

# การพอกผิวแข็งเพลลาใบจักรด้วยกรรมวิธีการเชื่อมซ่อมแบบกึ่งอัตโนมัติ

## Propeller Shafts Hardfacing by Semi-Automation Welding Repair Process

ศิวะ สิทธิพงษ์,<sup>1</sup> ประวิทย์ ไตว์ตนะ,<sup>2</sup> อำนวย สิทธิเจริญชัย,<sup>3</sup> ประภาศ เมืองจันทร์บุรี<sup>4</sup>

Siva Sitthipong,<sup>1</sup> Prawit Towatana,<sup>2</sup> Amnuay Sitticharoenchai,<sup>3</sup> Prapas Muangjunburee<sup>4</sup>

### บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลที่ได้จากการพอกผิวแข็งเพลลาใบจักรด้วยกรรมวิธีการเชื่อมซ่อมแบบกึ่งอัตโนมัติ ซึ่งเพลลาใบจักรที่ทำการศึกษานี้ผลิตจากเหล็กกล้าผสมทนแรงดึงสูงเกรด AISI 4140 ในการเชื่อมพอกเพลลาโลหะแบบกึ่งอัตโนมัตินี้จะเชื่อมพอกในโหมดสเปรย์และทำการทดสอบเพื่อหาค่าความแข็งของผิวเชื่อมพอกตามมาตรฐาน ASTM E384-89 ผลการศึกษาพบว่าค่าความแข็งเฉลี่ยโดยรวมของผิวเชื่อมพอกอยู่ที่ 275 วิกเกอร์ โดยบริเวณที่ได้รับผลกระทบจากความร้อนมีค่าความแข็งเฉลี่ยอยู่ที่ 300 วิกเกอร์ ข้อมูลเบื้องต้นนี้จะถูกนำไปใช้ปรับปรุงพัฒนาหาค่าพารามิเตอร์ที่เหมาะสมเพื่อเพิ่มประสิทธิภาพในการเชื่อมซ่อม

**คำสำคัญ:** การเชื่อมซ่อมแบบกึ่งอัตโนมัติ เหล็กกล้าผสมเกรด AISI 4140 ค่าความแข็ง

### Abstract

This research aims to study the result of propeller shafts Hardfacing by Semi-Automation Welding Repair Process, which was made from AISI 4140 alloy steel. Spray transfer MAG welding process is used for shaft metal spray, and then the weld surface was taken to test the hardness, corresponding to ASTM E384-89. As the result, it is found that the average value of hardness is 275 Vickers, and the heat affected zone has the average hardness value of 300 Vickers. The data will be used for investigating and improving parameters of shaft metal spray, in order to use it more effectively.

**Keywords:** Semi-Automation welding repair process, AISI 4140, hardness properties

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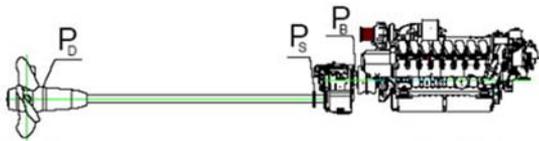
<sup>1</sup> นักศึกษาปริญญาเอก สถาบันทรัพยากรทะเลและชายฝั่ง, <sup>2</sup> รองศาสตราจารย์ สถาบันทรัพยากรทะเลและชายฝั่ง, <sup>3</sup> ผู้ช่วยศาสตราจารย์ สถาบันทรัพยากรทะเลและชายฝั่ง, <sup>4</sup> ผู้ช่วยศาสตราจารย์ ภาควิชาวิศวกรรมเหมืองแร่และวัสดุ มหาวิทยาลัยสงขลานครินทร์ อ.หาดใหญ่ จ.สงขลา 90110,

<sup>1</sup> Doctor Degree Student, Marine and Coastal Resource Institute, <sup>2</sup> Assoc. Prof., Marine and Coastal Resource Institute, <sup>3</sup> Asst. Prof., Marine and Coastal Resource Institute, <sup>4</sup> Asst. Prof., Minerals and Materials Engineering Department, Prince of Songkhla University, Hat Yai, Songkhla 90110, Thailand.

