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Finite element method for stress analysis in the frame holder of generator translation and rotation motion on vertical direction mechanism for sea wave power plant

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Abstract. Finite element method (FEM) has been used to calculate stress analysis in many field of engineering or industry (metal, automotive, power plant and etc.). FEM can be applied to reduce cost of product processing before manufacturing process. Requirement of design of product is cheaper, good properties, effective and efficient depend on function of product. Stress analysis depend on the properties of material, load, static and dynamic and shape of product or component. In the metal processing, FEM is applied for stress analysis in the conveying roll component due to the load on the roll and thermal stress analysis in the component of low pressure die casting machine. In the power plant, FEM is applied in the frame holder of generator to get stress due to static and dynamic load. Requirement properties of material frame holder of generator is stable, high strength, high stiffness, high corrosion resistance, and etc. In this research focus on the stress in the frame holder of generator translation and rotation motion on vertical direction. Varying load and material has been used for frame holder of generator such as cast iron, stainless steel, steel and thermoplastic resin. In the previous study, frame holder of generator has been used from cast iron and thrust force direction come from horizontal direction. The results get the maximum value (σ_{max}) of von mises of generator is is 643.4 MPa and the deflection value is 6.13 mm. By applied of vertical thrust force direction on the frame holder of generator translation and rotation is found that the maximum stress von misses value $\sigma_{vm}$is 74845 MPa and displacement is 17.9 mmby load 10 KN and using cast iron to frame holder of generator material.

Keywords: material, frame holder of generator, FEM, stress analysis, displacement, vertical direction mechanism

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1. Introduction
Finite element method (FEM) is ones method to calculate the stress analysis in the design of component. FEM analysis can be found in the metal industry, automotive industry, manufacture, building, structure and etc. FEM can be used to reduce cost of product before manufacture process is applied. Also by using FEM changed material and shape of design of component become easily. Requirement of design of component is cheaper, good properties (mechanical, chemistry, physic, environment and etc.), effective and efficient depend on function of product. Stress analysis of component depend on the properties of material, load, static and dynamic, and shape of component. FEM for stress analysis consist on the stress, strain, deformation (displacement), pressure contact, factor safety and etc.

In the metal processing, FEM is applied for stress analysis in the conveying roll component due to load and thermal effect on the roll [1-3]. In the metal processing for automotive component thermal stress analysis is applied in high low pressure die casting component [4-6] due to high temperature processing condition. In the generator of sea wave power plant [7-12], stress analysis is applied on the frame holder of generator due to static and dynamic load. Requirement properties of material frame holder of generator is stable, high strength, rigid, high stiffness, high corrosion resistance due to sea environment, and etc. Stable of generator can make motion of component generator become smooth and constant moving up and down like shaft in piston (tube generator). Rigid, stiffness and strength of the frame holder of generator is important due to stress and deformation appear at the generator. Strength of component generator influenced by the thrust force of piston, material of piston and frame holder generator. Material and shape of the frame holder of generator have effect on the stiffnessof generator. Stiffness of generator consist on the stress and deformation that occur on the frame holder of generator. The rigid frame holder of generator will produce small stress and deformation. The amount stress and deformation that occurs at the Frame holder of generator translation and rotation can be obtained by using the finite element method (FEM).

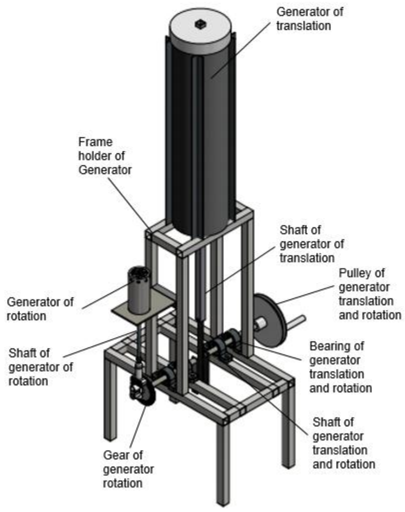

Figure 1. Component of generator translation and rotation motion on vertical direction mechanism

