

## STUDY ON DEVELOPMENT OF AN AUTOMATIC MARKING ROBOT

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**ABSTRACT:** *This paper studies on development of an automatic marking robot. To welding the “Draft Mark” for a ship, an automatic welding system, called automatic marking robot, is developed. Software and hardware of the system are designed for this purpose. Experiment has been done to verify the proposed solution.*

## 1. INTRODUCTION

Outside of the ship there are some kinds of mark used to describe some properties of the ship, such as: name of ship, port of registry, draft mark, ... as shown in Fig.1. In ship building manufacturers, this work has been done by skill welders. However, manual work welding is poor work surroundings and time-consuming. To overcome these disadvantages, some researchers focus to design an auto welding robot which can carry out the task with high speed and accuracy degree. S.W. Ryu et al.<sup>[1]</sup> in Samsung Heavy Industry had developed SR-MARK robots to weld draft mark automatically. There are two kinds of SR-MARK robot: SR-MARK I uses for welding draft mark on the flat surface and SR-MARK II uses for welding draft mark on the curved surface. Both of them have been experimented successfully in laboratory.

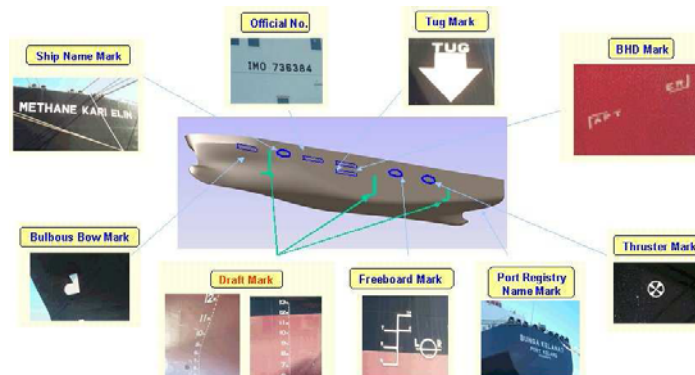


Fig1. Marks outside of the hull<sup>[1]</sup>

In Vietnam, the shipbuilding industry trades and production achievements have increased with the annual growth rate reaching 30 percent. The development target to 2010 is regarding and improving the shipyards in order to have technology equal to the ASEAN shipbuilding industry, while the localization rate of domestically made products will rise to 60-70 percent of the products. (Source: VINASHIN). Therefore, searching and achieving new technology for applying in to shipbuilding industry is very important.

This study includes two steps: the first step aims to solve the problem of automatic welding draft mark in the flat surface; and the second step is to extend the results for general ship hull surface. This paper deals with the first one: CAD interface and robot structure design including hardware and software. The project is going on in Machine Design Laboratory. Experiment had been done and some conclusion remarks base on the results are given.

## 2. LOAD LINE STANDARD IN BRIEF[6]

The purpose of a load line is to ensure that a ship has sufficient freeboard and thus sufficient reserve buoyancy. The freeboard on commercial vessels is measured between the uppermost continuous deck and the waterline and this must not be less than the freeboard marked on the Load Line Certificate issued to that ship.

This symbol, also called an international load line or Plimsoll line, indicates the maximum safe draft, and therefore the minimum freeboard for the vessel in various operating conditions. The original "Plimsoll Mark" was a circle with a horizontal line through it to show the maximum draft that a ship may load to. Additional marks have been added over the years to allow for different densities of water and expected sea conditions.

Letters may also appear to the sides of the mark indicating the classification society that has surveyed the vessel's load line. The initials used include AB for the American Bureau of Shipping, LR for Lloyd's Register, and NV for Det Norske Veritas. These letters should be approximately 115 millimeters in height, 75 millimeters in width and 25 millimeters in thickness.

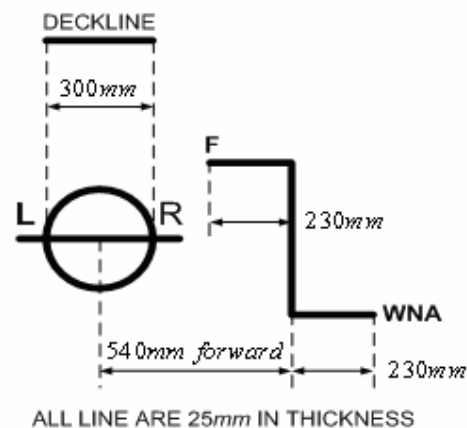


Fig 2. Load line mark and line for commercial sailing vessel

The letters on the Load line marks have the following meanings:

- TF - Tropical Fresh Water
- F - Fresh Water
- T - Tropical Seawater
- S - Summer Seawater
- W - Winter Seawater
- WNA - Winter North Atlantic

