

Analysis and Dynamic Behavior of Portal Structure Due Rotating Machines Loads

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Abstract

Rotating machines can be regarded as live load when the machine is operating at a period of time at a certain speed will result in vibration on the structure. The purpose of this research to perform dynamic analysis of the portal structure in order to know how much influence the dynamic load due to the machine that is operating on the structure and get a large ratio of displacement, velocity, and acceleration when the load is given a static and dynamic load. This dynamic analysis is done with the help of SAP2000 V.20.0.2 software. From the results of this study, it was found that the first ten shape modes of the structure did not experience resonance, although in a third mode natural frequency obtained at 57.466 Hz which has a result of 0.865 Hz and is said to be close to resonance, but the frequency does not have much impact on the structure. In addition to considering the resonance value, the structure also considers the value of all amplitudes and the results of the internal forces of the structure. From the results of the amplitude of displacement, velocity, and acceleration shows that vibration does not affect humans and does not damage the structure in accordance with applicable regulations and standards.

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Keywords: Dynamic Analysis, Portal Structures, Dynamic Loads, Displacement, Acceleration, Velocity, Frequency

1. Introduction

On the operating machine this creates vibrations that can impact the structure that supports the machine itself and the workers who are located around it, it takes a foundation that can withstand the weight of the machine.

The foundation that supports a high-vibration frequency machine can be affected by vibrations caused by the unbalanced engine forces and also by the static weight of the machine [2]. If these vibrations are excessive, the vibration can damage the machine and cause the machine to malfunction or work properly, even exploding. Furthermore, such vibrations can adversely affect buildings or people working around the machine.

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2. Methods

The method used in this thesis research is the literary study method, the study of literature is to looking for theoretical references in accordance with the case or problem found.

