Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 296-315

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

History of Elements and Welding processes (article paper)

[1]Yassin Mustafa Ahmed, [1]Khairul Salleh Mohamed Sahari, [2]Mahadzir. Ishak, [3]Basim Ali Karim

[1]*Department of Mechanical Engineering, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia.*
[2]*Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia*
[3]*College of Technique Engineering, Sulaimani Polytechnic University, Sulaimani, Kurdistan region, Iraq*

ARTICLE INFO

Article history:
Received 25 June 2014
Received in revised form
8 July 2014
Accepted 25 July 2014
Available online 20 August 2014

Keywords:
Quran; welding processes;
.Element of the Erath

ABSTRACT

Methods adopted for joining metals have been acknowledged for thousands of years, where for most of this period the only form of welding came in the form of forging welding by a blacksmith. The most recent welding evidence can be revisited in the Bronze Age. An early example of welding such as welded gold boxes reported to have been found in the Bronze Age. The Egyptians also studied welding as a form of art. Several iron tools of theirs were made through welding. In the middle Ages, some experts called blacksmiths was made known to the public. In the middle Ages they had welded a lot of iron tools using a method called hammering. The welding methods had kept on being used until the 19th century, as a number of brand-new welding principles began to be introduced. Enough electrical current could then be generated for both resistance welding and arc welding. All fusion-welding methods produce the weld by way of moving a molten pool along the joint. This is completely different in welding processes which have to rely on both pressure and temperature. In friction welding, explosive welding, Brazing and diffusion welding joint the pieces to be welded are based on the impact of heating or pressure or the integration of both. The fusion of the base metal and metal fillers is the cause to the welding process.

To Cite This Article: Yassin Mustafa Ahmed, Khairul Salleh Mohamed Sahari, Mahadzir. Ishak, Basim Ali Karim., History of Elements and Welding processes (article paper). ***Aust. J. Basic & Appl. Sci.,*** *8(13): 296-315, 2014*

List of Abbreviations

AW	Arc Welding
ASME	Mechanical Engineers American Society of
ASTM	Testing Materials American Society for
DW	Diffusion welding
EBC	Electron Beam Cutting
EBW	Electron Beam Welding
EGW	Electro gas Welding
EXW	Explosion Welding
FRW	Friction welding
GMAC	Gas Metal Arc Cutting
GMAW	Gas Metal Arc Welding
GTAC	Gas Tungsten Arc Cutting
GTAW	Gas Tungsten Arc Welding
HPW	Hot Pressure Welding
LBC	Laser Beam Cutting
LBW	Laser Beam Welding
OFC	Oxy Fuel Cutting
OFC-H	Oxy hydrogen Cutting
OFW	Oxy fuel Gas Welding
OHW	Oxy hydrogen Welding
PAC	Plasma Arc Cutting
PAW	Plasma Arc welding
PEW	Percussion Welding
RSEW	Resistance Seam Welding
RSW	Resistance Spot Welding
RW	Resistance welding
SAW	Submerged Arc Welding
SMAC	Shielded Metal Arc Cutting
SMAW	Shielded Metal Arc Welding

Corresponding Author: Yassin Mustafa Ahmed, Department of Mechanical Engineering, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000 Kajang, Selangor , Malaysia.
E-mail: aryazerak@yahoo.com

Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 296-315

SW	Stud Arc Welding
TW	Thermite Welding
USW	Ultrasonic Welding

INTRODUCTION

The fascination of man towards metals from the dawn of mankind is in many forms. From simple items discovered in the fire to advancements in the metal formation that converts the plain metals into trinkets, jewels, to weapons. Welding can be recalled through its historic development that had taken place back in the ancient era. Some of the earliest examples came from the Bronze Age. Small gold circular boxes were produced by pressure welding lap joints together. It is assumed that these boxes were created more than 2000 years ago. Back in the Iron Age, the Egyptians and people in the eastern Mediterranean area had learned how to perform welding on pieces of iron. Many tools had been discovered which were made approximately in 1000 B.C. During the middle Ages, blacksmithing had been in progress and many iron-based items were produced through a welding method of hammering. Before 1434, Quran had mentioned the metals, or specifically copper, silver, gold and iron in Quran verse 23. Also, there is a Surah in the Quran named iron. Furthermore, clear evidence on the use of welding methods for making or building a full construction is stated in the Qur'an in the cave and the story of Dhul-Qarneyn600 years BC, where a dam was constructed by pieces of iron, and the pieces joint together by molten copper (Figure 1). Verses 83-98 of Sura kahf in the Holy Qur'an narrate the story of the commander of Dhul-Qarnayn and Gog and Magog who are [great] corrupters in the land, and dam builders a metals dam by using a pieces of iron and molten copper. As God Almighty says: "Bring me sheets of iron" - until, when he had leveled [them] between the two mountain walls, he said, "Blow [with bellows]," until when he had made it [like] fire, he said, "Bring me that I may pour over it molten copper." (Ayat 96),(Sayyid Quthb, Tafsir Fi Zhilalil Quran, 2003; Muhammed Asad, 1980; Imam Ibn Kathir, 2000).

Fig. 1: Schematic Diagram of Dhul- Qarnayn metal dam

Timeline:

Timeline of significant discoveries, inventions, and events of welding.

The historic development of welding goes back to ancient times. The earliest examples can be noted coming from the Bronze Age. It was discovered then, that two metals mixed, which is also termed as alloys, were stronger together than any of the metals taken individually. This was perhaps discovered at about the same time when the extractive metallurgy was discovered. The finding that the addition of tin alloy can solidify copper was the main highlight of the era (Reardon, A.C., 2011). The Sumerians, in 3000 B.C, during the Bronze Age in Ur (Iraq), swords- metal joint was made using the hard soldering technique. Gold was, found in the Queen Puabi tomb, in Mesopotamian plain in Iraq (Figure 2). Also they found a gold bowls with a wire twisted handle that was brazed to the external wall (Adams, L.O., 2003). The Egyptians heated iron ore in a charcoal fire and consequently it was reduced to sponge iron; the particles that had been welded by hammering. This "pressure" welding or alternatively "solid-phase" welding was the first to have been recorded. Cobalt has been used for many centuries approximately 2250 B.C., when Persians made use of cobalt to color glass. Small, circular gold boxes were made by pressuring the welding lap joints. It is hypothesized that these boxes had been around for more than 2000 years ago.

Fig. 2: Bust of Lady Puabi (Adams, L.O., 2003)

At the tomb of Vizier Rekhmire at Thebes in Egyptian, a wall painting portrays a brazing operation. Items made from bronze and iron excavated near the Egyptian pyramids were discovered to be forge- welded. The metalworking technology would seem to have a crucial role, but ample literature segregate the Bronze from the Iron Age, thus neatly steering clear of the transition. The extractive metallurgy of later prehistory is even less popular than that of the Bronze Age and there has been a concentration on Iron Age iron production with particular attention directed at the non-ferrous metals (D.C. and M.P. Justine Bayley, 2008). In the Iron Age, the Egyptians and eastern Mediterranean peoples had been taught to perform iron welding. Many tools made approximately in 1000 B.C were found. At County Roscommon in Ireland many metal boxes had been found. They were made from a gold sheet and assembled by pressuring welding (hammering) lapped joints. Bronze was remarkably stronger than pure copper and was effective as a tool and as a weapon. A photograph of an ancient bronze casting is exhibited in (Figure 3), and this casting is an example of a masterpiece achieved through the Chinese foundry "technology" in the 7th century B.C. The bronze in this casting has less tin than the typical bronze weapons from the same era (Reardon, A.C., 2011). In the middle Ages, the art of blacksmithing was developed and many items made from iron were produced using the welding method of hammering (Figure 4) (Reardon, A.C., 2011; Adams, L.O., 2003; D.C. and M.P. Justine Bayley, 2008; Roberts, J.M., 1993; Laurie Rozakis, P.D., 2001; Krebs, R.E., 2006).

Fig. 3: A bronze Kuei handled vessel, cast in China in the 7th century B.C. (Reardon, A.C., 2011)

Fig. 4: Iron Age sword with brass appliqués (D.C. and M.P. Justine Bayley, 2008)

Gaius Plinius Caecilius Secundus, (61-113 A.D.) better known as Pliny the Younger, concentrates on Gold Brazing and the salts used for the flux. Descriptions on the color (oxides) of the metal and an investigation to see if it would braze with ease or with difficulty, are provided. 300-400A.D. Iron Pillar of Delhi, India (Figure 5, 6) was made of iron billets forge-welded by blacksmiths. The pillar was measured at 23-25 feet high, 12 inches at the top and 16 inches at the base and weighed 6 tons. Similar items were found in countries like Rome, Scandinavia and England (Roberts, J.M., 1993; Co., M.E.M., 2006; AWS). Iron was only available in little amount from the meteors [4]. Native iron is different from meteor iron where it carries 6-8 percent nickel in its composition. Iron is not always in its original state, and in many world regions many antiquities discovered were made of iron (Figure 4),(Reardon, A.C., 2011; D.C. and M.P. Justine Bayley, 2008; Roberts, J.M., 1993; Krebs, R.E., 2006; D.M.S. and F. Neumann, 2002). Natural gas was obtained from springs and channeled right into the sea using bamboo poles to evaporate sea water in China (Kuhn, O.,).

