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Review on different welding techniques of Titanium and its alloys

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ABSTRACT

Titanium and its alloys are the most commonly and most widely used due to its significant properties like good biocompatibility , good tensile strength , low density , and good creep property up to 300 degrees centigrade .It is used in the major engineering fields like civil engineering , nuclear engineering , aerospace engineering etc., but the welding of titanium in industries has become a major challenging objective to the fabricators because, a lot of titanium alloys are found in the form of sheets , problem arises mainly while fabricating the space crafts , marine bodies , jet engine's where the ends are need to be joined through welding with a similar or dissimilar metals and titanium possess to have a very high tendency to oxidize at higher temperatures .As Titanium becomes highly reactive to chemicals in its environment. In regular air, welding contaminates titanium with carbides, nitrides, and oxides that make the weld and HAZ (heat-affected zone) brittle, resulting in lower fatigue resistance and notch toughness. so, In order to get a perfect weld it is very important to avoid the molten metal to the exposure of atmospheric air , which will lead to porosity and results into a poor welding conditions or welding defects. This paper reviews the different methods of welding titanium and its alloys.
Keywords : Titanium, Welding, Titanium Alloys

I. INTRODUCTION

Titanium and its alloy are considered as important engineering materials for industrial applications because of good strength to weight ratio, superior corrosion resistance and high temperature applicability. Titanium alloys have been widely used in the aerospace and aircraft industry are due to their ability to maintain their high strength at elevated temperature, and high resistance for corrosion. They are also being used increasingly in chemical process, automotive, biomedical and nuclear industry.Titanium grade 5 has outstanding resistance to corrosion in most natural and much industrial process environmental.

The metallurgy of titanium has a large influence on the machining characteristics of Ti alloys. Pure titanium undergoes an allotropic transformation at 882,5°C, and changes from alpha to beta phase, from HCP crystal structure to BCC.The precise temperature at which this transformation occurs can be affected by the presence of other chemical elements, some of which stabilize the alpha form and thus raise the effective transformation temperature, and some which stabilise the beta form and so have the opposite effect.

These additions also alter the physical properties of the metal, and so change the machining characteristics. Titanium alloys can therefore be classified into four distinct groups:

nalloyed titanium – these possess excellent corrosion resistance but low strength properties. They are used largely in cryogenic applications.
Alpha structure – with alpha stabilizer elements present, these alloys possess excellent creep resistance. They are also used largely in cryogenic applications.

Alpha Beta structure – this group contains both alpha and beta stabilizer elements. This is the largest group in the aerospace industry.

Beta structure – with beta stabilisers this group has high hardenability and high strength, but also a higher density.

Welding is a method of repairing or creating metal structures by joining the pieces of metals or plastic through various fusion processes. Generally, heat is used to weld the materials. Welding equipment's can utilize open flames, electric arc or laser light. The process of welding actually started a very long time ago, particularly during the Middle Ages. Many artifacts (small boxes) have been found, which date back to the Bronze Age. These small boxes were welded together with lap joints; however, no one is exactly sure what these boxes were used for, however these boxes might have served important purpose during those period, and nevertheless the welding process has evolved since then there were several significant inventions in the welding process as illustrated in the chart shown in figure 1.

II. METHODS OF TITANIUM WELDING

1. Gas-tungsten arc welding (GTAW)
2. Gas-metal arc welding (MIG) or (GMAW)
3. Plasma arc welding (PAW)
4. Electron-beam welding (EBW)
5. Laser-beam welding (LBW)
6. Friction welding (FRW)
7. Resistance welding (RW)
8. Diffusion welding (DW)
9. Explosive welding (EW)
10. Brazing welding

III. PROPERTIES OF TITANIUM ALLOY

Titanium is so highly valued due to its interesting properties. The key properties of titanium are:

