Practical Workbook

MY-209 Metal Forming & Shaping Processes

Name________________________
Roll No______________________
Batch________________________
Year_________________________
Department___________________

Department of Metallurgy Engineering
NED University of Engineering and Technology

Practical Workbook

MY-209 Metal Forming & Shaping Processes

PREPARED BY

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(Assistant Professor, MYD)

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

Approved by:

Chairman
MYD

Department of Metallurgy Engineering
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 Department of Metallurgy Engineering.

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

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MY-209 METAL FORMING & SHAPING PROCESSES

Experiment No. 1

Aim of the Experiment
To Study the general safety rules for metalworking operations

Safety in Cold Metalwork

- .Keep the work area clean. Wipe up oil and grease spills immediately to prevent injuries caused by slipping and falling. Keep paths to exits clear.
- Use eye protection. When doing cold metalwork, wear approved safety glasses or a face shield.
- Store rags safely. Store oily and greasy rags in a fireproof metal container to prevent the spreading of spontaneous fires.
- Use the correct lifting method. Serious injury may result from straining due to incorrect lifting. Lift heavy objects with the leg muscles, not the back muscles. When lifting heavy objects, obtain assistance.
- Use proper tools. Always use the proper-sized tools and equipment for the job.
- Obtain the instructor's permission. Use equipment only with the instructor's permission. Notify the instructor immediately if you are injured.
- Wear proper clothing. Wear clothing that is not loose or bulky and wear hard-toed shoes with non-skid soles.
- Ground electrical equipment. Each electrical tool should be equipped with a three-prong plug and plugged into a grounded three-hole receptacle. When used outside, portable tools should be connected to ground fault circuit interrupter outlets.
- Restrain long hair. Restrain excessively long hair with a band or cap to keep hair from getting entangled in machines. When using a drill or drill press, be extremely careful with long hair.
- Secure stock. Be certain that stock to be cut, filed, or chiseled is securely fastened in a vise or by clamps to prevent tools from slipping.
- Mount holding devices securely. Mount vises, anvils, and clamps securely for cold metalwork Safety Practices for Using Hand Tools in Cold Metalwork

Safety Practices for Hot Metal Working

- Obtain the instructor's permission. Before using any tool or machine, you must obtain the instructor's permission. The instructor must be aware of all laboratory activities and will know if the equipment is in safe working order.

- Wear industrial-quality eye protection. To protect the eyes from sparks and metal chips, wear approved eye protection.

- Wear proper clothing. To protect against burns, wear clothing such as coveralls, high-top shoes, leather aprons, and leather gloves. Remove all paper from pockets, and wear cuff less pants.

- Protect hair and scalp. To protect the hair and scalp, restrain Excessively long hair and wear a cap.

- Know emergency procedures. In the event of an emergency, all students involved in or observing the emergency should call for help immediately as well as assist in correcting the situation. You should know the location of fire extinguishers and fire blankets and how to use them. You should also know the approved procedure for exiting the laboratory.

- Report all injuries or accidents to the instructor immediately, no matter how slight. The instructor will secure medical help.

- Keep work area and tools clean. Dirty, greasy, and oily tools and floors can cause accidents. Clean and put away all unneeded tools and materials. Clean up oil spills and scrap metal from the floor and equipment.

- Use correct tools. Always use the right size tool and only for its intended purpose. Use tongs or pliers for carrying hot metal.

- Avoid horseplay and loud talk. Loud talking as well as pushing, running, and scuffling while working with hot metal can cause serious accidents. Keep your mind on your work.

- Work in a well-ventilated area. Fumes and intense heat are part of hot metalwork and require that work be done outdoors or in a forced-ventilated area. This especially true when you are working with zinc (galvanized iron or pipe), cadmium, or beryllium.

- Use correct lifting methods. When lifting heavy objects, obtain help. Lift with the legs and not the back. Straining to lift heavy objects can cause serious injury.

- Store hot metal in a safe place. To avoid the possibility of accidental burns, keep hot metal in a safe place until it cools. Do not offer hot stock to the instructor for inspection.

- Never touch suspected hot metal. Test metal with moistened finger tips before actually touching it. Use tongs or pliers for handling hot metal.

- Turn off heat source before leaving work area. Before leaving the laboratory or work station, make certain the heat source is shut off and cool.

- Avoid using hot metalwork around flammable material. Do not perform hot metalwork on wood floors or near flammable material. Never work on containers that have been used for storage of combustible material without first having cleaned and safeguarded them.

- Protect welder cables and hoses when you are hot metalworking. Keep cables and hoses from coming in contact with hot metal and sharp objects. Never point a flame at cables or hoses.

- Use warm water instead of quenching oil for quenching. Quenching oil is easily confused with other oils. It is difficult to identify. If quenching oil is used, take it from new, previously unopened cans. Safety Practices for Using a Gas Furnace

Questionnaire

Q1. What safety practices are used in your shop to promote general safety?

Q2. What equipment and machines in your shop must run, separate safety tests before you are allowed to operate them?

Q3. What personal safety protection devices or clothing must you wear while working in the shop?

Q4. What instructions are given for handling and storage of your job's material?

Q5. What procedure should you follow if you see an accident happen?

