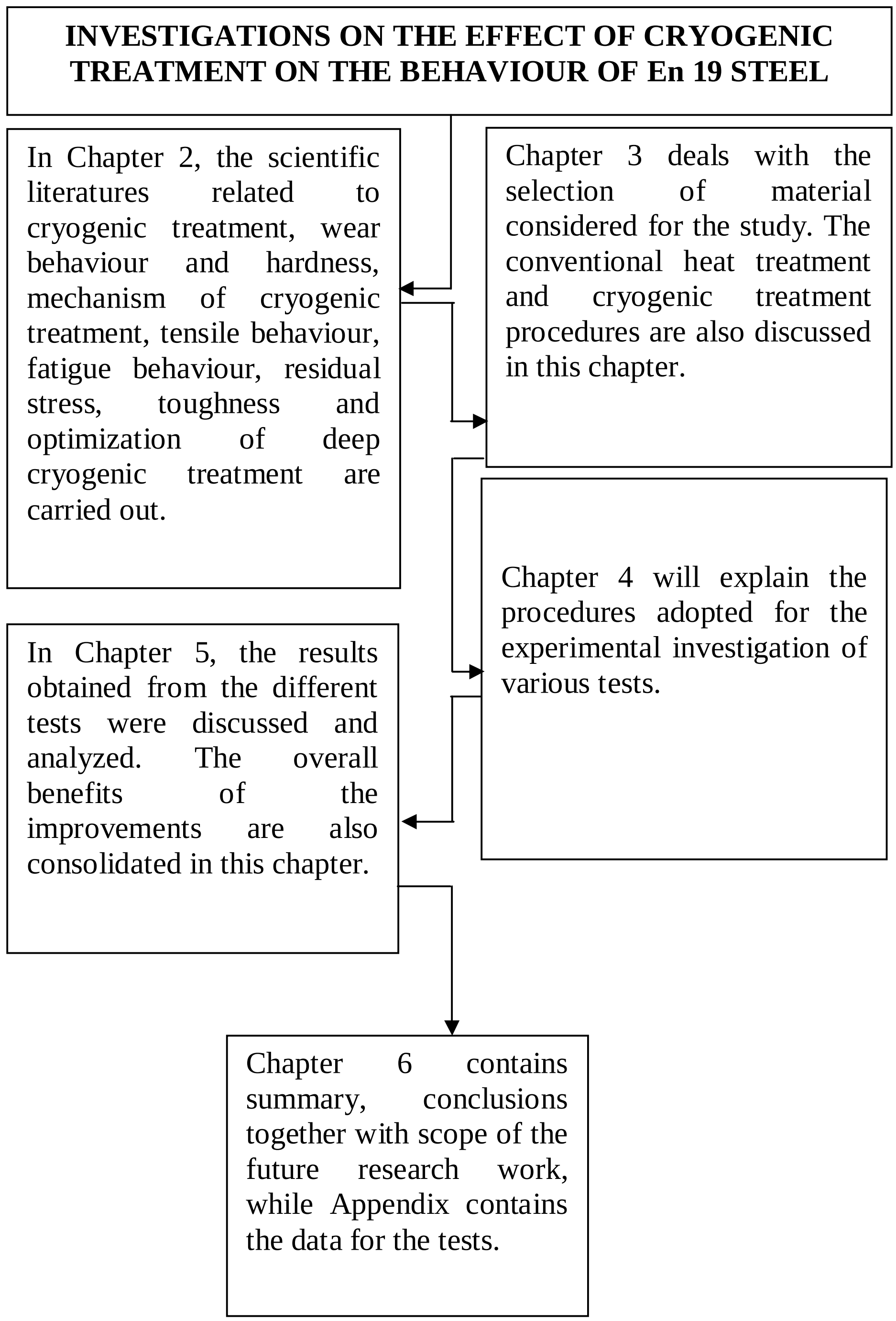

Figure 1.3 Organization of the Thesis