

ENGINEERING WORKSHOP TECHNOLOGY

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Published by:

University of Ilorin Publishing House,
University of Ilorin, Ilorin, Nigeria.

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First Edition 2017

ISBN

ACKNOWLEDGEMENTS

The job of writing and publishing a textbook on Engineering Workshop Technology in Nigerian academic environment is a herculean task due to lack of quality or insufficient fit for purpose reading resources. Therefore, the production of this thought-provoking first edition makes it important to appreciate those who had worked assiduously to ensure its reality. First and foremost, the editor-in-chief wishes to acknowledge and commend the efforts and immeasurable contributions of the editorial board members, comprising Prof. S.M. Adedayo, Dr. J.O. Aweda, Dr. K.R. Ajao, and Dr. S. Abdulkareem. Many thanks go to the contributing authors, who made the writing of this book possible within the time scale. The editors as well as the authors are equally grateful to Prof. Y.A. Jimoh, Dean, Faculty of Engineering and Technology, University of Ilorin for writing the foreword, and other colleagues in the department and faculty at large who have encouraged us and provided insights during the writing and production processes.

Above all, I give glory to the Almighty for granting the relevant staff members of the Department of Mechanical Engineering, University of Ilorin the opportunity and means to produce this book.

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FOREWORD

Engineering technology is one of the general engineering courses included in the Benchmark for Minimum Academic Standards (BMAS) by both the National Universities Commission (NUC) and Council for the Regulation of Engineering in Nigeria (COREN). The Nigerian engineering curriculum is structured such that it takes effect from the second year after a year of studies of courses in physical and mathematical sciences as well as other generic subjects. At the second year, core engineering training for all engineering courses commences. Thus, it is proper that all students are exposed to the fundamentals of engineering workshop technology as the basis for further technical studies.

This textbook on Engineering Workshop Technology was written by relevant staff members of the Department of Mechanical Engineering, University of Ilorin as a resource material for engineering students in the University of Ilorin as well as other tertiary institutions. The exercise was motivated by the desire to make available to engineering students a textbook, which would be comprehensive and simple enough for their needs, meeting the course objectives for training in engineering workshop technology. Moreover, it is observed that, in preparing this book, cautious efforts had been made to ensure that it has satisfactory quality to meet the standard of a scholarly publication. The chapters were well researched and their presentations are in conformity with standard publication style. Likewise, experts in the relevant areas edited all the chapters. It is, thus, my hope that this book would serve a beneficial purpose as a resource material for engineering students, in particular, for those in their second year, and as a scholarly material for research scholars.

The book contains six chapters. In chapter one, Dr. Ajimotokan and Dr. Abdulkareem present an introduction to workshop practice, highlighting its relevance. The authors examine plant and workshop layouts, sections/ types of workshops as well as the general safety rules and work procedures in workshops, among others. In chapter two, Dr. Aweda, Dr. Mahamood and Engr. Abdulrahman examine industrial safety, emphasising the relevance of safety and health in an industrial organisation. Chapter three focuses on machine tools. In this chapter, Dr. Abdulkareem and Dr. Ajimotokan examine the different types of machine tools and their uses, specifications and cutting parameters, among others. Dr. Mahamood, Dr. Ajimotokan and Dr. Aweda introduce fabrication technology in chapter four and examine basic fabrication techniques with examples. Dr. Ajao and Engr. Rabiou present an overview of the use of hand tools in chapter five, by describing the different types of hand tools and their uses. While

chapter six deals with engineering approach to design. Here, Prof. Adedayo examines engineering design and its basic steps.

Genuine efforts have been made to present the contents of this book in a simple language, with self-explanatory simplified illustrations that are easy to reproduce. This is the first edition of this book, which I wish the authors should plan to review periodically and update its contents as experience and skill sets dictate. In order to enrich the contents of this book and enhance its quality, comments and constructive criticisms are welcome from its users. Do not fantasise that it is perfect as it is, despite the sincere attempts made to ensure that, in its present form, it meets the course objectives for training in engineering workshop technology.

