Fatigue Life Assessment of Weld Surfacing of LB-52 Solid Wire on SCM 440 Alloys Steel Propeller Shafts

Siva Sitthipong, Prawit Towatana, and Amnuay Sitticharoenchai

***Abstract*—The damage to the propeller shaft, a principal mechanical component in the power transmission system of the Kolek Boats makes engines work harder than normal attributed to less transmission efficiency. Operating boats with the damaged propeller shaft increases the rate of fuel consumption per distance and cost of fishing which affects income of coastal fishermen. The result of a preliminary survey of Cut-Stern Kolek Boats at Kaoseng Community revealed that the service life of the damaged propeller shafts caused by the fatigue failure would be repaired by shield metal arc welding process. The statistical analysis showed that the useful life depended on fatigue endurance limit of welding surface. When they were back to be used again. The objective of this research was to study the fatigue life of hardfacing surface LB-52 solid wire. The method of this research included)a) building up the hardfacing surface (b) forming specimen from hardfacing surface and (c) finding out the fatigue life by fatigue testing machine base on ASTM E739-91 standard. The results of this research indicated that hardfacing surface LB-52 could not receive fatigue stress exceed 500 MPa. The propeller shafts after being repaired will have very short service life, which is not feasible in engineering economy.**

***Index Terms*—Propeller shaft, hardfacing surface, solid wire fishing boats.**

I. INTRODUCTION

The popular southern local fishing boats are the Kolek boats which are modified by the presence of engines and long tail shaft at the cut-stern. A traditional Kolek boat then becomes a cut-stern Kolek boat, as shown in Fig. 1.

Fig. 1. The cut-stern kolek boats.

There are several reasons why the Cut-Stern Kolek boat are more popular than the traditional Kolek boats. The cost of building tradition Kolek boats are 2 times higher than the cut-stern one. For the second reason, it has the abilities to maintain good balance and mobility against winds and waves. Its shallow hull prevents itself from tipping over. Lastly, its smaller size and lighter weight require lesser driving force and fuel. Only 2-3 people are needed to operate the boat for fishing. From these reasons, the cut-stern Kolek boats are popular among the fishermen, while the traditional Kolek are just the past generation models which were continuously used and deteriorated with times [1], [2].

The cut-stern Kolek were driven by using driving forces from engines. The propeller shaft, as shown in Fig. 2, was the part of main machine in the transmission system of the cut-stern Kolek [3]. While the boat is being used, the shaft works all the time. The shaft receives cyclic loads continuously, which it has a high statistical damaged rate from fatigue mechanism. Welding resurfacing by using shielded metal arc welding process is the current welding repair technique [4], [10]. Some propeller shafts can only be used shortly, while others may last for a long time, since the fatigue life was limited by the weld metals' hardness from the information and reason above, this research aims to investigate the fatigue life of hardfacing surface of LB-52 propeller shafts.

Fig. 2. Propeller shafts.

II. MATERIALS AND EXPERIMENTAL PROCEDURE

A. Creating the LB-52 Hardfacing Surface

The SCM 440 alloy steels were formed as c-shape with 3 inches cross-sectional area. The chemical compositions and mechanical properties of SCM 440 alloy steels are shown in Table I and II. After that, the specimens were cut into 18 pieces. Each specimen has a length of 30 cm. Then, the inner surface of c-shape channel was hardfaced by using shielded metal arc welding, as shown in Fig. 3, with 4mm LB-52

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coated electrodes. The height of hardfacing surface is 20 mm, as shown in Fig. 4. The beads were deposited in zigzag patterns. Electrodes were baked at 350°C for half hour, but there is no preheat and post weld heat treatment. The chemical compositions of welding electrodes are shown on Table III. LB-52 is a basic coated low hydrogen electrode suitable for welding heavy structures, high tensile strength jobs where impact strength at sub-zero temperatures are required. The basic coated formulation ensures a defect-free radiographic quality weld. The superb and well established flux formulation ensure excellent performance of the electrode in AC/DC (+) in all welding positions except vertical down.

Fig. 3. Shielded metal arc welding.

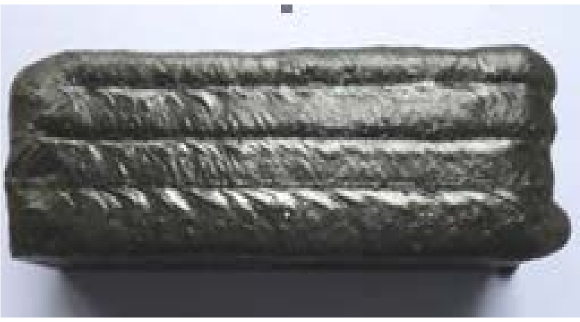

Fig. 4. Hardfacing surface.

