CHAPTER - 5
SAMPLE PREPARATION AND TESTING

5.1 Procurement of material

5.2 Assessment of mechanical properties
SAMPLE PREPARATION AND TESTING

5.1 PROCUREMENT OF MATERIAL

A list of suppliers for Raw material and Weld consumables was made and the required AISI 1020 steel rods and weld consumables required for samples were procured.

5.2 ASSESSMENT OF MECHANICAL PROPERTIES

In the industry the question of replacement comes due to the wearing out of the parts duet to repeated use. The basic aim of hardfacing is to improve or extend the life of various components used across the industry owing to the high cost of replacement of original part. Hence the sample preparation and testing in the present research is carried out to study the wear characterisation. In order to optimise the process selection and parameters for selecting the best process of hardfacing on AISI 1020 steels the following test procedures are adopted:

- Wear testing
- Micro hardness testing
- Metallography of base metal, deposited metal and wear samples

5.2.1 Wear testing

Wear testing is a method for assessing erosion or sideways displacement of material from its "derivative" and original position on a solid surface performed by the action of another surface. This test is commonly used as a simple measure of workability of material in service. Materials behave differently in friction state so it may be important to perform mechanical tests which simulate the condition the material will experience in actual use. A standard result review for wear tests, defined
by the ASTM standards should be expressed as loss of material during wear in terms of volume. The volume loss gives a truer picture than weight loss, particularly when comparing the wear resistance properties of materials with large differences in density.

5.2.1.1 Sample preparation

Test samples are prepared as per ASTM standards. AISI1020 round rods of diameter 10mm are taken and cut into cylinders of required lengths as per ASTM standards. The sample pieces are thoroughly cleaned to remove oil and dirt. The faces are finished by removing the burr to maintain flat surface. Weld deposit is done on the flat face of each sample using three different methods namely, Gas Welding, Arc Welding and TIG welding. Turning is done with fine cuts to get smooth cylindrical finish and maintain the required size as per ASTM standards. The Weld deposit height is maintained at least 5 mm in the total sample length as shown in figure.

![Sample Preparation](image)

**Fig. 5.1 SAMPLE PREPARATION**

All the test samples were ensured that they are flat at their ends by using belt grinder set up on drilling machine as flat surface is definite requirement for POD testing.

5.2.1.2 Pin on disc tester

In the present research a computerized pin on disc tester was used. The pin on disc tester provides a quick and easy method of kinetic friction and sliding wear measurement. The pin on disc tester measures the friction and sliding wear properties
of dry or lubricated surfaces of a variety of bulk materials and coatings. The pin on disc tester consists of a rotating disc of the material to be tested against a stationary sphere, usually made of cemented carbide, referred to as the pin. Although the pin surface can also be wear and friction tested. The normal load, rotational speed, and the wear track diameter are all be set by the user prior to the pin on disc test. Most pin on disc testers are computer controlled and store the measured friction versus time or distance plots for future reference. When the friction is monitored during the pin on disc test the friction starts at it’s highest level but after a certain amount of time (or running in) the friction drops to a steady state level. The coefficient of friction is calculated by dividing the friction by the applied load.

![Fig. 5.2 PIN ON DISC TESTER](image)

The pin on disc tester is used extensively to measure the friction and wear rate of low friction coatings such as diamond like carbon prior to coating actual components such as automotive valve trains. As the valve train in an engine is responsible for approximately 10% of the engine’s total energy losses due to friction at high engine speeds (this increases at low engine speeds). Low friction coatings therefore increase the efficiency and lifetime of these components significantly. As the use of low friction coatings becomes more widespread so does the requirement for wear and
friction measurement and hence the use of the pin on disc tester. Testing is done under ASTM G99 standard.

5.2.2 Micro-hardness

Micro hardness testing is widely used to study fine scale changes in hardness. The usual method to achieve a hardness value is to measure the depth or area of an indentation left by an indenter of a specific shape, with a specific force applied for a specific time. Here the applied load and the resulting indent size are small relative to bulk tests, but the same hardness number is obtained.

5.2.2.1 Sample preparation

The samples made as described in the previous section are tested for finding out the micro hardness after performing the wear test. This is because after wear test the worn sample will expose different areas of the sample at different depths of weld penetration.

5.2.2.2 Micro-hardness tester

In the present research micro-hardness was measured using Vickers hardness tester. The Vickers hardness test method, also referred to as a micro-hardness test method, is mostly used for small parts, thin sections, or case depth work. The Vickers method is based on an optical measurement system. The Micro-hardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from a few grams to one or several kilograms, although "Macro" Vickers loads can range up to 30 kg or more. The Micro-hardness methods are used to test on metals, ceramics, and composites - almost
any type of material. Since the test indentation is very small in a Vickers test, it is useful for a variety of applications: testing very thin materials like foils or measuring the surface of a part, small parts or small areas, measuring individual microstructures, or measuring the depth of case hardening by sectioning a part and making a series of indentations to describe a profile of the change in hardness. The Vickers method is more commonly used.