Fig. 5: Iron Pillar of Delhi, India (Balasubramaniam, P.R., 2009)

Fig. 6: Iron Pillar of Delhi, India (Balasubramaniam, P.R., 2009)

By 1374 the Hindus had identified zinc as a new metal, the eighth metal, as known back then, and zinc production and trading was already slowly being used although with limitations (D.M.S. and F. Neumann, 2002). In 1735, Platinum was introduced by the pre-Columbian Indians of Ecuador, who made things both from pure metal and crude platinum-gold alloy. From a full list of chemical elements, platinum has fascinated more distinguished scientists than any others since its first introduction in 1750. Its high melting point coupled with the great difficulties faced in rendering its invaluable properties available for practical use frustrated many skillful men over a long period of years and the story of their struggles serves to be one of perseverance and ingenuity (Mauskopf, S.H., et al., 1984). In 1751, the first relatively pure sample of nickel was produced by a Swedish chemist Baron Axel F. Cronstedt, who obtained it from German ore miners (Sparrow, G., 2005). The name ‘nickel’ is derived from the name of the mine, named Kupfernickel. Oxygen was discovered in 1774 by Joseph Priestley in England and two years earlier, by Carl W. Scheele in Sweden (Thomas, M., 2005), although the latter has never been published. Molybdenum was found in 1781 and was primarily used as an addition to steels (Reardon, A.C., 2011). Tungsten, which original name was wolframium, was first refined from an ore in 1783. The word tungsten takes after a Norse word "thungr-steinn," or in English heavy stone (Reardon, A.C., 2011). Zirconium was found in 1789 (Krebs, R.E., 2006). Titanium was found in 1790, but because of the fact that it was hard to release titanium from oxygen and nitrogen, it was not readily available as a structural material until the 1940s. Titanium is not easy to process and to mould, but it boasts off high strength and low density. This makes titanium a desirable property with a high strength-to-weight ratio that makes titanium alloys very appropriate for aircraft and spacecraft applications. Owing to its natural resistance to corrosion, titanium is adopted in the chemical industry and for orthopedic implants (Reardon, A.C., 2011). Chromium was found in 1798 and is used mainly as an addition in steel production. Chromium enhances steel resistance to oxidation and

Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 296-315

corrosion and is an essential metal in stainless steels (Reardon, A.C., 2011).

The arc production between two carbon electrodes using a battery was introduced by Sir Humphrey Davy (1778-1829) of London England in 1801, a scholar who had experimented and shown the function of the arc between two carbon electrodes that use a battery. This was the predecessor of electric-arc lighting (Weman, K., 2004; Cary, H.B., 1998). Before the end of the 19th century the electric welding was not using because may factors one of the factors for the fact that the lack of appropriate power sources. At the end of the 18th century, the Italians, named Volta and Galvani, had come to introduce electric current with galvanic elements. A crucial development was translated into Michael Faraday's basic principles for the transformer and generator in 1831, (Weman, K., 2004). In 1836, an English chemist named Edmund Davy (1785-1857), had provided description of the properties of acetylene, but he failed to give the correct formula (Weman, K., 2004; Cary, H.B., 1998). Years between 1808 -1812, an Englishman, Sir Humphrey Davy, was the first to concentrate on what he suspected to be a new metal that merged with iron from its naturally-occurring ores. Davy named the new element "aluminum," stemming from alum, its bisulfate salt, which was already acknowledged among the ancient Egyptians for its dyeing purposes. Hans Christian Oersted first celebrated his success in making aluminum on a laboratory scale in Denmark in 1825, and Friedrich Wohler had followed suit in Germany not long after. Finally, in 1854, a Frenchman, Henri-Etienne Sainte Clair Deville (who named the ore "bauxite"), had discovered a chemical process in which aluminum (Weman, K., 2004). In 1856, James Joule, an Englishman, had experimented with a bundle of wires in charcoal and welded the wires by heating them with an electric current. This was the first example of heating through internal resistance for weld production. Years later, Elihu Thomson had improved the process of what would later be known as a resistance welding (Weman, K., 2004). In the mid-nineteenth century, the electric generator was invented and the arc lighting was made commercialized. The late 1800s saw the development of gas welding and cutting. Arc welding, with the carbon arc and metal arc was developed, and resistance welding became a practical process (Weman, K., 2004; Cary, H.B., 1998). Sir Henry Bessemer was born in the village of Charlton, near Hitchin in Hertfordshire, UK in 1813 and he was best known as the inventor of the Bessemer Converter, which was arguably the first pneumatic bulk steelmaking process. Bessemer had published his invention in 1856 and the first commercial application was noted in 1858. The process was still operating worldwide well into the 1950s (Martinón-torres, M. and T. Young, 2012). The higher demand for steel in the 19th century and the restrictions of the existing steel production had given an impetus for further advances in technology, and the increased production capacity that followed had led to new applications for steel; exemplified by the casting of large steel artifacts by Vickers Company and Sons from the 1850s. The first large castings produced by Vickers were steel church bells, and these quickly became a crucial part of Vickers' business (Figure 7) (D.C. and M.P. Justine Bayley, 2008).

Figure 7: A

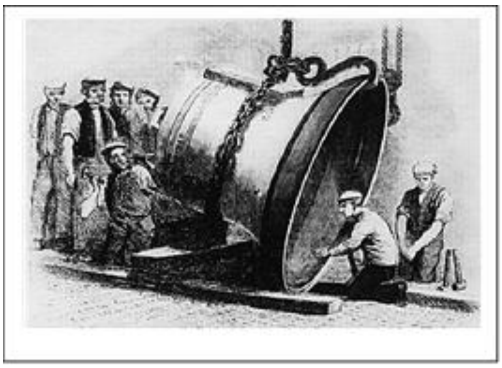


Figure 7: B

Fig. 7: Casting a bell weighing about 5 tons for the San Francisco fire station in 1860 (D.C. and M.P. Justine Bayley, 2008)

In 1860s, an Englishman named Henry Wilde (1833 –1919) had employed the theories of Volta and Davy and the primitive electric sources of the time, to make "Joins". He had received a patent for the earliest form of welding currently acknowledged as "Electric Welding". He melted together small pieces of iron, and, in 1865, he was granted a patent for welding - the first patent related to Electric welding [20]. The electric arc, however, fascinated the scientific scholars only until 1881, when the carbon-arc street lamp was introduced. Shortly thereafter, the electric furnace had been introduced in England. One of the earliest was installed in 1886 for the production of aluminum alloys. This particular application of the electric arc marked the early development of the aluminum industry (Eltxtric, T.L. and T.L. Electric, 1973). In 1885 N. N. Benardos obtained a Russian Patent "Electric Arc Welding" with carbon electrode called "Elecktrogefest" or "Electrohephaestus" (Figure 8). The method of cutting and welding metals by the arc was termed "Electrohefest" in memory of Hephaestus, the ancient Greek god of Fire and also accounting for Blacksmith work. (The Romans had changed the name from Hephaestus to Vulcan) (Weman, K., 2004; Cary, H.B., 1998). In 1890, C.L. Coffin in Detroit Michigan was given the first U.S. Patent for metal electrodes. This was the first record of the electrode-melting metal based on the arc to deposit filler metal in joint to perform welding. One electrode was carbon; the other electrode was filler material (Co., M.E.M., 2006; Kuhn, O.,; Cary, H.B., 1998). Sir William Ramsay and Lord Rayleigh were the first to tell the world about the discovery of argon as a chemical element in 1895, the name being is derived from the ancient Greek a´rgo´n, Argos, which means 'lazy' (Coburn, M., et al., 2012). Acetylene gas had been discovered much earlier when Edmund Davy, in England, summed up that a flammable gas was released when carbide was decomposed in water. The gas, upon burning, had proven to be superb for illumination, and this soon became acetylene's primary use. However, massive explosions had taken place when the gas was transported. It was discovered that acetone could dissolve acetylene in great amount, especially when the pressure had escalated. In 1896, Le Chatelier had devised a secure method of storing acetylene using acetone and a porous stone inside the cylinders, something that had inspired many other countries (Weman, K., 2004; Cary, H.B., 1998).

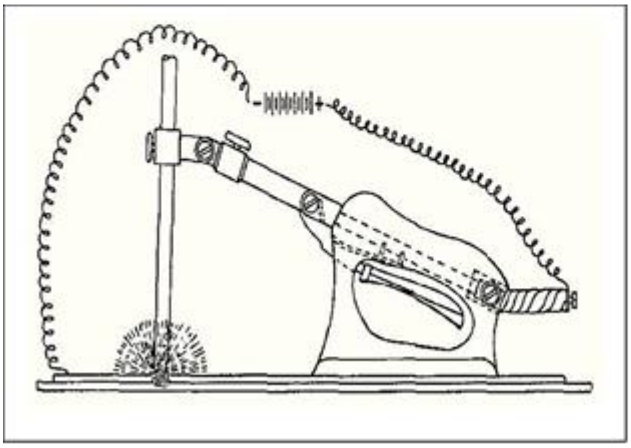


Fig. 8: Benardos' method for welding with a carbon electrode (Eltxtric, T.L. and T.L. Electric, 1973)

In 1900, Strohmenger had come up with a coated metal electrode in Great Britain. A thin coating of clay or lime, had somehow provided a stronger arc (Cary, H.B., 1998).