Experiment No. 2

Aim of the Experiment

To **operate** the cold rolling equipment **under supervision** for non-ferrous metal and study its effect on properties

Material /Apparatus

Rolling mill, nonferrous metal, hardness tester, metallurgical microscope

Theory

Cold rolling is a process by which the sheet metal or strip stock is introduce between rollers and compressed and squeezed. Cold rolling is done below recrystallization temperature. After cold working its grains are in distorted condition. Plastic deformation or cold working affects all the properties of a metal that are dependent on the lattice structure. The amount of strain introduced determines the hardness and other material properties of the finished product. By cold rolling tensile strength, yield strength and hardness are increased, while ductility is decreased. Distortion of the lattice structure hinders the passage of electrons and decreases electrical conductivity in alloys. The increase in internal energy, particularly at the grain boundaries, makes the material more susceptible to inter granular corrosion, thereby reducing its corrosion resistance.

The advantages of cold rolling are good dimensional accuracy and surface finish. However more power is required in cold rolling to deform higher strength starting material and overcome the additional resistance caused by strain hardening

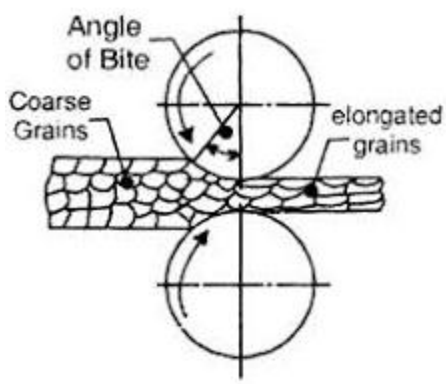

Fig. 1: shows the Cold rolling process

Cold rolled sheet can be produced in various condition such as skin-rolled, quarter hard, half hard, full hard depending on how much cold work has been performed. This cold working (hardness) is often called temper, although this has nothing to do with heat treatment temper.

Procedure

Take the hardness of the material before rolling. Set the gap between the two rollers with the help of the adjusting knob. Turn on the mini rolling mill. Enter the material from the inlet side of the roller and collect the rolled material from the other side. Again measure the hardness of the rolled metal. The procedure is repeated at different reduction percentages.

Observations

Material used ....

Initial dimension ……………………………………………………………..

Reduction (%)						
Hardness						

Results

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

Advantages

- High production rate.
- Suitable for production of plates, sheets and foils.
- Good dimensional accuracy and finish

Limitations

- High equipment cost.
- Deformation limited to small reductions.

Questionnaire

Q1. Discuss cold rolling process? Also describe the effect of roller size on the process and its disadvantages?

Q2.Discuss the straightening and roll bending process?

Q3. Discuss the problems in maintaining uniform thickness in a rolled product and some of the associated defects?

Q4. What is neutral point in rolling process?

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Instructor's Signature with Date:	

Experiment No. 3

Aim of the Experiment
To **operate** and measure the formability of sheet metal via formability test.

Material /Apparatus
Blank sheet, a punch

Theory
Metal formability refers to the ability of sheet metal to be formed into a desired shape without necking or cracking. Necking is localized thinning of the metal that is greater than the thinning of the surrounding metal. Necking precedes cracking. From the metallurgical perspective, the metal formability depends on a metal's elongation, which is the total amount of strain measured during tensile testing. A metal with a large elongation has good formability because the metal is able to undergo a large amount of strain (work) hardening.
Formability limits are a hard constraint when sheet metal parts are manufactured, but also in bulk metal forming, formability limits can be reached leading to faulty parts. In general, the success of a forming process depends on three parts: the material being formed (the work piece), the forming tooling, and the process conditions like lubrication, blank holder settings, sheet metal properties like elongation, anisotropy, types of die, die materials and equipment etc. In general the term "formability" usually refers to sheet metals. Typical metal sheets measure between 0.4 (1/64") mm and 6 mm (1/4) and are widely used across consumer and industrial applications such as beverage cans, automobile bodies, aircraft fuselages, appliances, metal furniture and filing cabinets.

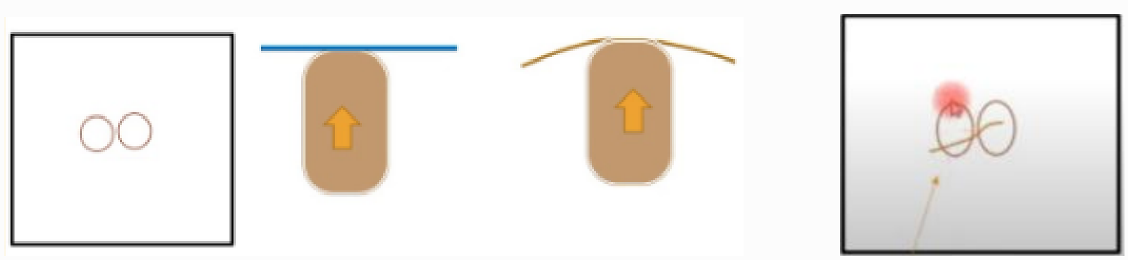

Fig. 2: shows the formability test of sheet metal

Procedure
Take the dimensions of the blank sheet before testing. Blank sheet is marked with the grid of the circles and measure the diameter of circles. Set the sheet over the punch and stretch it until the grid pattern deforms where necking and tearing occurs. The circle turned into ellipse where tearing occurs. Measure the major and minor axis of the ellipse which gives major strain and minor strain respectively.