- *Strength*-Titanium possesses high strength when alloyed with additional metals and elements. This can produce the desired level of strength or ductility. Titanium is just as strong as steel
- *Lightweight* - Titanium is also lighter than steel whilst having a similar strength. This quality is very desirable for medical and construction applications. Titanium's high strength-to-weight ratio is very appealing to builders as they continually look to produce buildings that are high in strength using lighter materials
- *Corrosion-resistant* - titanium is highly resistant to most types of corrosion. Most metals will corrode in the presence of salt water, acids, and other chemical solutions, however Titanium shows surprising resilience to these. Titanium is also very resistant to stress corrosion cracking unlike steel.
- *Biological Compatibility* - Titanium can be used within the human body due to its bio-inert qualities. This means that titanium is not toxic to the human body and will not be rejected as easily when used in processes such as Osseo integration; when a foreign object is fused to human bone in order to provide structural support for prosthetics or implants.

IV. APPLICATIONS OF TITANIUM ALLOY

Because of the hugely diverse set of properties titanium possesses, it is an incredible metal to work with. Titanium is suitable for a range of applications including the following:

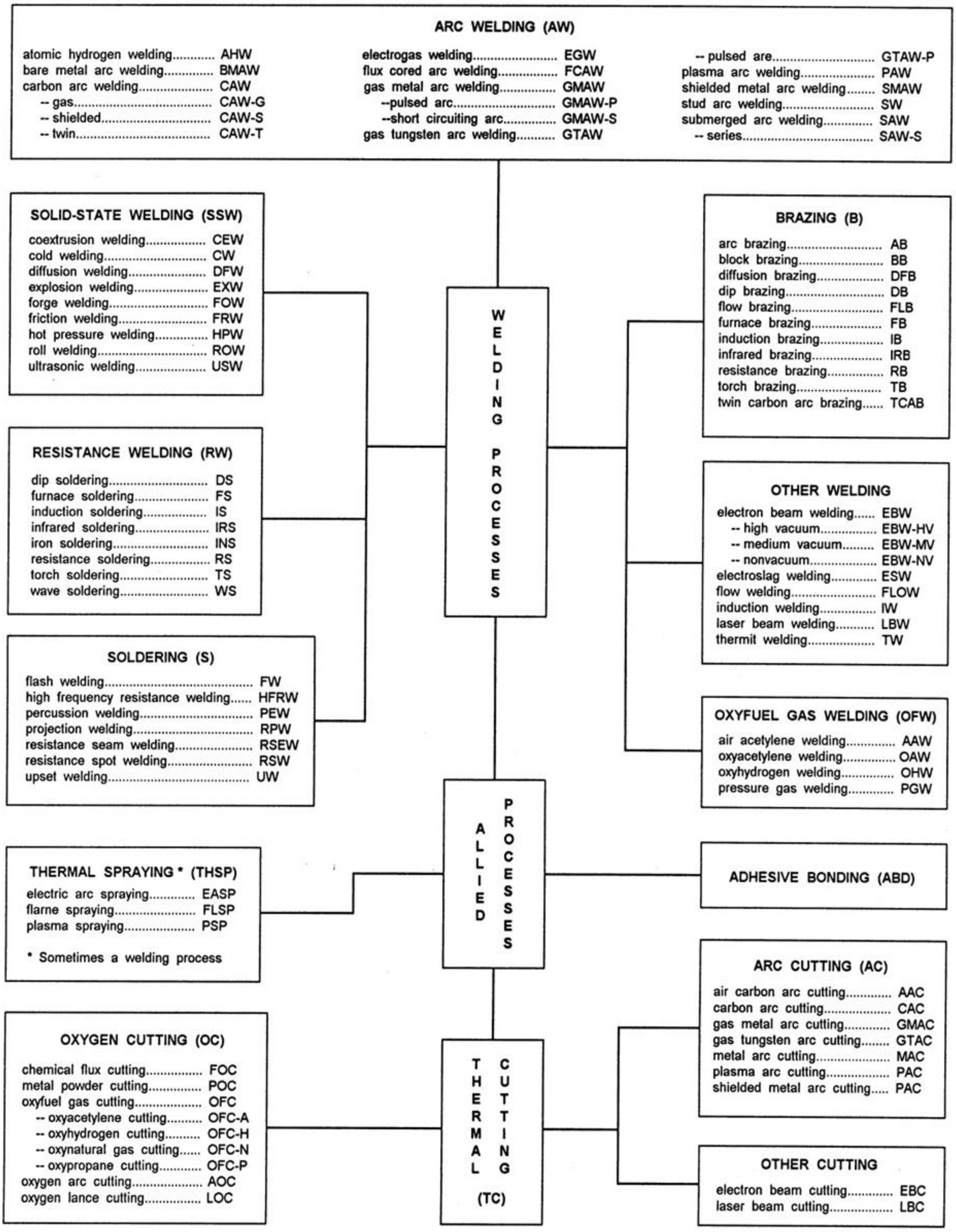

Figure 1 Welding Processes (Image : Yassin, A. et al. (2012))

- Medical - In the medical field, titanium has become one of the most widely used metals. It is bio-inert, it does not react with anything inside the body, making it the prime candidate for use in procedures such as dental implants, orthopaedic rods, bone plates, and other prosthetics. It can also be used to produce a range of medical instruments such as scalpels and drills.
- Aircraft - The most common use for titanium is in aircraft construction. Titanium is the leading metal used in the construction of jet engines and airframes. Its lightweight characteristics make it especially important for use in increasing jet efficiency.
- Automotive - Titanium is staple for the car and motorcycle industry. Since these machines have several moving parts, the need for durable material is very high. Titanium alloys offer the ideal solution for car and motorcycle parts such as rods, valves and camshafts. Titanium parts such as these are crucial to the racing industry.
- Industrial - There are also different industrial applications for titanium. Constantly new uses for titanium in construction are being discovered. It makes an excellent building material for outdoor applications since it is lightweight and resistant to corrosion.
