Preliminary Design on Automatic Production Line of High-frequency Induction Welding Light Gauge H-beam

Donglin Li
School of Mechanical Engineering, Hubei Univ. of Technology, Wuhan 430068, China

Abstract: *The automatic production line of high-frequency induction welding H-beam is preliminarily designed, which is applied to produce the H-beam of the web plate with the height less than 100mm. In the first place, the technological process for the whole production line is framed based on the principle of the HF induction welding. Subsequently, the scheme design is conducted by dividing the production line into pre-welding processing, HF induction welding and post-welding processing. Finally, the software SolidWorks is applied to design the virtual prototype which consists of the feature modeling of the parts and the virtual assembly of the machine, and carry out the motion simulation in order to check the interference and movement coordination of mechanisms. process provides an effective basis and good guidance for the succeeding design of the production line.*

Keywords: *High-frequency (HF) induction welding H-beam Quality control Web plate Wing plate Virtual prototype*

1.Introduction

With the rapid development of steel structure, the demand for H-beam is growing, especially for the HF induction welding H-beam of the web plate with the height less than 100mm which is now being widely applied because of its economic and rational cross-section and its highly accurate size in the construction, bridges, machinery, shipbuilding, light industry and other industries. The small size of the cross-section of this type of HF welding H-beam, however, usually leads to series of problems such as difficulties in adjusting the welding contact and controlling the welding quality as well as the large welding deformation[1,2]. So the automated production line technology for this specification has always remained the focus of the research and development at home and abroad.

This paper will probe into the preliminary design of automatic production line of high-frequency induction welding H-beam of the web plate with the height less than 100mm. In the first place, the technological process for the whole production line is framed based on the principle of the HF induction welding. And then, the scheme design is conducted with the view of improving the welding quality. Finally, the software SolidWorks is applied to design the virtual prototype of the whole production line and carry out the motion simulation, calculate out the smallest traction of the automatic production line. This process provides important data reference for the practical design.

2.The Method of HF Induction Welding H-Beam

HF induction welding is the welding achieved by rapidly heating the steel through the use of skin and proximity effects of the HF current. When welding the H-beam, first of all, the upper and lower wings will form a V-angle[3,4]. And then, supply power to the wings and the web through electrode to form the back-and-forth loops and liquid beam at the joining point. With the forward movements of the work piece, the beam will continuously extrude the liquid metal and oxide from the edge under the compression of the rolling. The remaining metal will keep in close contact with each other, producing plastic deformation and re-crystallization and resulting in the solid welding line. HF induction welding method of the H-beam diagram is shown in Figure 1.

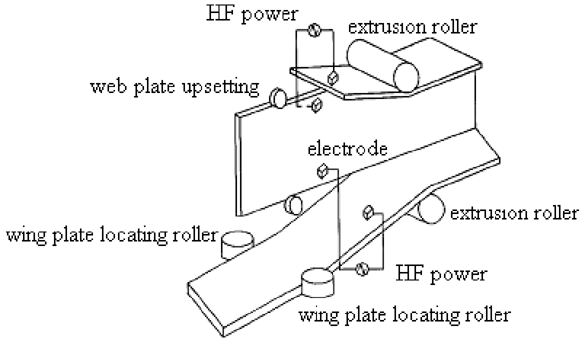

Fig.1 The schematic diagram of HF induction welding method

3.The Technological Process

The technological process of the entire automatic production lines is shown in Figure 2. Production line machines include the flattening machine, angle-controlled machine, HF induction welding machine, deburring machine, correcting machine, traction engine and others, totaling to 28 sets of unit constructions. By the application of these unit constructions, many functions such as sheet flattening, upsetting web plate, HF welding, deburring, post-welding cooling, profiles correcting are expected to be achieved.

4.The Scheme Design of The Production Line

In order to effectively control the product quality, the design of the entire production line divides into pre-welding processing, HF induction welding, post-welding processing.

4.1 Pre-welding Processing

4.1.1 Loading Material, Decoiling and Clipping

The raw materials of HF induction welding light gauge H-beam are hot-rolled strip steel coil[5], so the equipment on the production line in the first place is the loading and decoiling machine of strip steel. The decoiled strip steel will then enter into the process of clipping during which the strip steel will undergo cutting according to the required size for wings and web plate.

4.1.2 Loop Storage, Cutting and Butt-welding

For uninterrupted production, loops and the equipment of cutting and butt-welding are required on the production line. Loops are used to store strip steel, the equipment of cutting and butt-welding to cut the ends of the strip steel. And then the two volumes of steel will be welded together smoothly, in order to ensure the non-stop production.