Observations

Material used ....

Sheet dimension …………………………………………………………………..

Initial Dimension	Circle Diameter ………………………………………	
Final Dimension	Major strain of Ellipse …………	Minor strain of Ellipse …………

Questionnaire

Q1. How formability is related with sheet metal properties?

Q2. Difference between formability and deformability?

Q3. What is the significance of formability in sheet metal working?

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Remarks	
Instructor's Signature with Date:	

Experiment No. 4

Aim of the Experiment

To **operate** the Lathe machine under supervision for performing secondary operations of metal forming process.

Material /Apparatus

Blank sheet, a punch, Lathe machine

Theory

Lathe machines create sophisticated parts for medical, military, electronics, automotive, and aerospace applications. A lathe is capable of performing numerous machining operations to deliver parts with the desired features. Turning is a popular name for machining on a lathe. Nevertheless, turning is just one kind of lathe operation. The variation of tool ends and a kinematic relation between the tool and work piece results in different operations on a lathe. The most common lathe operations are turning, facing, grooving, parting, threading, drilling, boring, knurling, and tapping.

Turning is the most common lathe machining operation. During the turning process, a cutting tool removes material from the outer diameter of a rotating work piece. The main objective of turning is to reduce the work piece diameter to the desired dimension. There are two types of turning operations, rough and finish. Rough turning operation aims to machine a piece to within a predefined thickness, by removing the maximum amount of material in the shortest possible time, disregarding the accuracy and surface finish. Finish turning produces a smooth surface finish and the work piece with final accurate dimensions.

Step Turning

Step turning creates two surfaces with an abrupt change in diameters between them. The final feature resembles a step.

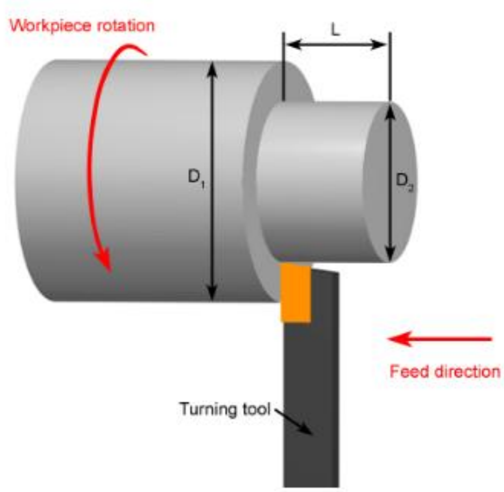

Fig. 3 shows Step turning process

Taper Turning

Taper turning produces a ramp transition between the two surfaces with different diameters due to the angled motion between the work piece and a cutting tool.

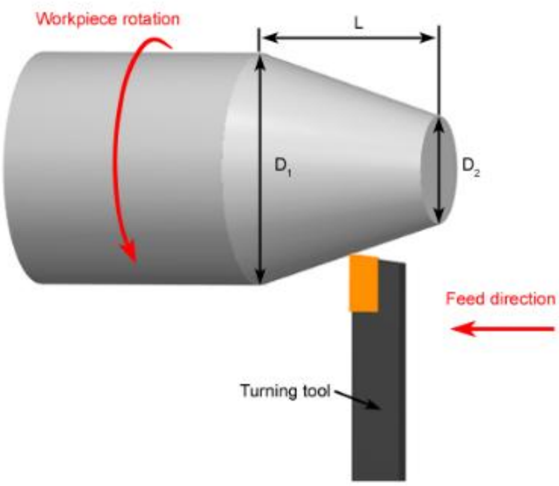

Fig. 4 shows Taper turning process

Chamfer Turning

Similar to the step turning, chamfer turning creates angled transition of an otherwise square edge between two surfaces with different turned diameters.

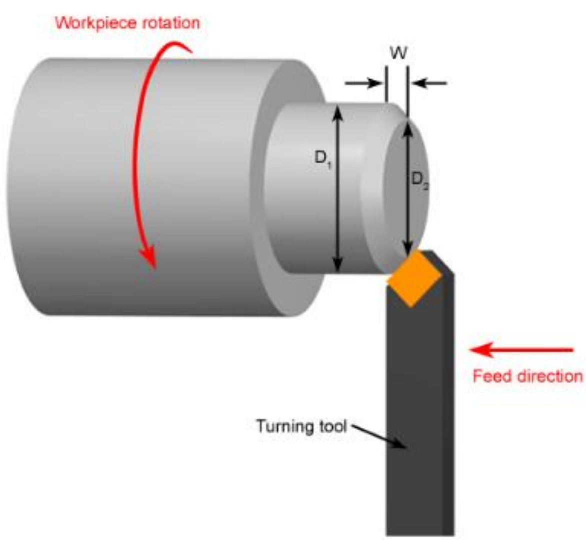

Fig. 5 shows Chamfer turning process

Contour Turning

In contour turning operation, the cutting tool axially follows the path with a predefined geometry. Multiple passes of a contouring tool are necessary to create desired contours in the work piece. However, form tools can produce the same contour shape is a single pass.