- Chemical Processing - Titanium is useful in the chemical and pharmaceutical world, where equipment is often in constant contact with hazardous and corrosive materials.
- Other - Titanium finds application in a variety of different industries, such as jewelry, clocks and watches, eyewear and golfing. These consumer goods last longer and have a lot of appeal. Marine industries have taken a special interest in titanium as well since materials that are in consistent contact with salt water demand a higher resistance to corrosion.

V. LITERATURE REVIEW

J. Sorina-M ller [8] has stated the use of FEM simulation of the linear friction welding of titanium alloy (Ti-6Al-2Sn-4Cr-6Mo) (Figure 3). A full structural– thermal coupled transient 3D-analysis was conducted. The temperature evolution was calculated at any point of time during the whole process of the linear welding, until the oscillation completely stops, and the axial shortening was calculated as a function of process time for every part separately and for the both together, they have also considered the friction flux, as a result of movement between the two specimens, heat conduction from the rubbing interface to the bulk of the specimens, convection losses to the surrounding air as well as thermal contact conductance in the faying areas directly, which could be achieved due to the three-dimensional modeling, and considers the variation with time of the surface contact area, material's properties and the frictional parameters, with the properties and friction coefficient of the material changing with temperature.

H. Zuhailawati [15] has welded titanium with nickel by Spot Resistance Welding; she has studied the shear strength and micro-structural characteristics of the spot brazed titanium and nickel base metal with and without addition of filler metal. To comprehend the influence of welding on the final properties of the joints the strength of the joints was assessed using a shear test mode, and the microstructure was studied using an optical microscope, scanning electron microscope, and energy-dispersive spectroscopy.

Fu Xin Wang [16] has used Micro-plasma arc welding to weld Ultra-thin Titanium plates. It is widely used in manufacture of thin-walled titanium tubes, automobile parts, medical and other industrial fields, is an excellent structural material.

K. Szymlek [17] has reviewed of methods of titanium and steel welding. Based on this study it is evident that, titanium can be joined with steel by means of explosive welding or brazing. Joining titanium with steel by TIG welding and friction welding methods is possible with the use of copper and tantalum or vanadium interlayer.