4.1.3 Sheet Flattening

The decoiled strip steel usually has certain deficiencies such as buckling, bending arc, wave shape and so on. Therefore, the sheet flattening is very necessary. Flattening is being carried out on the roll flattening machine equipped with the interlaced top and bottom working rollers. During the process of flattening, the clearance between the top and bottom working rollers should be adjusted a little less than the thickness of the steel plate being flattened. In addition, the intake side must be ensured to undergo complete plastic deformation, and the delivery side must undergo complete elastic deformation. The steel will undergo a couple of times of forward and backward alternating bending and finally become flat and smooth.

4.1.4 Upsetting of the Web Plate

Relying on the self-melting welding, the deposition rate of the HF induction welding H-beam can only reach 85 %～90 %, and the width of the weld seam can only be the 85% of the web plate. The strength of the weld seam cannot exceed the strength of the base metal. In order to expand the width of the weld seam equal to the width of the web plate, it is necessary to upset both sides of the web plate by the use of rolling mill before welding in order to expand the area of the ends by 30%. By the use of the U-shaped groove within the rollers, the rolling mill upsets the web plate through the extruding force produced from between the top and bottom rollers.

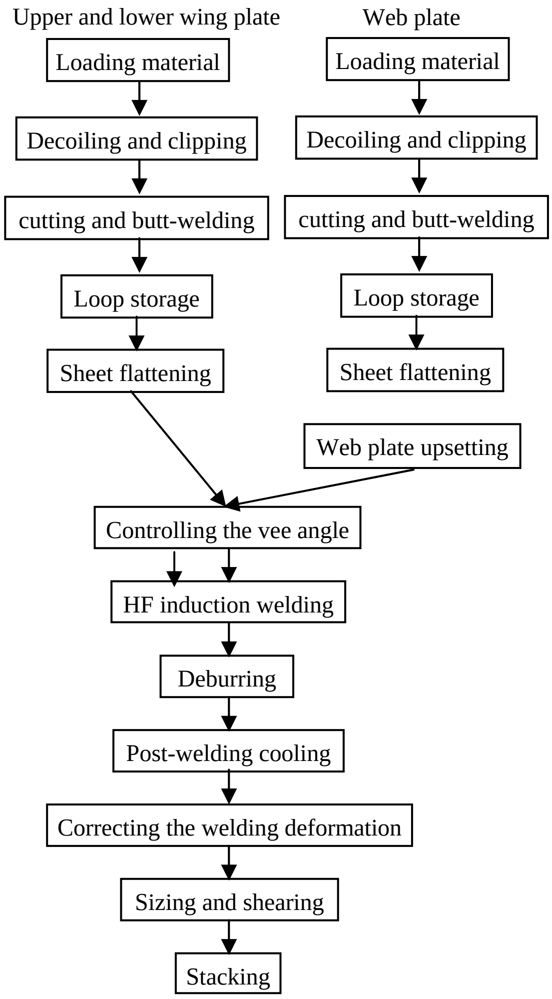

Fig.2 The technological process

4.2. HF Induction Welding

4.2.1 Control of the Vee Angle

In order to make an effective use of the skin and proximity effects of the HF current, it is required to set an angle control machine in the front of a HF induction welding machine to form a vee angle by the upper and lower wings and web plate. The most crucial point in the design of the angle control machine is to control the size of the angle because the size has a large impact on the stability of the HF flashing process and the welding quality as well as the welding efficiency. In many cases, the vee angle is required to be less 10°. The size of the vee angle needs the succeeding study.

4.2.2 The Best Location of the Welding Contactor

During the process of welding, the two contactors respectively belonging to the upper and lower HF induction welding machine heat the web plate and wings separately, as shown in Figure 1. The position of the contactors determines the length of the heating period, and produces a large impact on the temperature field and stress field of the H-beam. In order to raise the efficiency of welding, contactors should be located close to the squeeze roller as much as possible. But as for the H-beam of the web plate with the height less than 100mm, the design and location of welding contactor have always remained a difficulty due to the limitation of spacing between the web plates.

4.2.3 Extrusion between the Welded Joints

Since welding is completed under the extrusion pressure when the sheet material is heated up to the fusing temperature, it is required to set up a squeeze roller above the wings where the sheet material is welded. Extrusion force has a strong impact on the quality of the weld seam. In production, the extrusion force is replaced by the extrusion quantity of the plates for welding which is adjusted and measured by alternating the gap of the squeeze rollers. On the premise of the welding quality to be guaranteed, the extrusion quantity should be reduced as much as possible in order to reduce the metal consumption.

4.3 Post-welding Processing

4.3.1 Deburring

It is inevitable to produce the unevenly scars in the four weld seams. Deburring is a requirement because the weld scars not merely influence the appearance of the weldment, but also leads to the uneven scatter of the stress in the weld seam. Two sets of deburring machine are arranged in symmetry on the production line, with a milling cutter and planning tool loaded respectively on each of the deburring machine. The first step is to mill the two weld seams in order to get rid of some larger scars. And then, some minor welding scars and burr after milling will be removed by the use of planning tool. In this way, the four weld seams will become even and smooth, which improves the quality of the H-beam’s appearance to a large extent.