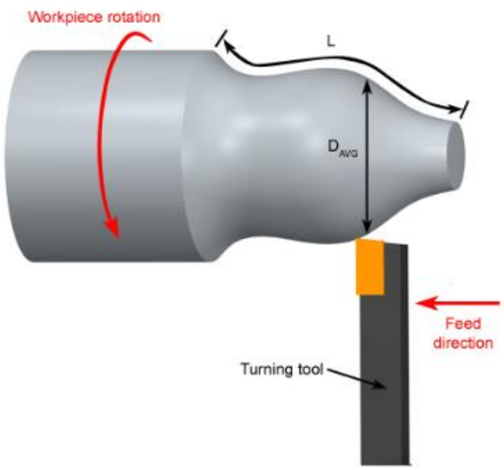

Fig. 6 shows Contour turning process

Supported Materials for Turning

Turning is a versatile process that can be used on a wide range of materials. Commonly turned materials include metals like steel, brass, aluminum, titanium, and nickel alloy, as well as plastics such as nylon, polycarbonate, ABS, POM, PP, PMMA, PTFE, PEI, and PEEK. Some turning operations also extend to wood and other materials, though metals and plastics remain the most common.

Procedure

Questionnaires

Q1. List down various secondary operations in metal forming process?

Q2. What are the limitations of turning process?

Q3.What are some of the attractive features of the Turning process?

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Experiment No. 5

Aim of the Experiment

To **practice** the Open Die Forging process for a given material.

Material /Apparatus

Forging press, dies and punches, reheating furnace, trimming and piercing, metal to be forged

Forging

Forging is the process by which metal is heated and is shaped by plastic deformation by suitably applying compressive force. Usually the compressive force is in the form of hammer blows using a power hammer or a press. Forging refines the grain structure and improves physical properties of the metal. With proper design, the grain flow can be oriented in the direction of principal stresses encountered in actual use. Grain flow is the direction of the pattern that the crystals take during plastic deformation. Physical properties (such as strength, ductility and toughness) are much better in a forging than in the base metal, which has, crystals randomly oriented.

Forgings are consistent from piece to piece, without any of the porosity, voids, inclusions and other defects. Thus, finishing operations such as machining do not expose voids, because there aren't any. Also coating operations such as plating or painting are straightforward due to a good surface, which needs very little preparation.

Forgings yield parts that have high strength to weight ratio-thus are often used in the design of aircraft frame members.

A Forged metal can result in the following

- Increase length, decrease cross-section, called drawing out the metal.
- Decrease length, increase cross-section, called upsetting the metal.
- Change length, change cross-section, by squeezing in closed impression dies. This results in favorable grain flow for strong parts

Common Forging Processes

The metal can be forged hot (above recrystallization temperatures) or cold (below recrystallization temperatures).

Open Die Forgings / Hand Forgings

Open die forgings or hand forgings are made with repeated blows in an open die as shown in the following fig: a. where the operator manipulates the work piece in the die. The finished product is a rough approximation of the die. This is what a traditional blacksmith does, and is an old manufacturing process.

Fig.6 shows the open die Hot Forging Operation

Impression Die Forgings / Precision Forgings

Impression die forgings and precision forgings are further refinements of the blocker forgings. The finished part more closely resembles the die impression. Fig: b clearly shows how impression die forging is to be carried out.

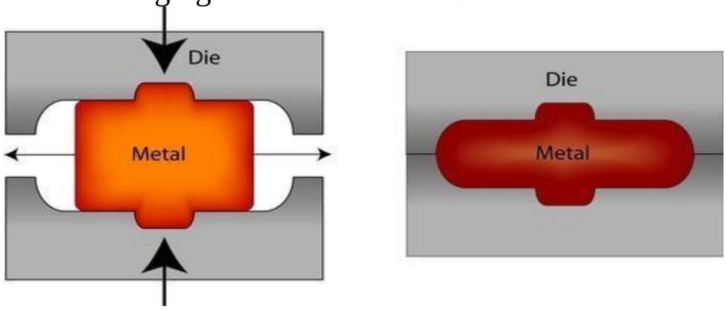

Fig.7 shows the Impression Die Forgings process

Press Forgings

Press forging use a slow squeezing action of a press, to transfer a great amount of compressive force to the work piece. Unlike an open-die forging where multiple blows transfer the compressive energy to the outside of the product, press forging transfers the force uniformly to the bulk of the material. This results in uniform material properties and is necessary for large weight forgings. Parts made with this process can be quite large as much as 125 kg (260 lb) and 3m (10 feet) long.

Design Consideration

- Parting surface should be along a single plane if possible, else follow the contour of the part. The parting surface should be through the center of the part, not near the upper or lower edges. If the parting line cannot be on a single plane, then it is good practice to use symmetry of the design to minimize the side thrust forces. Any point on the parting surface should be less than 75º from the principal parting plane.

- As in most forming processes, use of undercuts should be avoided, as these will make the removal of the part difficult, if not impossible.
- Recommended draft angles are described in the following table.

