VIRAM series

WORKSHOP TECHNOLOGY

As per AICTE Curriculum for Diploma

R. K. Jain

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Investing in Learning

Workshop Technology

(for Diploma Course)

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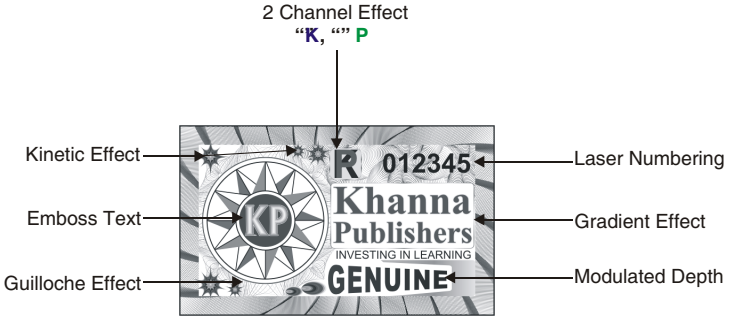

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Preface

The subject of Workshop Technology is very basic for a Mechanical Engineer. In workshop technology, engineer learns about various fabrication and manufacturing techniques. Welding shop, casting and foundry shop provide initial basic knowledge about joining of parts by welding — a very versatile technique for joining of metals welding operation can be performed by various methods like gas welding, resistance welding, arc welding and other modern welding techniques. All these aspects are covered in simple way in this book.

Manufacturing of parts by casting a fundamental technique to obtain desired shape of parts in convenient way casting also involves the making of pattern whose understanding is important for success in casting techniques. Casting involves use of molten metal for which knowledge of various type of furnaces is necessary.

All such requirements of workshop technology have been covered in simple and logical way in this book. Each chapter deals with numericals, simple questions and answers, objective type question to enable engineers to understand basic concepts and to clear their examinations with flying colours.

It is hoped that students will find this book useful, serving their purpose of scoring high marks with thorough understanding of subject matter.

Author is thankful to Mr. Kratu Khanna and Ms. Akshita Khanna (children of Mr. Vineet Khanna and grand children of Mr. Romesh Chander Khanna) for their keen interest in bringing out full series of books for diploma engineers.

Any suggestion for improvement of the book shall be welcome.

3rd April, 2021 —R. K. Jain

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Chapter 1

Principle of Welding

1.1. PRINCIPLE OF WELDING

Welding is used where permanent fastening is required. Welding is usually done by heating the part edges to be joined, filler metal deposited in specially prepared joint.

The term welding is used to cover a wide range of bonding techniques. Broadly, welding process could be classified as fusion welding and solid-phase welding.

Fusion Welding is the process of joining two pieces of metal by application of heat. The two parts to be joined are placed together, heated, often with the addition of filler metal, until they melt, and solidify on cooling. The heat may be developed in several ways *viz*. combustion of fuel gas with oxygen (oxygen—acetylene gas welding), electric arc, electric resistance heating, plasma arc, electron beams, laser beam etc. Along with the application of heat, in some cases pressure is also applied in order have better action of joining. For additional strength sometimes filler material is also used. It is a very old art and this started with joining of metals by heating them to very high temperature (which is sufficient to cause cohesion) and then hammering. The various ways of applying pressure in order to effect welding are hammering and rolling. In welding without the application of pressure, the metals are brought to fluid state and joined by some filler material.

Solid-phase welds are produced by bringing the clean faces of components into intimate contact to produce a metallic bond with or without application of heat, but application of pressure is essential to induce plastic flow.

Now-a-days many processes of welding have been developed and probably there is no industry which is not using welding process in the fabrication of its products in some form or the other. This is the most rapid and easiest way of fabrication and assembly of metal parts. The research carried out in this field has given various ways and methods to weld practically all metals. Means have also been found out to weld dissimilar metals. One beauty of welding in comparison to other processes of joining metals is that by this process we can have more than 100% strength of joint and it is very easy process. We shall be dealing with all the various processes of welding in use these days, the equipment used for each process and the ways of preparation of joint and the various operations necessary.