LB-52 is suitable for all sorts of joining, repairing and fabrication of structural works which are suitable for medium and high tensile steels of grade 550 N/mm^2., The applications include; welding of structures, highly restrained joints, bridges, railway coaches & wagons, plants, ships, tugs, barges, trawlers, dredgers, storage tanks, boilers, pipelines, grills etc., The electrode can be used as a non-machinable electrode on castings. Welding current condition is shown on Table IV. The controlled parameters for welding, using the coated electrodes, are illustrated in Table V, and Table VI shows the mechanical properties of LB-52 solid wire.

TABLE I: CHEMICAL COMPOSITION OF SCM 440

Element	Content (%wt)
C	0.38-0.43
Si	0.15-0.35
Mn	0.60-0.85
P	Max.0.03
S	Max.0.03
Cr	0.9-1.2
Mo	0.15-0.30
Ni	Max.0.25
Cu	Max.0.30

TABLE II: MECHANICAL PROPERTIES OF SCM 440

Tensile Strength	>980 MPa
Yield Strength	>830 MPa
Brinell Hardness	285-352 HB
Percentage of elongation	>12%
Percentage of area reduction	>45%
Impact value (charpy test)	>59J/cm^2

TABLE III: CHEMICAL COMPOSITION OF LB52 SOLID WIRE

Element	Content (%wt)
C	0.08
Si	0.6
Mn	0.94
P	0.011
S	0.006

TABLE IV: WELDING CURRENT CONDITION

Size	Current
2.5×350mm	70-100A
3.15×150mm	90-140A
4.00×450mm	140-200 A
5.00×450mm	190-250 A

TABLE V: WELDING PARAMETERS

Types of electrode	LB-52
Diameter of wires	4.0 mm
Welding current	140 A
Welding voltage	24.5 V
Welding speed	150 mm/min
Heat Input	1.37 KJ/mm

TABLE VI: MECHANICAL PROPERTIES OF LB-52 SOLID WIRE

Tensile Strength	540 N/mm^2
Yield Strength	460 N/mm^2
Percentage of elongation	26%
Percentage of area reduction	75%
Impact value	47J

Fig. 5. Cutting with square-band saw.

Fig. 6. Specimen after cutting.

B. Forming the Specimens from LB-52 Hardfacing Surface That Had Been Created

Twenty pieces of hardfacing surface of LB-52 were taken for cutting with 12.5 mm width ×226 mm length square-band saw, as shown in Fig. 5 and 6. Sixty pieces of specimens were obtained after cutting.

Then, face milling the specimens was conducted, as shown in Fig. 7. The specimens were lathed, as illustrated in Fig. 8, to obtain the diameter of 12.18 mm and length of 226 mm. Both ends were dropped off shoulders at 1 mm with 45 degree angle. At 65 mm from both ends, the fillets of 30 degree angle were created, as shown in Fig. 9. Lastly, the specimens were polished to obtain the smooth and shiny surface before testing as shown in Fig. 10.


Fig. 7. Face milling the specimens.


Fig. 8. Lathed the specimens.

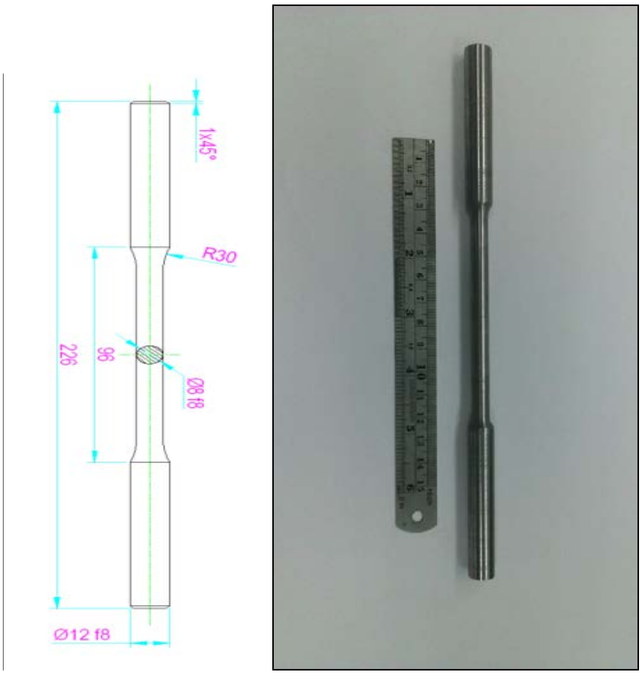

Fig. 9. Fatigue testing specimens.

C. Testing the Fatigue Strength of Specimens Created from LB-52 Hardfacing Surface

The research is highly reliable, since it follows the ASTM E739-91standards [11], [12]. Every single specimen was exposed to the x-ray beam to search for any defection feature. The example shown in Fig 11. The failed specimens were screen out.

