CHAPTER 3

MATERIAL AND TREATMENT PROCEDURE

3.1 SELECTION OF MATERIAL

The combination of high strength and ductility makes steel much superior when compared with non metallic materials and other alloys. Numerous highly stressed steel components namely gears, crankshafts, connecting rods, axles and equipment for the mineral processing industries are manufactured from alloy steels subjected to conventional heat treatment to achieve a combination of toughness and high strength, being En 19 steel one of the most used grades. En 19 is a low alloy steel, which has been generally used for the manufacturing equipments used in mineral processing industry. Vibrating screening equipment is one of the well-known equipments tends to wear during mineral processing. En 19 steel is also used in automotive driving elements such as crankshafts, front vehicle axles, axle journals, gears, high tensile bolts and studs, propeller shafts joints, tool joints, tool holders, hydraulic machinery shafts, oil industry drill collars, sprockets, tool holders, couplings, spindles, and steering components. En 19 steel is usually preferred when high strength is required. This kind of steel is categorized as quenched-tempered steel, which in dominant phase after conventional heat treatment is tempered martensite as reported in ASM Handbook (1991).

3.2 RESEARCH METHODOLOGY

The research methodology has been indicated in the flow chart is shown in Figure 3.1.

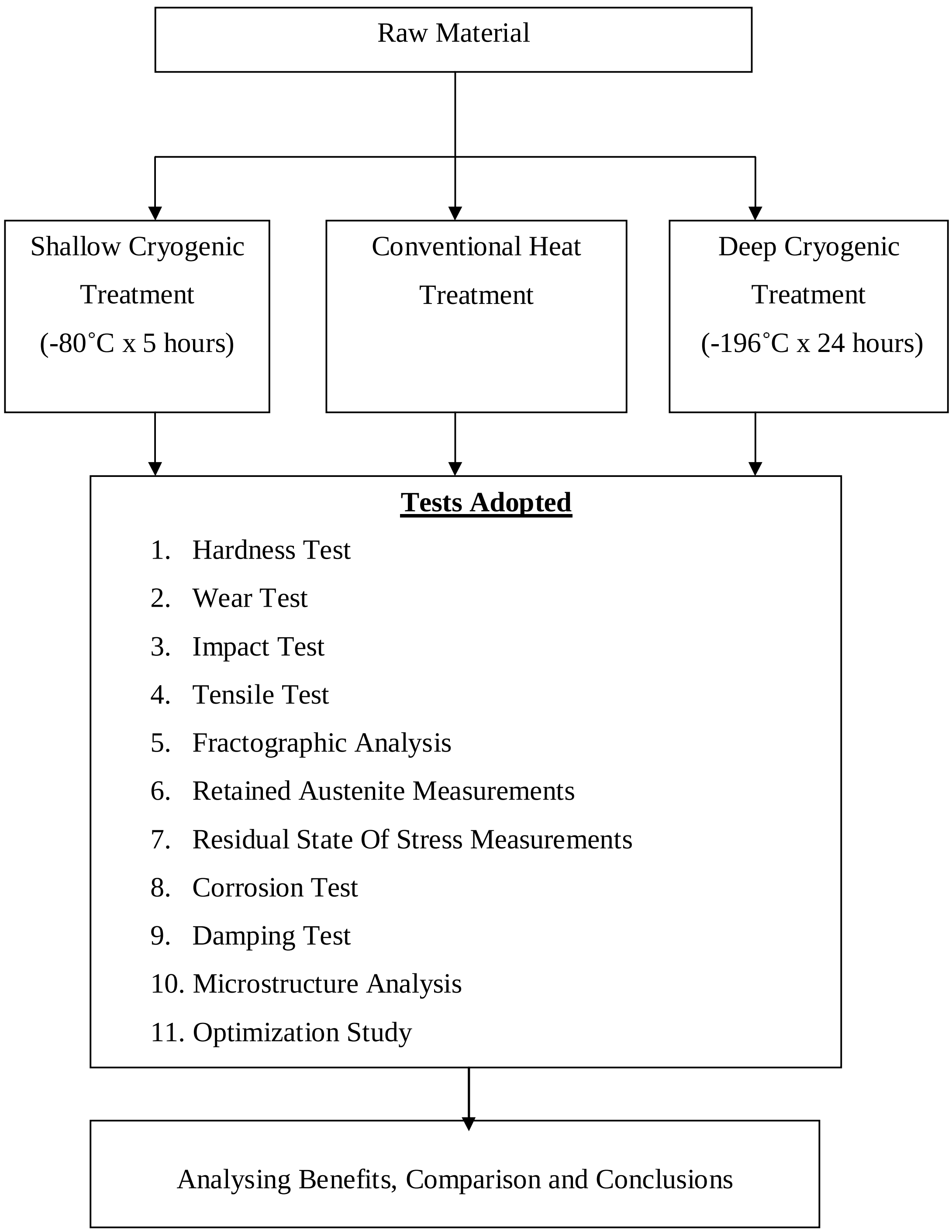

Figure 3.1 Research Methodology

It is expected that the cryogenic treatment will develop the tribological behaviour and other properties of En 19 steel. The mechanism behind the cryogenic treatment is the transformation of retained austenite to martensite along with the fine and homogenous carbide precipitation. These metallurgical changes will enhance the wear resistance and compressive residual stress of steel. Thus the present investigation is carried out to study the effect of cryogenic treatment on the behaviour of En 19 steel. Two kinds of treatment namely shallow cryogenic treatment and deep cryogenic treatment are adopted for this study. Finally, the optimization of deep cryogenic treatment parameters to reduce wear loss of En 19 steel is also studied.

3.3 CONVENTIONAL HEAT TREATMENT

In the general sense, heat treatment may be defined as an operation or combination of operations involving the heating and cooling of a metal or alloy in the solid state for the purpose of attaining certain desirable conditions or properties. The conventional heat treatment procedure is explained by Kamenichny (1969)**.** It consists of heating metals and alloys to a certain temperature, holding and cooling them at various rates with the aim of altering their structure and properties. Each of the heat treatment process comprises the following operations.

1. Heating to a prescribed temperature
2. Soaking for certain period to complete the structural changes