Table 1: shows the types of material with allowable draft angle

Material	Draft Angle (º)
Aluminum	0 - 2
Copper Alloys (Brass)	0 - 3
Steel	5 - 7
Stainless Steel	5 - 8

- Generous fillets and radius should be provided to aid in material flow during the forging process. Sharp corners are stress-risers in the forgings, as well as make the dies weak in service. Recommended minimum radiuses are described in the following table.

Table 2: shows the minimum radius allowable for Forging process

Height of Protrusion mm (in)	Min. Corner Radius mm (in)	Min. Fillet Radius mm (in)
12.5 (0.5)	1.5 (0.06)	5 (0.2)
25 (1.0)	3 (0.12)	6.25 (0.25)
50 (2.0)	5 (0.2)	10 (0.4)
100 (4.0)	6.25 (0.25)	10 (0.4)
400 (16)	22 (0.875)	50 (2.0)

- Ribs should not be high or narrow; this makes it difficult for the material to flow.

Tolerances

- Dimension tolerances are usually positive and are approximately 0.3 % of the dimension, rounded off to the next higher 0.5 mm (0.020 in).
- Die wear tolerances are lateral tolerances (parallel to the parting plane) and are roughly +0.2 % for Copper alloys to +0.5 % for Aluminum and Steel.

- Die closure tolerances are in the direction of opening and closing, and range from 1 mm (0.040 inch) for small forgings, die projection area < 150 cm^2 (23 in^2), to 6.25 mm (0.25 inch) for large forgings, die projection area > 6500 cm^2 (100 in^2).
- Die match tolerances are to allow for shift in the upper die with respect to the lower die. This is weight based and is shown in the following Table 3.

Table 3: shows the types of material with allowable Die match tolerances

Material	Finished Forging WeightTrimmed kg (lb)		
	< 10 (< 22)	< 50 (< 110)	> 500 (> 1100)
	Die Match Tolerancemm (in)		
Aluminum, Copper Alloys,Steel	0.75 (0.030)	1.75 (0.070)	5 (0.200)
Stainless Steel,Titanium	1.25 (0.050)	2.5 (0.100)	6.5 (0.260)

- Flash tolerance is the amount of acceptable flash after the trimming operation. This is weight based and is shown in the following Table 4.

Table 4: shows the types of material with allowable Flash Tolerance

Material	Finished Forging WeightTrimmed kg (lb)		
	< 10 (< 22)	< 50 (< 110)	> 500 (> 1100)
	Flash Tolerance mm (in)		
Aluminum, Copper Alloys,Steel	0.8 (0.032)	3.25 (0.125)	10 (0.4)
Stainless Steel,Titanium	1.6 (0.064)	5 (0.2)	12.5 (0.5)

A proper lubricant is necessary for making good forgings. The lubricant is useful in preventing sticking of the work piece to the die, and also acts as a thermal insulator to help reduce die wear.

Procedure

A typical forging operation involves the following sequence of steps.

1. Prepare a slug, billet, or perform by shearing (cropping), sawing or cutting off, either cold or hot. If necessary, clean surfaces by such means as shot blasting.
2. For hot forging, heat the work-piece in a suitable furnace and, if necessary, descales it after heating with a wire brush, a water jet, or steam or by scraping. The scaling may also occur during the initial stages of forging. The scale, which is usually brittle, falls off during plastic deformation of the part.
3. For hot forging, pre heat and lubricate the dies; for cold forging, lubricate the blank.
4. Forge in appropriate dies and in the proper sequence. If necessary remove, remove any excess material, such as flash, by trimming, machining or grinding.
5. Clean the forging, check its dimensions, and, if necessary, machine it to final dimensions and tolerances.
6. Perform additional operation, such as straightening and heat treating, for improved mechanical properties. Perform any finishing operations that may be required.
7. Inspect the forging for external and internal defects.

Advantages of Open Die Forging

- Inexpensive tooling and equipment
- Simple to operate.
- Wide range of work piece sizes can be used.
- Suitable for low production volume.

Limitations

- Can be used for simple shapes only.
- Fairly skilled operators are required.
- Production rate is low.
- Dimensional accuracy and surface finish achieved are poorer
- Finishing required for achieving final shape.

Advantages of Closed-Die Forging

- Suitable for high production rate.
- Can be used for production of complex shapes.
- Good dimensional accuracy and reproducibility.

Limitations

- High equipment and tooling cost.
- Appropriate die set for production of each component.
- More than one step required for each forging.
- Finishing required for achieving final shape

Questionnaires

Q1. Describe the factors to be considered during the designing of a die for forging?

Q2. What would happen to a brittle metal such as white cast iron, if it were formed by closed die forging?

Q3. What attractive features are offered by counterblow forging equipment?

Q4. Discuss the importance of lubricant in forging process?

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Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

Experiment No. 6

Aim of the Experiment
To **operate under supervision** the drawing equipment of an Aluminum wire

Material /Apparatus
Dies (of required sizes), Pure Aluminum drawing Oil, Nose Pliers, Pair of Hand Gloves, Safety Goggles, Wire Drawing Machine, Pointing Machine.

