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A SIMPLIFICATION OF MACHINERY SEATING ON AN EXAMPLE OF MARINE DIESEL ENGINES

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Summary. An installation simplification of power plant machinery was presented. Simplifications involved steel replaced by polymer chock, diminishing of polymer chock, decrease of foundations bolts retightening and decrease of a foundation bolts number and diameter on example of MAN B&W 12V32/40 marine diesel engine and 550 kW Paxman diesel generator set.

Key words: machinery seating, ship power plant, polymer chocking

INTRODUCTION

Polymer chocks originally answered a ship repair need for a diesel engine rechocking method that eliminated foundation and bedplate machining. Service experience quickly showed that polymer chocking was not only faster and cheaper, but also superior to steel chocking. Adoption of the new construction came slowly but today is standard procedure for many shipyards.

For a ship machinery polymer rechocking there must be carried out the calculations and drawings for chocks and their arrangement on the machinery frame foot. A manufacturer of machinery in general has calculations and drawings for chocking of ship machinery with polymer [Rigid seating V 32/40 Marine 1995]. Such projects were provided also by some polymer manufacturers [Technical Bulletin 2000].

CALCULATIONS AND DRAWINGS OF MAN B&W 12V32/40 PROPULSION DIESEL ENGINE POLYMER CHOCKING

From documentation of MAN B&W 12V32/40 marine diesel engine the following data were obtained [Rigid seating V 32/40 Marine 1995]:

– arrangement of foundation and jack bolts, Fig. 1,
– profile of engine seating, Fig. 2,
– deadweight of diesel engine including water and oil G = 56 tons.

Number of bolts:

30 through foundation bolts M33x2 undercut to 24.5 mm in diameter on 237 mm length.

2 fitted foundation bolts M33x2 undercut to 24.5 mm in diameter on 130 mm length and fitted to 38k6 mm in diameter on 127 mm length.

The length of the foundation bolts and its thread were chosen so that the thickness of the chock can vary between 20 and 60 mm considering a machined top plate thickness of 50 mm.

The load from diesel engine weight on chocks:

$$F_m = G \cdot g = 56000 \cdot 9.81 = 549360 \text{ N}$$

The hold down bolt tension must total at least 2.5 times the engine weight [Technical Bulletin 2000]. In this calculations it was assumed that the hold down bolt tension was in total 5 times the engine weight.

$$F_{st} = 5 \cdot F_m = 5 \cdot 549360\ N = 2746800 \text{ N}$$

The load from pre-tensioning on one foundation bolts:

$$F_{so} = \frac{F_{st}}{32} = \frac{2746800}{32} = 85838 \text{ N}$$

The foundation bolts of MAN B&W 12V32/40 marine diesel engine were manufactured from 42CrMo4V steel with tensile strength 1000÷1200 MPa, yield point 750 MPa and elongation 11%, which conformed Germanischer Lloyd requirement that tensile strength of the bolt was at

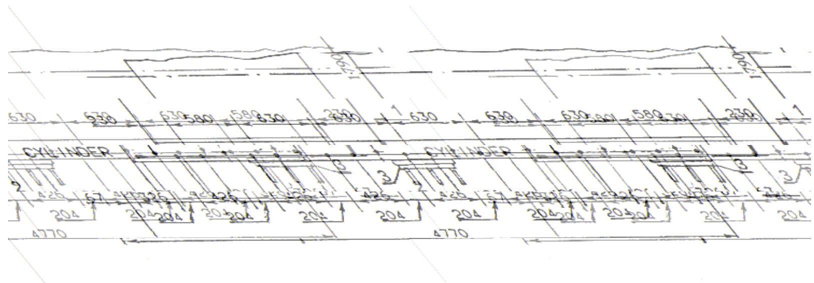

Fig. 1. Arrangement of foundation and jack bolt holes for rigid seating of the MAW B&W 12Y32/40 marine diesel engine [Rigid seating V 32/40 Marine 1995]: 1 – arrangement of jack bolt holes, 2 – arrangement of foundation bolt holes, 3 – stopper

least 600 MPa [Germanischer Lloyd 1995]. Well pre-tensioning of foundation bolts by polymer chocking is much lesser than by steel chocking, foundation bolts in this case can be manufactured with a reduced diameter or from cheaper steel, for instance 34CrMo4V with tensile strength 850÷950 MPa, yield point 550 MPa and elongation

14%, to ensure sufficient elongation and thus avoiding loosening. In this design, however foundation bolts from 42CrMo4V steel were left.