3. Cooling at a prescribed rate.

All the samples are subjected to conventional heat treatment (CHT) process. It consists of quench hardening in oil at 875 ºC for one hour. Afterwards the samples are subjected to the tempering process.

3.3.1 Tempering Process

According to ASM Metals Handbook (1991) tempering is defined as “Reheating hardened steel to some temperature below the eutectoid temperature to decrease hardness and/or increase toughness." Tempering is important for steels. Tempering is the process of reheating the steel below its critical temperature in order to increase toughness and decrease brittleness. Tempering of steels is performed to attain the desired strength and improve ductility after cryogenic treatment. After the hardening process, the steel becomes brittle, hard and some internal stress is developed. Tempering is carried to decrease brittleness even by decreasing some hardness and increasing the ductility and toughness. The structure of hardened steel consists of tetragonal martensite and a small quantity of austenite.

The tetragonal martensite structure and residual austenite structure are unstable in the hardened steel. As a result hardened steel has a tendency to pass into equilibrium in stable conditions. But this equilibrium is not achieved at room temperature because of low mobility of atoms at this temperature. As the temperature increases the mobility of atom increases and phase structure modifies and finally equilibrium is achieved. Hence, the sub microscopic particles of carbon in the martensite become more stable form during tempering. To obtain a homogeneous distribution of temperature within the steel component and to prevent non uniform relief of hardening stress that would cause wrapping or cracking, heating to the tempering temperature should be done slowly. A rapid rate of heating to the tempering temperature may result in cracking of steel components owing to increase in volume of surface. Hence a rapid rate of heating should be avoided. During the process of tempering, the tetragonality of martensite is reduced and the resulting lath martensite is close to body centered cubic (BCC) structure. The heat treatment process results in deposition of iron carbides and alloy carbides of submicron size, which act as strengthening agents by pinning dislocations reported in the literature (Ohmori and Sugisawa 1973).

The cryogenic treatment transforms almost all retained austenite into martensite. This martensite is known as primary martensite, which is brittle. It should be heated to reduce this brittleness. To obtain better structure of the steel to get the most desired properties, it is recommended by most researchers to execute cryogenic treatment after completion of quenching and before tempering in conventional heat-treatment cycle. For En 19 steel the tempering temperature is 200ºC and the time duration is an hour.