OFC and OFW involve processes that employ fuel gases and oxygen to weld and cut metals, respectively. French engineers named Edmond Fouché and Charles Picard became the first to introduce oxygen-acetylene welding in 1903 (Technologies, N. and F.A. Ardelean,). In 1903, Hans Goldschmidt of Essen, Germany invented Thermite Welding (TW) (Cary, H.B., 1998). In Germany, a welding generator was produced in 1905. It was driven by a three phase asynchronous motor and it had some fitting characteristics for welding. It weighed 1000 kg and developed 250 A, (Weman, K., 2004). In 1907, Two German welders arrived in the U.S., and formed Siemund-Wienzell Electric Welding Company. They patented a metal arc welding method. Lincoln Electric Company of Cleveland Ohio began by manufacturing electric motors in 1895. By 1907, Lincoln Electric was at the stage of manufacturing the first variable voltage DC welding machine (Eltxtric, T.L. and T.L. Electric, 1973). Approximately, between 1907-1914 Oscar Kjellberg (Figure 9) of Sweden and the ESAB (Elektriska Svetsnings- AtkieBolaget) Company introduced the covered or coated electrode by dipping bare iron wire in thick carbonates and silicates mixtures. The aim of the coating was to shield the molten metal from oxygen and nitrogen. His pioneering work of covered electrode development paved the road during the following two decades in researches related to dependable flux coated electrodes (Figure 10), (Weman, K., 2004; Cary, H.B., 1998).

Fig. 9: Oscar Kjellberg's (Weman, K., 2004)

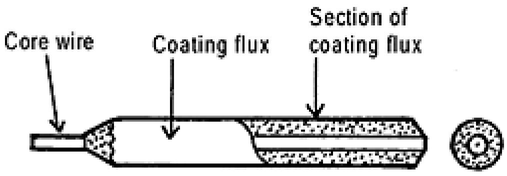


Fig. 10: Structure of covered electrode (Edition, F., 2011)

Fig. 11: AWS (AWS, 2012)

In 1908, Oscar Kjellberg received the Patent for the coated welding electrode (Weman, K., 2004). Stainless steel was discovered independently by British and German researchers in 1913. In August 1913, in Sheffield in UK, and for the first time stainless steel was melted, initiated by Harry Brearley (Weman, K., 2004). From 1910 to 1920, dipped electrodes had been used in Europe under the licensing agreements with ESAB. Despite being regarded as "thick-coated", they had rather porous coating and produced little slag. The welding technique using these electrodes necessitates ambidextrous handling: the left hand controls the electrode; and the right hand uses a hammer to fake porosity from the weld. Oscar Kjellberg mentioned in his writing that a sound weld is characterized by its regular fish-scale pattern, resulting from the hammering (Weman, K., 2004). In 1912, Lincoln Electric Company introduced the first welding machines after it started an experiment in 1907 (Eltxtric, T.L. and T.L. Electric, 1973). In 1917, due to the gas shortage taking place in England, the use of electric arc welding to manufacture bombs, mines, and torpedoes had served as the main fabrication method (Eltxtric, T.L. and T.L. Electric, 1973). In the years between 1917 -1920 welding uses were widespread with regards to the production of aircraft, ships and related repairs in both Germany and Britain. Alternating Current (AC) was invented in 1919 by C. J. Holslag for welding, but it was not well-established until 1930s, when the heavy-coated electrode was used widely (Cary, H.B., 1998; Eltxtric, T.L. and T.L. Electric, 1973) World War I brought a soaring demand for armament production, and consequently welding had been brought into practice. Many companies had started operating in America and in Europe to manufacture welding machines and electrodes to cater for this demand. The American Welding Society (AWS) was founded in 1919 under the leadership of Avery Adams and twenty members of the wartime welding committee of the emergency fleet corporation had been well-remembered for their work in welding and allied process advancement (Figure 11) (Cary, H.B., 1998; AWS, 2012).

The first fully-welded ship in the UK, the " Fullager", carved its name in history in 1920 as it was completed and sailed for seventeen years, before it finally sunk in 1937, (Weman, K., 2004). The first formal classification rules were established in 1920 when Lloyds Register issued a set of rules laid out tentatively for welding. Ships built under these rules had an addition to the class-notation; "Experimental". In 1932, revised rules had included the criteria for strength tests and these had become the foundation for rules adopted today (Weman, K., 2004). In 1920, automatic welding was established as the brainchild of P.O. Nobel of the General Electric Company. It was used to construct worn-out motor shafts and crane wheels. The automobile industry had also used it to create. In 1920, automatic welding was invented by the P. O. Nobel of the General Electric Company, in the 1920s multiple welding electrodes were developed, some of which include the Mild steels electrodes for welding steels of less than 0.20% carbon, higher carbon and alloy electrodes, and Copper alloy rods. By 1930, covered electrodes were used extensively. Welding codes were then introduced, where they necessitated higher-quality weld metal, which altogether enhanced the applicability of covered electrodes. Back in the 1920s there was many research in shielding the arc and weld area by gases which were applied externally. Atomic hydrogen was used from the 1930s to 1940s for exclusive welding applications. In 1926 a chemist Irving Langmuir, who served for General Electric Company had developed the Atomic Hydrogen Welding (AHW) Process. H.M. Hobart and P.K. Devers were doing work that was consistent with one another, but they had used atmospheres of argon and helium. In their patents applied in 1926, the arc welding utilizing gas supplied around the arc had become the prototype for the gas tungsten arc welding process. They also demonstrated the welding with a concentric nozzle and with tungsten electrode being supplied as a wire through the nozzle. These processes were executed and improved much later. In 1927, the Soviet Union(CCCP) had produced butt welding Resistance Welding machines (Cary, H.B., 1998; Eltxtric, T.L. and T.L. Electric, 1973).

The 1930 saw the inception of invention (GMAW). H. M. Hobart and P. K. Devers had obtained a Patent for "Arc Welding" for using a concentric nozzle with a wire feed metals. This was later established as Gas Metal Arc Welding (GMAW) (Figure 12) (Cary, H.B., 1998; Jeffus, L., 2000; Praxair, 1998). In the same year the "New York Navy Yard to bind wood to steel", was developed stud welding (SW) (Cary, H.B., 1998). The Submerged Arc Welding (SAW) process was invented in 1935 (Figure 13) (Edition, F., 2011). In 1939 Aluminum Spot Welding had been applied in the Aviation Industry. Also, the stud Welding as introduced by the "Nelson Stud Welding Company" was used by the US Navy to mitigate the time installing studs during the fabrication of ships and aircraft carriers. In the period of 1930-1940 the Atomic hydrogen arc welding process was developed (Cary, H.B., 1998). A 1939 American Society for Testing and Materials (ASTM) standard, the Classification of Copper-Base Alloys, codified 23 distinct alloy families leaning on general compositional limits. Some popular designations such as "Leaded Brass," "Tin Bronze" and "Aluminum Bronze" were linked for the first time with certain composition ranges (Society, N.-F.F., 1994).

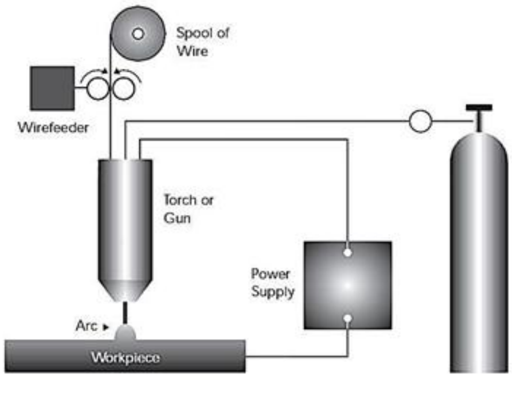
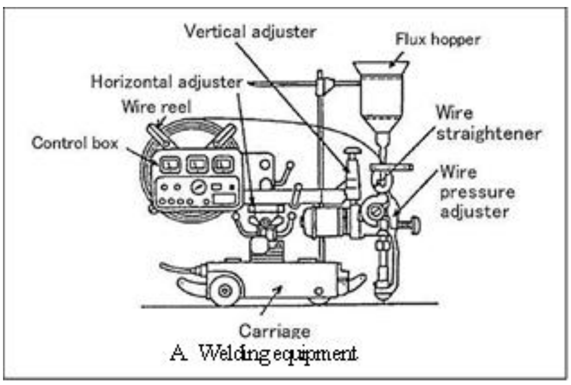


Fig. 12: Basic GMAW system (Edition, F., 2011)



