Study on Joint Structure and Fatigue Properties of Magnesium Alloy Active TIG Welding and TIG Welding

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Abstract. Magnesium alloys have many advantages, such as light weight, anti-seismic, anti-electromagnetic interference, high damping, high negative electricity and easy recycling. They are widely used in automobiles, motorcycles, and aerospace and are known as green engineering materials in the 21st century. Because of the special physical and chemical properties of magnesium alloys, the weldability of magnesium alloys is poor, which seriously hinders the use of magnesium alloy structural parts. Therefore, this paper analyses the welding problems of magnesium alloys, and discusses the fatigue properties of magnesium alloys.

Keywords: Magnesium Alloy, Active TIG Welding, TIG Welding, Fatigue Performance

1. Introduction
AZ31 magnesium alloy with thickness of 10 mm was welded by TIG welding and active TIG welding [1]. The appearance, morphology and microstructures of the joints welded by the two methods were analyzed by optical microscopy and scanning electron microscopy [2-4]. The results show that both methods can obtain beautifully formed welds, but better penetration effect can be obtained by using activator. The grain size of the joints obtained by these two methods is the largest in the weld zone and the smallest in the base metal zone and the structure morphology of the bottom welding and the cover welding are not identical. In contrast to the surfacing of AZ31 magnesium alloy, oxide as activator can increase the weld penetration slightly. The effect of chloride as activator on increasing weld penetration is quite obvious. The effect of CdCl2 activator on AZ31 is more obvious [5-11]. Magnesium alloy is a special welding wire for repairing magnesium alloy fracture, crack and trachoma pore [12-14]. This paper shows that CdCl2 activator can effectively increase the penetration of magnesium alloy weld [15] compared with non-activator weld. The microstructures and hardness distribution of weld joints of magnesium alloys coated with activator CdCl2 are not significantly different from those without activator. Tensile test results show that the strength of joints is not
affected by activator CdCl2. Fracture analysis shows that the mixed fracture is composed of cleavage and plastic pit [16-18]. On this basis, the mechanism of A-TIG welding process is discussed [19-20].

2. Overview of Magnesium Alloys and Fatigue Properties of Welding

2.1 Magnesium alloy properties.

The mechanical properties of pure magnesium are not high, so it cannot be used as a direct functional material. The addition of various alloying elements to magnesium, namely the alloying of magnesium, is the simplest, most practical and most effective means in the actual production process. Plastic strengthening and deformation strengthening are often based on the elemental alloying of magnesium. Magnesium alloys are alloys based on magnesium and added to other elements. Its characteristics are: low density (about 1.8g/cm3 magnesium alloy), high strength, large modulus of elasticity, good heat dissipation, good shock absorption, large impact load capacity than aluminum alloy, good resistance to organic and alkali corrosion. The main alloying elements are aluminum, zinc, manganese, cerium, lanthanum and a small amount of zirconium or cadmium. Currently the most widely used is magnesium-aluminum alloy, followed by magnesium-manganese alloy and magnesium-zinc-zirconium alloy. Mainly used in aviation, aerospace, transportation, chemical, rocket and other industrial sectors. It is the lightest metal in practical metals. Magnesium has a specific gravity of about 2/3 of that of aluminum and 1/4 of iron. It is the lightest metal in practical metals, high strength and high rigidity. The basic alloy series currently in industrial production is based on the following alloying elements: manganese, aluminum, zinc, mis- and rare metals. They can be roughly divided into four alloy series: AZ (Mg-AL-Zn) series, AM (Mg-AL-Mn) series, As (Mg-AL-Si) series, AE (Mn-AL-Re) series. AZ series magnesium alloy has balanced mechanical properties and casting properties, high yield strength, AM series magnesium alloy has excellent toughness and plasticity, AS series magnesium alloy has good creep resistance, high strength and good plastic toughness, but filling Poor capacity, AE series magnesium alloy has better creep resistance than AS system, but has poor oxidation resistance and low fatigue performance. The above series of magnesium alloys can generally be classified into two types: aluminum or aluminum. The first magnesium alloys used in the industry are aluminum, zinc and manganese, and the magnesium-aluminum-zinc-manganese magnesium alloy is the most widely used magnesium alloy. In the AZ series of magnesium alloys, the aluminum element reaches the maximum in the magnesium element at 473 °C. The thickness of the magnesium alloy TIG welding process and the joint performance study is 12.7%, and it drops to about room temperature. 2%. It can be formed by discontinuous precipitation, and even coarse cells (Mg12, AL17) extend out of the grain boundaries. Therefore, the magnesium alloy containing aluminum can improve the strength, corrosion resistance and hardness of the alloy, and can widen the solidification interval and improve the related properties of the alloy, but the crack sensitivity also becomes stronger. Among all structural alloys, magnesium alloy is the lightest type, so magnesium alloy can reduce the weight of aluminum or iron parts without reducing the strength of the part. The specific strength of magnesium alloy is significantly higher than that of aluminum alloy and steel, and the specific stiffness is comparable to that of aluminum alloy and steel. When a magnesium alloy is subjected to an impact load, in the elastic range, the absorbed energy is greater than the absorbed energy of the aluminum alloy. Therefore, the magnesium alloy has good noise reduction performance and shock resistance. Under the same load, its vibration reduction ability is 100 times that of aluminum and 300 to 500 times that of titanium alloy. Good electromagnetic shielding. The casing of 3C products (mobile phones and computers) should provide excellent anti-electromagnetic protection, while the magnesium alloy casing can fully absorb electromagnetic interference at frequencies exceeding 100db. The texture is good, the appearance and feel of the magnesium alloy are excellent, which makes the product more luxurious and more resistant to air corrosion.
2.2 Magnesium alloy welding performance.