## 3. MAJOR PROBLEMS

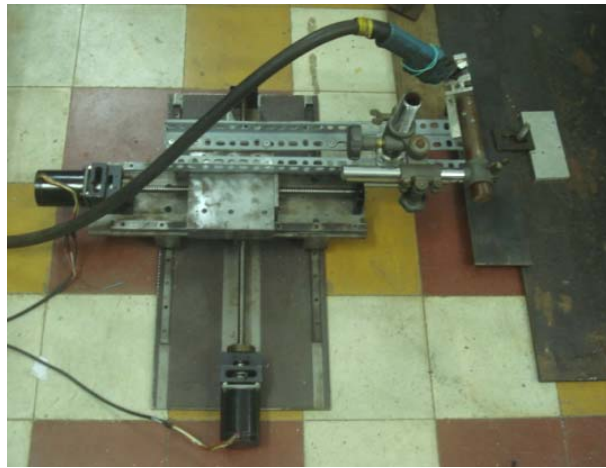
There are two important points which need to be solved. The first one is to track the designed welding line. In this problem we control the movement of welding torch to create a contour which alike as the profile designed by users. The second one is to control of welding speed according to the shape of welding line. To solve this problem is to maintain the width of welding path as constant as possible.

## 4. PROPOSED SOLUTIONS

### 4.1 Hardware design overview

The hardware is design to test the accuracy of the data transmission program and robot tracking control system. The designed robot can move welding torch follows the specified profiles (include lines and circular line) by controlling  $X - Y$  coordinates. With these purpose, the experimental equipment includes two sliding arm for two perpendicular directions which is something similar to 2D table as shown in the Fig.3. One slide uses for  $X$  direction and the other uses for  $Y$  direction. They are driven using 2 step motors. The accuracy degree of the designed model depends on pitch of screws and the revolution of these step motors. This model can perform in size of  $0.8m$  length and  $0.6m$  width. The welding speed is up to  $1m/min$ .

The control system includes a PC-base processor used to generate the Cartesian coordinate due to interpolation algorithm; and a microcontroller used to transmit the data from PC and control the welding motion.



**Fig3.** Experiment setting-up

### 4.2 Data transformation

Currently, many companies use CAD program to design their products. In this study, information from CAD files is used to generate robot welding programs and well-known AutoCAD software is chosen to draws letters which will be welded. General welding line compounds from straight and circular line. Therefore tests with letters and numbers are used. One letter was just in area of  $70 \times 70mm^2$  as shown in Fig.4.

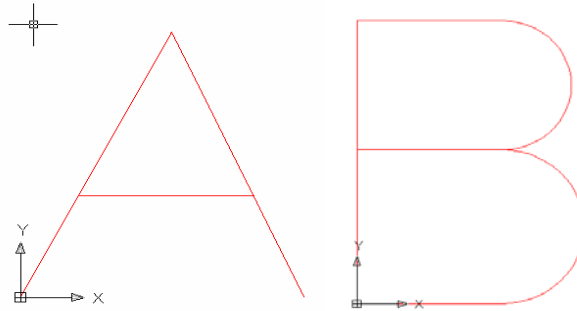


Fig 4. Letter A (only lines) and letter B (lines and arcs) in dwg format

The flow of data is processed as shown in Fig.5.

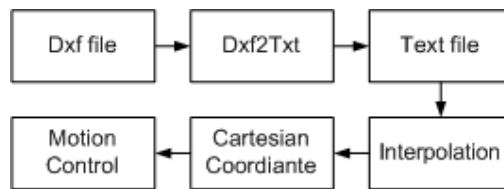


Fig5. The flow of data

AutoCAD software can generate different types of format including the dxf one, an ASCII file. It includes all the information about the drawing such as: start point and end point of line, center point and radius of circular, ... This information can be extracted and saved as text format by a simple application called Dxf2Txt. Therefore a text file can be read and processed easily. It is used to stored position information.

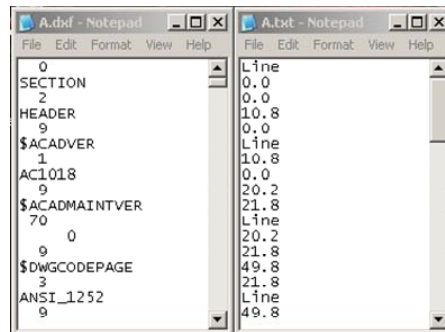


Fig 6. The original file and the coordinate file generated by Dxf2Text application

### 4.3 Interpolation algorithm[6]

As we known, data in txt files just use to define lines or arcs in the drawing and can not be used to control the hardware. To solve this problem, an interpolation program was written. It can read data in files and give all points coordinates in lines or arcs with a pre-identified revolution. This program based on the well-known Bresenham interpolation algorithm.

