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Form 3

Abstract of Thesis

Name (洪 聖旻)	
Title	Joining Mechanism of Aluminum Alloy to Galvanized Steel by Pulsed Gas Metal Arc Welding (パルスガスメタルアーク溶接によるアルミニウム合金と亜鉛メッキ鋼板の接合メカニズム)

Abstract of Thesis

Based on the joint quality of aluminum alloy to hot-dip galvanized (GI) steel by gas metal arc welding (GMAW) is mainly determined by the growth of Fe-Al intermetallic compound (IMC) and presence of Zn which are sensitive to the heat input to the base metal, the purpose of the present study is to develop and optimize the pulsed GMAW based joining process on dissimilar materials; aluminum alloy to GI steel. Especially, this study gave attention to alternating current (AC) pulse GMAW process which can control the current wave form as a mixture of electrode positive (EP) polarity and electrode negative (EN) polarity for reducing the heat input to base metal. The influence of different process parameters on the joint quality, and corresponding growth of the IMC layer and defects are studied extensively. A coupled experimental and numerical analysis were carried out. A three-dimensional numerical heat transfer model which contains the thermal effect of Zn evaporation was developed using finite element method (FEM). IMC layer thickness at the joint interface was estimated from numerically analyzed temperature histories and validated with the corresponding experimental results. As next to the understanding of thermal characteristics of the aluminum alloy to hot-dip galvanized steel joints by AC pulse GMAW, this study investigated the applicability of additional magnetic field to the AC pulse GMAW process to join the aluminum alloy to GI steel joining process by improving the energy balance for the reduction of Fe-Al IMC and defects.

In chapter 1, a review of dissimilar materials joining process and the characteristics of GMAW were described. Based on the reviewed issues, the purpose of this study was determined.

In chapter 2, a numerical study was carried out to investigate the effect of zinc evaporation and the effect of current waveform on the joint quality in AC pulse GMAW. A 3D heat transfer model was developed through FEM. EN ratio was varied as a process parameter and applied to the "with Zn evaporation" and the "without Zn evaporation" model, respectively, for the heat conduction analysis and estimation of the IMC layer growth.

In chapter 3, effect of current wave form as process parameters on the formation of IMC layer and on the mechanical properties of aluminum alloy to steel joints by AC pulse GMAW was investigated. A comparative experimental study was carried out by evaluating the joints characteristics through high-speed camera, macroscopy, scanning electron microscope with energy dispersive X-ray spectroscopy (SEM-EDS), and electron probe microanalyzer (EPMA). Moreover, the mechanical characteristics of the joints were investigated through Vickers hardness test and tensile-shear strength test to secure the reliability of AC pulse GMAW process.

In chapter 4, the effect of the gap bridging on the joint properties of the aluminum alloy to GI steel joints by AC pulse GMAW was investigated. A comparative experimental study on the joints was carried out by evaluating the joint characteristics through macroscopy and SEM-EDS. Further, the mechanical strength of the joints was investigated through tensile-shear strength test to secure the reliability of gap bridging.

The last chapter is, an applicability of the additional underneath magnetic field on the aluminum alloy to GI steel joining process by AC pulse GMAW was investigated. The effect of the additional magnetic field direction on the weldability was mainly focused. In here, the current waveform and the direction of a constant additional magnetic field were varied as process parameter; the current waveform as direct current (DC) and AC as 20% of EN polarity ratio, and the magnetic field direction to the aluminum, steel, rear, and front side, respectively. As a result, the joint efficiency was increased up to almost 87% by applying the additional magnetic field to rear side, which induces the additional Lorentz force to the steel side.

様式７

論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

本論文ではパルスガスメタルアーク溶接によるアルミニウム合金と亜鉛メッキ鋼板の接合メカニズムを、実験及び数値シミュレーションの両面から明らかにしている。具体的には極性比率や電流値、接手形状と言った基本的な溶接パラメータを変化させた際のアーク現象を高速度ビデオカメラにより観察するとともに、溶接後試験片に形成される金属間化合物層(IMC 層)の光学観察及び引張強度の計測等も実施し、接合強度向上に特に影響する因子を明らかにしている。また、これと併せて数値シミュレーションも実施し、亜鉛メッキの蒸発が接合界面のエネルギーバランスの変化を通じて IMC 層の成長に及ぼす影響等を理論的に解明している。さらに、上記の検討を通じて得られた知見に基づき、外部磁場印加により IMC 層の成長を抑制し、引張強度を大幅に向上可能な新たな溶接プロセスを開発している。

本研究で明らかにされている点は以下の通りである。

(1)　溶接パラメータとしては極性比率の影響が大きく、電極マイナス(EN)の期間が長いほど母材への入熱が低下し、IMC 層の成長が抑制され引張強度が向上することがわかった。

(2)　溶接中に亜鉛メッキが蒸発することにより接合界面のエネルギーが奪われ、これが IMC 層の成長を妨げ引張強度が向上することがわかった。

(3)　外部磁場の印加を通じてアーク姿勢及び溶融池流動を制御することで、IMC 層の成長を抑制し引張強度を大幅に向上可能な新たな溶接プロセスを開発した。

以上のように、本論文ではパルスガスメタルアーク溶接によるアルミニウム合金と亜鉛メッキ鋼板の接合メカニズムを詳細に研究し、IMC 層の成長及び引張強度を支配する主な因子を明確にしている。本研究により得られた知見はアークを利用した異材接合プロセスの高能率・高効率の実現に大きく貢献できるものと期待できる。

よって本論文は博士論文として価値あるものと認める。