Effect of Engine Fastening Points' Amount on the Vessel's Foundation towards Vibration Transmissibility Value in Traditional Vessel Structures

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Abstract: In the rubber damper designed in the previous study, vibration was reduced by 65% on engine no. 1 and 59% in engine no. 2 with a considerable amplitude value of 0.0276 mm and 0.0282 mm, respectively. By using the Barkan engine's allowable amplitude ranging from 0.02 mm - 0.03 mm, after the installation of a rubber damper, the vibration can be reduced to safe limit. The research continues by analysing the machine foundation-stretching system with the amount of fastening points of 2, 3, and 4. The increase in the number of fastening points causes the amplitude to be reduced even further. The calculation results can be seen by reducing the value of the transmission force to the foundation. By doing so, the amplitude value decreases as the engine's load decreases due to the system's work. The number of fastening points affects the value of the distribution of the bending stress (s) and shear stress (ss). Increasing the fastening point reduces the value of the bending stress (s) and shear stress (ss). The allowable bending stress (s) and shear stress (ss) used are 6.4 MPa and 0.45 MPa consecutively, given by the National Design Specification. The calculation results show the value is below the allowable limit. Based on the calculation results, the smallest amplitude value is obtained at the four-point fastening points. Therefore, it is better if the amount of existing fastening points is increased. From these results, it can be seen that the foundation is still within the safety limits.

1 INTRODUCTION

Ships with outboard engine type, vibrations transmitted to the foundation beam without damping exceeded Barkan permissible amplitude, i.e., 0.02 mm to 0.03 mm in the vertical direction (Srinivasulu, 1980). This condition indicates that the system requires a damper that can reduce vibration to a safe limit. Calculations must be made using Barkan permissible amplitude limits. Also, the vibration limits are permitted for structural damage, machinery vibration, and human perception in graphical form for operator safety (Hopcroft and Skinner, 2005). Damping in this study uses rubber material with E value at 2.3 x 109 N/m2 . The rubber dimensions are determined through variations in prices of c and k with thickness t = 0.2 cm to 3 cm (Lekatompessy et al., 2013). Based on measurement at Point F around the beam foundation, an effective damping rubber dimension is obtained at 8 x 5 x 2 cm.

At this point, the most significant excitation force (F0) and the smallest excitation frequency (ω) are obtained, with the most substantial amplitude value (Lekatompessy, 2003).

In further research, the fishing factor is seen by analysing the effect of the number of fishing spots on the distribution of vibrations and loads on the wooden ship's engine foundation (Ariana, 1998).

2 LITERATURE REVIEW

2.1 Engine Vibration

Imbalance in a rotating machine is a common source of vibration excitation. The mass-spring system is limited only to moving in a vertical direction and stimulated by a rotating machine (Jensen and Chenoweth, 1991). From Figure 1, an equation is obtained as follows:

$$m + c + kx = (me\omega^2)\sin\omega t \tag{1}$$

By replacing F_0 with $me\omega$

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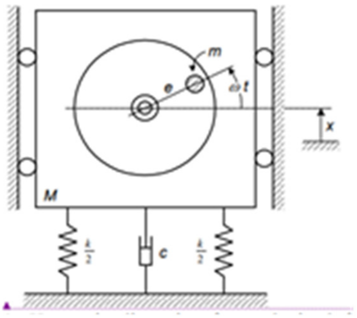

Figure 1: Harmonic disruptive force obtained from an imbalance of the rotating mass.

From Equation (1), the steady-state solution can be replaced by:

$$x = \frac{me\omega^2}{\sqrt{(k - M\omega^2) + (c\omega)^2}} \quad (2)$$

$$\tan\phi = \frac{c\omega}{k - M\omega^2} \quad (3)$$

2.2 The Rotating Mass

In mechanical systems and structures, displacement indicates stress and strain, which fail the system. Resonance conditions must be avoided (Seto, 1992). The amplitude can be calculated using the following equation:

$$x = \frac{\frac{F_o}{k}}{\sqrt{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left[2\xi\frac{\omega}{\omega_n}\right]^2}} \quad (4)$$

Excitation force is obtained using the following equation:

$$F_o = k.x\sqrt{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left[2\xi\frac{\omega}{\omega_n}\right]^2} \quad (5)$$

2.3 Comparison with Applicable Standards

The effects of vibration can damage the machining system. It can affect the health of the machine operator too. Therefore, the machine's vibration level must be limited so that safety and comfort for the operator and the system can be maintained.