#### *Interpolating a segment of the straight line*

Consider the simplest line which passes the origin of coordinate and  $(a,b)$  point  $(a > b > 0)$ . This method is called the midpoint interpolation algorithm (Fig.8.a). The equation of the straight line is  $bx - ay = 0$  with  $k$  is the increment of  $(x,y)$  coordinates after each interpolation step. It is also known as the revolution of interpolation. The smaller  $k$  is,

the more points are interpolated and the more accuracy the lines are. The flow chart of straight line interpolation is shown in Fig.7.

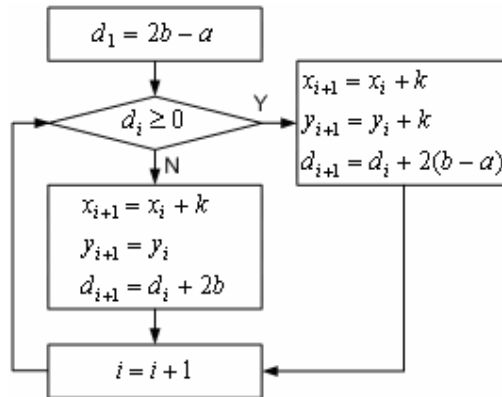


Fig7. The flow chart of straight line interpolation

By exchanging  $x$  and  $y$  coordinate or starting point and ending point, we can transform all lines into the mentioned above form. Therefore, any lines in the coordinate plane can be interpolated using this method.

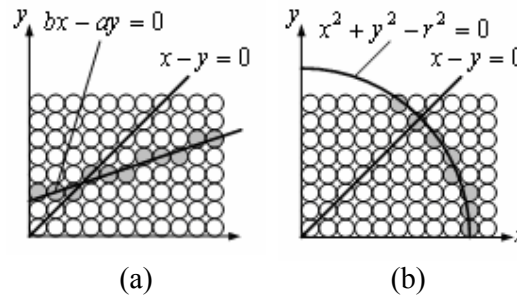


Fig 8. Interpolation algorithm for (a) a straight line, and (b) a circular line

*Interpolating a circular line*

Consider the circular line in the first 1/8 coordinate plane and its center point is the origin (Fig.8.b).

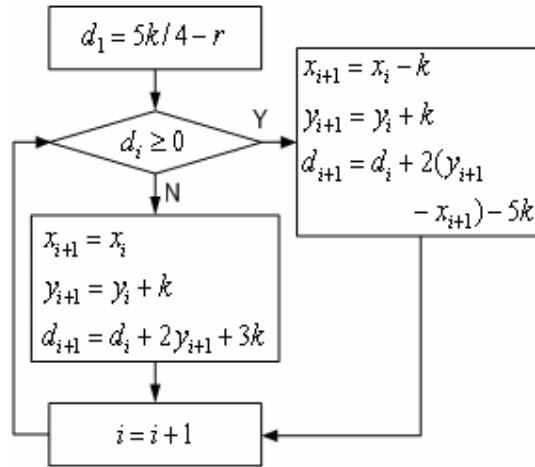


Fig 9. The flow chart of circular arc interpolation

The circle equation is  $x^2 + y^2 - r^2 = 0$ . Following the same steps, we can calculate formulas to interpolate for all circular line in the coordinate plane. The flow chart of circular line interpolation is shown in Fig.8.

*Users interfaced application*

Based on the above algorithm, the interpolation program was written. This application can get the letters which the user wants to weld. Then it reads the appropriate text file and defines the elements of the letter such as the starting point and the ending point of line. After that, program interpolates the letter into an array of points. These points are Cartesian coordinates of  $X$  and  $Y$  axes. From this array, the application redraws the letters will be welded. This function helps users check whether it is working properly.

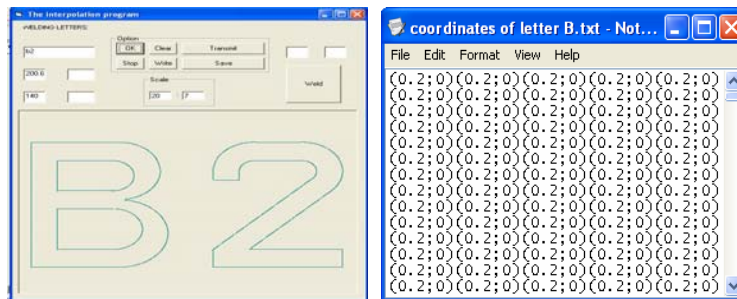


Fig 10. (a) The interpolation program and (b) Result of the interpolation: array of coordinates

**4.4 Data transmission**

The interpolation processing interpolates character into an array of points. The array is stored in specific location in PC. Then the robot controller will be connected to PC to download the appropriate data array. This data transmission program includes the simulation application based on Visual Basic 6.0 and a data line through RS232 serial port. Due to many advantages, I2C protocol is used to connect the microcontroller with external components. This protocol is as simple and high speed as required.