Therefore in this research focus on stress analysis in the design of frame holder of generator translation and rotation motion on vertical direction mechanism. Varying load and materials component are applied in this design because the performance of component of generator depend on the high strength and stiffness, high corrosion resistance. Some requirement of frame holder of generator such as stable on the moving (smooth), high strength and stiffness, high corrosion resistance, balance and etc. is need to increasing the performance of generator. Component of generator translation and rotation motion on the vertical direction mechanism consist on generator of translation and rotation motion, shaft of generator, bearing, pulley, gear and frame holder of generator as shown in Figure 1.

In this paper stress analysis is considered in the design of frame holder generator by varying materials and loads. FEM analysis is applied to calculate stress and deformation appear in the frame holder generator [5-9] before manufacturing process. By FEM analysis it's obtained that good material and load for design of frame holder generator and also reduce of cost production for manufacturing.

2. Method

FEM is applied to calculate stress analysis in the frame holder of generator translation and rotation motion on vertical direction mechanism. 3D model has been used for design of frame holder of generator with varying load and material such as cast iron, stainless steel, steel and thermoplastic resin. Material properties of frame holder of generator in this research can be seen in **Table 1.** Input power of generator by using manual process (rotated by hand). Resources of load input by thrust force in pulley of generator translation and rotation by using varying load from 1000 N to 20 KN.

Dimension and shape of generator translation and rotation motion on vertical direction mechanism can be seen in **Figure 2**. Diameter of tube generator is 219 mm, length of tube generator 800 mm and length of generator and frame of holder is 1780 mm. In FEM simulation model of generator translation and rotation have number of elements is 162264 and 307941 number of node.

Table 1. Properties of material frame holder of generator [8]

Material	Young's Modulus (GPa)	Poisson's Ratio	Tensile Strength (MPa)
Cast Iron	120	0.3	758
Steel	210	0.3	330
Stainless Steel	190	0.265	480
Thermoplastic resin	2.0	0.4	40

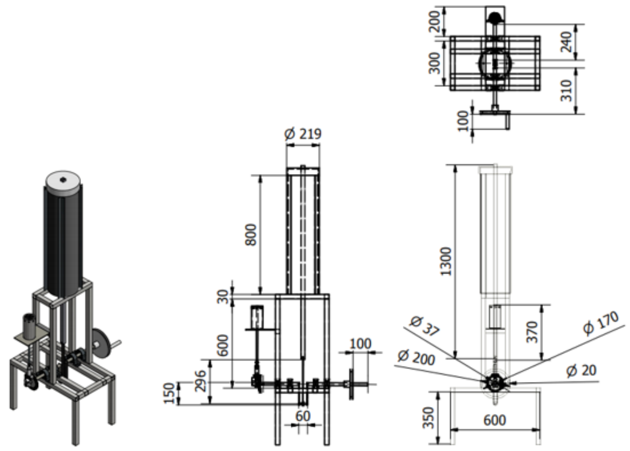

Figure 2. Design and dimension of generator translation and rotation motion on vertical direction mechanism

3. Result and discussion

Results of FEM analysis for stress in the design of frame holder of generator translation and rotation motion on vertical direction mechanism using cast iron with load 10 KN can be seen at **Figure 3** and **4**. **Figure 3** shows the stress distribution, displacement, contact pressure and safety factor value of frame holder of generator translation and rotation. As shown in **Figure 3** the maximum value of von misses $\sigma_{vm}$is 74845 MPa and stress maximum value appear at the Z direction due to the thrust force resources in Z direction. The maximum stress σ_{max} in Z direction is 18180 MPa. Maximum stress value appear at the shaft of generator translation and rotation due to the rotation resources of stress come from thrust force in Z direction (rotation resources in plate of pulley). For principle stress in tensile condition the maximum stress value is 50850 MPa and compression condition with maximum value is -50788 MPa. For displacement, factor safety and contact pressure of generator translation and rotation can be seen in Figure 4 whereas maximum value of displacement is 17.9 mm. Factor safety have big value on the tube of generator is 15 (SF 15) and small value in the shaft of generator is 0.03 (SF 0.03). This value show that at the shaft of generator must be careful for stress and displacement if they have small value of safety factor (see **Figure 4**).