Table 1: Allowable amplitudes.

Type	Permissible amplitude (cm)
Low speed engine (500 rpm)	0.02-0.025
Hammer foundation	0.1-0.12
High speed engine	
a) 3,000 rpm	
• Vertical vibrations	0.002-0.003
• Horizontal vibrations	0.004-0.005
b) 1,500 rpm	
• Vertical vibrations	0.004-0.006
• Horizontal vibrations	0.007-0.009

Source: Srinivasulu, 1980

3 RESEARCH METHODS

This research focuses on the vibration on the traditional motorboat's foundation system with outboard engine type, with two pieces of high-speed diesel motor (2200 rpm) as a driving force (Ghozali, 2007).

The questions of this research are to see whether the system is in a safe condition? How much is the vibration from the ship's engine that the channel system can damp? How significant is the role of rubber as a damper in the system? Whereas economically, used car tires are the material of choice because they are cheap and easy to obtain (Lekatompessy et al., 2014).

The problem that arises is how to obtain a rubber size to be effective as a vibration damper without changing the size of the engine supporting channel. Technically, the channel's size must be replaced because one of the solutions to reduce the system is that a large mass supports the system. This condition does not benefit the fishermen and the ship's skipper because it requires burdensome costs. This study aims to determine the effect of the number of fastening spots on the machine's transmissibility value to the surrounding structures. The parameters used as a limitation are the Barkan permissible amplitude and the graph of the allowable limits for Structural Damage Machinery Vibration and Human perception (Inman D. J., 1996).

From Table 2, it can be seen that the installation of rubber at point F is capable of reducing vibration by 54% in engine 1 and 53% in engine 2.

Table 2: Vibration reduction in the beam foundation area before and after damping

	Before	After	Diff	%
Engine 1	0,059	0,027	0,032	54%
Engine 2	0,060	0,028	0,032	53%

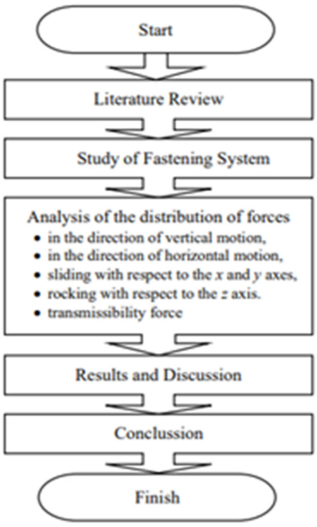

Figure 2: Research flow chart.

4 RESULTS AND DISCUSSION

4.1 Foundation Strength Calculation for Engine 1

The foundation strength is calculated based on the maximum bending moment M and the transverse shear force V. The data needed for this calculation are:

- Weight of engine and engine bed = 23.445 N
- Transmission Force (F_{TR1}) = 1,610.7009 N

4.1.1 2-Points Fastening

Load Distribution of Engine 1 at the engine foundation with 2-point fastening has seen in Figure 3. The maximum bending moment is calculated using the following equation:

$$M = P_{tr}.a \tag{6}$$

Where,

P_{tr} : ¼ (engine and engine bed + transmission force)

a : 1,350.5 mm

then,

M = ¼ (23.445+1,610.7009) . 1,350.5
= 551,728.7 N.mm

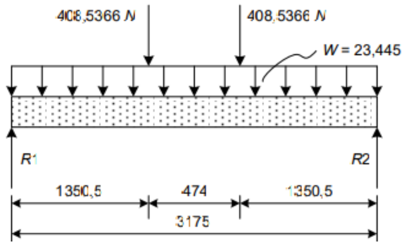

Figure 3: Load distribution at the foundation with 2-points fastening.