3.4 CRYOGENIC TREATMENT

Two kinds of cryogenic treatment are adopted in the present research work namely shallow cryogenic treatment and deep cryogenic treatment. After quench-hardening process, part of samples is then subjected to shallow cryogenic treatment (SCT) and deep cryogenic treatment (DCT). By Shallow Cryogenic Treatment the conventionally quench hardened samples are directly put in a freezer kept at -80ºC and soaked for 5 hours to attain thermal equilibrium. Samples are then extracted and left to reach room temperature in air.

The cryogenic treatment consists of slow cooling of conventionally hardened steel samples to a prescribed temperature, soaking for certain duration, followed by slow heating back to the room temperature for subsequent tempering. It is already patented the rate of cooling for some steels by the investigators. They proved that slow cooling (descent), soaking and heating (ascent) in a deep cryogenic treatment cycle will increase the wear resistance of steels. This method of processing avoids the cracking of the material. This typical cycle is generally followed by the industries for treating the steel components. By Deep cryogenic treatment, the conventionally quench hardened En 19 steel samples are slowly cooled from room temperature to -196ºC at 1.24 ºC/ minute, soaked at -196ºC for 24 hours and finally heated back to room temperature at 0.62 ºC/ minute as indicated in Bensely et al (2007). The typical cycle of deep cryogenic treatment process is shown in Figure 3.2. All samples are finally subjected to tempering or stress relieving at 200ºC for 60 minutes. The experimental procedure for CHT, SCT and DCT is schematically shown in Figure 3.3. The standards used for various tests are tabulated in Table 3.1.