Sample preparation is usually necessary with a micro-hardness test in order to provide a small enough specimen that can fit into the tester. Additionally, the sample preparation will need to make the specimen’s surface smooth to permit a regular indentation shape and good measurement, and to ensure the sample can be held perpendicular to the indenter. Usually the prepared samples are mounted in a plastic medium to facilitate the preparation and testing. The indentations should be as large as possible to maximize the measurement resolution. (Error is magnified as indentation sizes decrease) The test procedure is subject to problems of operator influence on the test results.

**Vickers Hardness Test**

![Vickers Hardness Test Diagram](image)

**Fig. 5.3 VICKERS MICRO HARDNESS TESTER**
5.2.3 Metallography of base metal, deposited metal and wear samples

Metallography is the study of metals by optical and electron microscopes. Structures which require high magnification to be visible are called microstructures. Metallography helps to study different aspects of the sample such as the number and size of passes, depth of penetration, extent of HAZ (Heat affected zone), and any defect such as pores and cracks on representative work pieces.

5.2.3.1 Sample preparation

The plain samples and welded samples made as described previously are subjected to microstructure study under optical microscope. The specimen surfaces are initially dry grinded and then wet grinded on abrasive belts. Then the surfaces are polished first roughly and then finely with emery belts. The final fine polishing is done by using a wet rotating wheel covered with a special cloth that is charged with fine polishing abrasives so that a mirror like fine polishing is achieved. As microstructure plays a key role in deciding the property, the micro structures of base metal and deposited metal are studied.

The samples made as described previously are subjected to microstructure study under the SEM after wear testing. The wear testing forms the wear track of the worn out metal on the sample test surface and examined under the SEM to study the microstructure.

5.2.3.2 Scanning Electron Microscopy (SEM)

In the present research micrographs were taken using a SEM. A scanning electron microscope (SEM) is a type of electron microscope that images a sample by scanning it with a beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition, and other properties such as electrical
conductivity. In a typical SEM, an electron beam is thermionically emitted from an electron gun fitted with a tungsten filament cathode. Tungsten is normally used in thermionic electron guns because it has the highest melting point and lowest vapour pressure of all metals, thereby allowing it to be heated for electron emission, and because of its low cost. Other types of electron emitters include lanthanum hexaboride ($\text{LaB}_6$) cathodes, which can be used in a standard tungsten filament SEM if the vacuum system is upgraded and field emission guns (FEG), which may be of the cold-cathode type using tungsten single crystal emitters or the thermally assisted Schottky type, using emitters of zirconium oxide.

The electron beam, which typically has an energy ranging from 0.2 keV to 40 keV, is focused by one or two condenser lenses to a spot about 0.4 nm to 5 nm in diameter. The beam passes through pairs of scanning coils or pairs of deflector plates in the electron column, typically in the final lens, which deflect the beam in the $x$ and $y$ axes so that it scans in a raster fashion over a rectangular area of the sample surface. When the primary electron beam interacts with the sample, the electrons lose energy by repeated random scattering and absorption within a teardrop-shaped volume of the specimen known as the interaction volume, which extends from less than 100 nm to around 5 µm into the surface. The size of the interaction volume depends on the electron's landing energy, the atomic number of the specimen and the specimen's density. The energy exchange between the electron beam and the sample results in the reflection of high-energy electrons by elastic scattering, emission of secondary electrons by inelastic scattering and the emission of electromagnetic radiation, each of which can be detected by specialized detectors. The beam current absorbed by the specimen can also be detected and used to create images of the distribution of specimen current. Electronic amplifiers of various types are used to amplify the
signals, which are displayed as variations in brightness on a computer monitor (or, for vintage models, on a cathode ray tube). Each pixel of computer video memory is synchronised with the position of the beam on the specimen in the microscope, and the resulting image is therefore a distribution map of the intensity of the signal being emitted from the scanned area of the specimen. In older microscopes image may be captured by photography from a high-resolution cathode ray tube, but in modern machines image is saved to computer data storage.

**Fig. 5.4 SCANNING ELECTRON MICROSCOPE**

Magnification in a SEM can be controlled over a range of up to 6 orders of magnitude from about 10 to 500,000 times. Unlike optical and transmission electron microscopes, image magnification in the SEM is not a function of the power of the
objective lens. SEMs may have condenser and objective lenses, but their function is to focus the beam to a spot, and not to image the specimen. Provided the electron gun can generate a beam with sufficiently small diameter, a SEM could in principle work entirely without condenser or objective lenses, although it might not be very versatile or achieve very high resolution. In a SEM, as in scanning probe microscopy, magnification results from the ratio of the dimensions of the raster on the specimen and the raster on the display device. Assuming that the display screen has a fixed size, higher magnification results from reducing the size of the raster on the specimen, and vice versa. Magnification is therefore controlled by the current supplied to the x, y scanning coils, or the voltage supplied to the x, y deflector plates, and not by objective lens power.
PLATE: 5.1 MAKING AND TESTING OF SAMPLES CARRIED OUT AT MECHTRIX ENGINEERS, BANGALORE, AND RESEARCH CENTRE OF GHOUSIA COLLEGE OF ENGINEERING, BANGALORE