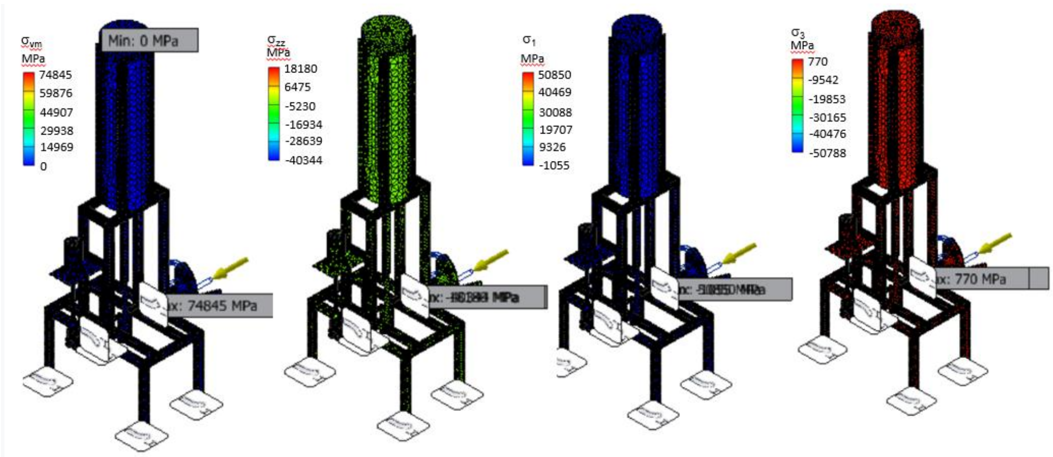

Figure 3. Stress distribution of generator translation and rotation motion on vertical direction mechanism

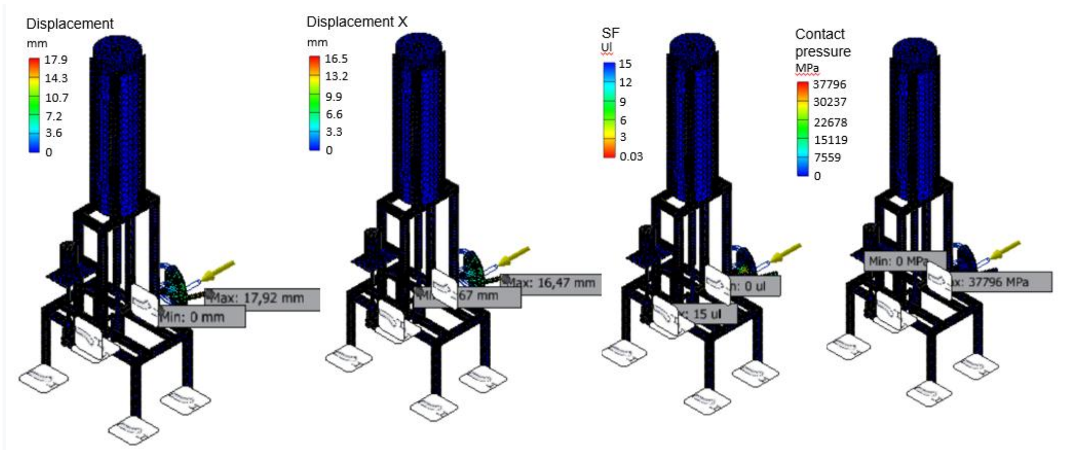

Figure 4. Displacement, safety factor and contact pressure of generator translation and rotation motion on vertical direction mechanism