Welding is now-a-days extensively used in the following fields : automobile industry, aircraft machine frames, structural work, tanks, machine repair work, ship-building, pipe-line

fabrication in thermal power plants and refineries, fabrication of metal structures. There is a big competition between welding and casting process now-a-days. Many of the cast products are now-a-days being fabricated by welding various parts together. Such construction has the advantage that the products are lighter and stronger. Gas cutting is another field of application of welding process which is playing a very important role in industry.

1.2. CLASSIFICATION OF WELDING PROCESSES

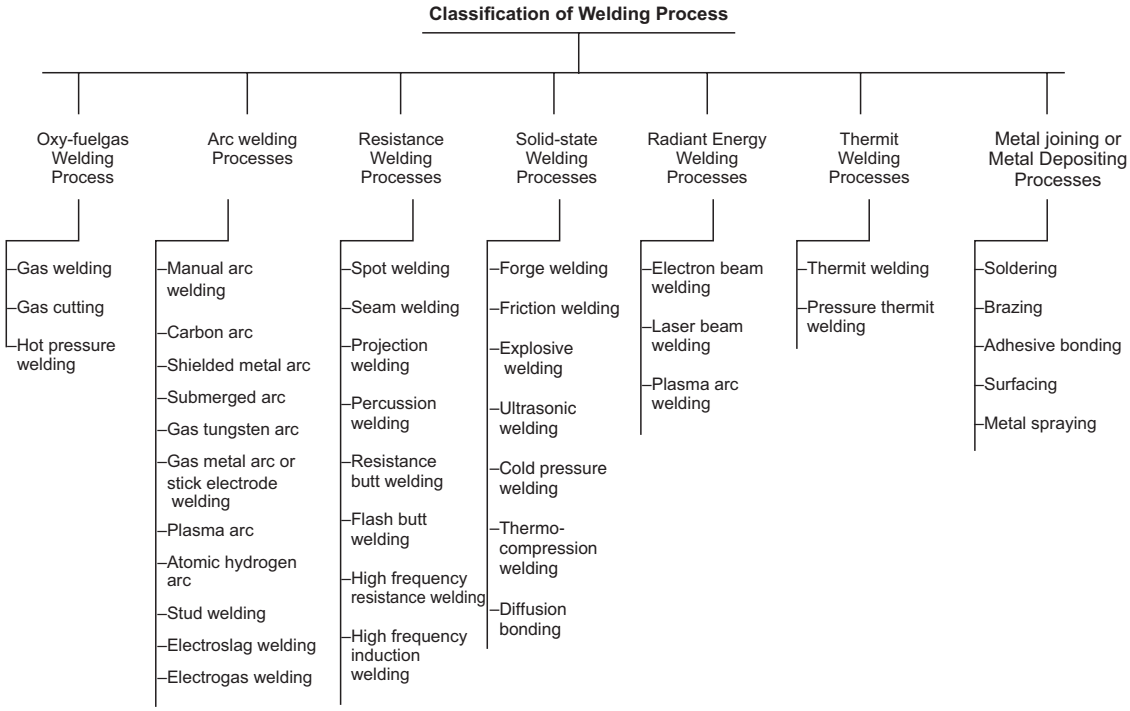

Fig. 1.1. Shows the classification of welding process.

Carbon Arc Welding. It is an arc welding process in which a pure graphite or baked carbon rod of 4 to 19 mm diameter and 300 to 450 mm long is used as a non-consumable electrode to create an arc between it and the workpiece by holding it in an electrode holder, with an electrode extension of 75 to 125 mm. The weld can be made by the application of heat with or without the addition of filler material. It is used for copper alloys.

Shielded Metal Arc Welding. It uses coated electrodes of 2.5 to 6.35 mm diameter and 300 to 450 mm long held in an electrode holder. It uses A.C. or D.C. constant current type power source. It is used for welding aluminium alloys; fabrication of ships, bridges, pressure vessels and structures.