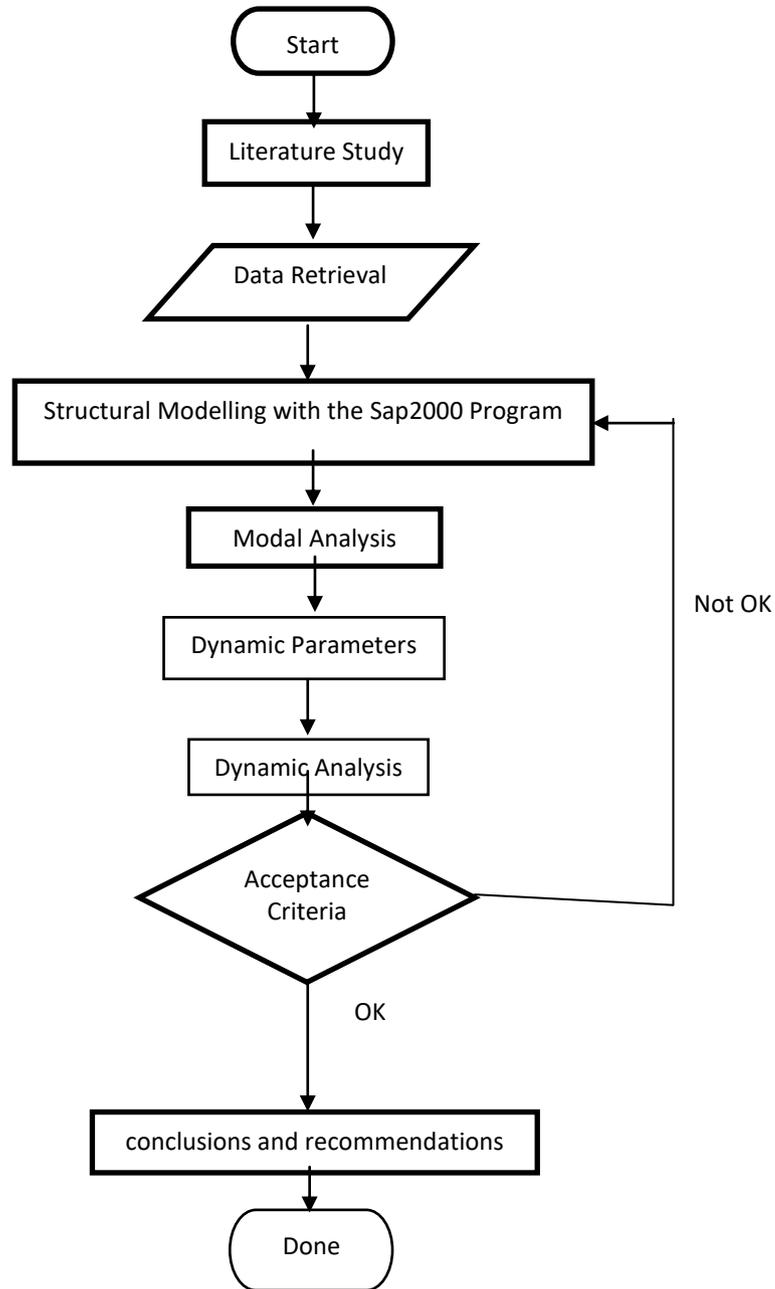


Fig. 1 3D Model Visible Structure Portal.
Source: Data in Research,2020.

2.1. Structure Data

To model this structure that supports the machines, this research will use a portal foundation rigid structures where the data provided in table 1 and figure 2.

Table 1 Structures Data

Structures	
Column Dimension 1	1000 mm x1000 mm
Column Dimension 2	800 mm x1000 mm
Column Height	3175 mm
Beam Dimension	1500 mm x 1000 mm
Plate dimension	7500 mm x 3900 mm
Plate and Beam Thickness	1400 mm
Concrete Quality	Fc 50
Reinforcement Quality	400 Mpa

Source: Data in Research,2020.

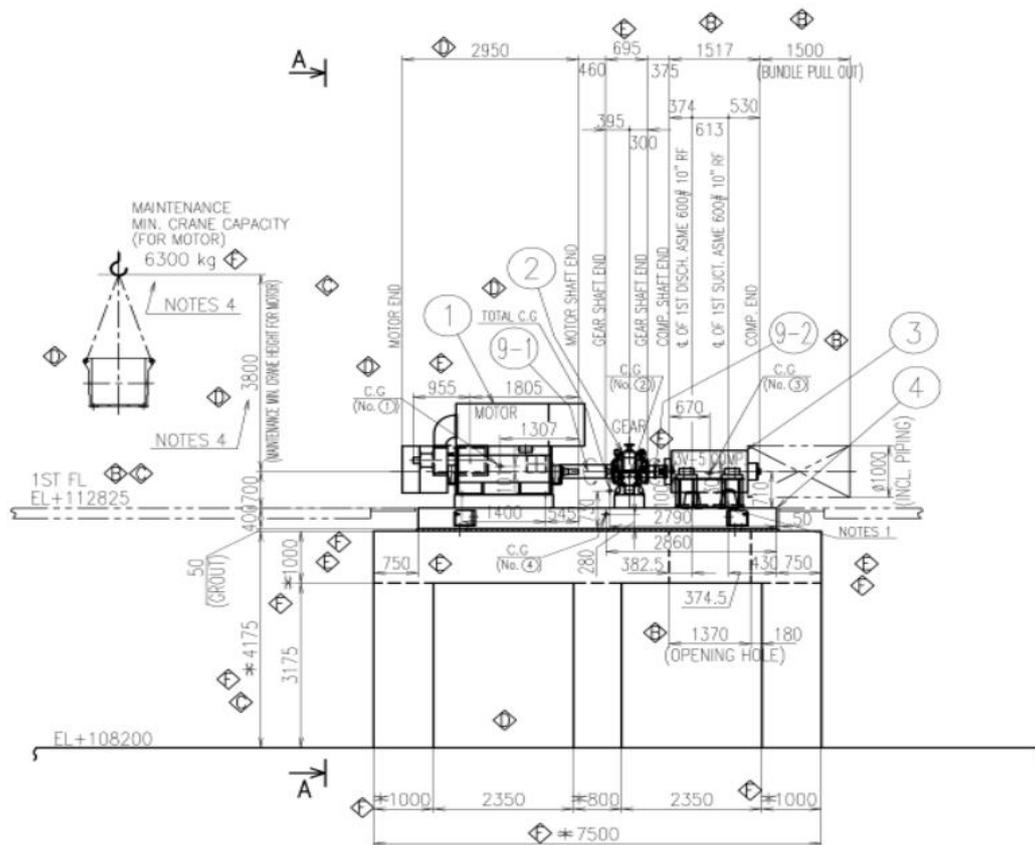


Fig. 2 Structure Portal and placement position of the engine.
Source: Data in Research,2020.