By applied varying load 1000 N to 20 KN in the frame holder of generator is found that the maximum stress value of generator translation and rotation on vertical direction mechanism become increase. At load 1000 N the maximum stress value von misses σ_{vm} is 7484 MPa with displacement 1.79 mm. When the load increase to 20 KN, so the maximum value von misses σ_{vm} is 149700 MPa and displacement is 35.85 mm as shown in Table 2. This value have bigger displacement value and make the frame holder of generator translation and rotation motion on vertical direction mechanism become failure when the load more than 20 KN.

Table 2. Result of stress and deformation on design of frame of generator translation and rotation motion on vertical direction mechanism

No	Material	Load (N)	Maximum Stress σ_{vm} (MPa)	Displacement δ_{mak} (mm)	Safety Factor (SF)
1	Cast Iron	1000	7484	1.79	15
2		2000	14969	3.58	15
3		4000	29938	7.17	15
4		5000	37422	8.96	15
5		6000	44906	10.75	15
6		8000	59876	14.34	15
7		10000	74845	17.92	15
8		20000	149700	35.85	15

Table 3. Result of stress and deformation on design of frame of generator translation and rotation motion on vertical direction mechanism

No	Material	Load (N)	Maximum Stress σ_{vm} (MPa)	Displacement δ_{mak} (mm)	Safety Factor (SF)
1	Cast Iron	10000	74845	17.92	15
2	Stainless steel		74958	17.84	15
3	Steel		74949	17.83	15
4	Thermoplastic resin		63744	19	15

Table 3 show the maximum stress and displacement of frame holder of generator by applied varying material. Material has been used in this design of frame holder of generator is cast iron, stainless steel, steel and thermoplastic resin. The maximum stress of frame holder of generator is 74845 MPa for cast iron and 17.92 mm for displacement. By using stainless steel the maximum stress of frame generator is 74958 MPa and 17.84 mm for displacement. The maximum stress and displacement of stainless steel and steel near same value compare with the cast iron and thermoplastic results. Because application of generator translation and rotation for sea wave power plant (corrosion environment) so selected material using for frame holder of generator is stainless steel. Stainless steel have advantage such as high corrosion resistance and also the stress near same with steel. From this results the maximum stress and displacement value of thermoplastic resin is smaller than other materials as shown in Table 3.

4. Conclusion

Selection material for generator translation and rotation motion on vertical direction mechanism is important for component such as frame holder of generator. Requirement of material properties of frame holder of generator is rigid, high stiffness and strength, high corrosion resistance and etc. To get design of generator with that requirement so finite element method (FEM) is applied to solve stress analysis. The conclusions can be made in the following:

- The maximum stress and displacement value of design frame holder of generator translation and rotation appear at Z direction due to the rotation resources of load come from Z direction (rotation resources in plate of pulley) with SF 15. The maximum stress von misses value σ_{vm} is 74845 MPa and displacement is 17.9 mm for load 10 KN and using cast iron to frame holder of generator material.
- Maximum stress of generator translation and rotation motion on vertical direction mechanism become large value when the value of load is bigger. By varying load 1000 N to 20 KN is found that the maximum stress value of generator translation and rotation on vertical direction mechanism become increase. The maximum stress value von misses σ_{vm} is 7484 MPa with

displacement 1.79 mm for load 1000 N and become increase at load 20 KN with maximum stress von misses σ_{vm} is 149700 MPa and displacement is 35.85 mm.

- The maximum stress of frame holder of generator using stainless steel is better than cast iron and thermoplastic resin. Even though the value is near same with steel material so frame holder of generator translation and rotation motion on vertical direction mechanism use stainless steel. Because application of generator translation and rotation for sea wave power plant and stainless steel have advantage such as high corrosion resistance.

5. Acknowledgement

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