Submerged Arc Welding. This process employs granular flux and a copper-coated wire in spooled form, thus making it possible to deposit long weld runs without interruption. Both A.C. or D.C. power source can be used. It is used for welding low carbon, low alloy stainless steels, high alloy steels, copper, aluminium and titanium. It finds extensive use for welding thick plates of pressure vessels, ships, bridges and structural work.

Gas Tungsten Arc Welding (TIG). It uses a nonconsumable tungsten electrode with an envelope of inert shielding gas like argon or helium around it. Both A.C. and D.C. power source

can be used. It is used for welding of aluminium, magnesium, stainless steels, copper, Nimonic alloys, monel, inconel, brass, bronze, tungsten, silver, molybdenum and titanium.

Gas Metal Arc Welding. It uses a consumable wire of 0.8 to 2 mm diameter and wound on a spool, which is fed through a welding torch wherein it is provided the electrical connection and the shielding gas like argon, helium, nitrogen, carbon dioxide, hydrogen or their mixtures. When inert gas is used, it is called MIG (Metal Inert Gas) and when CO_2 is used, it is called MAG (Metal Active Gas) welding. If finds extensive use in welding of steels, aluminium, magnesium alloys, nickel alloys, copper alloys and titanium.

Plasma Arc Welding. The plasma arc is created between a tungsten electrode and the workpiece. Energy for plasma welding is obtained from a D.C. power source of the constant current type. It is used in the aeronautical, precision instrument industry and jet engine manufacture.

Plasma-MIG Welding. Here the electrode wire is enveloped in a plasma sheath which controls heat and droplet transfer in such a way that higher speeds and deposition rates are reached as compared with MIG or MAG. It is used for welding thin and thick materials of mild, low alloy-creep resistant, strainless, and heat resistant steels as well as nonferrous metals such as aluminium and copper.

Atomic Hydrogen Welding. It employs two tungsten electrodes held in a special atomic hydrogen torch. The electrodes are connected to a constant current A.C. power source. It is used for the manufacture of alloy steel chains and repair of dies and tool steel components.

Stud Welding. This process is used for welding stud or stud-like pieces to flat workpieces like plates. It combines arc and forge welding processes. It finds wide applications in ship building and automatic rail road machinery manufacturing.

Electroslag Welding. It is the process of joining heavy steel sections in a single run. The weld joint is made in a vertical position. It is used for construction of pressure vessels, press frames, water turbines and heavy plate fabrication industries.

Electrogas Welding. It is an arc welding process using the vertical orientation of the weld joint. The wire used is of the flux-cored type. It is used for welding metal thickness of 12 to 75 mm in ship building and site fabrication of storage tanks.

Resistance Welding Processes. In resistance welding processes, the heat is generated at the interface of contacting workpieces due to resistance offered to the flow of electric current.

Resistance Spot Welding. In resistance spot welding process, overlapping sheets are welded by the flow of current between two cylindrical electrodes. It is mainly used for lap welding of thin sheets particularly in the welding of automobile and refrigerator bodies, and high quality work in aircraft engines.

Resistance Seam Welding. In seam welding, the electrodes used are in the form of wheels or rollers and welds are made in an overlapping way to give stitch welds. It gives leak proof joint. It is capable of welding thin materials only in the range of 2.5 to 4.75 mm thickness like hot-rolled grades of low alloy steels. It is used for making flange welds and water tanks.

Projection Welding. In this process, a large number of spot welds are made at one time. It is used for high carbon and low alloy steels, stainless and high alloy steels, zinc die castings and titanium alloys. It finds applications for manufacture of steel mesh for reinforcing concrete panels and basket containers.

Resistance Butt Welding. The pieces to be welded are held in clamps supported on two plates, one of which is fixed and the other movable. The ends to be welded touch each other before the current is switched on. After passing heavy current the two pieces are pressed together

firmly at a temperature of 870 to 925°C to get the weld. It is used for end joining of rods, tubes, bars and similar other sections.

Flash Butt Welding. It consists of one fixed and one movable workpiece through which current is passed. As the distance between the workpieces decreases a flash occurs and heats their ends. At the same time the workpieces are forced together to get a weld. It is used for welding mild steels, medium carbon steels, and alloy steels as well as aluminium alloy nimonic alloys and titanium. Dissimilar metals can be also be welded. It finds applications for welding of rails, steel strips, window frames, automobile axles, wheel rims, aircraft engine rings, and anchor chains for ships.