Reaction to support (R) can be calculated as follows:

$$R = \frac{8M}{2L} = \frac{8 * 551{,}728.7}{2 * 3{,}175} = 695.09\ \text{N} \tag{7}$$

The transverse shear force V is equal to the value of R (V = R), i.e. V = 695.0912 N. To determine the maximum bending stress, the equation is:

$$s = \frac{M}{Z} \tag{8}$$

Where,

$$Z = bh^2/6 \tag{9}$$

Noted that,

b = 220 mm
h = 225 mm

then,

$$Z = \frac{220 * 225^2}{6} = 1{,}856.250\ \text{mm}^3$$

Therefore,

$$s_{\max} = \frac{551{,}728.7}{1{,}856{,}250} = 0.297\text{MPa}$$

For the maximum shear stress (s_s) of a rectangle:

$$s_s = \frac{3V}{2A} \tag{10}$$

Where,

A = (220)(225)
= 49,500 mm^2

Therefore, the shear stress can be determined as follows:

s_s = 0,021 *MPa*

The closest quality of wood is used to determine the permitted bending stress (s) and shear stress (s_s), namely pine ponderosa No. 1, with s *permission* = 6.4

MPa and s_s *permission* = 0.45 *MPa*, approved by National Design Specification. From the calculation results, it can be seen:

$$s < s_{\text{permission}}$$
$$0.297 < 6.4(\text{MPa})$$
$$s_s < s_{s\ \text{permission}}$$
$$0.021 < 0.45(\text{MPa})$$

From these results, it can be seen that the foundation is still within the limits of permission in accepting the load of working on it. Other calculation results can be seen in Table 3.

4.1.2 3-Points Fastening

Load Distribution at the engine foundation with 3-points fastening has seen in Figure 4.

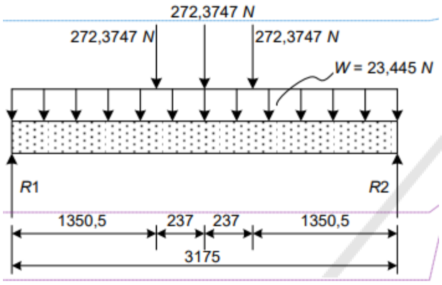

Figure 4: Load distribution at the foundation with 3- points fastening.

The calculation is done in the same way as 2-points fastening, where the results can be seen in Table 3.

4.1.3 4-Points Fastening

Load distribution at the engine foundation with 4-points fastening has seen in Figure 5. The calculation is done in the same way as above, where the results can be seen in Table 3.

4.2 Foundation Strength Calculation for Engine 2

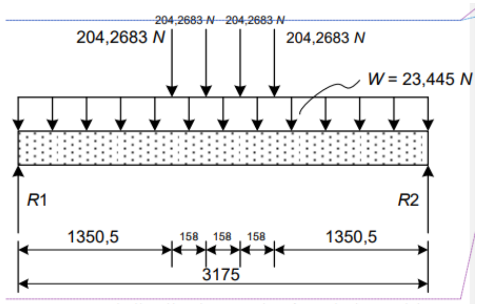

Figure 5: Load distribution at the foundation with 4- points fastening.

The foundation strength is calculated based on the maximum bending moment M and the transverse shear force V. The data needed for this calculation are:

- Weight of engine and engine bed = 21.916 N
- Transmission Force (F_{TR1}) = 1,638.0009 N

4.2.1 2-Points Fastening

The maximum bending moment is calculated using equation (6), therefore,

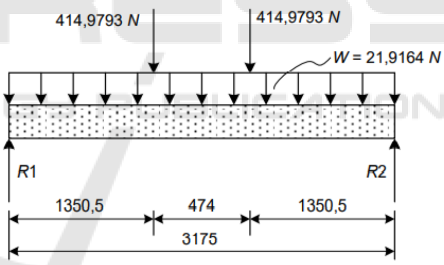

Figure 6: Load distribution at the foundation with 2- points fastening.

