Study on Mechanical Properties of Bimetal Hydroforming Die Using A New Longitudinal Electromagnetic Field Hybrid GMA Welding Technique

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Abstract - With development of tube hydroforming techniques, the low cost and long service life of hydroforming die has a larger market demands, the application of bimetal die can be effectively settled these requirements. But it is a lack of good welding technique manufacturing the bimetal hydroforming die. In this paper, a new longitudinal electromagnetic field hybrid GMA welding method (LMF-GMAW) is applied to fabricate bimetal hydroforming die or mould, in order to improve the wear resistance and hot deformation resistance with a low cost and high performance. The microstructure and mechanical properties of LMF-GMAW workpieces with bimetal deposited layers are studied by SEM and other techniques. The results show the LMF- GMAW technique increase the surfacing hardness, reduce the friction loss, improve the wear resistance property and enhance the thermal physical mechanical property of bimetal specimens.

Keywords - Bimetal hydroforming die, hybrid overlay welding, electromagnetic field, mechanical property

I. INTRODUCTION

The die or mould is important technological equipment on the tube hydroforming process, which plays a key role in modern metal formation industry. Because there has some extremely severe working conditions, such as high working pressure, large inner stress, big friction force and wearing loss, the die or mould need be of several properties in order to accompany with the hydroforming processing, such as high working performances, high precision, high surface hardness, high wear resistance and good ductile plasticity. But these properties are ambivalent characteristics each other for a single material's mould or die. So the bimetal material used in field of hydroforming die or mould is subjected to the rigorous working environment on the hydroforming process [1].

Currently, overlay welding technique is a simple, effective and economic method to be used to repair the mould or die usually. Recently, the overlay welding technique is considered as an advanced method for manufacturing the bimetal mould or die to improve inner mechanical properties and surface wear resistance [2]. The GMA Welding with a longitudinal electromagnetic field (LMF-GMAW) is one of new modern overlaying welding technique, which is of a low cost and high performance to manufacture the bimetal hydroforming die or mould for a long lifetime [3]. The LMF-GMAW technique can bring into play the different kind of materials' good property. In recent years, the electromagnetic stirring (EMS) process has found a wide application in metal processing for the benefit of obtaining refined solidification microstructures [4]. However, there is still a lack of practical detailed understanding of mechanical property of bimetal hydroforming die or mould about the LMF-GMAW workpieces [5].

In this paper, the aim is to fabricate functionally gradient material or gradient surfacing layer of bimetal hydroforming die or mould by LMF-GMAW. The microstructure of workpieces is analyzed by means of scanning electron microscope (SEM). The wear-resistance characteristics of the surfacing layer of the functionally gradient material is evaluated by using a MRH-3 high speed ring-block abrasion tester. Thermal physical simulation testing is carried out by GLEEBLE1500D thermal-force simulation machine. The effects of LMF on the microstructure and mechanical properties of the specimens are also discussed.

II. EXPERIMENTAL PROCEDURES

A. Material

In this experiment, the base metal is a 45# low carbon steel (Fe-Mn-Si series) with a dimension of 40mm×20mm×8mm. The wires are the Cr-Ni-Mo series and Cr-Mo-W-Nb series material with a diameter of 1.2mm, which is used in the transition layer and surface layer respectively.

B. Equipment and Parameters

The experiment equipment is EWM-PHOENIX300 type welding machine which equipped with a special additional field hybrid welding system. The welding system can provide a variable polarity pulse alternating electromagnetic field. The welding system can be used to EMS and EM treatment process, the basic principle of LMF-GMAW welding system is schematically shown in Fig. 1.

In this paper, the welding current is 200A, magnetic field frequency is 8Hz, magnetic field intensity is 0.04T, welding speed is 0.4 m/min and preheating temperature is 200℃.