2.2. Machines Data

A machine that were analysed in this research is the rotating machines with total machines weight 37.035 kg. The dynamic force of the compressor engine from the moving part of the gear and that part is used in calculating the excitation frequency, amplitude of displacement, velocity, and acceleration (figure 3).

Table 2 Machines Data

Machines	
Machine Frequency	2981 RPM
Dynamic Weight	464 Kg
Motor Weight	5250 Kg
Gear Weight	1100 Kg
Compressor Weight	5200 Kg
Base Plate Weight	11000 Kg
Total Machine Weight	37.035 Kg

Source: Data in Research,2020.

3. Results and Discussion

3.1. Structural modelling

Modelling the structure of this portal is done in 3D using SAP Program 2000 V. 20.2.0 where in the modelling structure, the beams and columns are modeled with Frame or portal elements. The effect of the frequency of this mode is taken into account in the analysis of free vibration and forced vibration. The model of the portal structure consists of 2 floors and functions of the building as a support place for the rotating machine.

3.2. Research results

The results of the research obtained from the process of running and literature studies. The running process is carried out on SAP2000 software. The running process is done after all the load pattern and load case already fit the load – the load that works on the machine and will be running. Load case is used as function of machine operating load case time history.

a. Excitation Frequency

Floor frequency due to excites is the frequency that occurs in the floor structure due to outside interference to the portal structure. The floor structure in the portal structure will resonate when excitation approaches the natural frequencies of the floor structure. When the floor structure receives a dynamic load from the machine that is operating, then the structure will experience vibration. So that each type of structure will have different frequencies according to the type of the structure itself when it receives the dynamic loads of the machine while it is operating.

This final assignment uses the guidelines or excitation frequency reference from the literature study described by [1] , where if dynamic frequencies are smaller than natural frequencies $\frac{f_{dynamic}}{f_{natural}} < 0.8$ (*high tuned*) and $\frac{f_{dynamic}}{f_{natural}} > 1.2$ (*low tuned*) the structure is said to have no resonance, but if dynamic frequencies are divided by natural frequencies between 0.8 and 1.2 then the structure is said to close to resonance. Structures can be said to resonate when dynamic frequencies is the same as the natural frequency.

Table 3 Dynamic frequency against natural frequency structure

Mode	F. Dynamic	F. Natural	Result	Explanation
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Mode	F. Dynamic	F. Natural	Result	Explanation
1	49.683	12.401	4.007	Not resonate
2	49.683	13.365	3.718	Not resonate
3	49.683	57.466	0.865	Close to resonate
4	49.683	69.823	0.712	Not resonate
5	49.683	134.963	0.368	Not resonate
6	49.683	155.209	0.320	Not resonate
7	49.683	155.841	0.319	Not resonate
8	49.683	169.127	0.294	Not resonate
9	49.683	175.436	0.283	Not resonate
10	49.683	175.564	0.283	Not resonate

Source: Data in Research,2020.

After conducting the natural frequency analysis, the structure in all modes except the third mode is stated to qualify from the literature study. So the structure can be said to be safe from vibration due to operating machinery.

While the structure in mode 3 is stated to be close to resonance but does not belong to the resonance category in the literature study, it is said that the structure in this mode still included in the safe category of vibration due to the operating machine.

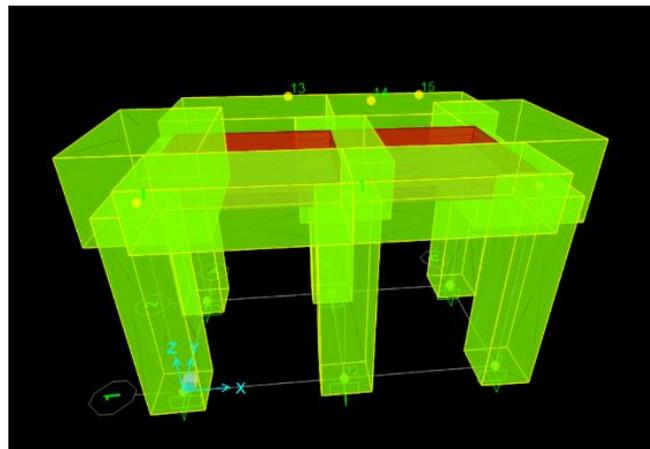


Figure 3 3D Model Visible Structure Portal.