Pre-tensioning of the foundation bolts were given stresses in undercut length of bolts:

$$\sigma_{so} = \frac{F_{so}}{S_{ub}} = \frac{85838}{471.4} = 182 \text{ MPa}$$

where:

S_{ub} – cross-section area in undercutting of the foundation bolt 471.4 mm^2.

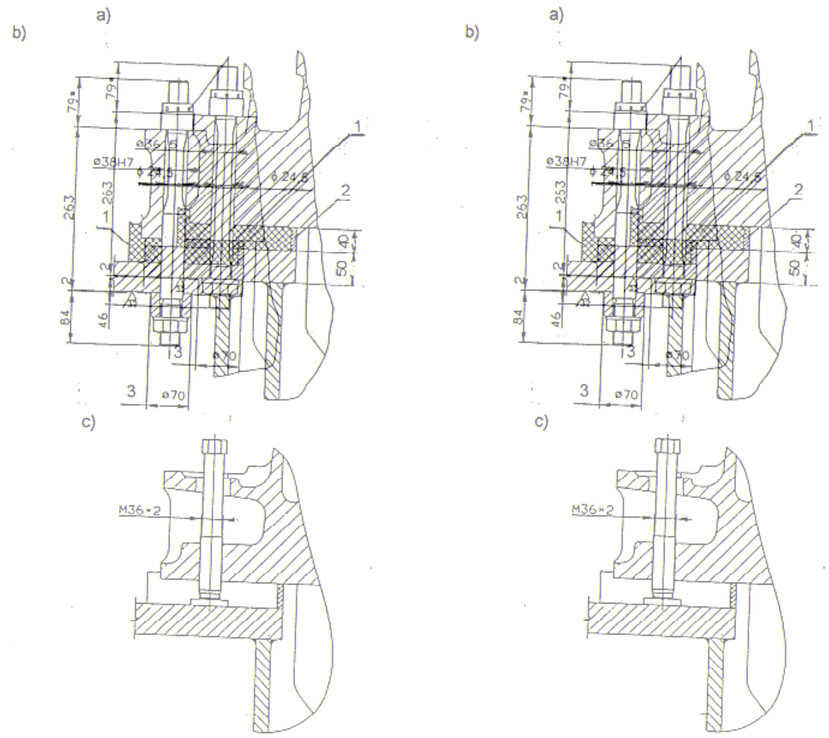

Fig.2. Profile of the MAN B&W T2V32/40 marine diesel engine sealing [Rigid seating V 32/40 Marine 1995]: a) through bolt, b) fitted bolt, c) jack bolt: 1 – polymer chock, 2 – dam, 3 – angefraest spot faced, x – minimum protrusion dimension prior to mounting the hydraulic tensioning device

This stress is of 0.24 yield point of the bolt from 42GrMo4V steel and gives factor of the safety 4.12.

In accordance with Germanischer Lloyd [1995] protection before undoing a nut of bolt may be neglected when the bolt stresses are at least 0.6 yield point of bolts. In this design of MAN B&W 12V32/40 marine diesel engine foundation this requirement be not performed and nut undoing shall be protected.

Tightening torque of bolt nut from Germanischer Lloyd formula [1995]:

$$M = \frac{F_{so} \cdot D}{5000} = \frac{85838 \cdot 33}{5000} = 567 \text{ N} \times \text{m}$$

where:

D – outer diameter of foundation bolt thread = 33 mm.

Tightening torque of bolt nut can be calculated also from the formula [CTO 2000]:

$$M = F_{so}[0.16h + 0.58d_p f + 0.25(d_m + d_h)f] \quad \text{N}\times\text{m}$$

where:

h – pitch of thread = 2 mm,
f – coefficient of friction = 0.15,
d – pitch diameter of thread = 31.7 mm,
d_h – diameter of hole for bolt = 40 mm,
d_m – outside diameter of contact the nut and the base = 50 mm.

$$M = 85838[0.16 \cdot 2 + 0.58 \cdot 31.701 \cdot 0.15 + 0.25(50 + 40) \cdot 0.15] = 554 \quad \text{N}\times\text{m}$$

This formula, although theoretically correct, is complicated for practical application and gives no large difference in assignation of tightening torque of bolt nut.

Elongation of the foundation bolts after pre-tensioning shall be calculated with the formula:

$$\Delta L = \frac{4F}{\pi E}\sum\frac{1}{d^2} \quad \text{mm}$$

where:

E – coefficient of elasticity of steel = 205900 N,
$\sum\frac{l}{d^2}$ – sum of ratios of length bolt segment to its diameter square.