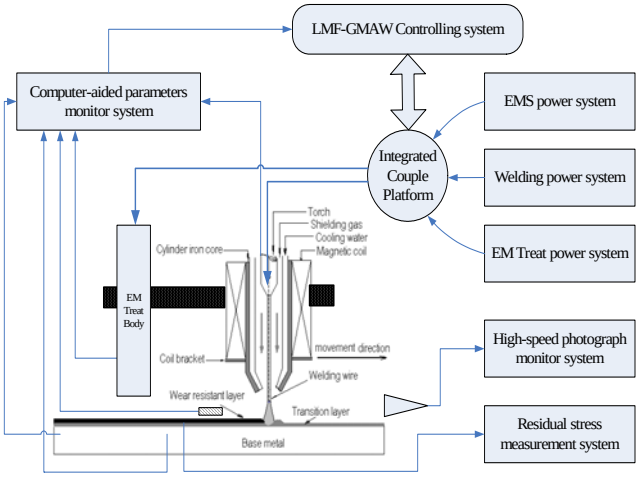
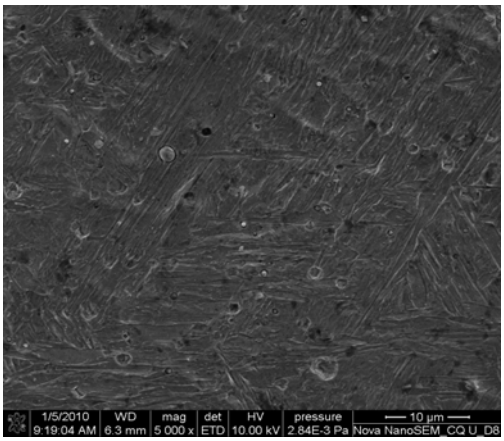


Fig. 1 Principle of LMF-GMAW welding system.

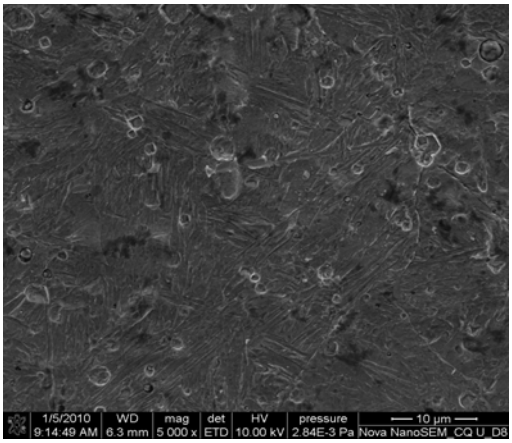
III. RESULTS AND DISCUSSION

A. Microstructure

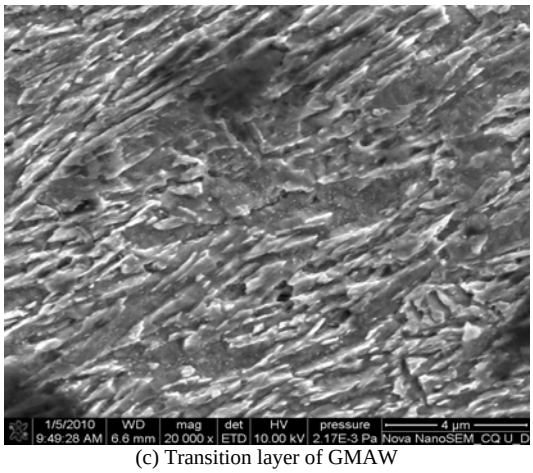
The microstructure of the overlay welding workpieces by the GMAW and LMF-GMAW are shown in the Fig. 2 respectively. The Fig. 2(a) and Fig. 2(b) present the microstructure image of the surface layer. There have some hardness phase particles distributed in the base phase matrix. The hardness phase particles make great contributions to the surface hardness and wear resistance of the overlay welding hydroforming die or mould's workpieces. It can be observed that the second phase particle of LMF-GMAW has more obvious dispersed and uniform distribution than that of GMAW. Compared with Fig. 2(c) and Fig. 2(d), the microstructure of transition layer of GMAW is of more strong directional growth of grain than that of LMF-GMAW. The grain size of LMF-GMAW is finer than that of GMAW, because the electromagnetic stirring plays broken dendrite role in welding pool when solidification is beginning.



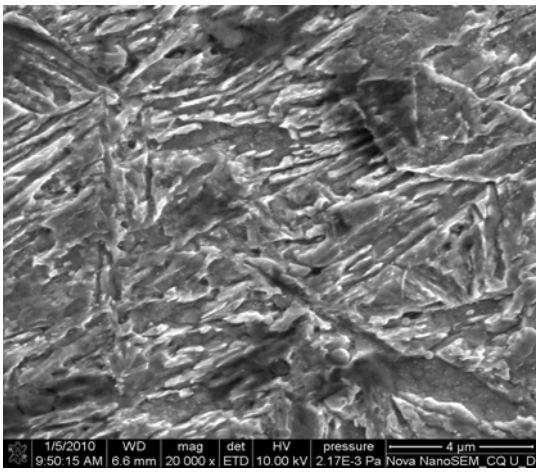
(a) Surface layer of GMAW



(b) Surface layer of LMF-GMAW



(c) Transition layer of GMAW



(d) Transition layer of LMF-GMAW

Fig.2 Microstructure of the overlay welding workpieces.