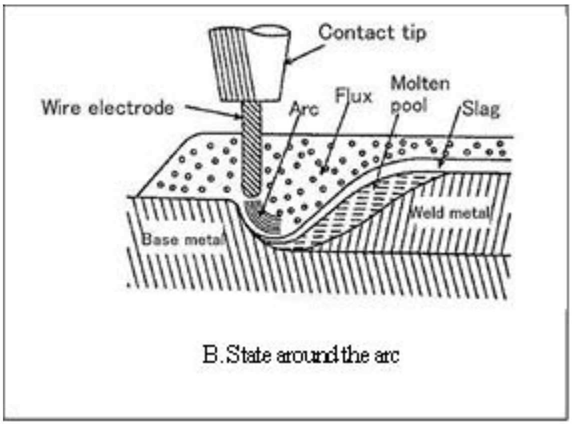


Fig. 13: Submerged Arc Welding Process (Edition, F., 2011)

The use of a granular flux with a continuously fed bare steel electrode had brought about the development of the submerged-arc process taking place in 1935, which first major use was evident in pipe fabrication and shipbuilding. A 521-ft tanker was fabricated by this process a year later. By 1940, the submerged-arc process had been well-received, as it was proven to be practical largely on steel plates over l/4 inches thick. In 1942, the process was improved to contain stock down to 3/32 inch thick, and, thus, it became a process feasible for automotive use other than for general metal fabrication (Eltxtric, T.L. and T.L. Electric, 1973). In 1942 the welding processes of non-ferrous metal took a great turn when the Gas Tungsten Arc Welding (GTAW) is created (Figure 14), V. H. Pavlecka, and Russ Meredith of Northrup Aircraft Inc. created the (GTAW) process to weld magnesium and stainless steel. Other names for TIG (tungsten inert gas) and Argon arc and Helium arc are the terms first applied to the GTAW process (Co., M.E.M., 2006; Cary, H.B., 1998; Praxair, 1998).

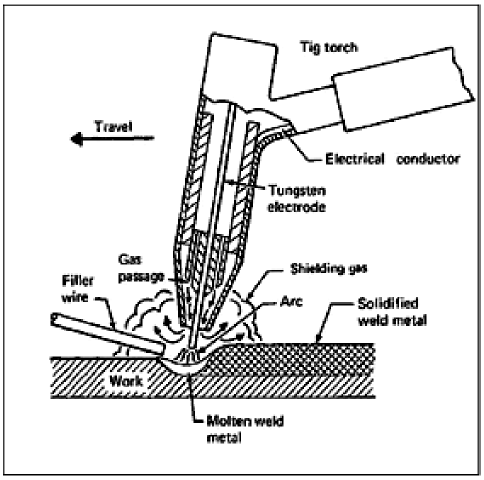


Fig. 14: Principle of Gas Tungsten Arc Welding Process (Eltxtric, T.L. and T.L. Electric, 1973)

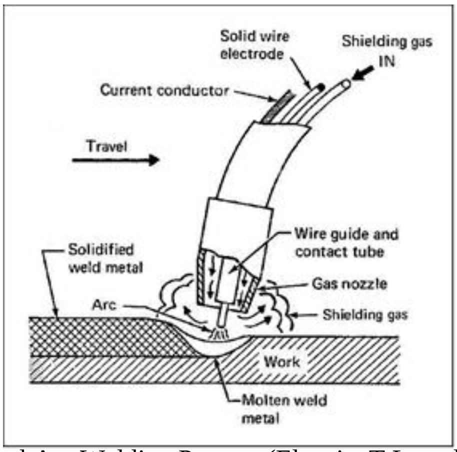


Fig. 15: Principle of the Gas Metal Arc Welding Process (Eltxtric, T.L. and T.L. Electric, 1973)

In 1943 Union-Melt is currently typically referred to as Submerged Arc Welding (SAW). The General Electric Company Ltd (UK) created the Cold Pressure Welding Process in 1948 (Fortune, 1950). Hand-held, semi-automatic guns were developed for the submerged-arc process in two years earlier. Voltage and current were automatically controlled, so that the weld quality became similar to one another and results did not differ much from the skill of the operator (Eltxtric, T.L. and T.L. Electric, 1973). In 1948, Air Reduction Company had worked on the Inert-Gas Metal Arc (MIG) process (Figure 15) (Co., M.E.M., 2006; Cary, H.B., 1998).

The Electroslag Welding process (ESW) (Figure 16) was actively used in the CCCP Union since 1951 but it was based on the work carried out in the United States by R.K. Hopkins who was granted patents 11 years earlier in 1940. It had been mentioned in an announcement by the Soviets at the Brussel World's Fair in Belgium in 1958, (Cary, H.B., 1998). As well as in 1950s the (EBW) process was developed in France by J. A. Stohr of the French Atomic Energy Commission but the first Public disclosure took place in 1957 (Figure 17) (Cary, H.B., 1998). In 1957, James Byron at all, was granted the first US patent for metal ultrasonic welding (Jones, J.B.,).

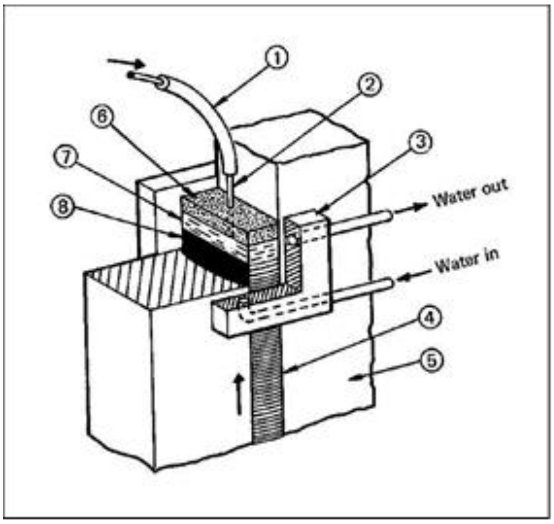


Fig. 16: Schematic sketch of Electroslag Welding Process. (1) Electrode guide tube, (2) electrode, (3) water-cooled copper shoes, (4) finished weld, (5) base metal, (6) molten slag, (7) molten weld metal, (8) solidified weld metal. (Eltxtric, T.L. and T.L. Electric, 1973; Edition, F., 2011)

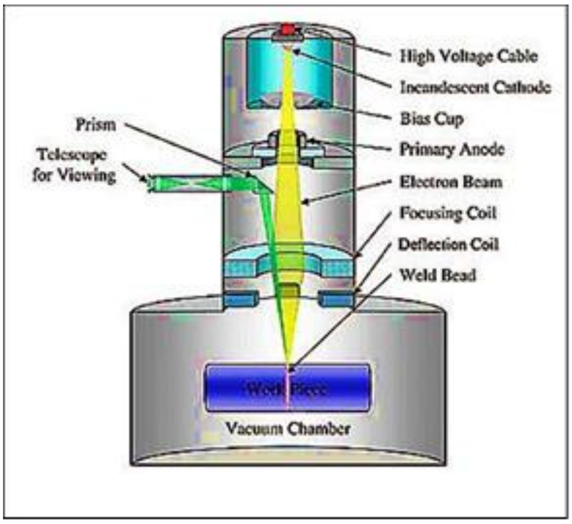


Fig. 17: Principle Electron Beam Welding Process

In 1953, Lyubavskii and Novoshilov announced the use of welding with consumable electrodes (GMAW) process in an atmosphere filled with CO2 gas (Figure15). The CO2 welding process is immediately preferred almost instantly since it utilized equipment developed for GMAW process, but which would currently work for economical welding steels (Cary, H.B., 1998). The Friction welding process (FW) during the Second World War was exploited for plastics welding (Figure 18). However, credits for developing friction welding into a commercially feasible process, in particular the welding of metallic materials, must be reserved for Chudikov who was granted a Russian patent in 1956. The Friction welding process had earned great reputation since its commercial application in 1956. Several industries globally are using this process for some proven benefits as many industrial applications are conceived every year (D.V.P.R. and M.D.S. Dr. K. Narasimha Murthy, 2011). Plasma Arc Welding (PAW) employs a constricted arc or an arc through an orifice, and in effect, it creates an arc plasma with higher temperature than the tungsten arc. PAW was invented by Gage in 1957 (Figure 19) (Cary, H.B., 1998).

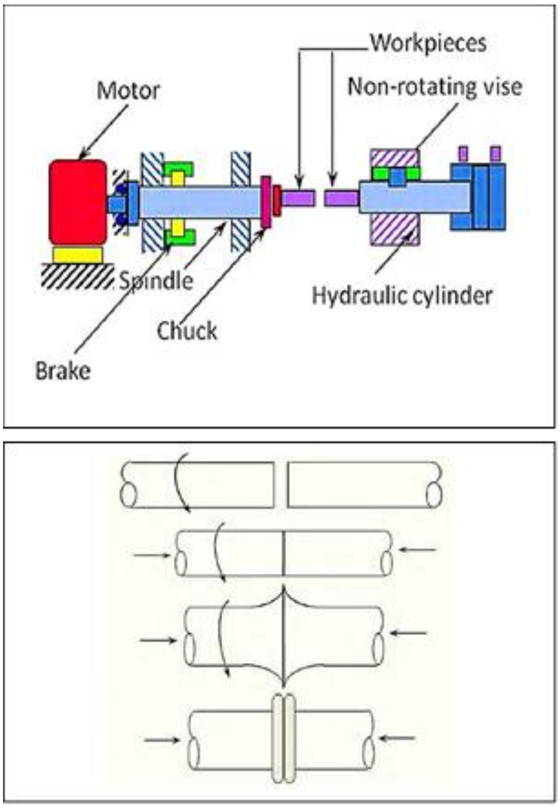


Fig. 18: Schematic of Friction welding (D.V.P.R. and M.D.S. Dr. K. Narasimha Murthy, 2011)

In the sixties, of the last century several innovations had been observed to use new welding methods. As aptly named, the Light Amplification by Stimulated Emission of Radiation “Laser” is a process that converts light radiation into heat. In 1917, studies conducted by Albert Einstein had fuelled the initiative to construct the first laser beam. The first laser was only built in 1960, and its inventor was Theodore Maimann, who created it in the Hughes research laboratories in California. The first laser was a solid ruby laser which used a mercury vapors fluorescent lamp (J.M.M. Silva, 2011). In the USA the first patent in Explosive Welding (EXW) was developed by DuPont in 1960 (Figure 21), (Cutter, D.,). The first robots which facilitated the resistance spot welding were sent by Unimation to General Motors in 1964 (Weman, K., 2004). In England the Laser Cutting was improved for cutting by Peter Houldcroft in 1966 (Weman, K., 2004). In 1967, an all-position electrode was introduced and this had considerably broadened the application of the process (Eltxtric, T.L. and T.L. Electric, 1973).

