Practical Workbook
MY-404 Advances in Special Steels

Name: ____________________
Roll No: ____________________
Batch: ____________________
Year: ____________________

Metallurgical Engineering Department
NED University of Engineering and Technology

PRACTICAL WORKBOOK

MY-404 Advances in Special Steels

PREPARED BY
Engr. Laraib Sarfraz Khanzada

This is to certify that this practical book contains _____ pages.

Approved by:

Chairman
MYD

Metallurgical Engineering Department
NED University of Engineering and Technology

CERTIFICATE

It is Certified that Mr. / Miss ____

Student of class _______________________________ Batch__________________

Bearing Roll No. ____ has completed

his/her course work in the subject of _____________________________________

as prescribed and approved by Board of Review of Materials and Metallurgical Engineering Department.

His/Her performance is reflected by index/contents of his/her practical workbook. This overall performance of the student is Excellent/Very Good/Good (satisfactory)/Not Satisfactory

____

Course Teacher

CONTENTS

PRACTICAL NO.1

OBJECTIVE: Micro Structural Studies Of Stainless Steels

APPARATUS: Metallurgical Microscope

THEORY:

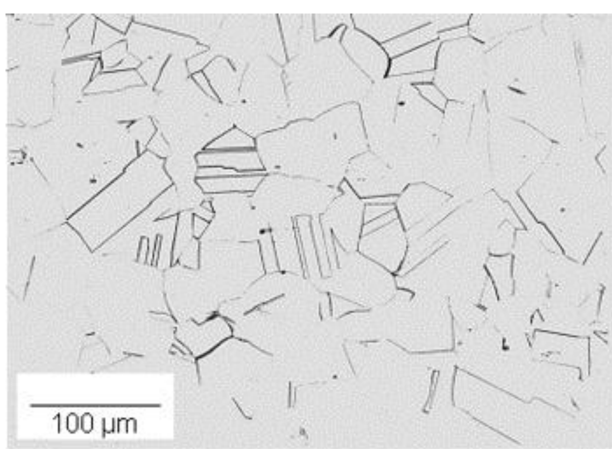
The Stainless Steels are highly resistant to corrosion (rusting) in a variety of environments, especially the ambient atmosphere. Their predominant alloying element is chromium, a concentration of at least 12 wt% Cr is required. Corrosion resistance may also be enhanced by nickel and molybdenum additions.

Stainless Steels are divided into three classes on the basis of the predominant phase constituent of the microstructure

1. Austenitic Stainless Steels
2. Ferritic Stainless Steels
3. Martensitic Stainless Steels

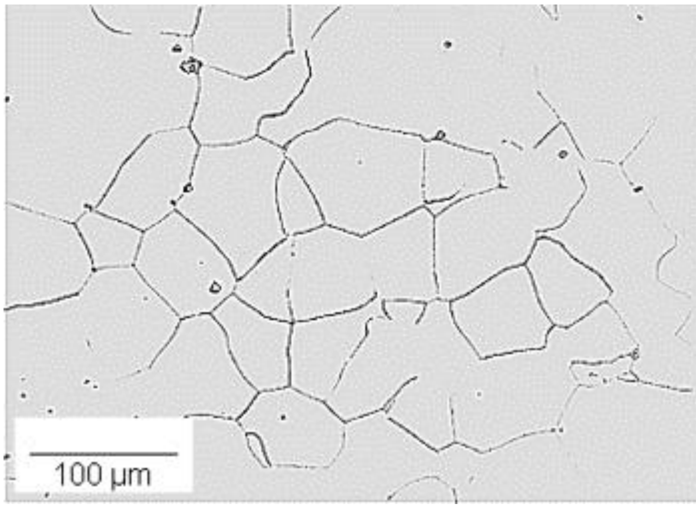
<u>Austenitic Stainless Steels</u>

Austenitic Stainless Steels comprise over 70% of total stainless steel production. They contain a maximum of 0.15% carbon, a minimum of 16% chromium and sufficient nickel and/or manganese to retain an austenitic structure at all temperatures from the cryogenic region to the melting point of the alloy. A typical composition of 18% chromium and 10% nickel, commonly known as 18/10 stainless is often used in flatware. Similarly 18/0 and 18/8 is also available.
Highly formable, ductile to low temperatures, Can only strengthen (not much) by work-hardening



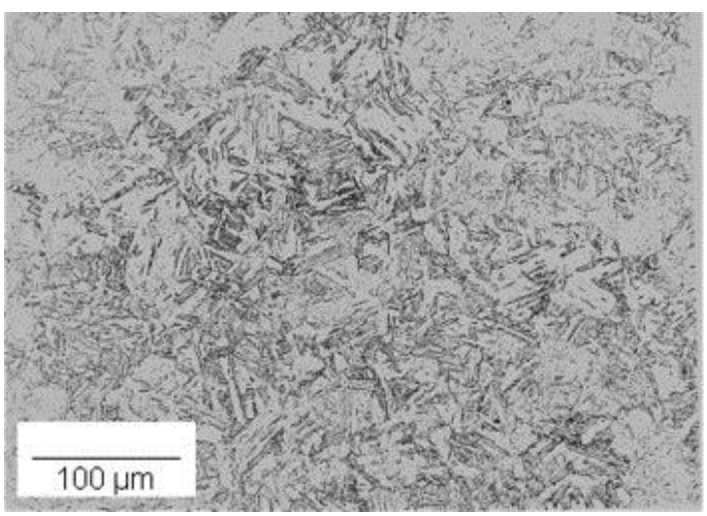
Ferritic Stainless Steels

Ferritic stainless steels are highly corrosion resistant, but less durable than austenitic grades. They contain between 10.5% and 27% chromium and very little nickel, if any. Most compositions include molybdenum; some, aluminum or titanium