Percussion Welding. In this process, two pieces are welded by a high intensity short duration arc followed by very rapid impacting of the workpieces. The molten surfaces are then squeezed together by collision and some of the metal is forced out to the side of the joint. This process is used for welding of dissimilar metals like copper to nichrome, copper wire to stainless steel plate, etc.

High Frequency Resistance Welding. Here the phenomenon of 'skin effect' by which the current flows near the surface of the conductor is utilised to weld materials at high speed of upto 300 m/min. The A.C. with a frequency range of 100 to 500 kHz is employed. It is used to weld steels, copper and its alloys, aluminium, nickel and its alloys, titanium and zirconium, It is particularly used for making thin sheet metal pipes.

High Frequency Induction Welding. In this process, the edges to be welded are heated by induction of high frequency current. As there is no direct contact between the induction coil and the workpiece so it eliminates replacement due to wear and tear. The forging action is provided by rollers in the production of tubes.

Solid-state Welding Processes. In these processes, the material to be welded is heated to a temperature below or just upto the solid state. The coalescene between the parts is achieved under pressure.

Forge (or Smith) Welding. The pieces to be welded are heated to above 1000°C and then placed together and given impact blows by hammering. Fluxes commonly used for low carbon steels are sand, fluorspar, and borax. This is commonly used for agricultural implements in rural areas.

Friction Welding. One piece is held stationary and the other is rotated in the chuck, brought to rub against each other under pressure. When the desired temperature is obtained the rotation is stopped and axial pressure increased to cause welding. It is used for welding of drill bits to shanks, engine valve heads to stem, automobile rear-axle hub-end to axle casting.

Explosion Welding. The weld is achieved by making one part strike against the other at a very high but subsonic velocity by using explosive like ammonium nitrate. It is used for cladding of thick plates by thin sheets, even foils. Tube to tube-sheet joints in heat exchangers, valve to pipe joint.

Ultrasonic Welding. A metallic tip vibrating at ultrasonic frequency is made to join a thin piece to a thicker piece supported on an anvil. It applications include aluminium and gold lead wire connections to transistors and diodes, helicopter access doors, metal joints in solar collectors, etc.

Cold Pressure Welding. The materials are joined in lap or butt joint form at room temperature by the application of pressure only. It is used for packaging foods, closing of aluminium cable sheaths and cases of semiconductor devices, lap and butt joints of wires and bus bars for electrolysis cells, communication lines, and trolley wires.

Thermo-compression Bonding. It is a pressure welding process which is employed at a temperature above 200°C. It is used in the electrical and electronic industries for welding fine wires of about 0.025 mm diameter to metal films on glass or ceramic.

Diffusion Welding. It is achieved by the application of pressure, of the order of 5 to 75 MPa, while the pieces are held at high temperature of 75% of the melting point.

Electron Beam Welding. A beam of electron is used to melt the metal where it has to be Fielded. It is used for welding of super alloys, refractory metals, reactive metals and stainless steels. It is widely used in the electronics, nuclear, missile and aircraft industries.

Laser Welding. A concentrated coherent light beam is made to impinge at the desired spot to melt and weld the metal. It is used for welding of corrosion-resistant steels and titanium alloys.

Thermit Welding. Thermit is a mixture of aluminium powder and metal oxide which when ignited results in a non-explosive exothermic reaction. The heat so generated melts and reduces the metal oxide to metallic form at a high temperature. This molten metal is used for joining metal parts by pouring in between them as for railroad tracks.

Gas Welding. It is a process in which a fuel gas such as acetylene, hydrogen, natural gas, etc. is mixed with oxygen in proper proportion to burn to get a flame which can be used for fusing and joining different parts.