In 1970, the British Welding Institute (Martin Adams) developed laser beam welding (LBW) (Figure 20) (Weman, K., 2004). The modern optimization methods sometimes referred to as the non-traditional optimization methods, have surfaced as powerful and popular methods used to fathom complex engineering optimization problems in recent years. The genetic algorithms were first introduced in 1975 by John Holland. The simulated annealing method leans on the mechanics of the cooling process of molten metals through annealing. The method was first developed by Kirkpatrick, Gelatt, and Vecchi (Rao, S.S., 2009).

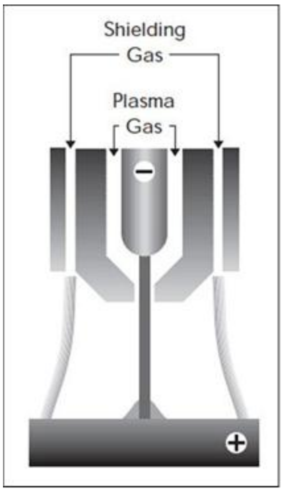


Fig. 19: Principle Plasma Arc Welding Process (Praxair, 1998)

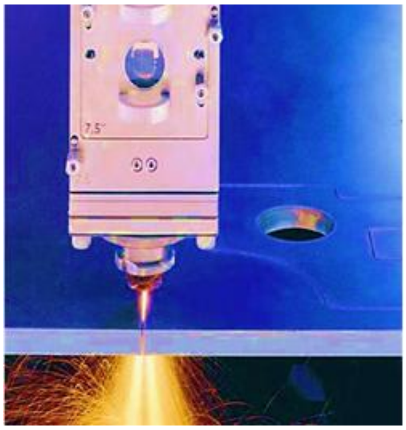


Fig. 20: Laser-beam machining use to cutting sheet metal (Technologies, N. and F.A. Ardelean,)

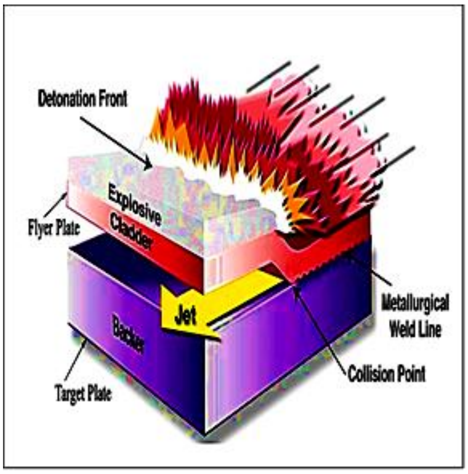


Fig. 21: Schematic Diagram of Explosive Welding Process (Zhang, Y., 2010)

In 1983 Homopolar pulse welding variation of the upset welding process research was pioneered at the University of Texas at Austen at the Center for Electro mechanics. The neural network methods lean on the massive computational power of the nervous system to solve a plenitude of perceptional problems in the presence of a lot of sensory data through its parallel processing capability. Early on, the method was used for optimization by Hopfield and Tank in 1985 (Rao, S.S., 2009). The fuzzy optimization methods were developed in order to solve optimization problems involving both vague and linguistic descriptions. The fuzzy approaches for the single and multi-objective optimizations in engineering design were first introduced by Rao in 1986

(Rao, S.S., 2009). In 1991, the TWI of Cambridge England develops the Friction Stir Weld (FSW) process in its laboratory. Unlike the conventional rotary technology this process entails a hard, non-consumable, cylindrical tool causing friction, plasticizing two metals into a Solid-State Bond (Figure 22) (2012; Ranjan Sahoo and Pinaki Samantaray, 2007). In February 1999, National Aeronautics and Space Administration (NASA) had published a "General Fusion Welding Requirements for Aerospace Materials used in Flight Hardware", according to NASA Technical Standard -STD-5006 (Aeronautics, N., 1999).

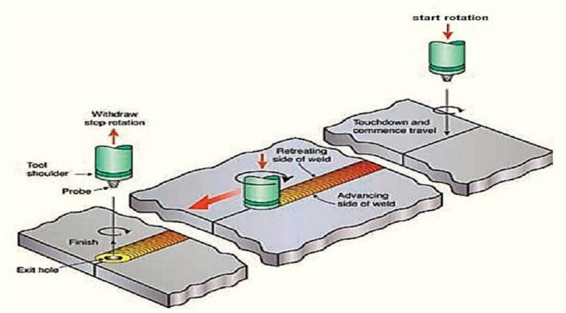


Fig. 22: Principles for friction stir welding Process. The rotating non-consumable pin-shaped tool penetrates the material and generates frictional heat, softening the material and enabling the weld. (2012)

Since 1969, Magnetic Pulse Welding "MPW" has been used for tube to tube impulse welding but it needs fairly high electrical energies (Zhang, Y., S. Babu and G.S. Daehn, 2010). "MPW" has been used on both similar and dissimilar metals. For example in years 1988 and 2002, two groups of researchers had worked together in welding aluminum tubes by "MPW" , the first group Tamaki and Kojima, and the second group Shribman et al. (Figure 23) (Zhang, Y., 2010). Other group used MPW to weld dissimilar metals, Hokari et al. in 1998 welded aluminum tube to copper tube, in 2007 Aizawa et al., welded aluminum alloys to carbon steel sheet, and in 2008 Ben-Artzy et al. welded aluminum to magnesium. Additionally, in 2009 Hutchinson et al. welded copper plate to zirconium-based bulk metallic glass plate (Zhang, Y., 2010). MPW has seen rather scarce, but rapidly growing, industrial applications. In 2001, AWS published a "Specification for Fusion Welding for Aerospace Applications", and the first commercial aviation welding specification was published in November 2010, (AWS; AWS, 2012).

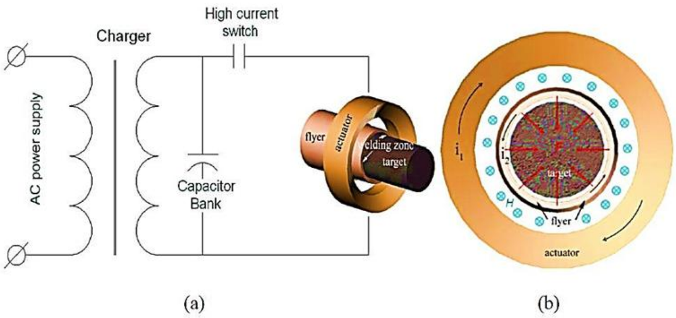


Fig. 23: Schematic of MPW system for tubular welding. (a) Electric circuit for welding system, (b) Induced electromagnetic field and repulsive force acting on the flyer tube. i1 is primary current in actuator and i2 is induced current in flyer. (Zhang, Y., 2010)

The purposes of some general trends in welding are obvious, where it seeks to increase productivity, improve the mechanization, and promote continuous researches for more successful welding processes. Constructions with reduction of weights achieved as new designs and the increased use of high strength steel and aluminum alloys had been obtained. A visit to a welding exhibition provides a good illustration that the development of electronic components, computer technology and digital communication can decide on the fate of development of the welding equipment. New processes have further been put forth. For example, by mix laser MIG and FSW, and so on. The researches and manufacturing processes intend to use welding processes to merge the non-ferrous materials, non-ferrous alloys, and polymers.