4.3.2 Post-Welding Cooling

Post-welding cooling is not only for decreasing temperature before correcting profiles, but also for the consideration of the changes in the structure property of the weld seams and the production of the residual stress. The post-welding processing of the HF induction welding H-beam generally adopts the normal water-cooling, with the control of the cooling rate and cooling temperature at the ordinary level. In order to produce the high quality H-beam, our design adopts the air-cooling craft. During the process of water-cooling, we increase the spray equipment and lengthen the period of air-cooling properly.

4.3.3 Correcting Profiles

Due to the uneven scatter of the temperature field, the steel in the post-welding will endure large deformation, especially regarding the light gauge H-beam, the condition is even worsening. Failure in the control and correction of the deformation will have a direct impact on the erection and connection, operational life span as well as its bearing capacity. The welding deformation of the H-beam lies mainly in the deformation of the angle of the wing plate. This condition requires the symmetric arrangement of two sets of correction machine on the production line. Each correction machine presses both sides of the wings through two sets of upper and lower rollers with conicity in order to produce the plastic deformation of the reversed direction during the process of continuous feed-in, completing the continuous correction of the H-beam steel wing plates.

4.4 Design of the Traction machine

The traction machine is the main driving force on the production line because it mainly depends on the traction force of the traction machine to facilitate the whole continuous and stable process from flattening, upsetting, vee angle controlling, to HF induction welding, deburring, correction and so on. In the production line are set up many direct-current and adjustable speed traction machine, which, using the principle of loops control, through the differential speed and the swing of loops, conducts the micro tension control over the steel material and then facilitate the smooth going of the whole process, providing guarantee to the welding quality, size and shape tolerance of the H-beam.

5.Design of the Virtual Prototype

After determining the technological process and the design scheme of the production line, we take advantage of the software SolidWorks' strong three-dimensional modeling function to carry out the virtual prototype of the production line, and conduct the motion simulation to test and verity the coordination of the movements of all the separate parts[6,7], providing the important design parameters for the concrete design of the framework.

5.1 Modeling of the Parts' Parametric Features

The design of the parts by the SolidWorks mainly depends on the basic operations such as drawing, rotation, scanning and so on to set up the three-dimensional solid model. As for the complicated parts, it is essential to choose correct way to generate because the incorrect choices are not only inefficient, but also cannot generate solid model at all in certain cases.

Take the modeling of the deburring machine as an example, due to its symmetric structure, half of the model can be built at first, and then another half can be completed through mirror. When constructing the half modeling, first, choose the sketch plane to enter the sketch mode and draw out the sketch of the framework. Then, generate the three-dimensional solid entities using the drawing method. The completed framework model of the deburring machine is shown in Figure 3.

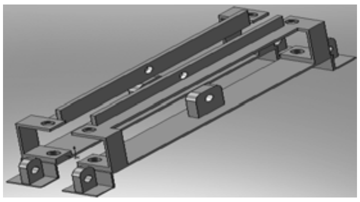

Fig.3 The framework model of the deburring machine

5.2 Virtual Assembly

After modeling the three-dimensional solid entities of the separate part, the virtual assembly is required for each of these parts. In the assembly module of the SolidWorks, it is workable to assemble these separate three-dimensional solid entities into a working machine, and check whether or not there is interference between different parts and whether or not the assembling entities move according to the requirements of design[8,9].

Take the deburring machine as an example, first, insert the machine framework which the system defaults as a built-in fitment. Then, insert the model of other parts and choose the location of each separate part. Finally, select appropriate assembly constraint types to complete the location of the parts model. The deburring machine model after virtual assembly is shown in Figure 4 (In order to achieve the true-to-life visual effect, H-beam is fitted together into the deburring machine).

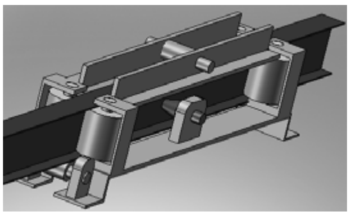

Fig.4 The assembling model of the deburring machine

5.3 The Motion Simulation of the Machine

This paper chooses the COSMOS Motion in SolidWorks to carry out motion simulation. Before simulation, it is necessary to enter the assembly environment to input some necessary parameters beforehand in order to confirm the moving parts, the fixing parts, the kinematics pair, and install the motion environment and simulation options.

The motion simulation of the deburring machine is shown in Figure 5. The highlighted parts shown in the picture are the kinematics pair between different machines. According to the requirements of the H-beam production line, with the given horizontal velocity, certain parameters such as the mean momentum and the average torque and others will be attained after the automated simulation calculation.