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CHAPTER ONE

INTRODUCTION TO WORKSHOP PRACTICE

H.A. Ajimotokan and S. AbdulKareem

Objectives

The objectives of this chapter are to:

- i. Define the terms engineering workshop, machining, and plant and workshop layouts,
- ii. Specify the primary goal and objectives of a good layouts,
- iii. Specify the basic requirements of a good layouts,
- iv. Discuss the types of layouts, and
- v. Describe various sections/ types of workshop,
- vi. Specify safety rules and work procedures in specific workshops, and
- vii. Describe personal protective equipment (PPE) and specify typical examples of PPE.

1. Introduction

Engineering workshop is a place where products are manufactured through processes, operations or trades such as machining, bench work and fitting, welding, woodworking, forging, foundry, and mechanical working, among others. In other words, engineering workshop is a place where various manufacturing processes are carried out using machine and hand tools for the benefit of mankind. Engineering workshop practice presents learners the opportunity to acquire fundamental knowledge of the various processes or operations involved in manufacturing. It builds learners competence in handling practical work in engineering environment and acts as the basis for further technical studies. Workshop practice requires the use of a number of simple machines and hand tools, and considerable manual efforts. Various manufacturing processes performed in the engineering workshop include: cutting, filing, drilling, welding, tapping, and turning operations, among others. The machine and hand tools used in the engineering workshop depend on the types of required operations to be carried out.

Machine tools though are capable of producing works at a faster rate, but sometimes, components require mechanical or manual process or bench work on the workshop

workbench. Sometimes, the workbench is required to replace or repair components, which must be fitted accurately with other component on re-assembly. This involves a certain amount of hand fitting. The assembly of machine tools, jigs, gauges, etc., also involves certain amount of bench work. The term bench work refers to the manual production of components on the workbench. The accuracy of work done depends upon the experience and skillset of the workshop user. However, the choice of the most appropriate technique for a specific job requires the knowledge of all-possible manufacturing processes. These manufacturing processes are classified into:

- i. Primary shaping processes, which include casting, forging, powder metal forming, gas cutting, extruding, bending and shearing, among others;
- ii. Machining operations (or processes), which include turning, boring, drilling, threading, chamfering, shaping, slotting, planning, milling, broaching, grinding, sawing and unconventional machining, among others;
- iii. Joining processes, which include welding, soldering, brazing, riveting, screwing, press fitting and adhesive bonding, among others;
- iv. Surface finishing processes, which include plating, honing, polishing, galvanising, painting and inorganic coating, among others; and
- v. Processes effecting change in properties, which include heat treatment, cold working and hot working, among others.

None of all the forming and shaping processes highlighted above is capable of producing components with specific aesthetic characteristics like threaded hole or holes on different surfaces of a component for mechanical assembly, without the components requiring additional manufacturing processes except machining operations. Machining is a general term, which describes any group of processes, comprising material removal and modification of the workpiece surfaces after being manufactured by different methods. Therefore, machining includes secondary and finishing operations, which comprises numerous types of material removal processes. The predominant types include cutting, which usually involves single-point or multipoint cutter (cutting tool), each with a clearly defined geometry; abrasive processes, such as grinding and related processes; and advanced machining processes utilising electrical, chemical, laser, thermal, and hydrodynamic operations to accomplish machining. The machine on which these operations are carried out is known as machine tool. It is expected that whatever the tool used in any type of operation, such should be done from the perspective of safety first. It is also important to know how to work safely in the workshop without causing damage to the equipment or injury to yourself and your co-workshop user(s). In order to avoid accident in the workshop, every workshop user needs to have a good

technical know-how of any equipment or tool before handling it. Moreover, workshop practice should take place in a supervised workshop environment with trainers and supervisors providing regular feedback.

