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Influence of stress to mechanical failure of long tail shaft in the power transmission system on local fishing boat

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Abstract

This research focuses on a study of failure mechanism of long tail shafts which are major machine components in mechanical transmission systems of diesel engines in the cut-stern Kolek boats, the important traditional fishing boats for fishermen in Kaoseng community, located on the Coast of Songkhla Lake. From onsite data collection of the failure of long tail shafts, it appears that the shaft suddenly fractures into two pieces while operating. When investigating the failure of shafts by examining on surface cracks, it shows that cracks initiated from the fillet shoulder of shafts. By analyzing the failure mechanism, it reveals that the weak point of shafts is at the area which has a high concentration of stresses. In the experimental program for the data above, different loadings are applied to long tail shafts to evaluate which load that the mechanisms of failure occurred. The conditions of loadings are No-load, Full-load, and Over-load. The benefit of this research will be used in designing new and appropriate long tail shafts.

Keywords: Cut-stern Kolek, Failure analysis, Long tail shaft

1. Introduction

The study on 2012-2015 Songkhla fisheries' strategic planning of Department of Fisheries, Ministry of Agriculture and Cooperatives, reveals that the strategy number 3 aims to establish sustainable management of aquatic resources by encouraging and demonstrating the use of fishing equipment, in order to promote fishermen to have their own tools, and to increase their income. With the purpose of restoring and conserving the sustainable fisheries, the co-management project of inshore fisheries has been carried out in partnership with the community, in order to encourage fishermen's participation in resource management.

From 2006, the rate of marine fisheries and inland fisheries expanded, which all the 2007 production of aquatic animals increased by 12.89%. The production of aquaculture increased by 23.88%, whereas only 0.75% for marine fisheries. The lower production rate of marine fisheries is due to higher cost and stricter policy over the territorial sea. Songkhla's geographical feature is perfect for inshore fisheries, which always play an important role in the province's economy. Songkhla province has an advantage on its geographical feature, which a part of it is a 200-nautical-mile exclusive economic zone. This zone contained fishery resources that help creating jobs and generating income for fishermen. The cut-stern Kolek, artisanal fishing boats, are widely used in fisheries.

The movements of Kolek boats were driven by the engine power, which the main machine-component of the boat's power transmission system is the long tail shaft with a mounted propeller. By surveying Kaoseng fishing community on the Coast of Songkhla Lake, 65 cut-stern Kolek boats were found. The failure of long tail shafts in the cut-stern Kolek boats has been reported frequently. The type of failure that occurred very often and almost all year-round is the minor failure which the system still works. The fracture or break off of shaft from fatigue is the severe failure which averagely occurs twice a year. When a shaft fails, it will be disable the boat from operating, bringing negative effects on lives and income to fishermen. This research aims to study the mechanical failure of long tail shafts in cut-stern Kolek boats, with the use of statistical principles, by collecting data on working stresses of different conditions from site investigation in order to interpret the significant factors that cause failure.