Martensitic stainless steels

Martensitic stainless steels are not as corrosion resistant as the other two classes, but are extremely strong and tough as well as highly machine able, and can be hardened by heat treatment. Martensitic stainless steel contains chromium (12–14%), molybdenum (0.2–1%), zero to less than 2% nickel, and about 0.1–1% carbon (giving it more hardness but making the material a bit more brittle). It is quenched and magnetic.



EXERCISE

1. What is the structure of austenitic stainless steel and its advantage?

2. What are the advantages of Ferritic Stainless Steels?

3. What are common applications of stainless steels? Which grades are most commonly used?

PRACTICAL NO. 2

OBJECTIVE: Volume phase count of Duplex Stainless Steel

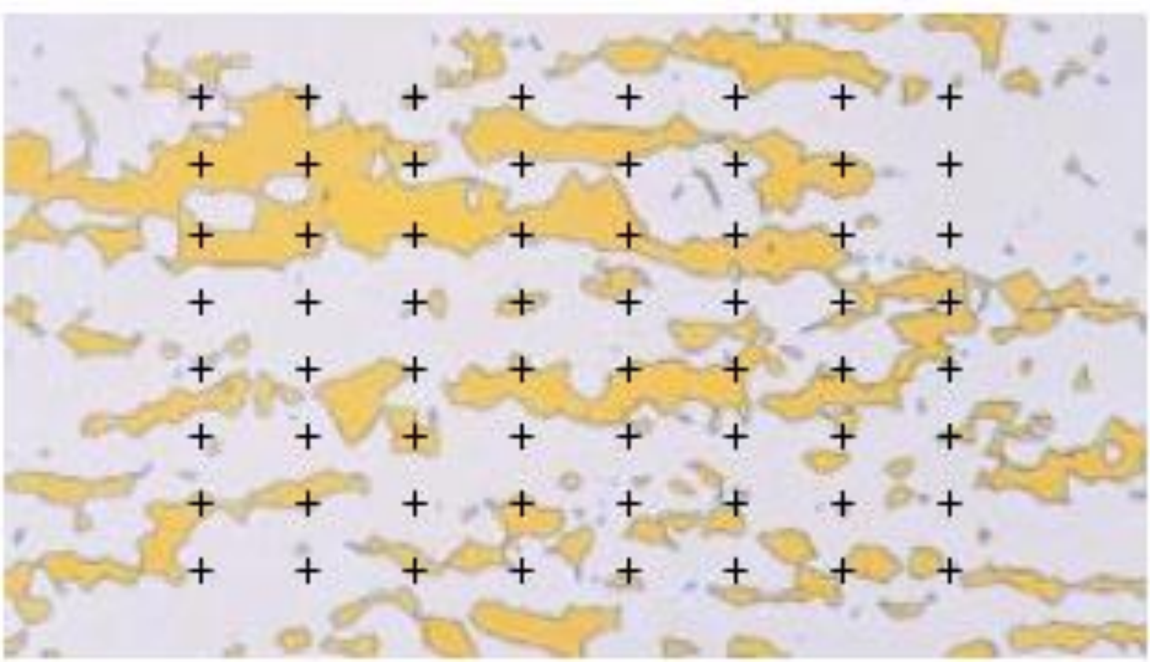
APPARATUS: Metallurgical Microscope, 10×10 (100 point) grid, MS Excel template

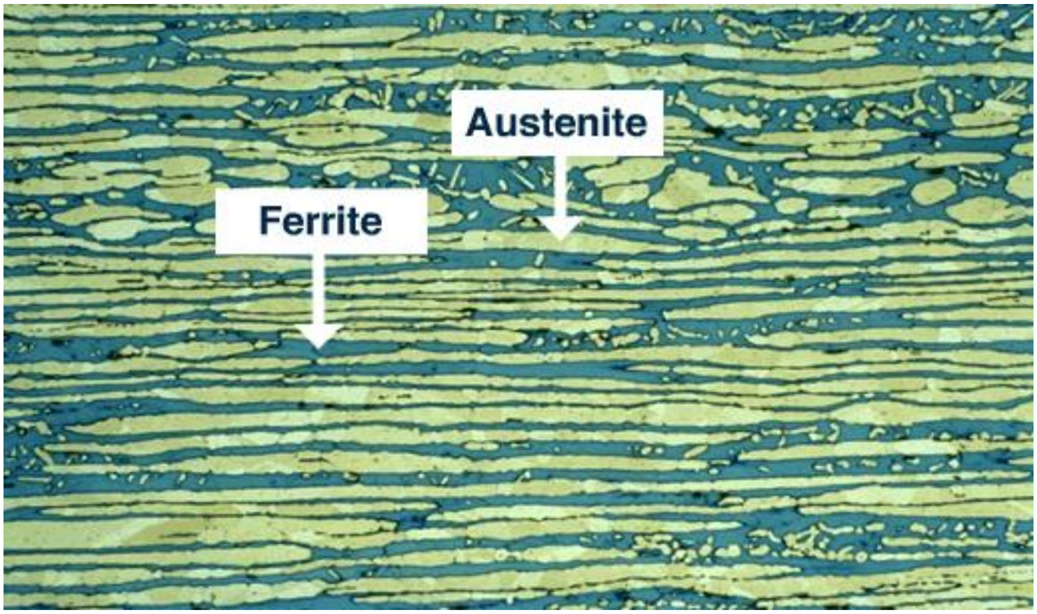
THEORY:

To get relative idea of phases volume phase count examination is performed on steel microstructure. this give idea of heat treatment and alloying so that this examination performed varying different variables to achieve desired properties.