Aluminum alloy has low density, good specific performance, good shock absorption, good electrical and thermal conductivity, good processability, poor corrosion resistance, easy oxidation and combustion, and poor heat resistance. And its processing, corrosion and mechanical properties have many characteristics: fast heat dissipation, light weight, good rigidity, certain corrosion resistance and dimensional stability, impact resistance, abrasion resistance, good attenuation performance and easy recycling; thermal conductivity and Conductive, non-magnetic, good shielding and non-toxic properties. The magnesium alloy oxide film is indistinguishable from the magnesium alloy solution in the molten state. It is difficult to observe the welding state, the welding temperature control is not easy, the weld seam collapses easily, the heat affected zone is too large, and the mechanical properties of the weld are degraded. In the welding process, the oxygen generated on the molten pool is removed by the cathode crushing function of the arc film. The magnesium alloy has low electrical resistivity, high thermal conductivity, large linear expansion coefficient (about 1.2 times that of aluminum), low temperature strength and large welding deformation, which brings certain difficulties to the welding process and welding parameter selection. Therefore, the welding equipment and welding method require the use of energy-concentrated welding heat source, and high-speed welding; otherwise it will easily cause the growth of the weld zone and the heat-affected zone, and reduce the mechanical properties of the welded joint. In the absence of shielding gas, there is a danger of burning during the welding of magnesium alloys, and inert gas shielding gas is required during the welding process. When welding magnesium alloys, it should also pay attention to: lining the back of the weld to speed up the cooling of the weld and protect the molten metal. It is required to install an exhaust system to eliminate welding fumes and protect the health of the welders.

2.3 Magnesium alloy welding defects

Magnesium alloys have the characteristics of low density and low melting point, large thermal conductivity, electrical conductivity and thermal expansion coefficient, strong chemical activity, easy oxidation and high melting point of oxides. The coarse-grained magnesium has a low melting point and high thermal conductivity. A high-power welding heat source is required for welding. The weld seam and the near-seam area are prone to overheating, grain growth, crystal segregation, etc., which reduces the joint performance; oxidation and evaporation. Magnesium is extremely oxidizing and easy to combine with oxygen. It is easy to form MgO during welding. MgO has high melting point (2500°C) and high density (3.2g/cm-3). It is easy to form fine-shaped solid-state clips in the weld. The slag not only seriously hinders the formation of the weld but also reduces the weld performance. Magnesium is also easy to combine with nitrogen in the air to form magnesium nitride at high temperature during welding. Magnesium slag inclusions also cause plasticity degradation of the weld metal and deteriorate joint performance. The boiling point of magnesium is not high (1100 °C), it is easy to evaporate at high temperature of arc; the burning and collapsing of thin parts in the welding of thin parts, due to the lower melting point of magnesium alloy, and the melting point of magnesium oxide is very high, the two are not easy to fuse It is difficult to observe the melting process of the weld during welding operations. When the temperature rises, the color of the molten pool does not change significantly, and it is easy to cause burn-through and collapse. The thermal stress and crack magnesium and magnesium alloy have a large thermal expansion coefficient, which is about 2 times that of steel and 1.2 times that of aluminum. During the welding process. Medium easy to cause large welding stress and deformation. Magnesium easily forms low-melting eutectic with some alloying elements (such as Cu, Al, Ni, etc.) (such as Mg-Cu eutectic point temperature of 480°C, Mg-Al eutectic point temperature of 430°C, Mg-Ni eutectic point The temperature is 508°C), the brittle temperature range is wide, and it is easy to form hot cracks. Studies have found that when w(Zn) > 1%, it increases the hot brittleness and may cause weld cracks. Adding w(Al)≤10% to magnesium can refine the weld grain and improve the weldability. Magnesium alloy containing a small amount of Th has good weldability and no tendency to crack; hydrogen pores are easily generated when the pores are soldered with magnesium, and the solubility of hydrogen in magnesium is also sharply reduced
with the decrease of temperature; magnesium and its alloys are welded in the air environment. It is easy to oxidize and burn, and it needs to be protected by inert gas or flux during welding. Therefore, when welding, the backing of the magnesium alloy sheet is backed; welding deformation: the data can be seen that the elastic modulus of magnesium and magnesium alloys are very low (the elastic modulus $E$ of the element depends on the chemical bonding force between the atomic atoms, combined the force depends again on the atomic spacing).