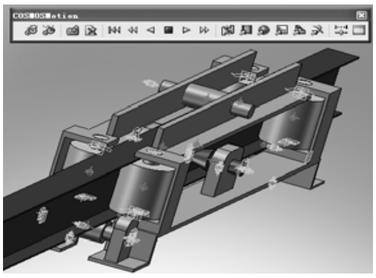

Fig.5 The motion simulation of the deburring machine

5.4 The Motion Simulation of the Production Line

In order to get a clearer and more direct-viewing glimpse of the whole production motion process, we carry out the motion simulation to the entire production line. Considering the fact that the entire production line is too bulky for the software to conduct a one-off calculation, we divide the production line into two stages: the pre-welded process of the HF induction welding which consists of the sheet material flattening machine, web plate upsetting machine and the angle control machine; the post-welding process of the HF induction welding which consists of the deburring machine and the correction machine.

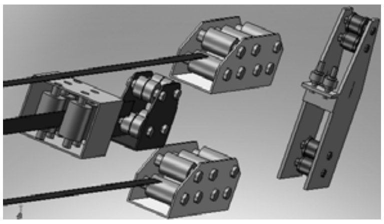

Fig.6 The simulation model of the pre-welding processing.

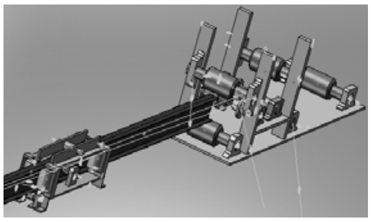

Fig.7 The simulation model of the post-welding processing.

The simulation steps for the entire production line are almost the same as that of the single machine. The simulation model of the pre-welding processing is shown in Figure 6. The simulation model of the post-welding processing is shown in Figure 7. After the process of simulation, the momentum and the torque of each moving parts can be accessible from the data-process module. For example, if the given horizontal velocity of the H-beam is 30m/min, the average traction torque of the H-beam will be 450Nm based on the calculated mean momentum and average torque.

6.Conclusion

The automatic production line of the HF induction welding H-beam has the advantage of high productive efficiency, stable quality and the convenience to alternate the varieties and specifications and so on. This paper has delved into the preliminary design of automatic production line of HF induction welding H-beam with the web plate's height less than 100mm. In the first place, the technological process of the production system is framed based on the principle of HF induction welding. Subsequently, the scheme design is conducted with the view of improving the welding quality. Finally, the software SolidWorks is applied to design the virtual prototype of the whole production line and carry out the motion simulation. All the preliminary design will provide a significant guidance for the succeeding engineering design in practice.

How to promote the welding quality and control deformation, however, still remains the largest problem in the automatic production line of HF induction welding light gauge H-beam. In this paper, such measures as steel material flattening, web plate upsetting, profiles correcting are adopted to guarantee the quality; nevertheless, the best location of the welding contactor and the size of the welding vee angle still remain the focus of the succeeding research and design.

7.Acknowledgements

The Emphasis Scientific and Technological Key Project of Wu Han City fund the project. (Contract No. 030877).

References

[1] Scott P. F. and Smith W. “A study of the key parameters of high frequency welding”. Tube China ’95. (1995) 161-181.

[2] Scott P. F. “The effects of frequency in high frequency welding”. Transactions of Tube 2000 Toronto, ITA Conference. (2000) 74-80.

[3] Asperheim J. I., Markegaard L., Induksjon E. and Lombard P. “Temperature distribution in the weld vee cross section”. Tube International. 17(70) (1998) 563-567.

[4] Asperheim J. I. and Grande B. “Temperature evaluation of weld vee geometry and performance”. Tube International. 19(110) (2000) 497-502.

[5] Wesling V., Schram A. and Rekersdrees T. “High-frequency welding of martensitic hot-rolled strip”. Welding Research Abroad. (1998) 145-162.

[6] Mao-Peng Chen and Wei-Fang. “Automatic modeling for modular fixture components based on SolidWorks”. Journal of South China University of Technology (Natural Science). (2005) 56-59.

[7] C.K.Chua, S.H.Teh and R.K.L.Gay. “Rapid prototyping versus virtual prototyping in product design and manufacturing”. The international journal of advanced manufacturing technology. 7(1999) 597-603.

[8] Yang Fuqin, Chang Degong and Wang Xianlun. “Dynamic simulation of the tripod sliding universal joint based on virtual prototype”. 2008 Asia Simulation Conference - 7th International Conference on System Simulation and Scientific Computing, ICSC 2008. (2008) 711-714.

[9] Li Feng, Li Shuguang, Zheng Lei and Lou Li. “Dynamic virtual prototype of soldier system”. Proceedings of the 27th Chinese Control Conference. (2008) 329-333.