The micro structural constituents, quantified through quantitative metallographic technique i.e. point counting method, and their effects on mechanical properties can be determined. A Microsoft Excel template for 100 point Grid available to predict the volume fraction of phases present. The template gave reliable results of Volume Fraction (Vv) with Relative Accuracy (%RA).

Duplex stainless steels have a mixed microstructure of austenite and ferrite, the aim being to produce a 50:50 mix although in commercial alloys the mix may be 40:60 respectively. Duplex steel have improved strength over austenitic stainless steels and also improved resistance to localized corrosion particularly pitting, crevice corrosion and stress corrosion cracking. They are characterized by high chromium (19–28%) and molybdenum (up to 5%) and lower nickel contents than austenitic stainless steels.





Procedure:

1. First of all prepare metallographic sample.
2. Study microstructure under microscope.
3. Get a photomicrograph print or use gridded eye piece.
4. Use 100 point grid to count point of phases.
5. In case of major and minor phase quantity, take lesser phase as point to count.
6. Take reading of points for desired accuracy level. Turn grid on various angles on same micrograph to obtain better representation of microstructure.
7. Put readings in excel template to find out Volume phase count.

Results

Precaution:

Observations:

EXERCISE

1. Why phase count is important? What idea we get from volume fraction of phase?

2. How best results can obtain?

3. Why we take help of Microsoft excel template?

PRACTICAL NO.**3**

OBJECTIVE: Tool steels, importance of heat treatment and effect on microstructure

APPARATUS: Metallurgical Microscope

THEORY:

These steels are fabricated into many types of tools or into the cutting and shaping parts of power-driven machinery for various manufacturing operations. They contain tungsten, molybdenum, and other alloying elements that give them extra strength, hardness, and resistance to wear.

Carbon is by far the most important alloying element for the hardening properties of all steel types, including tool steels. As a rule of thumb, harden able steels should contain at least ~0.2 wt-% carbon dissolved in the iron matrix. At carbon contents up to ~1 wt-% the matrix hardness is continuously increasing and it reaches a maximum of ~65 HRC (plain carbon steels).

A correct heat treatment is of great importance for the properties of tools made from hot work steel.

Carbides contribute to strengthening of tool steels in two different ways.

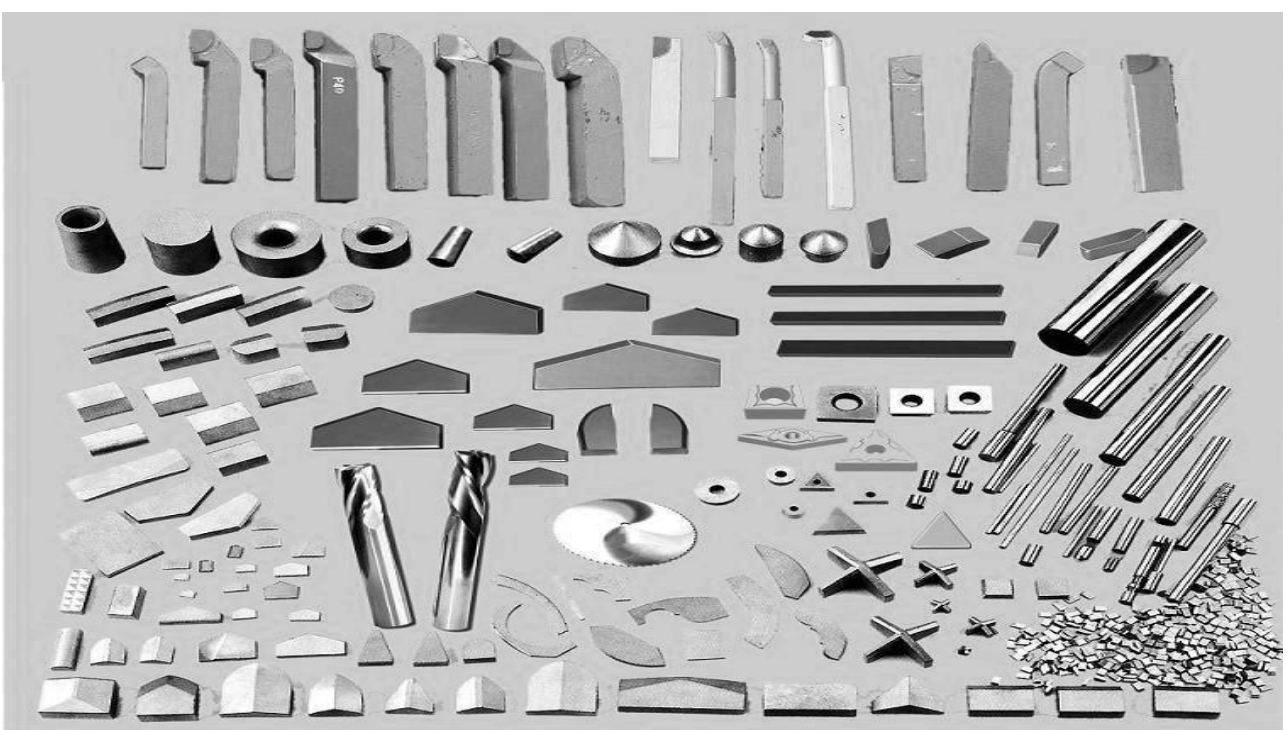
1. Since especially the alloy-carbides are significant harder than the matrix, carbides provide resistance against abrasive wear.
2. They contribute to the high yield strength of especially some tool steels by impeding the mobility of matrix dislocations.