M = 560,429.6 N.mm

Reaction to support (R) (Equation 7):

R = 706.053 N

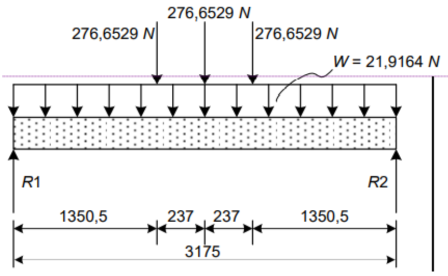

Figure 7: Load distribution at the foundation with 3- points fastening.

The transverse shear force V is equal to the value of

R $(V = R)$, *i.e.*, $V = 706.053$ N.

Equation (6) is used to determine the maximum bending stress as follows:
Where,
$Z = 1{,}856.250$ mm^3

Therefore,
maks $s = 0.3019$ MPa

Equation (10) was used to determine the maximum shear stress (ss) of a rectangle:
Where,
$A = 49{,}500$ mm^2
thus,
$s_s = 0.0214$ MPa
From the calculation results, it can be seen:

$$s < s_{\text{permission}}$$
$$0.3019 < 6.4(\text{MPa})$$
$$s_s < s_{s\ \text{permission}}$$
$$0.0214 < 0.45(\text{MPa})$$

From these results, it can be seen that the foundation is still within the limits of permission in accepting the load of working on it. Other calculation results can be seen in Table 3.

4.2.3 3-Points Fastening

Load distribution of engine 2 to the engine foundation with 3-points fastening has seen in Figure 7. The calculation is done in the same way as above, where the results can be seen in Table 3.

4.2.4 4-Points Fastening

The distribution of loading at the engine foundation with 4-points fastening has seen in Figure 8. The calculation is done in the same way as above, where the results can be seen in Table 3.

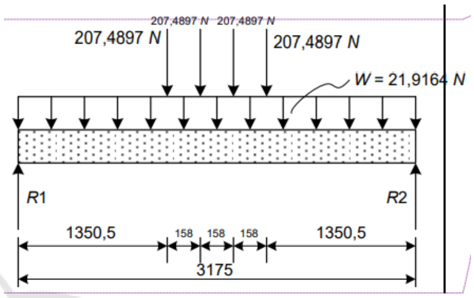

Figure 8: Load distribution at the foundation with 4- points fastening.

5 CONCLUSIONS

Based on the comparison, we can see that the shear force's magnitude and the bending moment have decreased. This change indicates that dissipation occurs with the addition of the amount of fastening.

The results have shown the reduction of the transmission force to the foundation. By itself, the value of amplitude to the base decrease due to the work of the system.

This study's results reinforce the results of previous studies where the damping and stiffness values were varied to obtain the smallest amplitude value. The increase in stiffness through the number of

Table 3: Results of foundation strength calculations.

Description	Unit	Engine 1			Engine 2		
		2-point	3 point	4-point	2-point	3 point	4-point
m	kg	23.446	23.446	23.446	21.916	21.916	21.916
F_{TR}	N	1,610.71	1,610.71	1,610.71	1,638.00	1,638.00	1.633001
P_{TR}	N	408.537	272.358	204.268	414.979	276.653	207.49
M	N	551728.7	367,319.10	275,364.30	560,429.60	373,619.70	230.2143
R	N	695,091	463.394	347.546	706.053	470.702	353.027
V	V	695,091	463.394	347.546	706.053	470.702	353.027
Z	mm^3	1,856,250	1,356,250	1,856,250	1,856,250	1,856,250	1,856,250
s		0.29723	0.19815	0.14861	0.30392	0.20128	0.0151
s_s		0.02106	0.01404	0.01053	0.0214	0.01426	0.0107

fixing points makes this research more optimal for reducing amplitude. The number of fixing points affects the value of the distribution of bending stress (s) and shear stress (ss). The increasing of the fastening point reduces the value of bending stress (s) and shear stress (ss).

Based on the calculations' results with the two, three, and four-point fastening models, the smallest amplitude value is obtained at the four-point drafting. Several other factors also affect increasing the value of structural stiffness apart from those in this study. The type of material and the dimensions of the foundation also affect the amplitude value. Further research can be done on this matter to support the research results that have been done.

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