Master Chart Of Welding Prosesses:

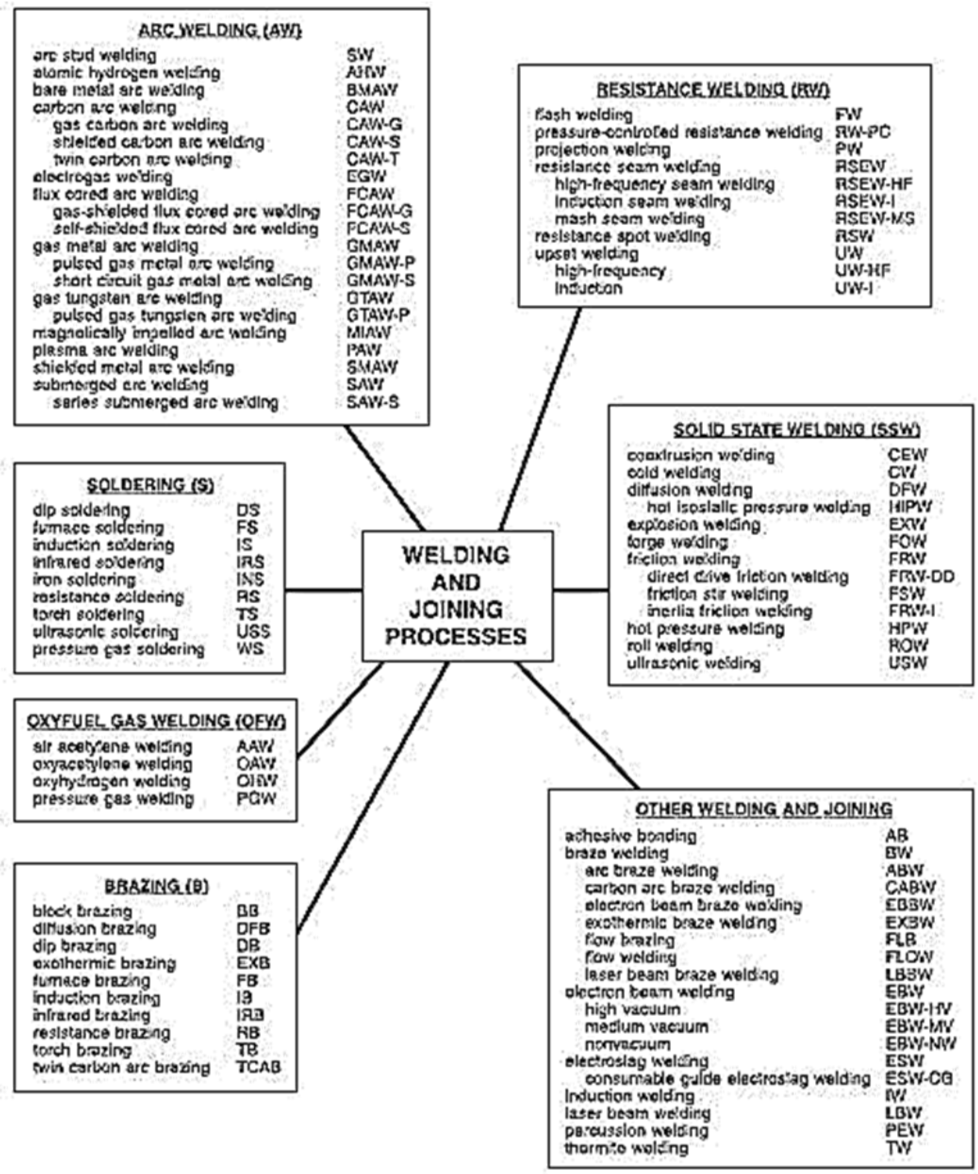


Fig. 24: Welding processes (AWS, 2005)

Welding Processes:

We have been presented with a brief review of the early discovery of some of the most important elements and minerals and most important types of welding operations. Welding processes have prospered and developed during the past 10 decades. Now there are more than 300 welding methods (Figure 24, 25) known to man, and below is some of the methods:

Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 296-315

Master Chart Of Allied Processes:

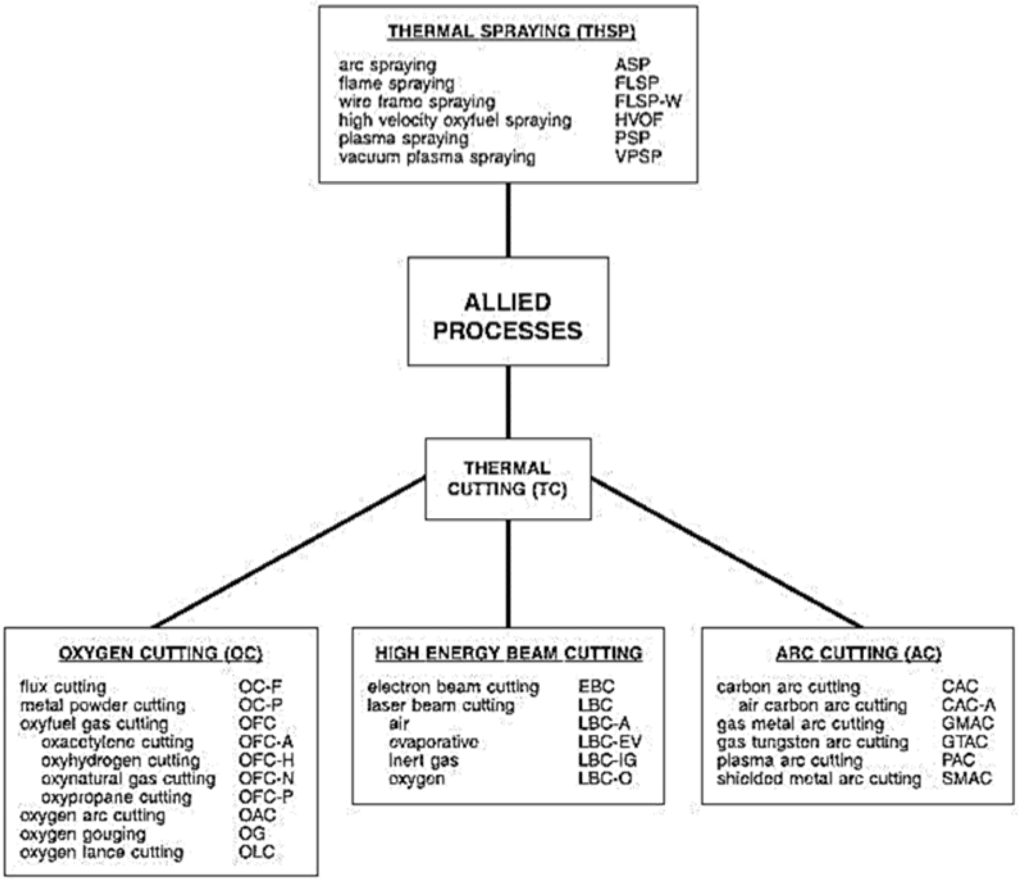


Fig. 25: Allied processes (AWS, 2005)

Discussion:

Welding processes are substantial in the industries. Most welding methods can be imposed on joint metal and non-ferrous and its alloys. The selection of the best method to weld any materials is determined by the purpose carried by the product. The summary of the discovery years of some metals and welding methods is as shown in (Table 1 and Table2):-

Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 296-315

Table 1: Elements discovered table

Name of Element	Chemical Symbol	Natural State	Inventor	Year of Discovered
Carbon	C	Solid	Carbon was known in prehistoric times in the form of charcoal and later as peat and coal deposits	
Copper	Cu	Solid	A few copper beads were found in Iraqi and Egyptian tombs	9000 BCE
Lead	Pb	Solid	Egyptian tombs and the ancient Romans	5000 BCE
Gold	Au	Solid	Iraqi and Egyptian tombs	4000 To 2000 BCE
Silver	Ag	Solid	Silver jewelry was found in Egyptian tombs	4000 BCE
Tin	Sn	Solid	written records of the Mediterranean region	3500 BCE
Antimony	Sb	Solid	Egyptian women used it as an eyeliner for both themselves and their children	3000 To 2000 BCE
Iron	Fe	Solid	Archeological artifacts made from smelted iron	3000 To 1000 BCE
Mercury	Hg	Liquid	The Chinese used mercury	2000 BCE
Arsenic	As	Solid	German alchemist Albertus Magnus	1250
Zinc	Zn	Solid	Johann Rudolf Glauber	1659
Bismuth	Bi	Solid	Johann Rudolf Glauber	1659
Phosphorus	P	Solid	Hennig Brand	1669
Niobium	Nb	Solid	first governor of Connecticut ,John Winthrop the Younger	1734
Platinum	Pt	Solid	Antonio de Ulloa and Charles Wood	1735
Cobalt	Co	Solid	Georg Brandt	1739
Nickel	Ni	Solid	Baron Axel Fredrick Cronstedt	1751
Nitrogen	N	Gas	Daniel Rutherford	1772
*Barium(oxide)	Ba	Solid	Carl Wilhelm Scheele	1774
Manganese	Mn	Solid	Johan Gottlieb Gahn and Carl Wilhelm Scheele	1774
Oxygen	O	Gas	Joseph Priestley	1774
Sulfur	S	Solid	Antoine Lavoisier	1777
Molybdenum	Mo	Solid	Peter Jacob Hjelm and Carl Wilhelm Scheele	1781
Tellurium	Te	Solid	Franz-Joseph Müller von Reichenstein	1782
Hydrogen	H	Gas	Antoine Lavoisier	1783
Tungsten	W	Solid	Don Fausto de Elhuyar and his brother Don Juan Jose de Elhuyar	1783
Yttrium	Y	Solid	Johan Gadolin	1789-1794
Uranium	U	Solid	Martin Heinrich Klaproth	1789
Strontium	Sr	Solid	Dr. Adair Crawford	1790
Titanium	Ti	Solid	Reverend William Gregor	1791
Chromium	Cr	Solid	Louis-Nicolas Vauquelin	1797
Beryllium	Be	Solid	Louis-Nicolas Vauquelin	1798
Tantalum	Ta	Solid	Anders Gustav Ekeberg	1802
Rhodium	Rh	Solid	William Hyde Wollaston	1803
Palladium	Pd	Solid	William Hyde Wollaston	1803
Osmium	Os	Solid	Smithson Tennant	1803
Iridium	Ir	Solid	Smithson Tennant	1803
Cerium	Ce	Solid	Jöns Jacob Berzelius, Wilhelm Hisinger and Martin Klaproth	1803
Sodium	Na	Solid	Sir Humphry Davy	1807
Potassium	K	Solid	Sir Humphry Davy	1807
*Barium	Ba	Solid	Sir Humphry Davy	1808
Magnesium	Mg	Solid	Sir Humphry Davy	1808
Calcium	Ca	Solid	Sir Humphry Davy	1808
Boron	B	Solid	Sir Humphry Davy	1808
Chlorine	Cl	Gas	Sir Humphry Davy	1810
Iodine	I	Solid	Bernard Courtois	1811
Lithium	Li	Solid	Johan August Arfwedson	1817
Cadmium	Cd	Solid	Friedrich Strohmeyer	1817
Selenium	Se	Solid	Jöns Jacob Berzelius and Wilhelm Hisinger	1817
Zirconium	Zr	Solid	Baron Jöns Jacob Berzelius	1824
Silicon	Si	Solid	Baron Jöns Jacob Berzelius	1824
Aluminum	Al	Solid	Hans Christian Oersted	1825
Bromine	Br	Liquid	Carl Jacob Löwig and Antoine Jerome Balard	1825-1826
Thorium	Th	Solid	Baron Jöns Jacob Berzelius	1829
Vanadium	V	Solid	Nils Gabriel Sefstrom	1830
Lanthanum	La	Solid	Carl Gustav Mosander	1839
Terbium	Tb	Solid	Carl Gustav Mosander	1843
Erbium	Er	Solid	Carl Gustaf Mosander	1843
Ruthenium	Ru	Solid	Karl Karlovich Klaus	1844
Cesium	Cs	Solid	Gustav Kirchhoff and Robert Bunsen	1860

Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 296-315

Rubidium	Rb	Solid	Robert Bunsen and Gustav Kirchhoff	1861
Thallium	Tl	Solid	Sir William Crookes	1861
Indium	In	Solid	Ferdinand Reich and Theodor Richter	1863
Gallium	Ga	Solid	Paul-Emile Lecoq de Boisbaudran	1875
Ytterbium	Yb	Solid	Jean Charles Galissard de Marignac	1878
Scandium	Sc	Solid	Lars Fredrik Nilson	1879
Samarium	Sm	Solid	Paul-Emile Lecoq de Boisbaudran	1879
Holmium	Ho	Solid	Per Theodor Cleve	1879
Thulium	Tm	Solid	Per Theodor Cleve	1879
Gadolinium	Gd	Solid	Jean Charles Galissard de Marignac and Paul-Emile Lecoq de Boisbaudran	1880-1886
Praseodymium	Pr	Solid	Carl Auer Baron von Welsbach	1885
Neodymium	Nd	Solid	Carl Auer Baron von Welsbach	1885
Germanium	Ge	Solid	Dmitri Mendeleev and Clemens Alexander Winkler	1886
Fluorine	F	Gas	Ferdinand Frederich Henri Moissan	1886
Dysprosium	Dy	Solid	Paul-Emile Lecoq de Boisbaudran	1886
Argon	Ar	Gas	John William Strutt and Sir William Ramsay	1894
Helium	He	Gas	Sir William Ramsay, Per Theodor Cleve and Nils Abraham Langlet	1895
Radium	Ra	Solid	Marie Sklodowska Curie and her husband, Pierre Curie	1898
Polonium	Po	Solid	Marie Sklodowska Curie and her husband, Pierre Curie	1898
Neon	Ne	Gas	Sir William Ramsay and Morris William Travers	1898
Krypton	Kr	Gas	Sir William Ramsay and Morris William Travers	1898
Xenon	Xe	Gas	Sir William Ramsay and Morris William Travers	1898
Actinium	Ac	Radioactive Solid	Andre-Louis Debierne	1899
Radon	Rn	Gas	Friedrich Ernst Dorn	1900
Europium	Eu	Solid	Eugene-Anatole Demarcay	1901
Lutetium	Lu	Solid	Georges Urbain, Carl Auer von Welsbach and Charles James	1907
Protactinium	Pa	Solid	Otto Hahn, Lise Meitner, Frederick Soddy and John A. Cranston	1918
Hafnium	Hf	Solid	Georg Karl von Hevesy and Dirk Coster	1923
Rhenium	Re	Solid	Walter Noddack and Otto Carl Berg	1925
Technetium	Tc	Solid	Emilio Gino Segre and Carlo Perrier	1937
Francium	Fr	Solid, unstable ,radioactive	Marguerite Catherine Perey	1939
Astatine	At	Solid	Dale Raymond Corson , Kenneth Ross MacKenzie and Emilio Gino Segre	1940
Neptunium	Np	Solid	Edwin Mattison McMillan and Philip Hauge Abelson	1940
Plutonium	Pu	Solid	Dr. Glenn T. Seaborg, Joseph W. Kennedy, and Arthur C. Wahl	1941
Americium	Am	Solid	Dr. Glenn T. Seaborg, Ralph A. James, Leon O. Morgan, and Albert Ghiorso	1944
Curium	Cm	Solid	Dr. Glenn T. Seaborg, Ralph A. James, Leon Morgan, and Albert Ghiorso	1944
Promethium	Pm	Solid	Jacob A. Marinsky, Lawrence E. Glendenin, and Charles D. Coryell	1944-1946
Berkelium	Bk	Solid	Dr. Glenn T. Seaborg, Albert Ghiorso and Stanley G. Thompson	1949-1950
Californium	Cf	Solid	Stanley G. Thompson, Kenneth Street, Jr., Albert Ghiorso, and Dr. Glenn T. Seaborg,	1950
Einsteinium	Es	Solid	Gregory R. Choppin, Stanley G. Thompson, and Albert Ghiorso and Bernard Harvey	1952
Fermium	Fm	Solid	Gregory R. Choppin, Stanley G. Thompson, and Albert Ghiorso and Bernard Harvey	1952
Mendelevium	Md	Solid	Albert Ghiorso, Dr. Glenn T. Seaborg, Stanley G. Thompson, Bernard G. Harvey, and Gregory R. Choppin	1955
Nobelium	No	Solid	Albert Ghiorso, Dr. Glenn T. Seaborg, John Walton, and Torbjorn Sikkeland	1958
Lawrencium	Lr	Solid	Albert Ghiorso, Torbjorn Sikkeland, Almon E. Larsh, and Robert M. Latimer	1961
Dubnium	Db	Solid	Scientists of the Joint Institute of Nuclear Research in Dubna, Russia	1967
Rutherfordium	Rf	Solid	Researchers at the University of California Lawrence Berkeley Laboratory	1969-1973
Seaborgium	Sg	Solid	Researchers at the University of California Lawrence Berkeley Laboratory	1974
Bohrium	Bh	Solid	Peter Armbruster and Gottfried Munzenberg (Nuclear laboratory in Darmstadt, Germany)	1981
Meitnerium	Mt	Solid	Peter Armbruster and Gottfried Munzenberg (Nuclear	1982

			laboratory in Darmstadt, Germany)	
Hassium	Hs	Solid	Peter Armbruster and Gottfried Munzenberg (Nuclear laboratory in Darmstadt, Germany)	1984
Darmstadtium	Ds	Solid	Peter Armbruster and Gottfried Munzenberg (Nuclear laboratory in Darmstadt, Germany)	1994
Röentgenium	Rg	Assumed to be solid metal	Peter Armbruster and Sigurd Hofmann (Nuclear laboratory in Darmstadt, Germany)	1994
Ununbium (112UUB-285) Copernicium	Uub, Cn	Assumed to be liquid metal	International group led by Peter Armbruster (Nuclear laboratory in Darmstadt, Germany)	1996
Ununtrium (113UUT-284)	Uut	Solid	Collaboration between (Nuclear Research Laboratory in Dubna, Russia, and the Lawrence Livermore National Laboratory in California, USA)	2003
Ununquadium (114UUQ) Flerovium	Uuq Fl	Assumed to be solid	Scientists of the Joint Institute of Nuclear Research in Dubna, Russia The name (Flerovium) was adopted by IUPAC on May 30, 2012	1999-2007
Ununpentium (115UUP)	Uup	Assumed to be solid metal	Collaboration between (Nuclear Research Laboratory in Dubna, Russia, and the Lawrence Livermore National Laboratory in California, USA)	2004
Ununhexium (116UUH) Livermorium	Uuh Lv	Presumed to be a colorless gas	The Joint Institute for Nuclear Research in Dubna, Russia, in cooperation with personnel of the Lawrence-Livermore Berkeley Group The name (Livermorium) was adopted by IUPAC on May 31, 2012	2000
Ununseptium (117UUS)	Uus	Expected to be a solid silvery metal	Collaboration between (Nuclear Research Laboratory in Dubna, Russia, and the Oak Ridge National Laboratory in the United States)	2010-2012
Ununoctium (118UUO)	Uuo	Expected to be a gas	Researchers Lawrence Livermore National Laboratory of California, USA Since 2002, only three or possibly four atoms of the isotope 294Uuo have been detected	From 2000 until now

*IUPAC: International Union of Pure and Applied Chemistry.