(AISI H13), as annealed structure Microstructure, Etched with 2%nital

Distribution of these particles significantly affect the service life of tool, so quantities analysis of these steels is very significantly tell us about the properties of tool steel. The alloying addition of most of tool steels is given in table.

Classification of tool steels

AISI classification	Division into groups by AISI standards	Important group characteristic	Principal alloying elements	Examples of applications
High speed steels	Group M, Mo-rich	High hardness for high speed cutting of materials, red hardness.	C, Mo, W, V, Cr	Cutting tools of all sorts.
	Group T, W-rich		C, W, V, Cr, Co	
Cold-work steels	Group A, air hardening	Deep hardening in air (up to 100 mm)	C, Mn, Cr, Mo	Punches, forming-, coining dies.
	Group D, high-C high-Cr	High wear resistance at normal temp.	C, Cr, (Mo)	Long run dies for blanking.
	Group O, oil hardening	High wear resistance at normal temp.	Varies	Dies for punches and blanking
Hot-work steels	Group H, Cr-hot-work steels	Deep hardening, high toughness	C, Cr, W, (V)	Dies for extrusion of Al and Mg.
	Group H, W-hot-work steels	Improved thermal stabilty relative to the Cr-Hot-work steels, properties similar to HSSs.	C, W, V, Cr, Co	Extrusion dies for brass, Ni alloys and steel.
	Group H, Mo-hot-work steels		C, Mo, W, V, Cr, Co	
Shock-resisting steels	Group S	High shock loading resistance	Mn, Si, Cr, W, Mo	Chissels, hammers, punches.
Mold steels	Group P	Low softening resistance at elevated temp.	Cr, Ni	Molds, critical-finish molds.
Spec.-purpose steels	Group L	Low alloyed steels. Group W- exhibits improved toughness relative to group L steels.	Cr, V, Ni, Mo	Various
Water-hardened ste	Group W		C	Woodworking-, coining tools.



EXERCISE

1. What parameters are controlled in tool steel heat treatment?

2. Which phase are of prime importance in tool steel heat treatments ? and why?

3. Which elements are added in high speed tool steel in high concentration?

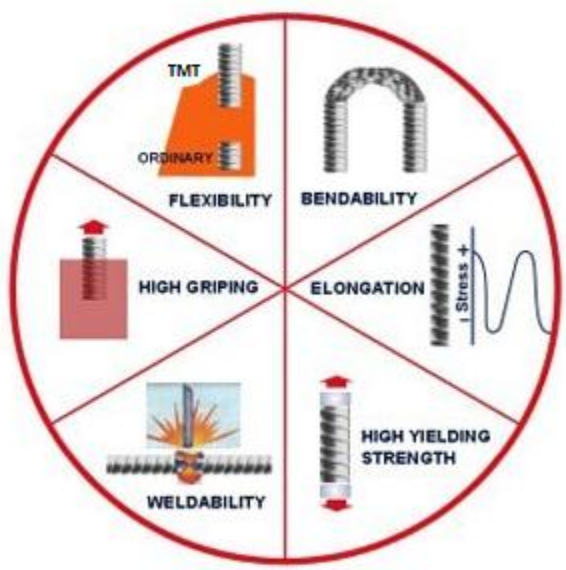
PRACTICAL NO.4

OBJECTIVE: Micro Structural Studies Of Thermo Mechanical Treatment Of Steels

APPARATUS: Metallurgical Microscope

THEORY:

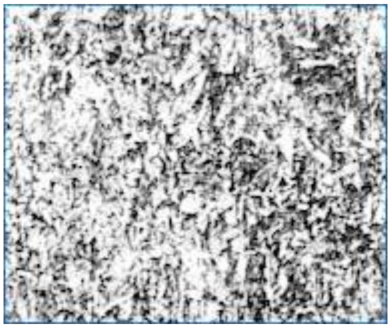
Thermo Mechanically Treated (TMT) steel can be described as a new super strength steel having superior strength , ductility ductility i.e. the percentage elongation, toughness and bendability, with good weldability.