In tension of the through foundation bolt there take part two segments of bolt length: the first that is a segment of bolt under-cutting with 237 mm length and 24.5 mm in diameter and the second that is segment of bolt thread with 76 mm length and 30.835 mm in diameter of thread root.

In tension of the fitted foundation bolt there take part three segments of bolt length: the first that is segment of bolt under-cutting with 130 mm length and 24.5 mm in diameter, the second that is segment of bolt fitted with 127 mm length and 38 mm in diameter and the third that is segment of bolt thread with 76 mm length and 30.835 mm in diameter of thread root.

With this data elongation after pre-tensioning of through foundation bolt is:

$$\Delta L_t = \frac{4 \cdot 85838}{3.14 \cdot 205900}\left(\frac{273}{24.5^2} + \frac{76}{30.835^2}\right) = 0.252 \text{ mm}$$

and elongation of fitted foundation bolt is:

$$\Delta L_f = \frac{4 \cdot 85838}{3.14 \cdot 205900}\left(\frac{130}{24.5^2} + \frac{127}{38^2} + \frac{76}{30.835^2}\right) = 0.204 \text{ mm}$$

According to Germanischer Lloyd [1995] the elongation after the tensioning of foundation bolt must be $\Delta L \geq 0.034 \cdot p$, where p is a permissible unit pressure on polymer chocks.

In this design of polymer chocking:

$$\Delta L \geq 0.034 \cdot 4.5 \geq 0.153$$

The calculated values of ΔL_t, and ΔL_f conform this requirement. Total load of chocks:

$$F_{mc} = G + F_{st} = 549360 \text{ N} + 2746800 \text{ N} = 3296160 \text{ N}$$

The classification society responsible has approved for chocks the polymer to be used for a unit pressure (engine weight + foundation bolts preloading) of 4.5 MPa and a chock temperature of at least 80°C. These polymer may be Chockfast Orange manufactured by ITW Philadelphia Resins Corp. Montgomery Ville, PA, USA Technical Bulletin 2000, Epocast 36 manufactured by H.A. Springer, Kiel, Germany [Rigid seating V 32/40 Marine 1995], and EPY manufactured by Marine Service Jaroszewicz, Szczecin, Poland [Grudziński and Jaroszewicz 1995]

$$S_{tch} = 4 \cdot 160 \cdot 140 + 14 \cdot 160 \cdot 340 - 32 \cdot 1256.64 = 810988 \text{ mm}^2$$

For the polymer used with the permitted unit pressure 4.5 MPa minimum area of total chocks:

$$S_{tc} = \frac{F_{mc}}{4.5} = \frac{3296160}{4.5} = 732480 \text{ mm}^2$$

In Fig. 2 it can be seen that the width of chocks may be max. 160 mm. From here the total length of chocks shall be:

$$L_{tc} = \frac{S_{tc}}{160} = \frac{732480}{160} = 5478 \quad \text{mm}$$

Taking into account the arrangement of foundation boltholes on the engine frame foot, there was designed a seating of an engine on 4 chocks 160×140 mm and 14 chocks 160×340 mm, Fig. 3. The arrangement of chocks on the foundation ledge was showed on Fig. 4.

Total sum of chocks bearing area after deduction of whole areas (32 holes 40 mm in diameter):

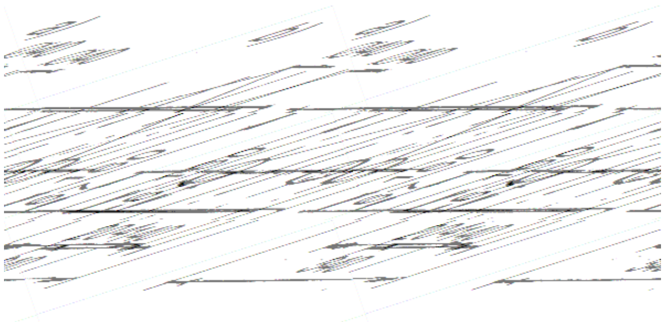

Fig. 3. Polymer chocks for rigid seating of the MAN B&W 12V32/40 marine diesel engine: a) end chock, b) middle chock