Table 2: The development of welding

Welding process	Abbreviation	Inventor	Year	Country
Electric welding		Henry Wilde	1865	England
Electric Arc Welding		N. N. Benardos	1885	Russia
Resistance welding	RW, ERW	Elihu Thomson	1886–1900	USA
Oxyacetylene Welding	OAW	Edmond Fouché and Charles Picard	1903	France
Thermit welding	TW	Hans Goldschmidt	1903	Germany
Manual metal arc welding	MMAW, SMAW	Oscar Kjellberg (Elektriska Svetsnings-aktiebolaget (ESAB))	1907	Sweden
Gas tungsten arc welding	TIG, GTAW	H. M. Hobart and P. K. Devers	1930	USA
Stud Welding	SW	New York Navy Yard to fasten wood to steel	1930	USA
Electroslag welding	ESW	R.K. Hopkins	1940	USA
Gas metal arc welding (Inert gas)	MIG, GMIW	Air Reduction Company	1948	USA
Submerged arc welding	SAW	National Tube Company for a new pipe mill at McKeesport, Pennsylvania	1935	USA
Gas metal arc welding, CO2	MAG,GMAW	Lyubavskii and Novoshilov	1953	USSR
Friction welding	FW	Chudikov	1956	USSR
Ultrasonic welding	USW	James Byron at al	1957	USA
Electron Beam welding	EBW	J. A. Stohr of the French Atomic Energy Commission	1957	France
Plasma Arc welding	PAW	Robert Gage	1957	USA
Laser Beam	LB	Theodore Maimann (Hughes research laboratories in California)	1960	USA
Explosive Welding	EXP	DuPont Company	1960	USA
Robots Resistance Spot Welding	RRSW	Unimation Company to General Motors	1964	USA
Laser cutting	LC	Peter Houldcroft	1966	England
Laser Beam Welding	LBW	Martin Adams (British Welding Institute)	1970	England

Friction stir welding	FSW	Wayne Thomas et al (TWI)	1991	England
Magnetic Pulse Welding	MPW	Tamaki and Kojima	1988	Japan

Based on table 1, conclusively the welding processes are growing every year.

Conclusion:

How does the future of welding processes look like? Who can inform us or confirm, exactly how welding will fare in the 21st century answering the questions in separation, we come to agree that the future is bright for welding. It will stay for long, and will continue to be a productive, cost-effective manufacturing approach. To ensure a promising future for welding processes in modern industries, robotic welding should be embraced as an option, because automation is a primary element to the future of manufacturing. The fact that the skilled workforce is running short, is a very striking factor which propels many companies to automate. More welders are retiring annually, leaving manufacturers at constant edge to fill the vacancy. Robotic automation can be a practicable solution to help retain the bright future of manufacturing processes.

REFERENCES

Sayyid Quthb, Tafsir Fi Zhilalil Quran, 2003, p. Jilid 7 pp: 297332.

Muhammed Asad, The Message of the Quran, Translated and Explained. Dar Al-Andalus, 1980, pp: 437-456.

Imam Ibn Kathir, 2000. “Tafsir Al- Quran”, Surat Al- Kahf, Beirut- Lebanon: Dar Al- Kotob Al-Ilmiyah, 3: 73-112.

Reardon, A.C., 2011. Edited by Materials Park , Ohio 44073-0002, Second edi. ASM International book.

Adams, L.O., 2003. “zwoje, ‘www.zwoje-scrolls.comzwoje35text11p.htm’ , Articles and poems in Polish,” published in Zwoje – The Scrolls.

D.C. and M.P. Justine Bayley, 2008. METALS AND METALWORKING A research framework for archaeometallurgy, no. 6. HMS Occasional Publication 6.

Roberts, J.M., 1993. History of the World. UAS: New York Oxford University Press.

Laurie Rozakis, P.D., 2001. The Big Book of Dates. McGraw-Hill Published.

Krebs, R.E., 2006. Our Earth ’ s Chemical Elements : A Reference The History and Use of Our Earth ’ s Chemical Elements, Second Edi. London: Published by GREENWOOD PRESS Westport, Connecticut , London, Printed in the United States of America.

Co., M.E.M., 2006. Welding And The World Of Metals. Miller book.

AWS, Specification for Fusion Welding for Aerospace Applications, Second Edi. American National Standard, AWS D17.1/D17.1M.

D.M.S. and F. Neumann, 2002. History of Zinc, its production and Usage.

Kuhn, O., “Ancient Chinese Drilling , Salt Drilling in Ancient China and other Stories,” no. issue 10: 12-17.

Mauskopf, S.H., D. McDonald and L.B. Hunt, 1984. “A History of Platinum and Its Allied Metals,” Technol. Cult., 25(4): 853.

Sparrow, G., 2005. The Elements Nickel, First Edit. Marshall Cavendish Corporation.

Thomas, M., 2005. Oxygen, First Edit. Published by the Rosen Publishing Group.

Weman, K., 2004. “A History of Welding,” EASB Weld. Cut. J., 59(1): 32-35.

Cary, H.B., 1998. Modern Welding Technology, Fourth Edi. Published by Prentice Hall Inc., Printed in U.S.A,

Martinón-torres, M. and T. Young, 2012. “I nside T he C rucible Editor,” 81.

Eltxtric, T.L. and T.L. Electric, 1973. Historical development of Fusion Joining, Twelfth Ed. Published by The Lincoln Electric Company, Printed in U.S.A, pp: 1.1–1 – 1.1–10.

Coburn, M., R.D. Sanders, D. Ma, M. Fries, S. Rex, G. Magalon and R. Rossaint, 2012. “Argon: the ‘lazy’ noble gas with organoprotective properties.,” Eur. J. Anaesthesiol., 29(12): 549-51.

Technologies, N. and F.A. Ardelean, “STUDY REGARDING MODERN CUTTING TECHNOLOGIES,” 1: 11-16.

AWS, 2012. “American Welding Society website,” American Welding Society , 8669 Doral Boulevard, Suite 130 ,Doral, Florida 33166, [Online]. Available: www.was.org.

Jeffus, L., Gas Tungsten Arc Welding, The Essential Welder, 2000. Fourth Edi. Published by Thomson Learning, Printed in U.S.A.

Praxair, Shielding Gases Selection Manual, 1998. Trademarks of Praxair Technology, Inc. Handbook. Published by Praxair Technology Inc.

Edition, F., 2011. The ABC’s of Arc Welding and Inspection, Fourth Edi. Kita-Shinagawa, Shinagawa-Ku,

Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 296-315

Tokyo, 141-8688 Japan: Published by Kobe Steel, Ltd.

Society, N.-F.F., 1994. Copper Casting Alloys, Compiled from intonations supplied by testing, research, manufacturing, standards, and consulting organizations that Copper Development Association Inc. 260 Madison A venue, New York, NY 10016: Published by Copper Development Association Inc.

Fortune, 1950. Cold Welding. Reprinted through the courtesy of editors of “Fortune” for the employees of Cold-weld Corporation.

Jones, J.B., “Ultrasonic Soldering Iron,” patent No. 2;803;735.

D.V.P.R. and M.D.S. Dr. K. Narasimha Murthy, 2011. “Friction Welding & Friction Stir Welding,” Indian Weld. Soc. IWS.

J.M.M. Silva, 2011. “Laser Welding of Aluminum Rings”, Autogenous welding of aluminum alloy AA6082-T651,” Instituto Superior Técnico, Technical University of Lisbon, Portugal.

Cutter, D., “What You Can Do with Explosion Welding,” Weld. J., pp: 38-43.

Rao, S.S., 2009. Engineering Optimization Theory and Practice, Fourth Edi. Hoboken, NJ, USA: John Wiley & Sons, Inc.

2012. The ESAB Technical Handbook, Friction Stir Welding. ESAB Welding Company, 2012.

Ranjan Sahoo and Pinaki Samantaray, 2007. “Study of friction welding,” , National Institute of Technology, Rourkela, Odisha, India.

Aeronautics, N., 1999. “General fusion welding requirements for aerospace materials used in flight hardware,”.

Zhang, Y., S. Babu and G.S. Daehn, 2010. “Impact Welding in a Variety of Geometric Configurations,” pp: 97-107.

Zhang, Y., 2010. “Investigation of Magnetic Pulse Welding on Lap Joint of Similar and Dissimilar Materials,” Ohio State University, UAS.

Balasubramaniam, P.R., 2009. Story of the Delhi Iron Pillar.

AWS, 2005. Safety in Welding, Cutting, and Allied Processes. Approved by American National Standards Institute, ANSI Z 49.1