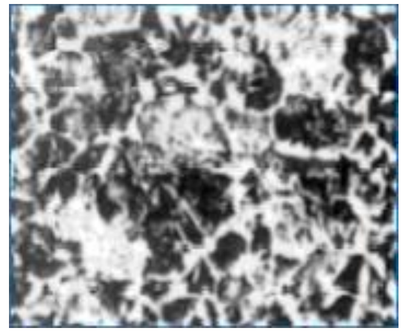
While a certain minimum carbon content in steel is essential to achieve the required strength, an excess of carbon content threatens its property of ductility and toughness. In TMT bars, this problem has been eliminated. In these bars, the carbon content can be restricted to 0.2% to attain optimum properties.

TMT bars can be bent and re-bent around very small mandrels of 2d and 4d respectively without problems, which have obvious advantages at construction sites.

Martensitic rim improves the corrosion resistance as well as the fatigue strength, when compared to traditional cold twisted bars. Ferrite-Pearlite core give toughness and ductility.



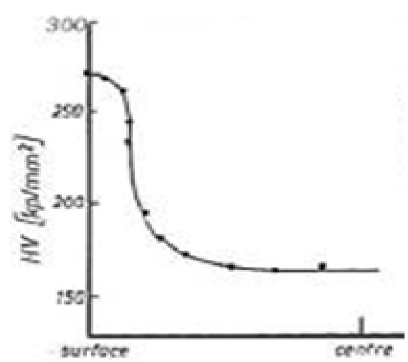
Tempered Martensite Rim



Ferrite-Pearlite core

Micro-hardness

Figure indicates the micro-hardness of a thermo-processed bar from the surface to the core.



Distribution of micro structural components and micro hardness along the radius of 32mm bar

Procedure (self explanatory)

What stages are involved in the production of TMT?

EXERCISE

1. What is the importance of quenching step in the production of TMT?

2. How case depth is measured TMT is measured?

3. Write down applications of TMT steels?

PRACTICAL NO.5

OBJECTIVE: Micro Hardness Of Steels And Construction Of Hardness Variation Curve

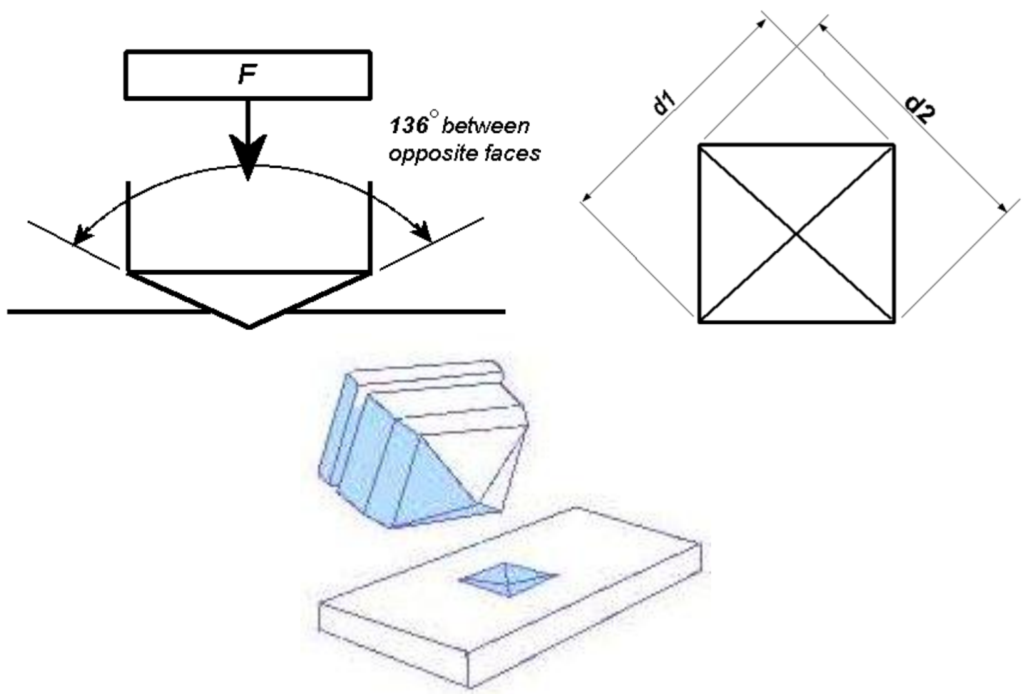
APPARATUS: Micro Vickers Hardness tester

THEORY:

Vickers Hardness Testing

Micro hardness testing of metals, ceramics, and composites is useful for a variety of applications for which 'macro' hardness measurements are unsuitable: testing very thin materials like foils, measuring individual microstructures within a larger matrix, or measuring the hardness gradients of a part along the cross section. Micro hardness testing gives an allowable range of loads for testing with a diamond indenter; the resulting indentation is measured and converted to a hardness value. The actual indenters used are Vickers (more common; a square base diamond pyramid with an apical angle of 136°). The result for Vickers micro hardness is reported in kg/cm^2 and is proportional to the load divided by the square of the diagonal of the indentation measured from the test.

The figure below shows the Vickers indenter geometry.



Vickers Indentation: The figure at the left is a schematic diagram the square base diamond pyramid Vickers hardness indenter and sample indentation.

The load on the Vickers micro hardness indenter usually ranges from a few grams to several kilograms. In contrast, 'Macro' Vickers loads vary from 1 to 120 kg. The indentations should be as large as possible, within the confines of sample geometry, to minimize errors in measuring the indentation (hence the reported hardness).