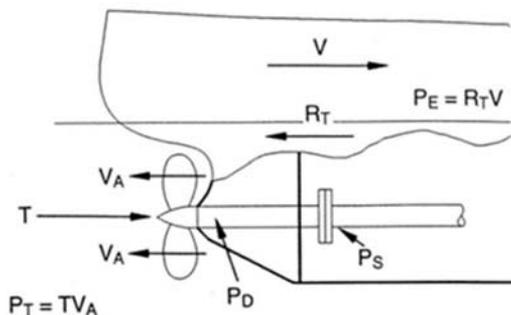
\* Corresponding author: Siva Sitthipong, Marine and Coastal Resource Institute, Prince of Songkhla University, Hat Yai, Songkhla 90110, Thailand.

## Introduction

The drive system of ship has prime mover, gear, shaft, and propeller or propulsor, as the major components <sup>1-3</sup>. For ships with diesel drive system, the details of components are as shown in figure 1. The calculation of a propeller shaft's drive power involves these values: Brake power,  $P_B$  is the drive power at the rear of the engine; Shaft power,  $P_S$  is the drive power from the gear to propeller shaft; and Delivery Power,  $P_D$  is the drive power that has been delivered to the propeller, which needs to be greater than the Resistance,  $R_T$  that occurred at various speed of ship. The delivery power is directly related to the Effective power,  $P_E$  as shown in figure 2, where  $\eta_G = \text{Gear Efficiency, } P_S/P_B$  and  $\eta_S = \text{Shaft Efficiency, } P_D/P_S$ .



**Figure 1** The assembly components in the drive System <sup>3</sup>.



**Figure 2** The relation of drive power <sup>3</sup>.

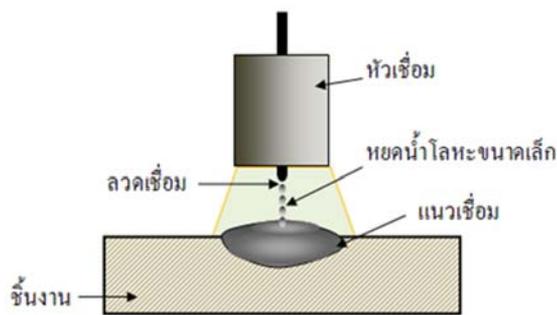
A propeller shaft has a very long length, which it needs bearing to support it continuously, with

periodic spacing. The position that the shaft needs to touch the bearing will have the sleeve to support the propeller shaft. Mostly, the end of a shaft will have the twist to lock the propeller and shaft flanges. The shaft that juts out from the ship will always expose to the sea water, therefore, the protective covering is needed for an alloy steel shaft, in order to prevent the rust formation when sea water reacts with the shaft. Propeller shafts are classified into 2 types, sorted by its characteristics. The first type is called the fixed pitch propeller shaft, which it has the solid shaft all the way through the end. For moving forwards and backwards, the propeller shaft needs to rotate reversely. On the other hand, the controllable pitch propeller shaft has a hollow shaft all the way through the end, which the hollow part inside is the runway of hydraulics oil that controls the pitch of a propeller shaft. It uses the angle adjustment of propeller shaft pitch to move forwards and backwards. Generally, propeller shafts are made from medium carbon steel, as shown in figure 3. It is widely used because of its cheap price and its high strength; however, it is corrosive when exposed to water and air, which will eventually cause rusting. Therefore, this type of shaft needs rubber or plastic covering, to prevent rusting problem. The copper alloys sleeve is put at a position where the shaft touches the bearing, since copper alloys have a high corrosion resistance to the sea water <sup>4,5</sup>.