Theory
In a typical wire drawing operation one end of the wire is reduced and passed through the opening in the die, griped and pulled to reduce its diameter. Drawing wire gets wrapped round a power driven-capstan which provides the required frictional drag to pull the wire through the die. By successive drawing through dies of reducing diameter the wire can be reduced to a very small diameter. Annealing before each drawing operation permits large reduction in area and de scaling treatments prolong the life of the dies. Tungsten carbide dies are generally used for drawing of hard wires, and diamond dies is the choice for fine wires

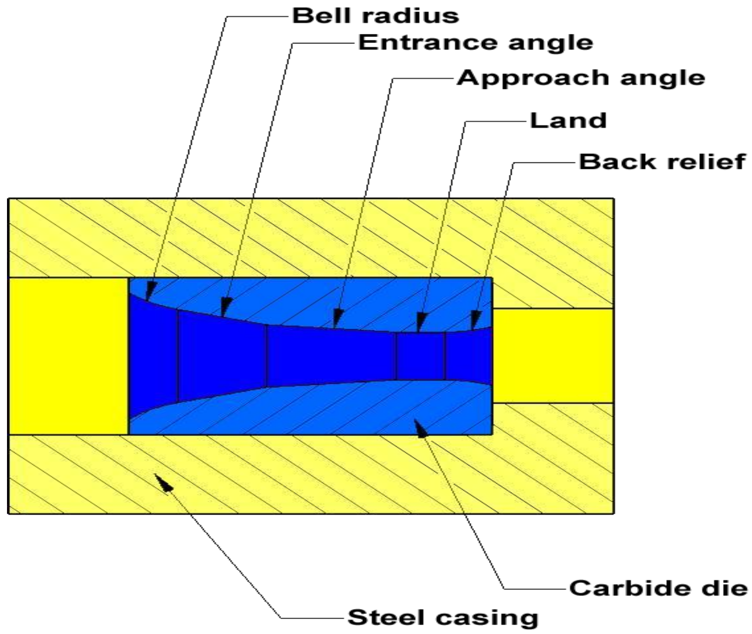

Fig. 8 shows the Wire drawing Die

Procedure

1. Check all the connections of machine including Electrical and Drawing oil pipes and valves, and capstan surface.
2. Switch On the main of the wire drawing machine and Pointing Machine.

3. Now take 9.50mm Aluminum Rod and make a point in pointing machine by passing between the rollers cavity (first pass it from largest cavity then to the smaller cavity and so on).
4. After sufficient reduction of wire diameter, fix the first die(9.30mm) in the die holder and pass the wire from it and pull it from die by the help of nose pliers.
5. Then Pull the wire by the help of capstan 6 to 10 m long.
6. Take another die and do the same process for all the other dies (do pointing further again if needed).
7. Take wire and make a round to the capstan or pass it from capstan of the shortest diameter stage.
8. Place the die in the die holder and pass it from another capstan then place a second die in the die holder and pass it to the capstan (Do it for the remaining dies).

Note: As the wire reduces it should pass from the greater diameter stage of capstan.

9. Check the wire diameter of the wire coming out from the final die with the help of micrometer screw gauge.
10. When all the dies are set in place, “inch” the machine so that the wire come outside the machine to the block and then to the take-up of the machine.
11. Load spool on the take up of the machine and fix the wire in it by passing it from a hole given in the flange of the spool.
12. Now turn On the take-up and Wire Drawing machine.
13. When spool is filled with Al. wire stop the take up and Wire drawing machine at the same time.
14. Unload the spool from the take-up. Now you have a wire of required diameter.

Questionnaires

Q1.How many types of wire drawing machine on the basis of process?

Q2. Which lubricant we use in copper, aluminum and steel wire drawing?

Q3. Can we do heat treatment after aluminum wire drawing?

Q4. What is the function of capstan in wire drawing machine?

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Experiment No. 7

Aim of the Experiment
To **practice** the deep drawing process.

Material /Apparatus
Drawing ring body, a pressure body, drawing plunger, and Die

Theory
Deep drawing is the manufacturing process of forming sheet metal stock, in this method a round sheet metal blank is placed over a circular die opening and is held in place with a blank holder, or hold down ring. The punch travels downward and forces the blank into the die cavity, forming a cup. The important variables in deep drawing are the properties of the sheet metal, the ratio of blank diameter to punch diameter, the clearance between punch and die, the punch radius, the die corner radius, the blank holder force, and friction and lubrication.
During the drawing operation, the movement of the blank into the die cavity induces compressive circumferential (hoop) stresses in the flange, which tend to cause the flange to wrinkle during drawing. This phenomenon can be demonstrated by trying to force a circular piece of paper into a round cavity such as a drinking glass. Wrinkling can be reduced or eliminated if a blank holder is kept under the effect of a certain force. In order to improve performance the magnitude of this force can be controlled as a function of punch travel.
The cup wall, which is already formed, is subjected principally to a longitudinal tensile stress. Elongation causes the cup wall to thin; if excessive, it causes tearing. Because of the many variables involved, the punch force is difficult to calculate; it increases with increase in the strength, the diameter, and the thickness of the sheet-metal blank.

