Robotic GMAW forming remanufacturing technology

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Abstract Robotic GMAW forming process with the advantages of high productivity and high bond strength has become an important forming remanufacturing technology. In this paper, our recent research achievements are introduced and our development prospect on robotic GMAW forming remanufacturing is declared.

Keywords Remanufacturing · GMAW forming · Robot

1 Introduction

Remanufacturing engineering in according with energy-saving, emission-reduction, sustainable development national policies, as a new industry [1], is being vigorously developed, and written to state law “Circular Economy Promotion Law of the People’s Republic of China” [2]. The remanufacturing forming technology which is based on disperse/stack principle is different from traditional direct rapid prototyping technology. It takes the worn part as foundation to restore the shape, dimension and performance of the original product [3]. While the direct rapid prototyping technology produces the whole part by the way of stacking [4, 5]. Welding process with the advantages of high productivity and high bond strength has become an important forming remanufacturing technology. Furthermore, forming remanufacturing technology based on robotic GMAW surfacing which meets the increasing demands of automation,

intelligence and easily controlling prototyping has attracted increasing attention recently.

Comparing the defective model of the part which is gained by reversing engineering technology with the normal model of metal part, the remanufacturing model is acquired, then the forming remanufacturing is implemented combined with GMAW welding process. Apparently, it will be an important way for part remanufacturing.

In this paper, our recent research achievements and our prospect on robotic GMAW forming remanufacturing technology are introduced.

2 Our recent research achievement

2.1 Rapid remanufacturing forming system exploitation based on robotic GMAW surfacing

National Key Laboratory for Remanufacturing has developed a rapid remanufacturing forming technology based on robotic GMAW surfacing to remanufacture damaged metal parts. The work principle of the rapid remanufacturing forming technology is shown in Fig. 1 [6].

The part to remanufacture is pretreated firstly. Then, the remanufacturing model is obtained by comparing damaged model with standard CAD model of part. Furthermore, the remanufacturing forming path plan is performed and finally the rapid remanufacturing forming is carried out by GMAW surfacing process.

Figure 2 is the rapid remanufacturing forming system based on robotic GMAW surfacing. The rapid forming remanufacturing system consists of four parts, the robotic system as implementing machine, a three-dimensional laser scanner as reversing system, GMAW surfacing deposition system and central control system [7].

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Fig. 1 System work principle

Fig. 2 System structure sketch map

It strives to integrate the robotic technique, reversing measurement technique and rapid prototyping technique on a robot so as to possess a lot of merits such as high measurement precision, rapid prototyping, high intelligence and large application area.

2.2 Non-contact scanning and data processing technology of damaged parts

Our main research achievements include central line pick-up arithmetic of laser light, calibration of the scanning system [8–10], obtaining and pretreatment of measure data [11], curved face restructuring of damaged parts, remanufacturing model of part, remanufacturing forming path plan of damaged parts [12], slicing method in remanufacturing forming technology [13], etc.

Central line pick-up arithmetic of laser light increases the accuracy of scanning light beam. Calibration of

(a)

(b)

Fig. 3 Metallurgical structure of two kinds of intensivism materials. **a** Metallurgical structure of strong-tough type weld sample. **b** Metallurgical structure of wearable type weld sample

scanning system including scanner calibration, positioner calibration and error compensation of repeat snatching at scanner improves the position accuracy of scanning process. Obtaining and pretreatment of measure data involving in Gauss smoothness, interactive removing noise and data reduction increase data processing efficiency. ICP arithmetic based on characteristic point performs more efficiently than traditional ICP arithmetic in data calculation. The threshold value method is used for remanufacturing forming path plan, which improves the efficiency of path plan greatly. In a word, these research efforts increase data processing efficiency and accuracy for remanufacturing forming.

2.3 Materials for remanufacturing based on intensivism design [14]

For acquiring the excellent comprehensive functional parts, the concept and realization of intensivism design for

forming materials were brought forward. The strong-tough type and the wearable type metal cored wires are developed to form the heart department and the working surface respectively, which is aimed to acquire the parts with high intensity, high toughness and high wear-resisting property without heat treatments. Figure 3 is metallurgical structure of two kinds of intensivism materials.

2.4 Shape control research of GMAW surfacing remanufacturing forming [15]

In this part, the deformation mechanism of GMAW surfacing remanufacturing forming is disclosed and a GMAW surfacing/CNC milling hybrid process is developed. Deformation mechanism of parts by GMAW surfacing

Fig. 4 Numerical simulation of the remanufacturing forming part. **a** Finite element model. **b** Temperature field. **c** Deformation field

Fig. 5 Remanufacturing net forming process of damaged typical part

remanufacturing forming technology is that the temperature field in GMAW surfacing remanufacturing forming is non-uniform, which results in non-uniform stress, and the stress induces deformation. Figure 4 is numerical simulation of the remanufacturing forming part.

For the sake of ensuring remanufacturing part precision, a combination of additive and subtractive technique is used to accomplish the deposition and the machining processes in the same setup. Figure 5 shows the remanufacturing net forming process of damaged typical parts by GMAW surfacing/CNC milling hybrid process.

3 Our work prospect

Robotic GMAW forming remanufacturing technology with many merits such as high efficiency, low cost and good quality of remanufactured products will become an important remanufacturing technology and will be applied to some weight load fields such as construction machinery, automobile, and shipping. While robotic GMAW forming remanufacturing technology needs develop in four aspects, including material, system, precision and performance. As regards with material, at present, robotic GMAW forming remanufacturing technology mainly faces to steel material. In the future, it will extend to some light metal material such as aluminium, titanium. Next step development direction of the forming remanufacturing system is automation, intelligence, digitalization and flexibility, which will control shape and performance more precisely.

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