**Figure 3** Carbon steel propeller shaft <sup>1</sup>.

Propeller shaft and Thordon, while working together, will always generate frictions against each other. Therefore, the wear damage will occur untimely. When the parts failed, it will be repaired by using the spray transfer MAG welding process, as shown in figure 4, which can occurs when the electric current is above 250A and the pressure is between 34-40 Volts. This process is suitable for a very thick shaft. The spray transfer which occurs at the end of a welding rod, which received high temperature, will melt into small particles, spray from the arc to the work piece in the direction where the end of the welding rod pointed to. The size of the alloy particle is equal to or smaller than the diameter of the welding rod slightly <sup>6-15</sup> .



**Figure 4** The spray transfer

## Materials and Methods

### 1. Step of repair maintenance shafts

The wear propeller shaft was taken to the shaft alignment bending machine by aligning both ends, using the surface gauge, to do the preliminary examination, as well as marking the wear position by using chalks or markers. After that, the shaft was put on a lathe machine to get fixed and aligned between the head stock and the tail stock, to prevent itself from swinging out. While lathing, prepare the surface of a workpiece to be on a steady rest, to support the shaft by marking the point, where the spraying will be applied on, with

the line drawing on the wear part at more than 5mm. The turning operation was done to the shaft to reduce its size by 4 mm. Then, the reduced-size shaft got fine threaded, to improve the assembling of metals that meant to be sprayed. After that, a paper or clean cloth was used to wrap the prepared surface of the workpiece, for cleanliness, to spray on easily. The propeller shaft was put on the shaft alignment bending machine again to get sprayed, as shown in figure 5.



**Figure 5** The spray transfer MAG welding process

Before turning on the spray machine, the surface of a workpiece needs to be cleaned by using acetone, then the alignment bending machine can be started to make the surface dry. After drying, the spraying operation and smoke vacuum were started. The head of the spray machine was placed away from the surface of a workpiece by 8 inches. The operation can start either from left hand side or right hand side and the rate of the sprayer head's movement was 0.5 foot per minute. While spraying, it is essential to inspect the smoothness of the surface. If the surface is patchy, due to the incompleteness of burning, the spraying will not attach on the surface of a workpiece. The operation will have to be stopped, and hammer and chisel were used to remove the unmelted particles from the surface of a workpiece. After the unmelted

particles were removed, the spraying operation was continued. It is important to spray the surface larger than the workpiece by 4 mm. After the spraying size was appropriate, the surface smoothness was checked and the outside micrometer was used to measure the surface. A flux stick or a candle was applied on the sprayed area, to cool down the heat and improve bonding between the spray particles and the surface of a workpiece. The alignment bending machine was run for 3-4 hours, to expel the heat. After that shaft has cooled down, it was put on the lathe machine and was turning the sprayed surface to have the same size as the original workpiece. Then, a fine sand cloth with lubricant was used, to smoothen and polished the surface of a workpiece evenly.

## 2. Materials

X111-T5-K4 flux cored wire; the chemical composition is as shown on table 1.

**Table 1** Chemical composition of X111-T5-K4 flux cored wire

Electrode Type	C	Mn
X111-T5-K4 (wg. %)	0.06	1.45

AISI 4140 grade alloy steel; the chemical composition is as shown on table 2.

**Table 2** Chemical composition of AISI 4140 grade

Base Metal	C	M
AISI 4140 Alloy steel (wg. %)	0.40	0.