Oxy-Acetylene Welding. In this process, acetylene is mixed with oxygen in the welding torch and is then burnt at the torch tip to give a flame which can melt most of the ferrous and non-ferrous metals in common use. It is a common practice to use a filler material and flux. Acetylene is stored in cylinders containing acetone and oxygen is stored in cylinders under pressure.

Soldering. It is a process of joining metal pieces usually in the form of overlapped joints by making a filler metal (i.e. solder) flow into the gap between them by capillary action. The solder most commonly used is a compound of tin and lead having a melting point between 185 to 275°C. Its typical uses include joining of electrical conductors, and plumbing of copper tubing to copper fittings.

Brazing. It is a process of joining metals by using a non-ferrous filler metal having a melting point above 450°C but below the solidus of the base metal. The base metal is not heated and the filler spreads by capillary action between the pieces being joined.

Braze Welding. Differs from brazing in that a much wider gap is filled with the brazing metal (mostly brass) with the aid of torch, and thus capillary action plays no part.

1.2.1. Steps in Executing Welding

- — Identification of welds, type of joint, calculation of weld area by stress analysis, preparation of drawing specifying all important features.
- — Selection of appropriate welding process depending on availability of equipment, skill of personnel, metallurgical and quality requirements, time available and overall economy.
- — Welding procedure, *viz.* welding (cutting, cleaning the plates, edge preparation, etc.) sequence, use of jigs and fixtures, fit up assembly, process planning, testing methods, etc.
- — Execution of welding with proper supervision and inspection at all the stages.
- — Slag removal, weld dressing.
- — Stress relieving by proper treatment.

— Testing, preferably by non-destructive methods for dimensional, metallurgical, crack detection, etc.
— Improvements for future based on feedback from existing systems to avoid defects.

1.2.2. Weldability of Metals

The term *weldability* has been defined by the American Welding Society as "the capacity of metal to be welded under the fabrication conditions imposed into a specific, suitably designed structure and to perform satisfactorily in the intended service". This means that if a particular metal has good weldability it must be welded readily so as to perform satisfactorily in the fabricated structure, and also it must not require expensive or complicated and exacting procedures in order to produce sound joints.

There are certain similarities and differences among the various welding processes depending upon the weldability of metals. The weldability of any metal can be changed by physical, chemical, thermal and metallurgical properties, *i.e.*, by using a proper welding procedure, shielding atmosphere, fluxing material, filler material and in some cases by proper heat treatment of metal before and after deposition. The following metals have good weldability in the descending order : Iron, carbon steel, cast steel, cast iron, low alloy steels and stainless steels.

1.3. ADVANTAGES AND LIMITATION OF WELDING

— Buildings, bridges and structures can be built lighter and thus higher due to reduction in weight.
— These are cheap also due to reduction in weight and material cost. Additional joint strength can be obtained by using considerably smaller structural members. Joints are compact and do not require additional plates as in case of rivetted joints.
— Welded joints have high corrosion resistance compared to bolted and rivetted joints.
— Welded joints are fluid tight for tanks and vessels.
— Welded structures can be altered easily and economically.
— Many different types of joints are possible in welded joints.

1.4. LIMITATION OF WELDING

Welding produces rays of longer wavelength compared to X-rays or gamma rays. These can be broken into visible light rays, infrared rays and ultraviolet rays. Visible light rays emitted can cause eye strain and general discomfort. Ultraviolet rays are invisible and can cause burns on unprotected skin. Infrared rays have a longer wavelength and these produce heat when they strike and are absorbed into a surface. Prolonged exposure can cause skin burns.

1.4.1. Protection of Welders

Welders have to protect themselves against sparks, hot metal, ultraviolet, infrared, and visible light rays, welding fumes, and other hazards. A welder should wear welding jacket or sleeves made of leather or denim, leather leggings, leather welding gloves fitting tightly upto the jacket sleeves, and high-top boots. Clothes should fit tight enough so that no bare skin is exposed to sparks or ultraviolet rays. Safety glasses or glasses with safety lenses fitted with side shields must be worn.