#### 4.5 Motion control

Continuously tracking the designed welding path is very important. The difference between the welding path and the designed path depends on the resolution of Cartesian coordinates of the hardware.

The more accuracy, the better welding path is. After downloaded from PC, coordinate array is stored in random access memory (RAM) of microcontroller. After welding a character, this memory is cleared to wait for the next one.

The size of Cartesian coordinate array depends on interpolative revolution. With high-revolution, this array will exceed the capacity of internal RAM of the microcontroller. In order to balance between the desired preciseness and the storable ability of microcontroller,  $0.05mm$  interpolative resolution is used. So each element of array is an 8-bit signed integer number. By processing this array, the motion control program can define the distance and the direction of the movement. Then it regulates the driven motors following these parameters.

In case of lack RAM due to big size of transmission data, external memory is used. With larger RAM capacity, bigger size letter with higher resolution can be performed.

### 5. EXPERIMENTS AND DISCUSSION

To verify the effectiveness of proposed modeling and controller, experiments have been done. As mentioned above, the resolution of  $0.5mm$  with  $70 \times 70mm^2$  is used for each character. All the parameters of welding process are setup and simulated before running. The current and voltage of welding machine are adjusted depending on the thickness of steel.

Experiment had been done with  $5mm$  thickness flat steel. The welding velocity is set with  $10mm/s$ .

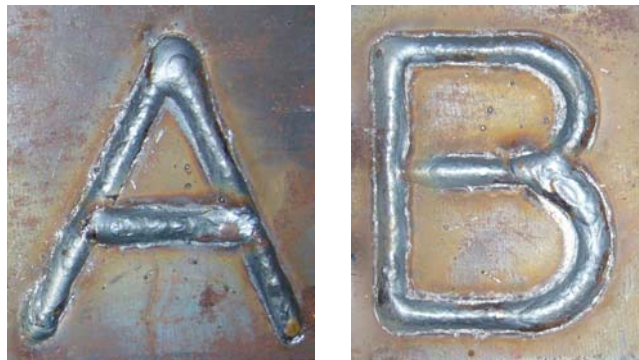


Fig 11. Result of the first welding test

Fig.11 shows the result of welding test. These shapes are same as the character designed. The width of welding path is  $8mm$ . It satisfies the request of welding. The height of character is  $78mm$ .

With intersected-contoured character, the work piece will be overheated and melted. This problem can be solved if the character is designed bigger. Thus, the work piece can avoid being heated at a same position for a long time.

#### *Alternative solution*

As discussing above, heat effect causes the welding path to melt. So, the width of welding path is not maintained constant. It isn't as good as required. With small size letters, this effect shows evidently as Fig.12.



**Fig 12.** Heat effect on welding path

To reduce heat effect, the letters size must be larger. As a result, the Cartesian coordinate array exceeds the capacity of RAM. An external EFROM is used to enlarge the system memory. These letters are designed in  $200 \times 200 \text{mm}^2$  area. This experiment is done with 6mm thickness flat steel and the velocity is  $8 \text{mm/s}$ .



**Fig 13.** Result of the last welding test

These parameters are defined in proper condition and may be changed in other cases.

*Further discussions*

Although heat effect is reduced in the last experiment, the width of welding path is not a constant. To completely solve this problem, we need an auto adaptive system which can adjust welding velocity to compensate the effect of heat.

Moreover, all experiments in this paper are done with flat steel while the surface of ship is curve. We need curve sensor to maintain constant distant along  $Z$  axis. This research will be accomplished in someday.



## 6. CONCLUSION

This paper studies on development of mark welding robot. The robot includes mechanical and control systems determined by many experiments. The control system, which is based on interpolate algorithm to generate Cartesian coordinate array, used to regulate the movement of two directions. The experiments results show that the robot can be used for welding every character having DXF data with high-qualified. In future, it can be developed into upper stage with three-directions welding.

## NGHIÊN CỨU ROBOT HÀN MỨC CHỈ THỊ

**Lê Hồng Loan, Phạm Đăng Khoa, Trần Thiên Phúc, Nguyễn Tấn Tiên**  
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**TÓM TẮT:** Bài báo trình bày các nghiên cứu bước đầu về khả năng thiết kế chế tạo một robot hàn mức chỉ thị ứng dụng trong việc hàn “Draft Mark” cho tàu thủy. Phần cứng và phần mềm cho hệ thống đã được thiết kế nhằm thử nghiệm khả năng này. Các thí nghiệm đã được triển khai trong phòng thí nghiệm để chứng minh mức độ khả thi của phương án đề nghị.

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