E. Akmanet al, has experimented laser beam butt welding of a small square shape(30mm×30mm×3mm) ti6al4v titanium alloy plates have been done using gsi lumonicsjk760tr series laser (class 4) system in a cnc cabin. The jk760tr series of laser is an Nd:yag laser which has 500 hz maximum repetition rate and0.3–50ms pulse length. The average power that can be achieved is 600watt and it also jk760 tr series laser has a pulse shaping ability. Output power of laser is givenvia a 600 jm radius fiber optic cable to the focus head at the workstation for process. In the experiment, square shape pulse has been used to all workpieces. The laser beam is pointed on titanium plates using 160mm plano convex lens. The least spot size on the plates has been 0.4mm. During welding operation, the laser beam has been focused on 2mm under the surface of the plates to get sufficient power density for the cross section. In this case the spot size on the plates is 0.65mm.the laser output parameters are changed in the experimentation. There is always a cracking risk due to the fast cooling of welded joint. To minimise this defect in welding, samples have been fixed on the ground by clamps.

Lima shown that pulse shaping technique can be used to prevent cracking in welded TiN coated titanium alloy through development in the transfer of nitrogen to the volume of the weld. The gap in-between the joint interfaces has been varied to evaluate porosity formation and/or reduction in the titanium alloy. They have shown that, acceptable results can be achieved when the gap distance is 0.1mm. In this study, the effect of pulsed laser seam welding parameters for joining 3mm thick Ti6Al4V has been investigated using the Lumonics JK760TR pulsed Nd:YAG laser.[1,2]

J. Niagaj worked on findings of investigation of the impact of activating flux and selected fluorides on a-tig welding of grade 2 titanium and concluded that the application of all activating fluxes (bc-ti and unary) during a-tig welding of grade 2 cp titanium causes increasing of the penetration depth if compared to that obtained during traditional tig welding. The most significant i.e. 76% increase is related to the application of single component flux in the form of magnesium fluoride (mgf2). As opposed to a-tig welding of steel and nickel alloys, in case of a-tig welding of titanium the application of activating fluxes is, first of all, aimed at increasing the penetration depth, as, due to some specific physical properties of titanium, welding shrinkage does not occur. The tensile strength and bend tests as well as the measurements of the hardness of a-tig-welded joint of 5mm-thick grade 2 titanium produced positive results, which qualifies the above method as having practical application.

Ho thi my nu ,1,2 truyen the le,1 luu phuong minh,2 and nguyen huu in this paper the rotary friction welding (rfw) method is used to study the feasibility of producing similar metal joints of high-strength titanium alloys. To predict the upset and temperature and identify the safe and suitable range of parameters, a thermo mechanical model was developed. The upset predicted by the finite element simulations was compared with the upset obtained by the experimental results and they concluded that a small forging pressure is preferred in the friction welding process. Therefore upset thresholds were determined between 5mm and 7mm for small-size specimens of ti6al4v. Below 5mm, insufficient bonding was observed, whereas the welding process became unstable above 7 mm.

Giuseppe casalinoa in this paper studied a simple and versatile model for simulating the laser welding process of lightweight metal sheets is presented. The study was aimed to predict the seam morphology and to improve the comprehension of the main thermal aspects involved in the process and in this work, they have concluded that the thermal simulation of fiber laser autogenous welding of ti6al4v joints in butt configuration was simulated by fem analysis.