3. Joint Structure Process of Active TIG Welding and TIG Welding of Magnesium Alloy.

3.1 Test material
The welding base material used for the test is AZ31 wrought magnesium alloy with an average size of 200mmx100mmx10mm in annealed state, and the filling material for welding is AZ61 magnesium alloy welding wire with a radius of 2.4mm. The welding wire is prepared by extrusion process. Remove the oil and oxide film on the surface of the wire and the plate before welding, dry the wire and the plate, and apply CdCl2 active agent on the wire. The welder is an InvertWSE-315P argon arc welder with a protective gas of 99.99% (mass fraction). Argon.

3.2 Test method
The test uses flat butt welding, A-TIG welding jointless gap TIG welding joint gap a is 3mm, using single-sided welding double-sided forming welding process, two horizontal plates are fixed before welding, and both ends of the spot welding the welding process parameters adopt the parameters after process optimization.

3.3 Test results and analysis
weld appearance appearance analysis and analysis of the weld front and back topography of the two welding methods. The appearance of the surface shows that the surface of the weld obtained by the two welding methods is continuous and uniform, beautiful in appearance, free from pores, cracks, unfused and other surface defects. The back is completely penetrated, and there is no obvious oxidation phenomenon, indicating that the back protection gas can be used to obtain an ideal back shape. However, by comparing the back formation of the two welds, the back penetration effect is better after the active agent is used.

4. Tissue Analysis of TIG Weld Joints

4.1 Measuring the effect of different active agents on weld penetration.
PbCl2, CaCl2, CdCl2, CeCl2, Cr3O2, TiO2, several active agents were applied on the surface of AZ31 plate respectively, and the AZ61 welding wire with a small 2.4 mm was used to weld the plate on the plate using the welding process parameters of AZ61 wire. After welding, take a cross section to observe the penetration of the weld. Measurement of the penetration depth of seven different active agents shows that the coating of chloride and oxide active agents can increase the weld penetration, and some of the oxide active agents have no effect on the weld penetration. The effect of the two active agents shows that the application of the chloride active agent increases the weld penetration to be significantly better than the coated oxide active agent. The results show that when the active agent is not used, the weld penetration is the shallowest. When the Cr3O2 and TiO2 oxide active agents are used, the penetration depth is not obvious, and the penetration of the CdCl2 active agent in the chloride active agent is the largest. The penetration depth is 2.5mm.

4.2 Analysis of the active TIG welding docking process
CdCl2 has the most obvious effect on increasing weld penetration, and CdCl2 is the best effect as a single coated active agent. Therefore, the active agent used in the experiment was CdCl2. In order to better study the effect of active agent on the weld depth of medium-thickness AZ31 magnesium alloy,
the docking process experiment was compared with ordinary TIG welding and CdCl2 active TIG welding. The general test uses butt welding, workpiece assembly, active TIG welding head without gap, the common joint TIG welding, set the joint clearance is 3mm, the welding process uses single-sided welding, double-sided molding, clamping two horizontal plates with welding fixtures, And the two ends of the workpiece are spot welded in advance, and the process parameters used for welding are the parameters of the optimized process in Chapter 3, and the back of the weld is protected by hydrogen. The appearance of the weld on the front and back of the weld with two different welding methods. From the appearance and appearance, the weld surface obtained by different welding methods has a continuous and uniform solder transition, and the molding is better, and there are no obvious weld surface defects such as pores, hot cracks and unfusion. The weld backs of both welding methods have been penetrated and there is no significant oxidation phenomenon, indicating that we have a good effect on the protective gas flow at the back of the weld, which can ensure better weld formation during the welding process. Comparing the reverse forming morphology of the welds of the two welding methods, the active TIG welding is used, and the penetration effect on the reverse side of the weld is better. In ordinary TIG welding, the macroscopic topography of the weld in the weld is an elliptical arc transitioning to the root of the weld. The macroscopic topography of the active TIG weld is a straight line that directly transitions to the root of the weld. According to the measurement, the root width of the weld is larger than the weld gap reserved by 3mm in advance. The reason for the weld characteristics is that the arc heat of the welding arc is generally used in ordinary TIG welding. The thickness of the magnesium alloy TIG welding process and the joint performance are studied in the upper part of the weld, and the activity is added when the active agent is added. After decomposing and evaporating under the action of arc, the vapor pressure is wrapped around the arc in atomic form, and the temperature around the arc is lower than the central region. The evaporated active agent atoms capture electrons and form negative ions, so that the electrons in the arc center region the number is reduced, the arc conductivity is reduced, the electrons in the arc are promoted to volatilize, and the arc is automatically contracted to concentrate the arc heat to the root of the weld.