1.1 Plant and Workshop Layouts

Plant layout can be defined as a floor plan for determining and arranging machine and hand tools, and equipment of the plant, established or contemplated in a single best place, to allow the quickest flow of material at the lowest cost and with the least amount of handling in processing the product, from the receipt of raw materials to the shipment of the finished product. A plant layout is such a systematic and functional arrangement of machine and hand tools, equipment and other support services of a plant, which would enable the smooth processing of product in the most effective, efficient and economical manner in the least possible time. It starts with the design and position of the building, and goes up to the location and movement of machine worktables. The workshop layout forms an integral part of factory planning or plant layout, in which itself performs a more specialised job. All the manufacturing facilities like raw materials, machine and hand tools, fixtures, and workers are provided an appropriate place in any workshop. In a best possible plant layout, material handling and its movement is minimised and efficiently controlled; and points of bottlenecks, congestions, etc. are gotten rid off such that raw materials and semi-finished goods could move unhindered from one workstation to the other. The key goal of any layout is to maximise profits by creating the best possible arrangements of all plant and workshop facilities, maximising the advantage of reducing the production cost for the proposed or undertaken products.

1.1.1 Principles of Layouts

The six principles of layout planning are the principles of overall integration, minimum distance, flow, cubic space, satisfaction and safety, and flexibility.

1.1.1.1 Principle of Overall Integration

A layout is considered the best when it integrates the workers, materials, machinery, facilities and other supporting activities in such a way that it allows the best arrangement.

1.1.1.2 Principle of Minimum Distance

The best layout is a layout in which the workers and materials are required to move the minimum distance between operations, all other things being equal.

1.1.1.3 Principle of Flow

The best layout is a layout that arranges the work area for each operation or process in the sequence, which forms, treats or assembles the materials, all other things being equal.

1.1.1.4 Principle of Cubic Space

The best layout is a layout in which all available floor space, both horizontal and vertical is utilised most economically and efficiently.

1.1.1.5 Principles of Satisfaction and Safety

The best layout is a layout that makes work satisfying, pleasant and safe for workers, all other things being equal.

1.1.1.6 Principle of Flexibility

The best layout is a layout that can be adjusted and re-arranged at the least cost and inconvenience, all other things being equal.

1.1.2 Objectives of a Good Layout

The objectives of a good layout are to:

- i. Reduce the production cost,
- ii. Manufacture improved quality products,
- iii. Evolve sufficient flexibility in the arrangement of machine and hand tools, equipment and facilities (in order to suit the minor future changes if any),
- iv. Minimise materials handling and their movement,
- v. Provide smooth product flow and reduce work in progress to the minimum,
- vi. Maximise the full utilisation of floor space,
- vii. Provide adequate safety and satisfaction to the delight of the workers,
- viii. Provide the best services to the customer,
- ix. Enable effective control and supervision,
- x. Evolve most preferable work methods and labour utilisation, and
- xi. Ensure optimum utilisation of machine and hand tools, equipment and facilities.

1.1.3 Basic Requirements of a Good Layout

A good plant and workshop layouts should meet the following basic requirements:

- i. Integration of manufacturing centre facilities in terms of man, machine and material,

- ii. Movements of production personnel and material handling should be minimised,
- iii. Smooth and continuous flow of production or manufacturing work with least possible points of bottleneck and congestion,
- iv. Floor space utilisation should be optimal as much as possible,
- v. Work places should be free from pollution and safe-working conditions should prevail in each section/ shop of the plant,
- vi. Handling of workpiece, semi-finished and finished products should be tackled optimally and effectively,
- vii. Plant and shop layouts must be flexible to enable changes in production needs, and
- viii. Provision of good working environment in relation to appropriate lightening, ventilation and other amenities like drinking water, toilets, etc. for the welfare of the workers.