Ning guo in this paper, underwater laser beam welding (ulbw) with filler wire was applied to ti-6al-4v alloy. Process parameters including the back shielding gas flow rate (bsgfr) (the amount of protective gas flowing over the back of the workpiece per unit time), focal position, and laser power were investigated to obtain a high-quality butt joint. Results in increasing the bsgfr, the protective effect on the weld metal became strong gradually. Then the bsgfr were 15 l/min and 25 l/min, ti-6al-4v alloy reacted strongly with oxygen, resulting in serious oxidation on the back of the weld metal,

Jianxiong lia in this paper the vaporizing foil actuator (vfa) spot welding was used to weld a titanium alloy (ti-1.2asn) to a stainless steel (436 ss) for the first time. The relation of process to microstructure was explored. Interfacial microstructure was studied through optical microscopy (om), scanning electron microscopy (sem), and transmission electron microscopy (tem). Chemical compositions of molten regions and jet zone were characterized by energy-dispersive x-ray spectroscopy (eds) and **the results** show that the impact spot welds have reproducible and understandable macro- and micro-structure and show spatial heterogeneities at large and small length scales. There is an unbonded zone at the center, flat interface with continuous melting, wavy interface with discontinuous melting, wavy interface with no melting and trapped jet zone in the corner. The wavy zone itself shows great spatial microstructural heterogeneity a in many regions, there are zones, several microns in thickness, that are highly heterogeneous and too thick to be explained by solid-state inter diffusion. They are created by a combination of solid and liquid state mixing. Tem analyses of mixed regions show that equated nano grains formed in the zone between ti and ss. During the formation of the mixed zone.

R. Kosturek1 in this research three different fsw joints of titanium grade 1 have been performed by using tool made of w25re alloy with different welding velocity values. In order to investigate the influence of fsw process on microstructure of joined material the light microscope observations have been performed on the etched samples. The light microscope observations revealed the microstructure of obtained joints tmaz microstructure is characterized by thinner grains than base material, with visible deformation texture. In this area, the material has been subjected to the plastic deformation, as well as, has been influenced by high temperature, but not in sufficient way to cause the dynamic recrystallization of the microstructure. It has been noticed that the number of twin boundaries in this zone increased compared to the base material. The microstructure of tmaz changes from the fine, fragmented grains to the grains elongated in the direction of material flow, and finally reaches the partially deformed grains zone.

G turichin in this article presents the results of investigation on the technological opportunity of laser-tig welding of titanium alloys. The experimental stand for implementation of process with the capability to feed a filler wire was made. The research of the nature of transfer the filler wire into the welding pool has been demonstrated. The influence of distance between the electrode and the surface of the welded plates on the stability of the arc was explained the nature of transport of metal filler wire into the weld pool has been investigated. The melting of it in front of the weld pool by arc with a uniform drop transport mechanism has been detected. The relationship between welding velocity, the position of focal plane of the laser.Beam and the stability of penetration of plates was determined.

Tim pasang briefly summarizes previous reports as well as some recent results on welding of various titanium alloys. He finally concluded that the strength and weakness of certain areas across the welds. For unalloyed titanium, hardness remained constant throughout. Near α alloys and α + β alloys showed an increase of hardness in the haz and fz, while the β alloys showed a decrease of hardness, hence, low strength in the haz and fz area.

A. N. Cherepanov concerns the possibility of obtaining a lasting permanent joint of dissimilar metals: technically pure titanium and stainless steel using laser welding and an intermediate composite insert. The insert was a four-layer composition of plates of steel, copper, niobium, and titanium welded by explosion.

The application of the composite insert obtained by explosion welding of titanium, niobium, copper, and steel plates using the continuous co2 laser allowed obtaining a permanent joint with the ultimate strength (uts =475.5 mpa) and yield (y = 302 mpa), which are comparable to the strength of the initial titanium (450 and 380 mpa, respectively).

VI. CONCLUSION

The overall studies and previous works has concluded the following:

1. More works can be performed and there is a scope of development in welding of dissimilar materials with titanium and its alloys.
2. There is requirement of improvement of welding strength of titanium materials so that the welded materials can be used at high strength application area.
3. Titanium can be welded by using many different technics in the welding industry. Titanium weldment has taken a wider range of uses in various fields of our life.
4. The methods GTAW, GMAW and RW has found out to have more applications and used in most of the industries.
5. The methods FRW and EW is treated as the unsafe process by the most industries and researchers.
6. The processes LBW, EBW and PAW are found to high cost and require high skills

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