The Vickers Diamond Pyramid harness number is the applied load (kgf) divided by the surface area of the indentation

$$HV = \frac{2F\sin\frac{136^o}{2}}{d^2} \qquad HV = 1.854\frac{F}{d^2} \text{ approximately}$$

Where: F= Load in kgf, d = Arithmetic mean of the two diagonals, d1 and d2 in mm
HV = Vickers hardness

Procedure: (Self Explanatory)

EXERCISE

1. What are the advantages of Micro Vickers testing?

2. Why preparation of sample is carried out in similar way, as required for metallographic examination?

3. How we construct Hardness variation curve by Micro Vickers hardness tester?

PRACTICAL NO. 6

OBJECTIVE: Micro structural characterization of different phases in Super Alloy

APPARATUS: Metallurgical Microscope

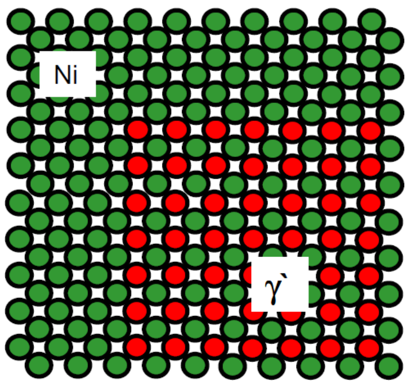
THEORY:

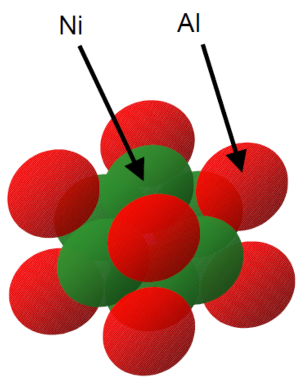
The term "Super Alloy" was first used shortly after World War II to describe a group of alloys developed for use in turbo superchargers and aircraft turbine engines that required high performance at elevated temperatures. The range of applications for which super alloys are used has expanded to many other areas and now includes aircraft and land-based gas turbines, rocket engines, chemical, and petroleum plants. They are particularly well suited for these demanding

Their versatility stems from the fact that they combine this high strength with good low-temperature ductility and excellent surface stability.
Super alloys are based on Group VIIIB elements and usually consist of various combinations of Fe, Ni, Co, and Cr, as well as lesser amounts of W, Mo, Ta, Nb, Ti, and Al. The three major classes of super alloys are nickel-, iron-, and cobalt-based alloys.

Compositions

Ni, Co and Fe Based Alloys





Solid solution strengthening

- Cr, Mo, Al, Nb, Ti and others

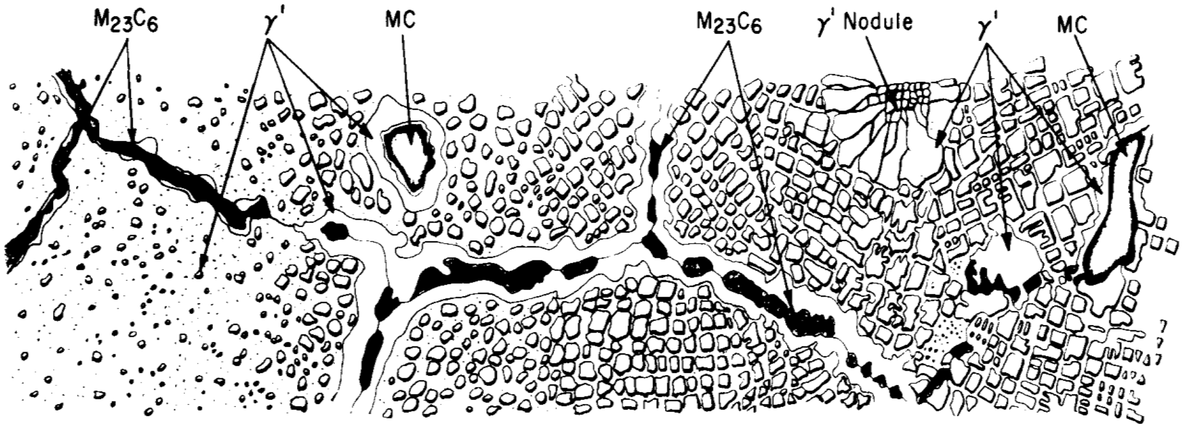
Precipitation strengthening

- Mostly due to Al and Ti
- Gamma prime **Ni_3 (Al,Ti)**
- Lattice mismatch, amount,
- size and morphology