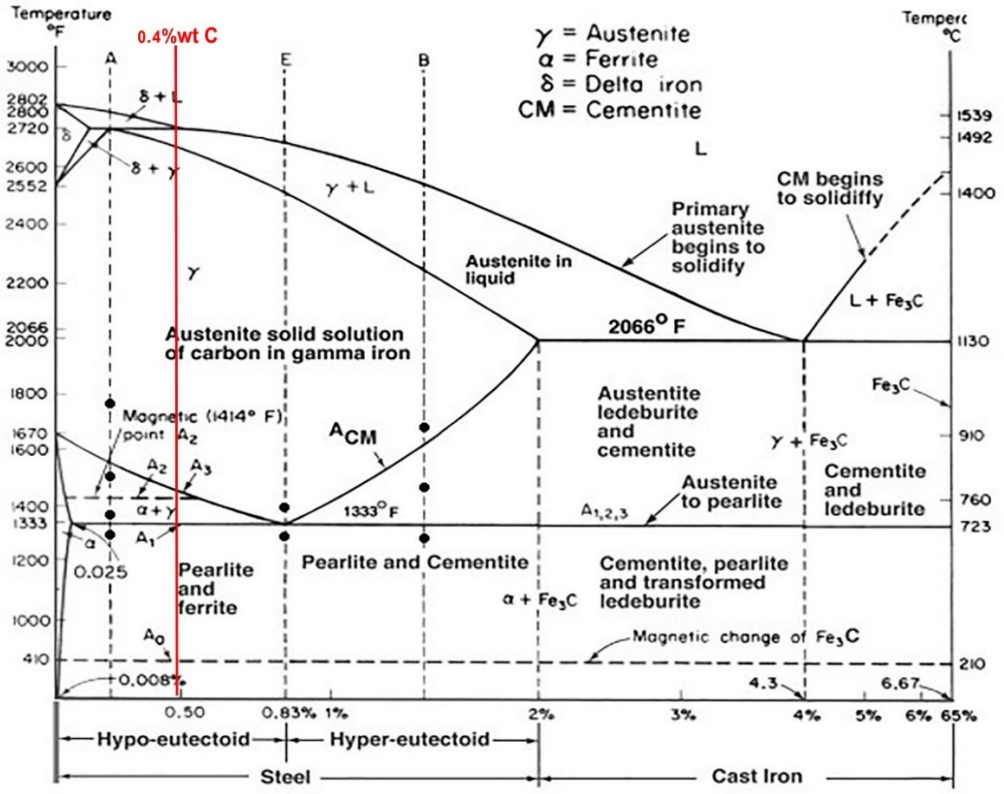

Fig. 1 Iron carbon transformation diagram of the AISI 4340 High Tensile Strength Low Alloy Steel [3]

2. Materials and Methods

AISI 4340 is a High Tensile Strength Low Alloy Steel, which its major compositions are Nickel, Chromium, and Manganese. The chemical compositions are shown in Table 1. The steel has a high fracture resistance. Moreover, its high tensile strength and great fatigue strength can be obtained by heat treatment conditions [1]. From the given properties, the AISI 4340 High Tensile Strength Low Alloy Steels were used in structural components such as aircrafts components, tank components, gear sets and transmission shafts. which use forging process to form shapes at the temperature of 1800-2250 °F. However, they are known to be vulnerable to corrosion [2]. The mechanical behavior of the heat affected zone during welding was different from its original due to the change of microstructure, as shown in Fig. 1.

Table 1 Chemical compositions of the AISI 4340 High Tensile Strength Low Alloy Steel

Elements	Component (%wt)
Carbon	0.37-0.43
Chromium	0.7-0.9
Manganese	0.7
Molybdenum	0.2-0.3
Nickel	1.83
Phosphorus	Max 0.035
Silicon	0.23
Sulfur	Max 0.04

3. Results and Discussion

By collecting the data from site surveying at the Kaoseng fishing community on the Coast of Songkhla Lake, 65 Kolek boats were found and categorized by types, as shown in Table 2.

Table 2 Quantities of different types of cut-stern Kolek boats

Honda 6.5 HP			Yanmar					
			11.5 HP			8.5 HP		
SS 400	SCM 440	AISI 4340	SS 400	SCM 440	AISI 4340	SS 400	SCM 440	AISI 4340
10	3	2	10	23	7	7	2	1

The researchers were interested in the study of Yanmar engines which have 11.5 HP and use AISI 4340 steel to make shafts, since the steel has greater service life and gives better result on welding repair process.

The working operations on long tail shafts are divided into 3 conditions, which are No-Load, Full-Load and Over-Load. The data were collected from 3 cut-stern Kolek boats, as shown in Table 3.

Table 3 Maximum stress in shafts occurred from each working condition

Sample size	Working operation		
	No Load (MPa)	Full Load (MPa)	Over Load (MPa)
1	302	474	949
2	275	432	915
3	240	517	890

After data collection, the researcher used the statistical program to analyze the accuracy and reliability of the obtained data, by finding an appropriate value of sample size in accordance with the statistical practice [4] as shown in Fig. 2.

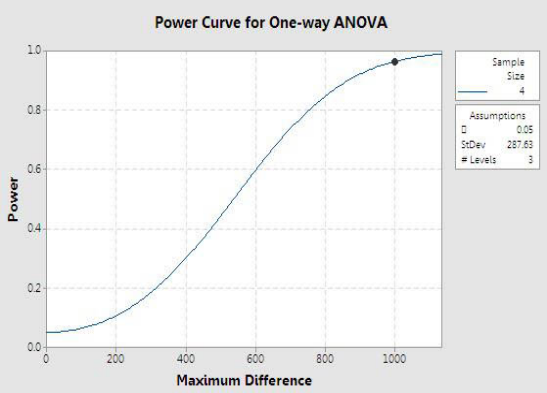

Fig. 2 The cut-stern Kolek boats' sample size

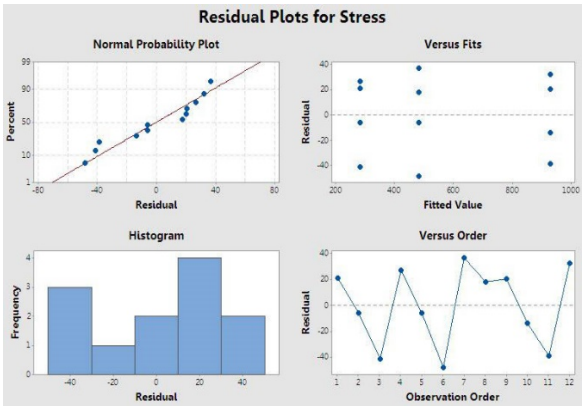

Fig. 3 Checking data correctness

Table 4 Maximum stress in shafts occurred from each condition of cyclic-static load