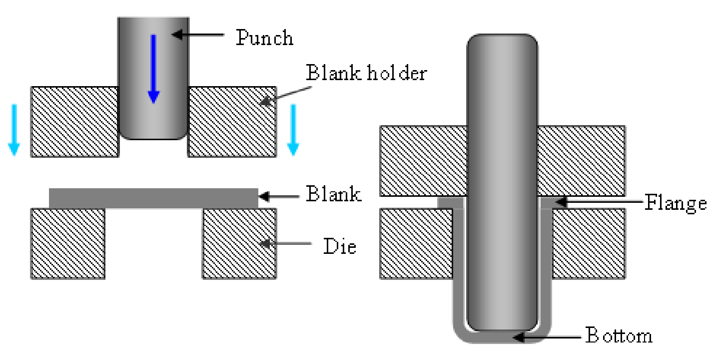

Fig. 9 shows the Deep Drawing process

Industries that rely on deep drawing include aerospace, automobile, dairy, lighting, pharmaceuticals, and plastics. Companies that manufacture deep drawn parts require engineer-designed operations and deep drawing presses are relatively expensive.
Accessories such as molds, tooling plates and columns are required to manufacture deep drawn parts. While a mold is needed for stretching the material over the mold's edge to produce the required shape, a tooling plate or column is needed as a surface for holding work pieces.

Lubrication

Lowers forces in deep drawing, increase drawn ability and reduces defects in the parts and wear on the tooling. In general, lubrication of the punch should be held to a minimum, because the friction between the punch and the cup improves drawn ability by reducing tensile stresses in the cup. For general, applications commonly used lubricants are mineral oils, soap solutions, and heavy-duty emulsions. For more difficult applications, coating, wax, and solid lubricant are used.

Questionnaires

Q1.What will happen to the blank if blank holder force increased and decreased?

Q2. In deep drawing why lubrication is kept minimum?

Q3. Why is important the corner radii of the punch and die?

Experiment No. 8

Aim of the Experiment
To manipulate the microstructure of rolled, forged, extruded and drawn parts

Material /Apparatus
Specimens to be examined, abrasive cutting machine, mounting machine, grinder, polisher, etchants, and metallurgical microscope.

Theory
What is Metallography?

- **Metallography:** is the science and art of preparing a metal surface for analysis by grinding, polishing, and etching to show microstructual component.
- **Microstructure:** is the geometric arrangement of grains and the different phases present in a material.

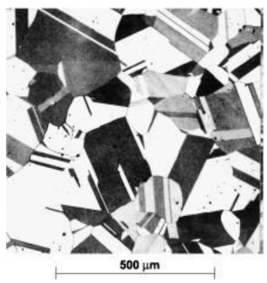

Fig. 10 shows a simple Microstructure

- **Grain Boundaries:** is the interface between two grains in a polycrystalline material where the crystal is disordered due to rapid change in crystallographic directions.

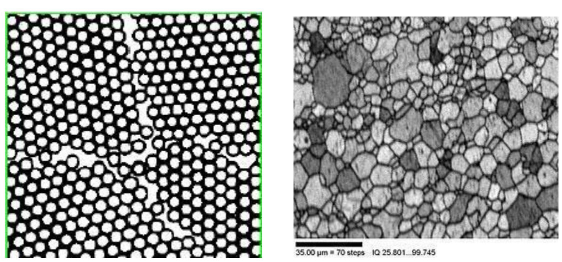

Fig. 11 shows Polycrystalline Material

- Most engineering alloys are polycrystalline this means that each piece of a metal is made up of a great number of single crystals, or grains, each having a regular crystal structure (for example, FCC, BCC, or HCP).
- Materials specialists are interested to see the grain boundaries in order to estimate the grain sizes. The average grain size in metals is usually in the order of several to tens of micrometers, which can be measured only by the use of an optical or light microscope

Sample Preparation

- **Sampling:** The preparation starts by cutting a small representative piece of the metal to be studied.
- **Mounting**: Small samples can be difficult to hold safely during grinding and polishing operations, and their shape may not be suitable for observation on a flat surface. They are therefore mounted inside a polymer block or mount.