1.5. INDUSTRIAL APPLICATIONS OF WELDING

Originally, the economic importance of welding was realised mainly for repairing and salvaging of all kinds of worn and damaged metal equipment and parts. The economies and improvements

brought about by the more recent techniques of the cutting and the welding processes have placed them as an outstanding tool for manufacturing, construction and maintenance purposes. Some of its applications are listed below.

Replacing Casting. A wide variety of machine parts, which were manufactured by casting, are now being designed and fabricated as weldments. Machinery base, frames and brackets are made up of standard steel shapes and rolled plates and joined by any one of the welding processes.

Replacing riveting and bolting. Welding is gaining importance day by day in the joining of metals as it gives speedy and sound joints and at the same time, the joined structure is lighter in weight.

Welding as the only means of fabrication. Welding is the only solution in cases where the equipment is to be constructed of steel plates, the thickness of which is greater than those joined by means of riveting and caulking.

Practical applications of welding in manufacturing, construction and maintenance. Welding has been successfully adopted by the aeronautical industry in the construction and maintenance of aeroplane engines and accessories, boiler shells, pressure vessels and tanks, bridges, manufacture of cranes, building construction, cutting tools and dies, earth moving equipment, furnaces and boilers.

1.6. WELDING POSITIONS AND TECHNIQUES

Depending upon the position during welding, all welds may be classified as downhand or flat, horizontal, vertical, and overhead welding (Refer Fig. 1.2.) In downward welding, welding can be performed in any direction on a horizontal surface. Downhand or flat welding is the most used position. Horizontal weld is one running horizontally on a vertical surface. Vertical weld is that which runs vertically on a vertical surface and an overhead weld is one that is deposited above the operator's head.

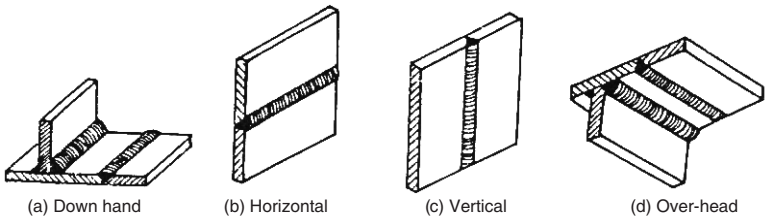

Fig. 1.2. Different positions in welding

In downhand welding the electrode is held at 90° to the workpiece with the electrode tilted through 10° to 25° in the direction of welding depending upon the voltage and current settings of the power source, and the thickness of the workpiece.

In case of a single-V edge in plate 6 to 8 mm thick, full penetration for thorough fusion of groove faces, the arc is started at the point 'A' near the edge of the bevel and then moved to point B into the groove so as to obtain a good penetration at the root of the weld.

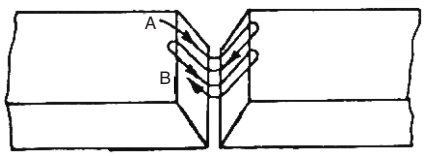

Fig. 1·3. Electrode movements for a single -V butt weld.

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About the Book

The purpose of this book is to provide the comprehensive knowledge and insight into various aspects of engineering materials. These are Welding and resistance welding, modern welding methods patterns and moulds, casting processes and furnaces, special attention has been given for their full coverage. Modern practices and recent trends being followed in manufacturing have been covered in each chapters of workshop technology. In this revised edition, also included four new chapters i.e., Carpentry, Fitting, Sheet Metal Working and Electrical House Wiring.

Numericals play an important role in clarifying the text and accordingly a large number of solved numericals have been added.

About the Author

R.K. Jain, author of this book on 'Workshop Technology' has been associated with Mechanical Engineering for more than 40 years. He started his career as Lecturer in Mechanical Engineering Department in REC, Kurukshetra. Then he joined Central Electricity Authority where he rose to highest level of chairperson of the organisation. Presently he is consultant with World Bank. He has experience in all the aspects of Electricity Industry. He was actively involved in design of thermal power plants, supercritical technology in the country, selection of suitable sites and developing compact layouts of thermal power plants. He has long experience in writing a number of books on Mechanical Engineering subjects. He also authored books like 'The Art of Happy Living' and 'Lifestyle for Total Development'.

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