Sample size	Working operation		
	No Load (MPa)	Full Load (MPa)	Over Load (MPa)
1	302	474	949
2	275	432	915
3	240	517	890
4	308	498	949

By calculating with the statistical program, it is found that at the target power of 0.95, 4 sample sizes are needed. Therefore, one more sample size was added, as shown in Table 4. After collecting all information from

the 4 sample sizes, the values of obtained data were used for statistical analysis to find the correctness of data. Conditions to use the One-way ANOVA are Normality, Independence and Constant Variance [5].

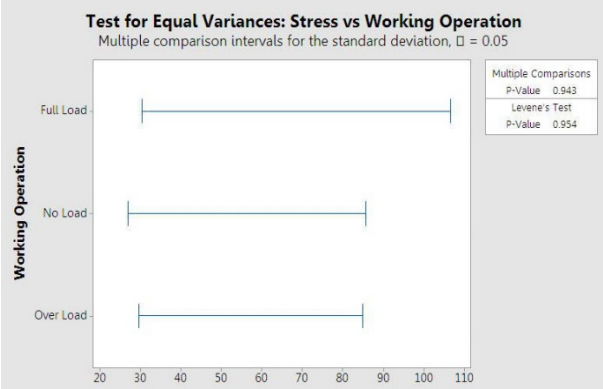

Fig. 4 Equal Variances

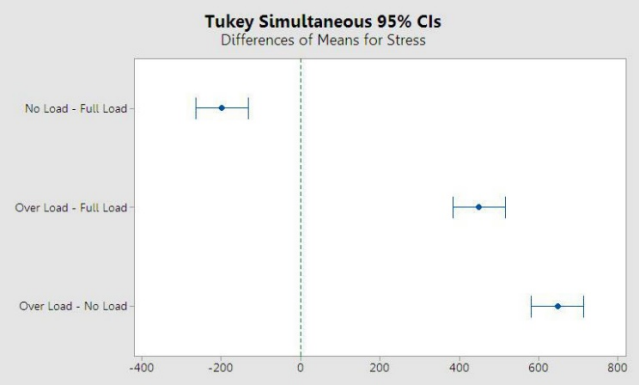

Fig. 5 Mean test of stress

Shown in Fig. 3 is the checking data correctness. It is found that there is not enough evidence to support the conclusion that the data is non-normal distribution. For the data independence, there is also no evidence to prove that the residual values have some patterns or tendencies. Also, the test of residual variance, which reveals the confidence interval of the comparison between 3-level stresses and working operation, shows no evidence to conclude that the variance values of all test level of stress are different. When comparing the p-value with the higher alpha value of 0.05, it can be concluded that it has an equal variance or constant value throughout all level of experiment, as shown in Fig. 4. Therefore, it can be concluded that the relationship of working operations and failure of long tail shafts of cut-stern Kolek boats can be suitably found by using the one-way ANOVA test design.

Table 5 One-way ANOVA analysis

Source	Df	Adj SS	Adj MS	F-value	P-value
Working Operation	2	880013	440006	393.63	0.000
Error	9	10060	1118		
Total	11	890073			

R-sq=98.87%

The analysis of variances shows that one of the working operations' variables is different from the group, which variables of working operations have significant effect on stress. The P-value is less than 0.05, as shown in Table 5. On the other hand, the Coefficient of Determination R-Squared is equal to 98.87%, which means that all controllable variability's in the experiment such as tools, materials, or other factors are set to be constant for measuring their values, which equals to 98.87. The other 1.13% occurs from other factors that are uncontrollable.

From Fig. 5, the analysis of differences between values of working operation conditions of each pair, by using the mean of stress, shows that all 3 working operation conditions produced significant differences. According to the obtained data, it can be interpreted that each load condition affected the stress that influences the failure of long tail shafts in the boats. These results also support the result of One-way ANOVA analysis.

4. Conclusion

The result of this experiment shows that all three conditions of working operations, which comprised of No load, Full load and Over load, affected the stress, especially when in Full load condition and Over load condition. However, the No load condition did not produce any significant effect. The average values of each load condition are 281.25 MPa, 480.25 MPa, and 925.75 MPa, respectively. The data given by this experiment can be used in designing a longer service life long tail shaft for the cut-stern Kolek boats. The requirement of minimum sample size of the cut-stern Kolek boats is 3.

5. References

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