4.3 Analysis of the microstructure of active TIG welding joints
Surfacing test AZ31 magnesium alloy is not coated with an active agent and a metallographic photograph of the weld after application of the active agent. It can be seen that the weld bead is small when the activity is not applied, and the weld bead is larger when the active agent is applied. It can be seen that the coating active agent has a certain influence on the microstructure of the weld. The microstructure of the weld depends on the temperature gradient of the weld pool. When the active agent is applied and uncoated, the microstructure of the weld is caused by the difference in the temperature gradient of the weld zone. Applying a certain amount of active agent on the surface of the magnesium alloy base material, due to the small thermal conductivity of the active agent, covering the surface of the weld pool and the heat affected zone during the welding process, the cooling rate of the molten pool is reduced, and the temperature gradient of the weld pool is changed. Decreased, resulting in coarse weld bead crystals. The application of the active agent was also observed in the active TIG welding of the magnesium alloy, resulting in a larger grain size in the weld zone. And after the application of the active agent, the weld fusion zone structure is dendritic, and only a small part of the columnar crystal is observed in the vicinity of the weld fusion line. The metallographic photograph of the weld microstructure of TIG welding, the bottom welding and the gold structure of the cover weld, it can be seen that there are more precipitation phases on the cover weld grain boundary. This is because after the bottom welding, the test plate has been preheated, so that the cooling rate of the weld metal of the cover weld is reduced, and the weld metal is increased at a high temperature, which is favorable for the precipitation of Al to the grain boundary and the Al content at the grain boundary is increased. According to the Al-Mg binary phase diagram, the p-Al12Mg17 phase is formed by Al and Mg at the grain boundary. The microstructure of the heat-affected zone and the base metal zone were compared by visual observation of the crystal structure of the two regions. The grain size of the
heat-affected zone was significantly larger than that of the parent metal, which belonged to the superheated structure. Comparing the grain sizes of the weld zone, the heat affected zone and the base metal zone; it can be found that the grain size of the weld zone is small. It can also be seen that the boundary between the weld zone and the heat affected zone is obvious. The heat-affected zone is a superheated structure, and the grains are columnar crystals; the grains in the weld zone are fine equiaxed crystals, which are significantly smaller than the grains of the base metal and the heat-affected zone, and are cast quenched structures. It can be seen that the base material grains are fibrous, apparently the deformed structure of the grains. The above-mentioned structure appears at the joint, mainly related to the thermal cycling process and thermal cycling process of the physical properties of the magnesium alloy during TIG welding.

4.4 Magnesium alloy TIG welding suitable process and materials

The weld zone structure consists of tiny equiaxed grains. The microstructure of the weld zone increases with the increase of aluminum content in the filler wire, and the eutectic phase structure in the weld zone and the heat affected zone increases gradually, showing a continuous network distribution, and the microstructure of the weld zone is refined. The gradual increase of the content of the eutectic (Mg17Al12) in the weld has a complicated effect on the performance of the welded joint. The tensile test results show that the joint strength of the AZ31 magnesium alloy is higher than that of the AZ31 welding wire when the AZ61 welding wire is used. In the magnesium alloy single-component active agent surface experiment, chloride as an active agent has a good effect of increasing the weld penetration. Some of the oxide active agent can increase the weld penetration to a small extent, and there are two kinds of oxides. There is no effect on the weld penetration, but it is reduced. Comparing the weld penetration, we can find that CdCl2 active agent increases the weld penetration to the maximum, and the depth of weld penetration can reach 2.5 times of the penetration depth of conventional TIG weld. The metallographic structure of the weld zone of the AZ31 10mm thick magnesium alloy welded joint coated with active agent is basically the same as that of the metallographic structure of the weld zone where the active agent is not coated. The difference is that the tissue of the active agent is coated Larger.

Summary

The mechanics of the joints showed that the performance of the welded joints was not affected. The distribution of hardness values was consistent with that of the uncoated active agents, and it was also the highest in the weld zone. The fracture morphology was the fracture morphology of the cleavage and plastic pit mixing. The application of the active agent has an effect on the distribution of the weld joint elements. There are two theories about the mechanism of magnesium alloy active TIG welding to increase the weld penetration. One is that the ions decomposed by the active agent interact with the welding arc to increase the arc voltage and the arc temperature. Second, by changing the surface tension of the molten pool, in turn, the mechanism of the weld pool is affected.

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