1.1.4 Procedure for Plant and Workshop Layouts

The procedure for a good plant and workshop layouts includes:

- i. Choosing machine and hand tools based on product design and volume of output to be accomplished,
- ii. Collecting the needed data like the machine load charts, machine data cards, etc.,
- iii. Developing process map,
- iv. Developing an overall operations flow plan,
- v. Choosing the most appropriate type of building,
- vi. Developing specifications for the building to house the layout and modify the floor plan to accommodates limitations of building details,
- vii. Constructing a flow chart and flow diagram to verify the achievement of the objectives of a good layout,
- viii. Submitting final layout chart and draft to specialists in different fields for comments, observations and suggestions,
- ix. Amending and submitting final draft to management for approval,
- x. Constructing the plant and install machines, equipment and other facilities, and
- xi. Conducting trial tests and adjust the layout where required.

1.1.5 Types of Layouts

Plant and workshop layouts can be classified into four basic types, which are fixed, process, product, and combination layouts.

1.1.5.1 Fixed Layouts

Fixed layout is also called position or project layout. In this type of layout, the main part of an assembly or material remains at a fixed position. All its accessories, auxiliary materials, machines and hand tools required and the labour are brought to the fixed site to work. Thus, the product, by virtue of its bulk or weight, remains at one location. The location of the major assembly, semi-assembly component and material is not disturbed till the product is ready for dispatch. This layout is suitable when one or a few pieces of an item are to be manufactured and material forming or treating operation requires only tools or simple machines. This layout is highly preferable when the cost of moving the major piece of material is high and the responsibility of product quality by one skilled workman or group of skilled workers is expected. This type of layout is mainly adopted for extremely large items manufactured in very small quantity such as ships, aeroplanes, boilers, reactors, etc. The main merit of this layout is the minimum movement of men, material, and tooling during manufacturing process. This layout is highly flexible as the type of product and the related processes could be easily altered without any alteration in the layout. The major demerits of this layout are that the cost of equipment handling is very high, labours and equipment are difficult to utilise fully, and it is limited to large items only. Figure 1.1 illustrates a typical fixed layout.

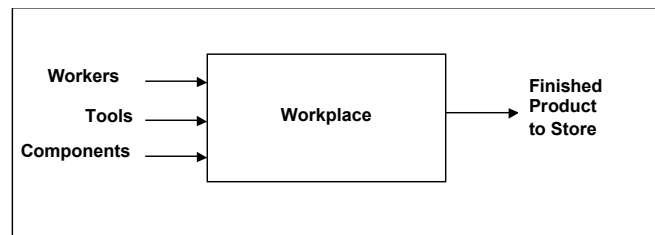


Figure 1.1: Schematic illustration of a typical fixed layout

1.1.5.2 Process Layouts

Process layout is also called functional layout. In this type of layout, arrangement of all similar machine and hand tools, production facilities and manufacturing operations are grouped together according to their functions in separate sections. This layout is adopted for batch or moderate production and it specifies the path for group technology. Machine tools of the same kind are arranged together such that all the similar operations are performed at the same place, e.g. all machine tools for different kinds of turning and threading operations in one section, for carrying out tapping work in another section, for carrying out milling work in another section, for buffing and polishing in another section, for carrying out surface finishing work in another section, etc. Process layout is typically preferred for the industries involved in job-order type of production

and/ or maintenance activities of non-repetitive type. This type of layout does not necessarily change every time the product or component changes, and a breakdown of any machine does not affect the production. This type of layout is highly suitable for batch production. Figure 1.2 illustrates a typical process layout.