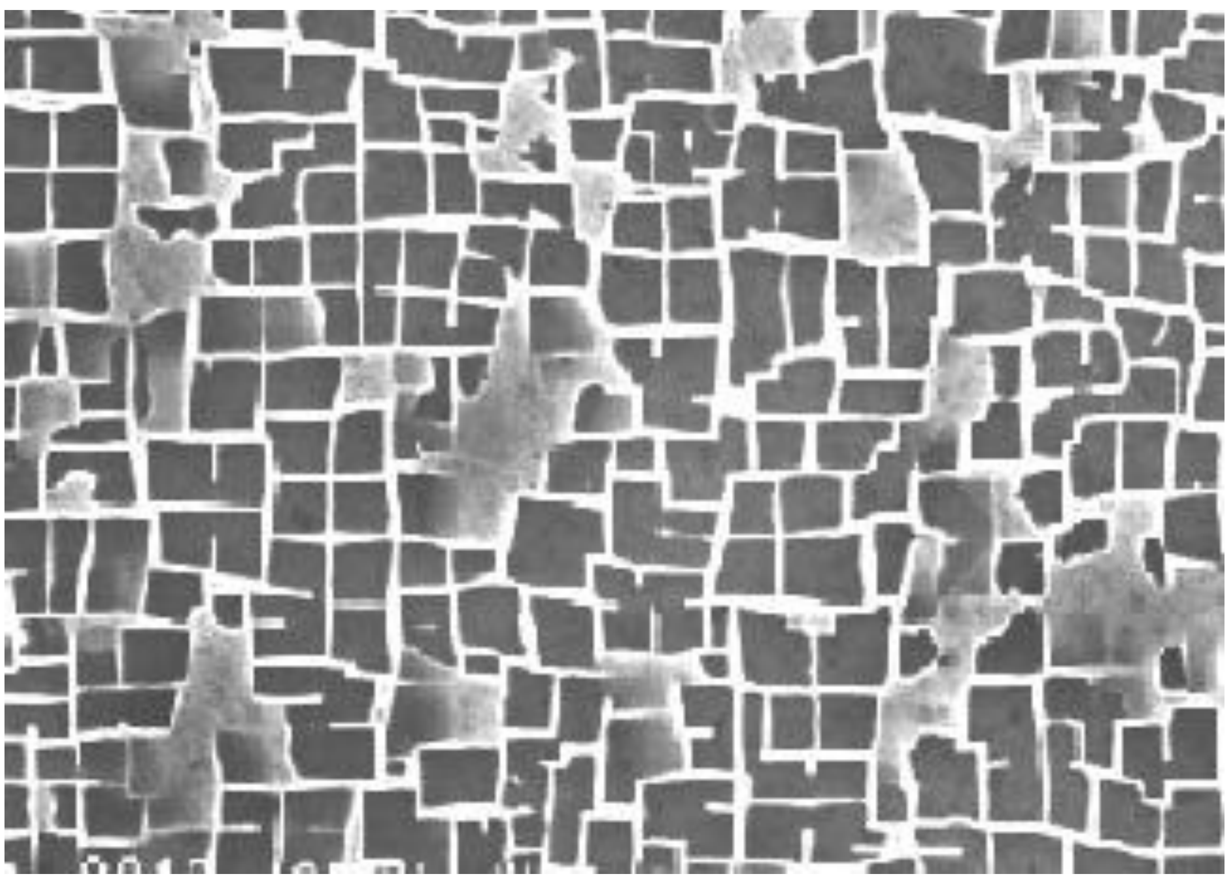
Carbide phases

- $M_{23}C_6$, M_6C or MC
- M can be Cr, Ti, Mo or W

Reference Microstructure.



γ'-Formers →	2.5 Ti, 1.3 Al	2.9 Ti, 2.9 Al	3.5 Ti, 4.3 Al	4.7 Ti, 5.5 Al	1.5 Ti, 5.5 Al, 1.5 Ta
Carbide Formers →	20 Cr, 2.5 Ti	19 Cr, 4 Mo, 2.9 Ti	15 Cr, 5.2 Mo, 3.5 Ti	10 Cr, 3 Mo, 4.7 Ti, 1 V	9 Cr, 2.5 Mo, 10 W, 1.5 Ta
Examples →	Nimonic 80A	U-500	N-115/ U-700/ R-77	IN-100/ R-100	MM-246



EXERCISE

Paste your micrograph here.

Observation:

PRACTICAL NO. 7

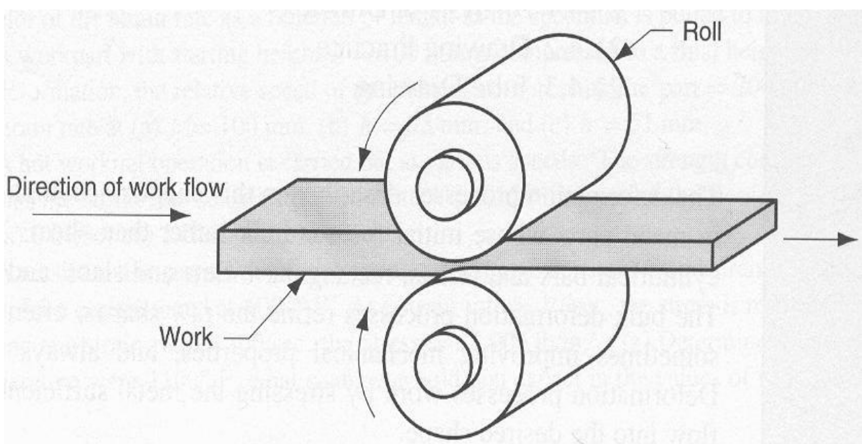
OBJECTIVE: Cold rolling of Steels.