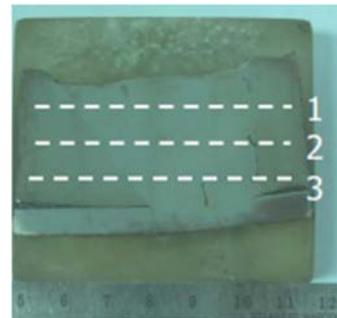
## 3. Microstructure investigation

Cut out 1 cm of workpiece's welded surface, do the resin casting with 5:1 accelerator, wait until the resin dried, then polish with no. 80, 120, 180, 360, 600, 800, and 1200 sand paper, respectively. Use

the ultrasonic wave to clean the workpiece for 5 minutes. Polish the workpiece again by using the woolen fabric with 5 and 1 micron alumina powder, respectively. After that, use the ultrasonic wave to clean the workpiece for 5 minutes again. Etch the surface with the solution of 5 ml Nitric acid and 190 ml water for 10 minutes. Then, rinse off with water and make it dry. The pictures of microstructure were taken by using the optical microscope.

## 4. Hardness test

Cut the workpiece that has been sprayed to test the hardness at a microscopic level, conforming to ASTM E384-89. The hardness values were taken from the base metal, heat affected zone, and weld metal, which were measured on every 0.5 mm in 3 directions, as shown in figure 6.

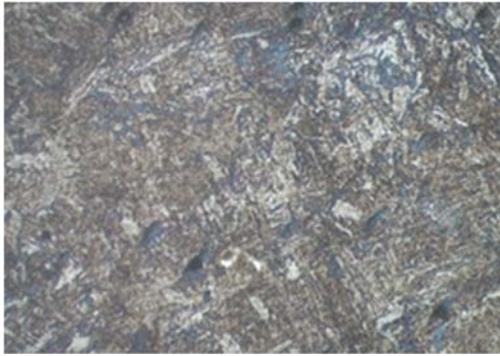


**Figure 6** 3 directions of hardness measurements.

## Results

### 1. Result of investigation on microstructure

The microstructure at the heat affected zone which was expanded 50 times is shown in figure 7, and the microstructure at the sprayed surface which was expanded 20 times is shown in figure 8.



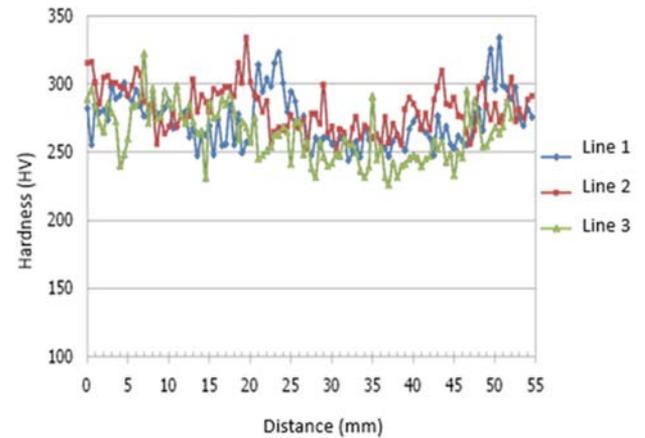
**Figure 7** The microstructure at the heat affected zone which was expanded 50 times.



**Figure 8** The microstructure at the sprayed surface which was expanded 20 times.

## 2. Result of hardness test

As a result of welding process, the heat affected zone has a different hardness value from the base metal. The hardness test starts from the base metal, to the heat affected zone, and then to the weld metal, by using the spray transfer MAG welding process. At 0-5 mm and 50-55 mm is the base metal, where the hardness value is the same as the original shaft because it is not affected by the heat. At 5-20 mm and 35-50 mm is the heat affected zone. On the other hand, the weld metal at 20-35 mm has the varied hardness values, as shown in figure 9.



**Figure 9** Hardness values of the shaft at the weld metal, heat affected zone, and base metal.

## Discussions

From the obtained experimental data, it can be seen that the use of x111-T5-K4 electrode is appropriate for metal spraying AISI 4140 shaft, since the sprayed surface has similar hardness value to the base metal. In addition, it is found that the microstructure at the sprayed area has the spiky weaving ferrite structure, which promotes the high strength at the welded level. From the above data, it can be concluded that the x111-T5-K4 electrode<sup>16-17</sup> can be used for metal spraying the propeller shaft, to prolong its service life.

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