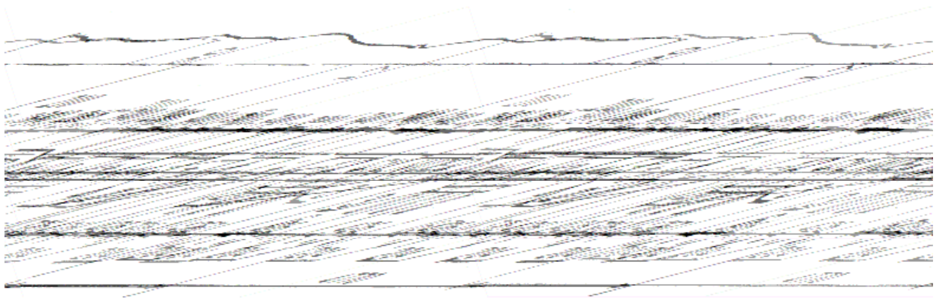

Fig. 4. Arrangement of the polymer chocks for rigid seating of the MAN B&W 12V32/40 marine diesel engine: 1 – polymer end chock, 2 – polymer middle chock, 3 – stopper, 4 – fitted foundation bolts, 5 – arrangement of polymer chocks, 6 – arrangement of foundation bolts.

The mean pressure of these chocks from engine weight:

$$p_c = \frac{F_m}{S_{tch}} = \frac{549360}{810988} = 0.68\,\text{MPa}$$

This means that the maximum value of 0.7 MPa laid down by the classification societies is not exceeded.

CALCULATIONS OF 550 KW PAXMAN DIESEL GENERATOR SET POLYMER CHOCKING

From documentation of 550 kW Paxman diesel generator set the following data were obtained [Wilson 1984]:

– deadweight of diesel generator set G = 31800 lb = 141453 N,
– number of foundation bolts:

16 through foundation bolts diameter 1 in = 25.4 mm and diameter of thread root 21.334 mm.

2 fitted foundation bolts diameter 1¼ in = 31.75 mm and diameter of thread root 27.102 mm.

If the bolts are slugged up, their tensions will be approximately:
trough bolt – 23000 Ib = 102309 N,
fitted bolt – 36800 Ib = 163694 N.

Total polymer chocks load will be:

$$F_{ct} = G + 16F_f = 141453 + 16 \cdot 102343 + 4 \cdot 102343 + 4 \cdot 163694 = 24331 \quad \text{N}$$

For seating diesel generator set using Chockfast Orange polymer, loading permitted is 1200 psi = 8.2737 MPa. From here the minimum total bearing surface of chocks will be:

$$S_{ct} = \frac{F_{ct}}{\sigma_c} = \frac{2433173}{8.2737} = 294052 \;\; \text{mm}^2$$

There are to be 20 chocks, so each chock must have at least:

$$S_c = \frac{S_{ct}}{n} = \frac{294052}{20} = 14703 \;\; \text{mm}^2$$

and if there in added the cross-section surface of hole 32 mm diameter for foundation bolt S_o = 804 mm, so bearing surface of each polymer chock will be:

$$S_{ch} = S_c + S_o = 14703 + 804 = 15507 \quad \text{mm}^2$$

The rail base flange is 7 in = 178 mm wide W and if it is taken away 20 mm by edge for dam of chock mould, it will be 158 mm. From here each polymer chock-minimum length will be:

$$L_c = \frac{S_{ch}}{W_c} = \frac{15507}{158} = 98\,\text{mm}$$

To simplify the chock mould dam it may be accepted that each chock has the dimension 125 by 125 mm.

Using Chockfast Gray polymer for seating diesel generator set, the loading permitted is 800 psi = 5.5152 MPa. From here after carry out of the same calculations have been obtained the dimensions of polymer chock would be 152 by 152 mm.

The presented calculations and drawings for polymer chocking of marine propulsion diesel engine and diesel generator set have to be accepted by the classification society. Performer of polymer chocking has to be accepted by a manufacturer of the polymer.

CONCLUSIONS

Calculations and drawings for polymer chocking of ships machinery must put to a good use loading permitted for polymer chocks and decreasing of foundation bolt pretensioning, which increases a profit from polymer chocking of ships machinery.

Calculations and drawings for polymer chocking of ships machinery are not complicated.

REFERENCES

CTO. Zamocowanie okrętowego silnika spalinowego. Gdańsk 2000.

Germanischer Lloyd. Regulations for the seating of propulsion plants. Hamburg, April 1995.

Grudziński K., Jaroszewicz W. 1995: Certyfikat ISO 9002 dla polskiego tworzywa EPY i posadawiania na nim silników okrętowych. Budownictwo Okrętowe i Gospodarka Morska.

ITW Philadelphia Resins Corp., Chockfast general guidelines for marine designers. Technical Bulletin No 692A. Montgomery Ville 2000.

MAN B&W Foundation. Rigid seating V 32/40 Marine. D 520.34.2. Status October 1995.

Wilson J.M. 1984: Marine epoxy resin chocks. Marine Technology. 21, 1.