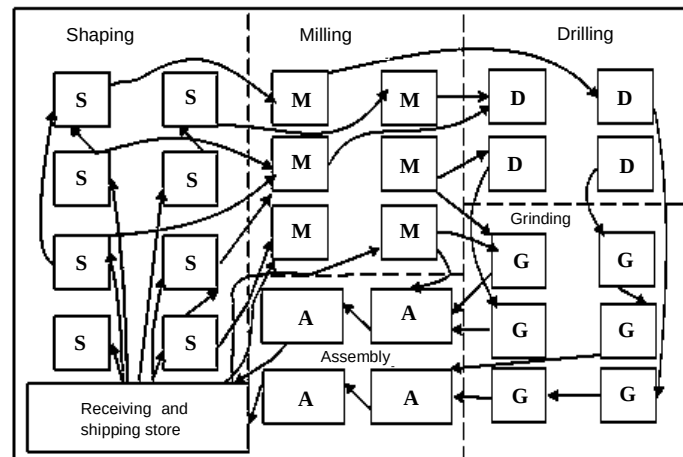


Figure 1.2: Schematic illustration of a typical process layout

1.1.5.3 Product Layouts

Product layout is also called line or straight line layout. In this type of layout, all machines and production facilities are arranged in a line, according to the required sequence of operations for the manufacturing of the product. That is, each machine or section is arranged to perform the next operation to be carried out by its preceding machine or section. Workpiece starts from one end of production line and moves from one machine to the next along a sequential path, which is mostly employed for assembling work. Product layout is advantageous for a continuous production system where the number of end products is small and the parts are highly standardised and interchangeable. It is suitable for products getting a steady demand. This layout may have operational sequence like forging, turning, drilling, milling, grinding and inspection before the product is sent to the finished goods store for packing and shipment. Product layout is used for mass production, and ensures smooth flow of materials and reduced material handling. Breakdown of any machine on the layout may result in stoppage of production. Figure 1.3 illustrates a typical product layout.

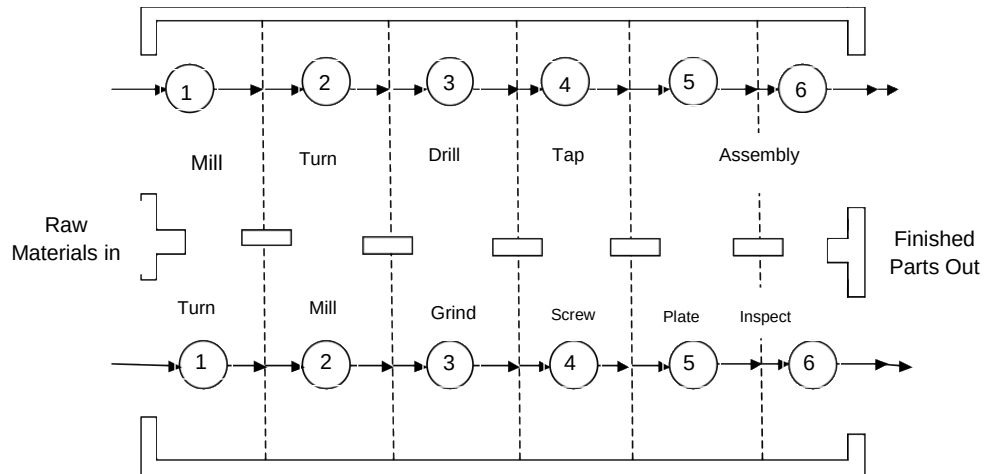


Figure 1.3: Schematic illustration of a typical product layout

Source: (Rajput, 2005)

1.1.5.4 Combination Layouts

Combination layout is also called group layout. In this type of layout, the process and product layouts are combined, maximising the advantages of both types of layouts. Combination layout groups together in sections, etc. a set of machine and hand tools, equipment and facilities, such that each set or group is used to perform similar operations to produce a family of components. Most manufacturing industries adopt this type of layout. Figure 1.4 illustrates a typical combination layout.