APPARATUS: 2 Hi Cold rolling Mill

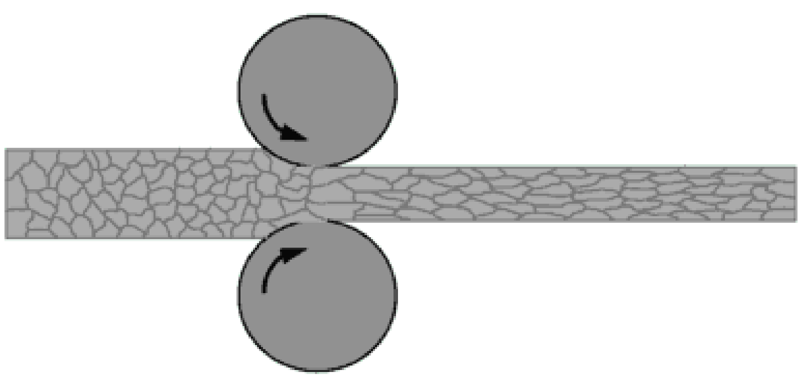
THEORY:

Cold rolling is carried out on steel to obtain close dimensional tolerance, improved surface finish, with higher strength.
Steel can cold rolled to skin rolled, quarter hard, half hard, full hard, depending upon how much cold worked is performed. This cold working is also called temper although this has nothing to do with heat treatment.
In skin rolling, the metal is reduced by 0.5 to 1% and result in a surface that is smooth. But in case where strengthening by cold rolling is main concern metal is subjected to much higher percentage of reduction to induce strength by strain hardening.

Schematic Drawing of Rolling Process

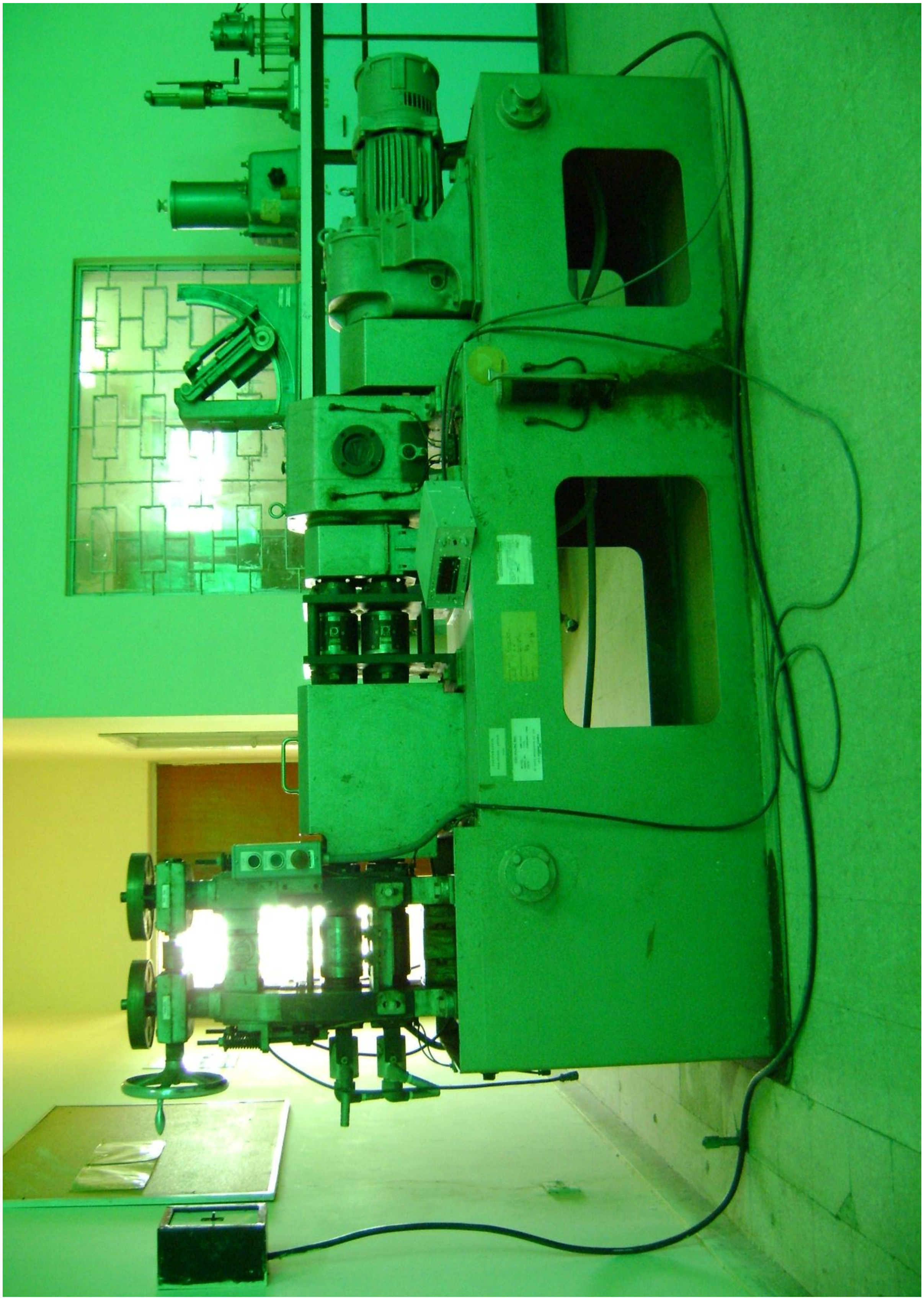


Rolling Process



Grain flow

Two High Rolling Machine



Precautions:

Draw table showing rolling parameters:

Procedure (self explanatory)

EXERCISE

1. What properties obtained through Cold rolling?

2. What are applications of cold rolled products?

3. Why we divide reduction in passes?

4. What happen if we give excessive deformation?