All the 60 specimens from shielded metal arc welding with LB-52 coated electrodes were taken for fatigue strength test, using the rotating beam fatigue testing machine, as shown in Fig. 12. This test conforms to ASTM E739-91 standards. The loads for testing the fatigue strength were changed by 10 loads, each load was tested by 6 specimens. The cyclic torsional-flexural loadings were applied on the specimens until they broke apart.


Fig. 10. Surface polishing.


Fig. 11. X-RAY images.

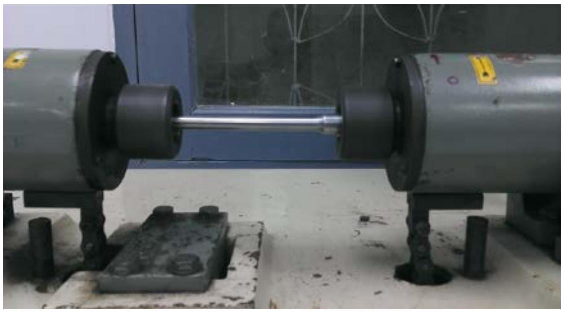
Fig. 12. Fatigue testing machine.

III. RESULTS AND DISCUSSION

Stress and cycle recorded data that make specimens fracture on Table VII and display their relationship on the graph as shown in Fig 13. Each value of stress used 6 specimens for testing, as stated in the standard. Each specimen produced similar fatigue strength to the others, making the average values from each stress interval reliable.

The use of LB-52 welding electrodes for hardfacing were proved to be ineffective for prolonging the service life propeller shafts. The research is highly reliable, since it follows the ASTM E739-91standards

TABLE VII: WELDING PARAMETERS

Stress for testing	Average cycle until fracture
150 MPa	Not fracture
200 MPa	1,026,310 Cycle
250 MPa	485,691 Cycle
350 MPa	50,067 Cycle
400 MPa	4,071 Cycle
450 MPa	1,730 Cycle
500 MPa	Fractured at low cycle
600 MPa	Fractured at low cycle
700 MPa	Fractured at low cycle
800 MPa	Fractured at low cycle

Remarks: Stop the testing at 1,000,000 cycles for each specimen; the specimen that can receive loadings more than 1,000,000 cycles will be reported as not fracture. In addition, the specimen that fracture before 1,000 cycles will be reported as fractured at low-cycle.

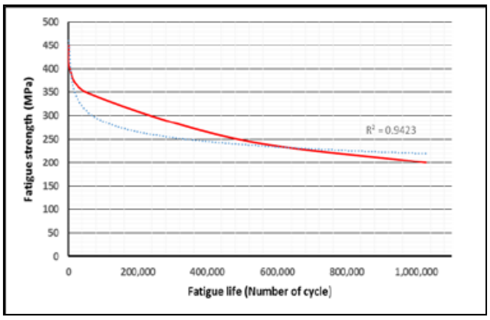

Fig. 13. S-N Curve of surface welding.

The analyzed cyclic stress (σ_R) were applied in (1) to predict the lifetime (N_R) of fatigue by using Basquin's power law [13]. The constants A and B are related to the experiment. By plotting the service lives against the applied cyclic stresses on shafts through (2).

$$\sigma_R = \mathrm{A}\mathrm{N}_R^B \tag{1}$$

$$\mathrm{N}_R = 10^{\frac{1}{-0.116}(\log \sigma_r - \log 2.997)} \tag{2}$$

Fig. 14. Set up semi-automation process.

Fig. 15. Propeller shaft hardfacing.

IV. CONCLUSION AND RECOMMENDATION

The LB-52 welding electrodes are inapplicable for welding repairs the propeller shafts of the cut-stern Kolek boats, since they hardfacing surfaces do not have enough strength to withstand the fatigue stresses that occurred on propeller shafts. The average fatigue stresses on propeller shafts of the cut-stern Kolek boats is 517 MPa. By using LB-52 welding electrodes for welding repairs, the propeller shafts after being repaired will have very short service life, which is not feasible in engineering economy. By baking welding electrodes before executing the shield metal arc welding, the welding process becomes easier. The quality of beads is also better. In addition, preheating and post weld heat treatment the specimens are recommended, in order to reduce the residual stresses within the specimens.

Propeller shaft design maintenance has to fulfill the operating requirements. The process of propeller shafts design maintenance consist of 4 stages: Concept Design Maintenance, Preliminary Design Maintenance, Contract Design Maintenance, and Detail Design Maintenance which are the iterative process according to the character of maintenance loop. All topics of propeller shaft design maintenance steps must be verified and defined in all the related design maintenance information. Service life, fatigue resistance and welding parameters are the importance topics that will be presented in this paper. The proving of propeller shaft design maintenance at the end is semi-automation hardfacing as shown in Fig.14 and 15 will be performed by sea trial.

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