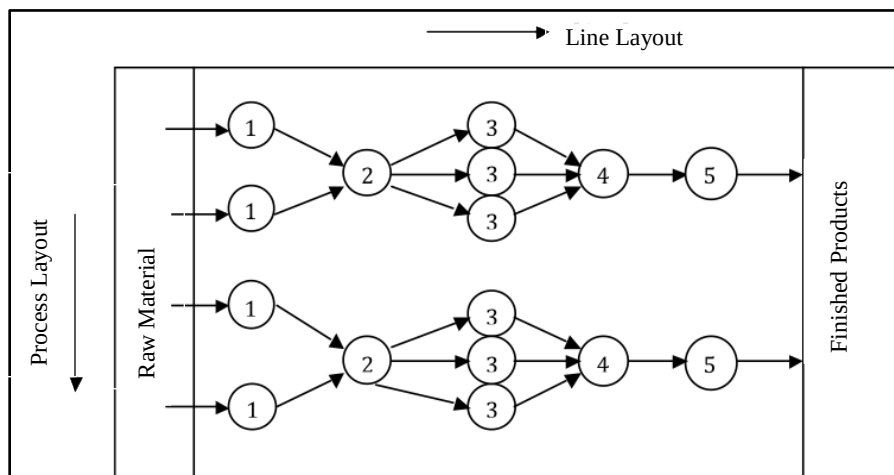


Figure 1.4: Schematic illustration of a typical combination layout

1.2 Sections/ Types of Workshops

There are various sections or types of workshops. The basic ones are machine, fitting, woodwork, forging, foundry, welding and numerical control sections or shops, among others.

1.2.1 Machine Shops

Machine shop is a place where metal parts are cut to the required sizes and shapes, and then join together to form mechanical units or machines. The machines so made are to be used directly or indirectly in the production of necessities and luxuries of civilisation. Machine shop is the base of all mechanical production. It is manage or handle by machinists.

1.2.2 Fitting Shops

Fitting shop is a place where fitting or assembling work is carried out. Some repairs and/ or maintenance and die punch work are also carried out in a fitting shop.

1.2.3 Woodwork Shops

Woodwork or carpentry shop is a place where the making of wooden components from marketable form of wood into finished product is carried out. Woodwork may be defined as the process of making wooden components, from a marketable form of wood into finished products. It deals with the building work, pattern making for concrete or casting work, furniture, cabinet making etc. joinery, i.e. preparation of joints - one of the important operations in all woodworks. It also deals with the specific work of carpenter like making different types of joints to form a finished product.

1.2.4 Forging Shops

Forging shop is a place where mechanical working or shaping of metals, in either cold or hot state, is carried out. Forging is a mechanical working or shaping of metals in either cold or hot state, which does not include machining, grinding or casting. But during mechanical working, the metal is actually shaped by pressure, in which forging, bending, twisting and/ or drawing, etc. is done, bringing it to its final shape. In these processes, some metals are shaped in both cold and hot worked.

1.2.5 Foundry Shops

Foundry shop is a place where desired shape of metal casting is obtained from melting and pouring molten metal into moulds. Foundry is one of the manufacturing processes, in which metal casting of desired shapes can be obtained from heated metal in its molten (liquid) state, poured into mould cavity. In metal forming, casting refers to a

process, in which molten metal is poured into a mould, containing a hollow cavity of the desired shape, which is then allowed to cool, solidify and wreck out of the mould to complete the process. This solidified component is also called casting. Usually, casting is used for manufacturing complex shapes, which would be hard or inefficient through other means.

1.2.6 Welding Shops

Welding shop is a place where permanent fastening of materials, usually metals or thermoplastics is carried out. Welding is a fabrication process for permanent fastening of materials, usually metals or thermoplastics, by heating the base materials to their melting temperature, with or without the application of pressure and filler material. The filler material typically has a melting point almost similar as those of the base materials. The filler material is added to form a pool of molten material known as the weld pool and forms the joint when cooled, which is typically stronger than the base material. The current carrying rods that are used in welding are called electrodes. A number of diverse energy sources may be employed for welding, which include the gas flame, electric arc, laser, electron beam, friction, and ultrasound. Welding, as an industrial process, can be carried out in diverse environments, such as in the open air, under water and outer space.