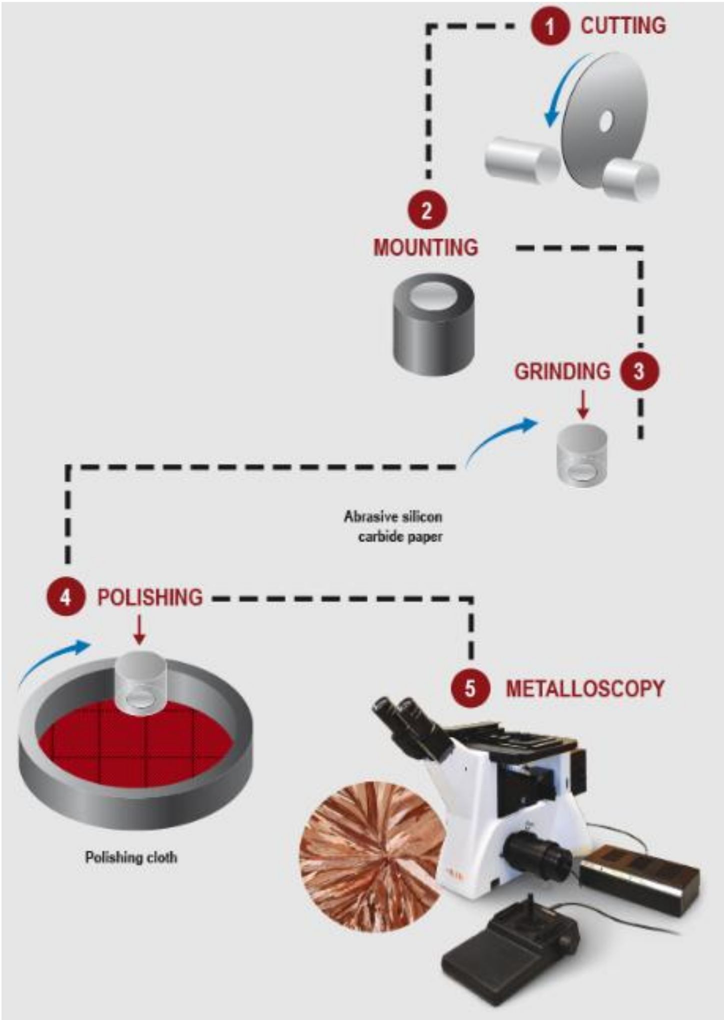

Fig. 12 shows all steps of metallography process

Mounting

- **Cold mounting** can be done using two components resins (epoxies) which are liquid to start with but which set solid shortly after mixing. it requires very simple equipment consisting of a cylindrical ring which serves as a mould and a flat piece which serves as the base of the mould. the sample is placed on the flat piece within the mould and the mixture poured in and allowed to set. Cold mounting takes few hours to complete.

- **Hot-mounting** the sample is surrounded by an organic polymeric powder which melts under the influence of heat (about 200 C). Pressure is also applied by a piston, ensuring a high quality mould free of porosity and with intimate contact between the sample and the polymer.

Grinding

- Grinding is done using rotating discs covered with silicon carbide paper and water.
- There are a number of grades of paper, with 180, 240, 400, 1200, grains of silicon carbide per square inch. 180 grade therefore represents the coarsest particles and this is the grade to begin the grinding operation. *Always use light pressure applied at the centre of the sample.*
- Continue grinding until all the blemishes have been removed, the sample surface is flat, and all the scratches are in a single orientation.
- Wash the sample in water and move to the next grade, *orienting the scratches from the previous grade normal to the rotation direction*. This makes it easy to see when the coarser scratches have all been removed.
- After the final grinding operation on 1200 paper, wash the sample in water followed by alcohol and dry it before moving to the polishers.

Polishing

- The polishers consist of rotating discs covered with soft cloth impregnated with a pre-prepared slurry of hard powdery alumina particles (Al_2O_3, the size ranges from 0.5 to 0.03 µm).
- Begin with the coarse slurry and continue polishing until the grinding scratches have been removed. *It is of vital importance that the sample is thoroughly cleaned using soapy water, followed by alcohol, and dried before moving onto the final stage.* Any contamination of the final polishing disc will make it impossible to achieve a satisfactory polish.
- Examining the specimen in the microscope after polishing should reveal mirror like surface.

Etching

The purpose of etching is two-fold.

- Grinding and polishing operations produce a highly deformed, thin layer on the surface which is removed chemically during etching.
- Etchant attacks the surface with preference for those sites with the highest energy, leading to surface relief which allows different crystal orientations, grain boundaries, precipitates, phases and defects to be distinguished in reflected light microscopy as demonstrated in following figure.

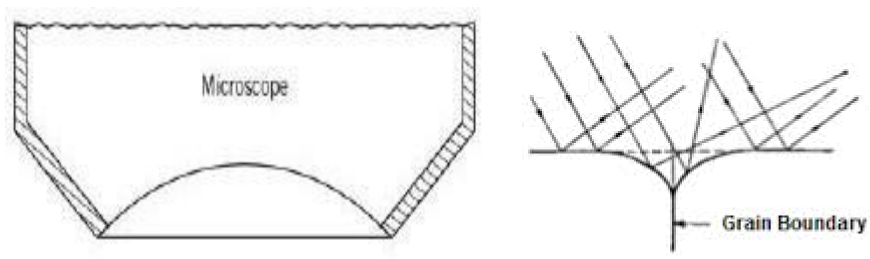

Fig. 13 shows high lighting of features after etching process

- Etching should always be done in stages, beginning with light attack, an examination in the microscope and further etching only if required.
- If you over-etch a sample on the first step then the polishing procedure will have to be repeated.
- The table below gives the etchants for alloys that will be examined in this experiment.

Table 5: shows the material with their etchants

Sample	Etchant
Al alloys	Keller's (2ml HF +3ml HCL + 5ml HNO_3+ 190ml water)
Cu-Zn alloy (brass)	10ml HNO_3+90ml water
Steel and cast irons	Nital (2% HNO_3 + 98% ethanol)

Microscopic techniques

- Optical microscopy used to obtain an enlarged image of a small object. In general, a compound microscope consists of a light source, a condenser, an objective, and an ocular or eyepiece, which can be replaced by a recording device such as a photoelectric tube or a photographic plate. The optical microscope is limited by the wavelengths of the light used and by the materials available for manufacturing the lenses.

Fig. 14 shows the Optical/Metallurgical Microscope

Results

Average grain size

The number of phases present

Sketch of the microstructures

Questionnaire

Q1. Briefly describe the microstructural information you got from different samples.

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