B. Thermal Mechanical Property

The thermal compression experiment is used to evaluate to thermal mechanical property of hydroforming die or mould's workpieces, the true stress- strain curves of overlay welding workpieces on the condition of 600℃ with a 70% deformation ratio and 5s-1deformation rate is shown in Fig. 3.

The thermal mechanical property shows the deformation resistance of LMF-GMAW overlaying

specimen is higher than that of GMAW overlaying specimen. The average difference value of stress is above 400MPa between the LMF-GMAW specimen and GMAW specimen at 600 ℃ deformation temperature. The deformation resistance of LMF-GMAW specimen is stronger than that of GMAW.

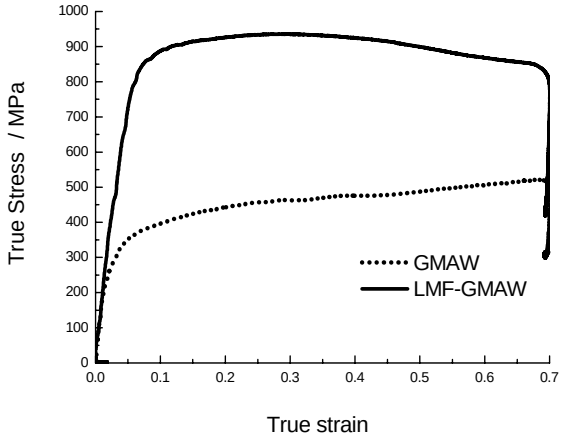


Fig. 3 True stress- strain curves of specimen.

After thermal compression experiment, the GMAW specimen is crack and the LMF-GMAW specimen keeps a complete shape shown in Fig. 4.

(a) Transition layer of LMF-GMAW

(b) Transition layer of LMF-GMAW

Fig. 4 The deformation of specimen.

C. Hardness and Friction Loss

The average hardness value of transition layer and surface in LMF-GMAW workpieces is 30.4 HRC and 62.7 HRC respectively. The average hardness value of transition layer and surface in GMAW workpieces is 35.6 HRC and 61.8 HRC respectively. The average friction loss of GMAW and LMF-GMAW workpieces is 0.433g and 0.387g respectively. So the transition layer hardness of LMF-GMAW is less than that of GMAW, but the surface layer hardness of LMF-GMAW is more than that of GMAW. It can be observed that hardness of LMF-GMAW specimen increases continuously and smoothly from base metal to surface, so this kind of hardness distribution of LMF-GMAW specimen has special advantages for high wear resistance. The friction loss result of specimen is also consistent with the hardness distribution characteristic.

IV. CONCLUSION

The additional field hybrid GMAW overlay welding can improve both surface wear resistance and inner ductile plasticity of bimetal specimens for manufacturing hydroforming die or mould. The microstructures are affected completely by the additional field, such as refined grain and uniform distribution of second particles, which contributed to the long lifetime of bimetal hydroforming die.

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REFERENCES

[1] J Luo, Q Luo, XJ Wang, XC Wang, "EMS-CO_2 welding: a new approach to improve droplet transfer characteristics and welding formation", *Materials and Manufacturing Processes*, 25 (2010): 1233-1241.

[2] Guoji Zhao, Qian Luo, Xiangjie Wang, Jian Luo, "Numerical simulation and experimental research on MAG surfacing deposited with electro-magnetic stirring controlling", *Advanced Materials Research*, 102-104 (2010):407-411.

[3] Luo J, "A new mixed-integrated approach to control and improved welded quality or surfacing layer property in three gas shield arc welding processes", *Journal of Advanced Manufacturing Systems*, 7(2008): 167-170.

[4] Luo J, Luo Q, Lin YH, Xue J, "A new approach for fluid flow model in gas tungsten arc weld pool using longitudinal electromagnetic control", *Welding Journal*, 82 (2003): 202s-206s.

[5] Luo J, Lin Y, Luo Q, Wu Y, "New structure of automatic torch and new approach for controlling drop transfer in rotating spray welding arc", *Science and Technology of Welding and Joining*, 9 (2004): 465-469.

[6] Jian luo, Xiaoming Wang, Dejia Liu, "Weld pool formation and flowing behaviors of aluminum alloy during TIG welding process with a longitudinal electromagnetic field". *Quarterly Journal of The Japan Welding Society*, 29(2011):71s-75s.