1.2.7 Numerical Control/ Computer Numerical Control Shops

Numerical control (NC)/ computer numerical control (CNC) shop is a place where the techniques of automation for the operation of machine tool components, based on coded instructions, are carried out. NC is a mode of automatically controlling the operation of machine tool components, based on a set of coded motion and machining instructions in the form of alphanumeric and special characters. The system operates by abstractly programmed commands, encoded on a storage medium, as opposed to manually controlled via hand wheels, levers, or mechanically automated via cams alone. The system automatically interprets these data and converts them to output signals, which in turn, control different machine components. The complete set of coded instructions responsible for executing an operation is called **part program**. Most NC machines today are computer numerically controlled; in which the computer plays an integral part of the control. In computer-aided part programming, much of the computational work required for manual programming is carried out by the computer microprocessor. This program is decoded into electrical signals to drive different motors to operate the machine to perform the needed processes. All NC/ CNC machine tools have drive motors and other accessories to perform auxiliary functions of the machine along with the worktable, spindle and other hardware of the conventional machine tools.

1.2.8 Computer-Aided Design/ Computer-Aided Manufacturing Labs

In computer-aided design/ computer-aided manufacturing (CAD/ CAM) lab, different jobs are accomplished with the help of CAD/ CAM design tools software, CNC mill and lathe software. These software are valuable tools in engineering workshop practice, which are required to design and manufacture different types of objects.

1.3 General Safety Rules and Work Procedures in Workshops

Before considering the different workshop processes or operations, there are a few items, which are of general interest to all workshop users. These include the adherence to the general safety rules, use of personal protective equipment (PPE), and adherence to safety rules and work procedures in specific workshops. The general workshop safety rules are as follows:

- i. Always wear eye protection equipment, preferably industrial quality safety glasses with side-shields. The lathe can throw off sharp, hot metal chips at considerable speed as well as spin off spirals of metal, which could be quite hazardous. Don't take chances with your eyes,
- ii. Wear protective shoes, preferably leather work shoes to protect your feet from sharp metal chips on the shop floor and from tools and chunks of metal that may get dropped,
- iii. Remove wristwatches, necklaces, chains and other jewellery. Tie back long hair so that it does not get caught in the rotating work. Think about what happens to your face if your hair gets entangled,
- iv. Always double check to make sure your work is securely clamped in the chuck or between centres before starting the lathe. Start the lathe at low speed and increase the speed gradually,
- v. Get in the habit of removing the chuck key immediately after use. Some users recommend never removing your hand from the chuck key when it is in the chuck. The chuck key can be a lethal projectile if the machine tool is started with the chuck key in the chuck,
- vi. Keep your fingers clear of the rotating work and cutting tools. This sounds obvious, but one is often tempted to break away metal spirals as they form at the cutting tool, and never place your hands under the tool or board,
- vii. Avoid reaching over the spinning chuck. For filing operations, hold the tang end of the file in your left hand so that your hand and arm are not above the spinning chuck,
- viii. Never use a file with a bare tang because the tang could be forced back into your wrist or palm.

- ix. Know the safety rules for each machine before plugging in the power cord,
- x. Inspect the tool, power cord, and cutter to be certain that they are in proper working order,
- xi. Never operate a tool with a dull or broken cutter,
- xii. Always clamp the stock to a bench or sawhorse before starting a cut,
- xiii. Never operate the tool near water or flammable gases or vapours, and
- xiv. Arrange the power cord so that it does not interfere with the cut and always keep your hands on the handles of the tool.

