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W4L20 VEBIC Genset dynamics—baseframe design

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Summary. This article describes the dynamic design of W4L20 VEBIC Genset, which consist engine, generator and baseframe. The engine creates the main excitations of the system. The eigenmodes of the Genset have to be adjusted by modifying the baseframe dimensions, so that the excitations are not in resonance with the eigenmodes. Eventually a feasible design has been found and shortly presented.

Key words: Wärtsilä, W4L20, natural frequencies

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Introduction

Wärtsilä Finland Oy is in collaboration with Vaasa Energy Business Innovation Centre VEBIC where the generating set introduced in this paper is used. This medium speed W4L20 diesel engine is the first combustion engine in the laboratory. This particular engine produces approximately 1 MW of power and it is paired with ABB generator.[8]

The ABB generator that is used for this generating set is originally designed as a motor and therefore the alignment between the crankshafts and rotors rotation axle is adjusted with step in the base frame that is not usually used. Normally the generator is selected so that the generator mounting surface to rotation axle distance is somewhat the same as the distance between the crankshaft rotation axle and the engine mounting surface to the baseframe.

The function of common base frame in a diesel generating set is to provide static support for the masses of the engine and generator and keep the crankshaft and rotor alignment during loading. The base frame joins the engine and generator as a one package that can be transported and lifted to VEBIC laboratory.

The dynamic behavior of the generating set needed to be calculated to ensure that the critical excitations are not near the eigenmodes of the system. For this task a finite element simulation was performed. The structure was modified according to the results and the final production model was also simulated to ensure that the changes from the base design and production model did not affect the system behavior.[9]

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Engine excitations

The typical engine excitation sources are unbalance of rotating masses, oscillating masses, cylinder pressure, camshaft and valve mechanisms, misalignments, pressure pulses [1], tooth meshing in gears [6] and so on. The excitations in a four-stroke diesel engine are expressed as a harmonic orders of the engine running speed. The first order is n/60 Hz, where n is the running speed of the engine in rounds per minute. Main excitations of a four stroke engine are created every half order: 1.0 ; 1.5 ; 2.0 etc. [7]

The main excitations can be divided into mass force excitations and gas force excitations. In the mass force excitations the rotating masses that are in unbalance create first order excitations and affect mainly as rigid body vibrations to the system and bending excitations. The oscillating masses, typically piston and connecting rod, excite the system mainly at lowest two full orders. Gas forces from the engine cylinders create excitations in all harmonic orders including half orders. These excitations mainly create torsion based deflections and vibrations to the engine. [3]

The in-line four cylinder engine creates vertical unbalance forces that are counter balanced with balancing axles. Two axles rotating in the opposite directions counterbalance the vertical forces without creating transversal excitations [7]. The main rolling and torsion moment excitations from balanced four stroke four cylinder in-line engine in order of significance are: 2.0, 1.5, 4, 2.5, 3.5. The main pitching and bending moment excitations are: 1.0, 2.0. The corresponding frequencies with nominal speed of 900/1000 rpm are listed in the **Table 1**.

	900 rpm	**1000 rpm**	**Significance 1-3**
1.0	15.0 Hz	16.8 Hz	2
1.5	22.5 Hz	25.0 Hz	3
2.0	30.0 Hz	33.3 Hz	3
2.5	37.5 Hz	41.7 Hz	1
3.0	45.0 Hz	50.0 Hz	0
3.5	52.5 Hz	58.3 Hz	1
4.0	60.0 Hz	66.7 Hz	2

Table 1. The excitation table of in-line four engine with corresponding excitation frequencies at 900/1000rpm and the excitation force degree of significance.

Simulation model

In this task a finite element method was used to solve the eigenmodes of the system. The engine assembly is modeled mainly using second order tetrahedron elements, for some parts of the model the density of the elements is scaled to compensate small missing components, but the larger components that are not modeled are replaced by point mass elements and the point mass is distributed to the structure through distributing elements. The base frame and oil sump are modeled by using shell elements. [2]

The model is divided into sub assemblies, power unit, base frame, and generator that are attached through distributing couplings in the corresponding area of bolted connections and the whole generating set assembly is resting on top of a spring pack.

The main simulation work is done using a commercial finite element program that in this case is Optistruct 14.0.220. [2]

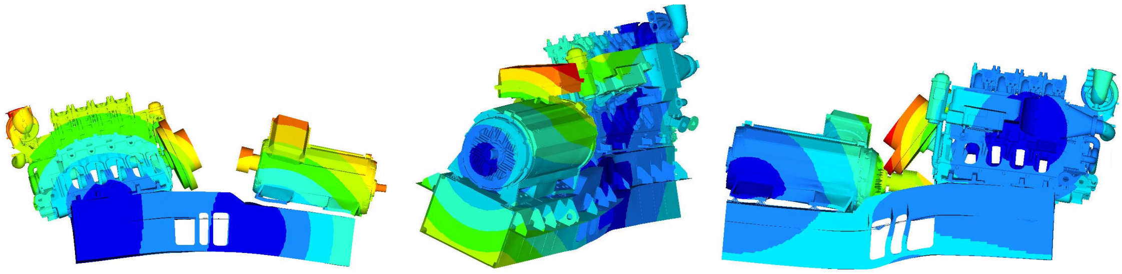

Figure 1. First three flexible modes: vertical bending, torsion and two point vertical bending.

At the beginning of the design work a base model was created according to general guidelines used in the previous base frame designs with the help of a parametric design tool [4]. First three eigenmodes of the system can be seen in **Figure 1**. In the process the instrumentation between the flexible coupling and generator increased the total length of the base frame. The goal was to adjust the vertical bending to 39 Hz or above and torsion mode under the 53 Hz. The final design with opened side plates gave the eigenmode of 39 Hz for vertical bending and 48 Hz for torsion. Three design phases can be seen in **Figure 2**. The vertical bending did not change more than 1 Hz from the beginning, but the torsion mode decreased almost 10Hz.

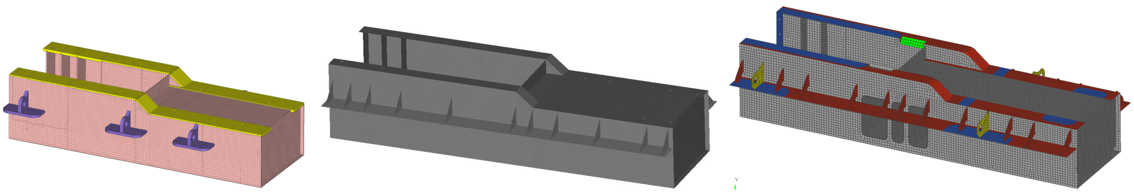

Figure 2. The base model of the base frame and the final product.

Finalization

By modifying the dimensions of the common base frame we could easily adjust the eigenfrequencies of the system and avoid resonances that can cause structural damage [10]. In more complex systems a topology optimization could be used and in cast parts this is very powerful tool for the basic design [5]. In this case the basic design work produced acceptable results very effectively. The torsion mode, 48 Hz is 9 % under the critical 3.5 excitation order and the bending mode, 39 Hz is 17 % above the critical 2.0 excitation order. The next step for this process is a on-site modal analysis of the generating set to validate the computer simulation model and vibration measurements of running generating set.

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