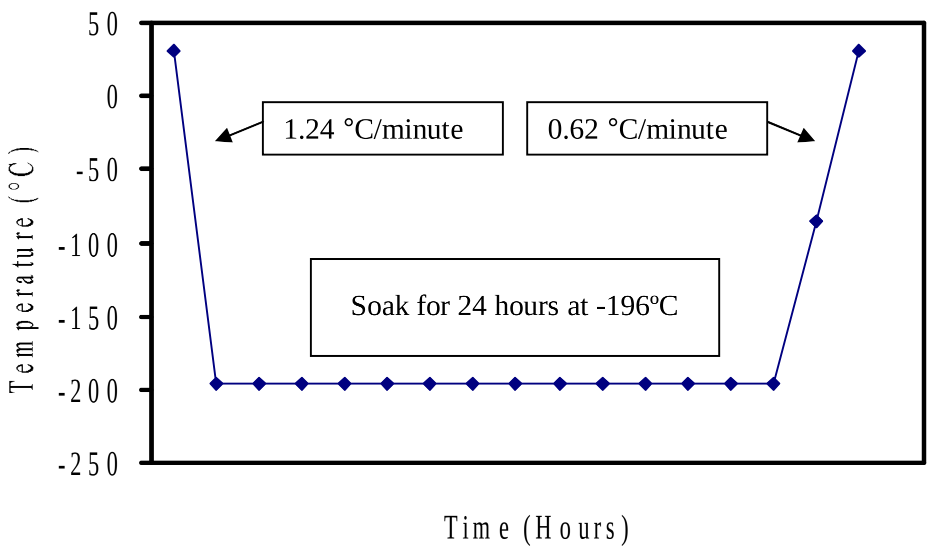

Figure 3.2 Deep Cryogenic Treatment Cycle

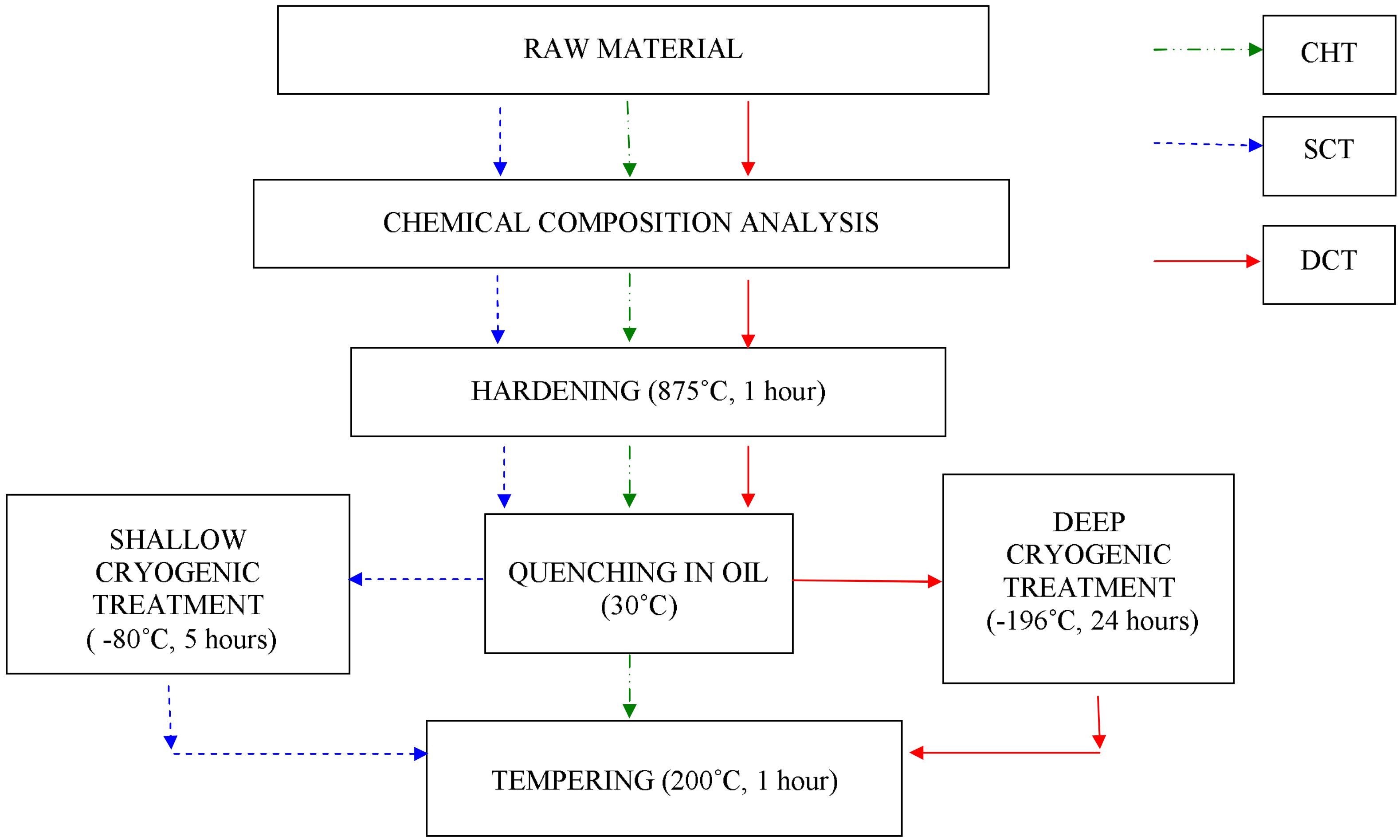

Figure 3.3 Experimental Procedure

Table 3.1 ASTM Standards Adopted for Various Test

Name of the Test	**Standard Adopted**	**Scope of the Test**	**Measured Experimental Parameters**
Vicker's Hardness Test	ASTM E 92-82	This standard describes the determination of Vicker's macro hardness of metallic materials	Surface Hardness
Pin on disk wear test	ASTM G99-95a	This test helps in determining the sliding wear of materials through pin on disk apparatus.	Wear loss
Tensile Test	ASTM E8M-01	This test covers the tension testing of metallic materials in any form at room temperature.	Tensile strength
Charpy Impact Test	ASTM E23-02	This test describes notched-bar impact testing of metallic materials by the Charpy (simple-beam) test.	Impact strength
Retained Austenite Measurements	ASTM E 975-03	This standard covers the determination of retained austenite in steel using with near random crystallographic orientation	Retained austenite
Residual state of stress measurements	ASTM E 1426-91	This test helps in determining the residual stress of steel	Residual state of stress
Corrosion Test	ASTM G59	This test covers the polarization technique to find the corrosion current density.	Corrosion current density
Damping Test	ASTM E756-05	This test measures the vibration-damping properties of materials	Damping Percentage