1.3.1 Personal Protective Equipment

There are prescribed dressing for anyone that is using the workshop for his/ her own safety. The following should be avoided when entering the workshop: wearing loose clothing, slippers or open shoes or wristwatches; uncovered or bonded long hair, handbag, etc. Moreover, workshop practice or training should take place in a supervised workshop setting, which gives trainees or students access to basic tools and PPE. PPE includes all clothing and accessories designed to protect against work environment hazards. Typical PPE would include overall, boot, safety glasses, gloves, ear defenders, and hard hats. The training area should be designed to enable trainees or students to view, hear and participate fully in the subject matter being taught. Typical workshops and practical areas should be well lit and well ventilated with clearly defined walkways. Training areas should have adequate floor space, workbenches with bench vices fitted, allowing each trainee to participate fully in practical demonstrations and exercises. There should also be a clearly marked storage area with tools cupboards and toolboxes/ trays and file racks.

1.3.2 Safety Rules and Work Procedures in Specific Workshops

The following are some of the safe and correct workshop practices in a fitting shop, with respect to the tools used.

- i. Keep hands and tools wiped clean and free of dirt, oil and grease. Dry tools are safer to use than slippery tools,
- ii. Do not carry sharp tools in pockets,
- iii. Wear leather shoes and not sandals, and do not wear loose clothes,
- iv. Do not keep working tools at the edge of the table,
- v. Position the workpiece such that the cut to be made is close to the vice. This practice prevents springing, saw breakage and personal injury,
- vi. Apply force only on the forward (cutting) stroke and relieve the force on the return stroke while sawing and filing,

- vii. Do not hold the workpiece in hand while cutting,
- viii. Use file with a properly fitted tight handle,
- ix. After filing, remove the burrs from the edges of the work, to prevent cuts to the fingers,
- x. Do not use vice as an anvil - a heavy iron block with a flat top and concave sides, on which metal can be hammered and shaped,
- xi. While sawing, keep the blade straight otherwise it would break, and
- xii. Clean the vice after use.

The following are some of the safe and correct work practices in carpentry shop, with respect to the tools used.

- i. Tools that are not being used should always be kept at their proper places,
- ii. Make sure that your hands are not in front of sharp edged tools while you are using them,
- iii. Use only sharp tools. A dull tool requires excessive pressure, causing the tool to slip,
- iv. Wooden pieces with nails should never be allowed to remain on the floor,
- v. Be careful when you are using your thumb as a guide in crosscutting and ripping,
- vi. Test the sharpness of the cutting edge of chisel on wood or paper, but not on your hand,
- vii. Never chisel towards any part of the body,
- viii. Do not use chisels where nails are present and never as a screwdriver,
- ix. Do not use a saw with a loose handle,
- x. Always use triangular file for sharpening the teeth,
- xi. Do not use a saw on metallic substances,
- xii. Do not use mallet to strike nails, and
- xiii. Do not use plane at the places, where a nail is driven in the wood.

The following are some of the safe and correct work practices in welding shop, with respect to the tools used:

- i. Always weld in a well-ventilated place. The fumes released during welding operations are unpleasant and in some cases may be injurious, in particular, from galvanised or zinc coated components,
- ii. Do not weld around combustible or inflammable materials, where sparks may cause fire,

- iii. Never weld containers, which have been used for storing gasoline, oil or similar materials, without first having them thoroughly cleaned,
- iv. Check the welding machine to make sure that it is properly grounded and that all leads properly insulated,
- v. Never look at the arc with the naked eye. The arc could burn the eyes severely. Always use a face shield while welding,
- vi. Prevent welding cables from coming in contact with hot metal, water, oil, or grease. Avoid dragging the cables around sharp corners,
- vii. Ensure proper insulation of the cables and check for openings,
- viii. Always wear the safety hand gloves, apron and leather shoes,
- ix. Always turn off the machine when leaving the work,
- x. Apply eye drops after welding is over for the day, to relieve the strain on the eyes, and
- xi. While welding, stand on dry footing and keep the body insulated from the electrode, any other parts of the electrode holder and the work.

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