Source: Data in Research,2020.

b. Displacement in Structure

Displacement is the distance of a single node or joint of a beam, column, plate, etc. that moves the place from its original location (figure 4). From SAP2000 results can be found maximum displacement occurs in element 30 with displacement in z direction of 0.054725 mm.

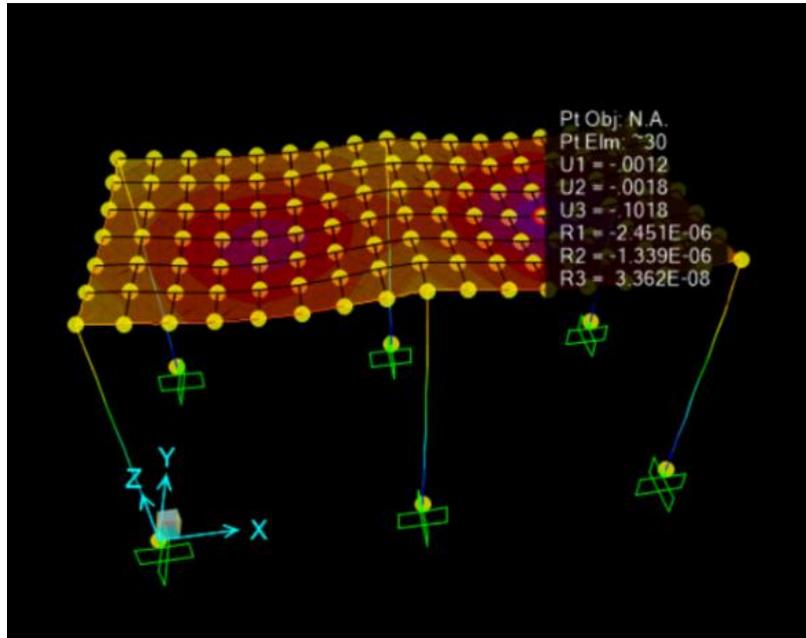


Figure 4 Displacement in portal structure
Source: Data in Research,2020.

c. Velocity in structure

Velocity is the amount of time needed when displacement occurs. At the center of gravity the portal vibration structure is reviewed by the author assuming the machine works for 5 seconds. Where after the modelling the structures and running analyze it will get a load function that shows the vibration speed of the machine. Transient velocity (temporary) is obtained by $3,05 \times 10^{-2}$ m/s or 30,5 mm/s and steady state speed (balanced) is obtained at $-2,46 \times 10^{-2}$ m/s or 24,6 mm/s (in figure 5).

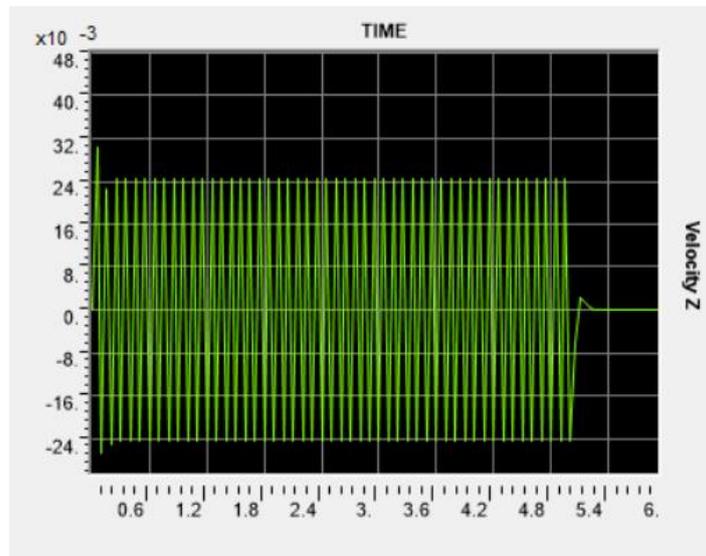


Figure 5 Velocity of Z-direction on portal structure
Source: Data in Research, 2020.

d. Acceleration in structure

Acceleration is the speed change of a force that moves or vibrates in a units of time. The acceleration of this study aims to analyze the user comfort of the portal structure that can be calculated with the parameters of the maximum acceleration or acceleration of the floor plate due to vibration occurring in the modelling and assumed Works for 5 seconds where after modelling the structure and running analyse will get a load function that shows the acceleration of vibration from the machine. Transient acceleration (temporary) and steady state (balanced) acceleration for x, y, and z directions as shown in figure 6, figure 7, and figure 8.

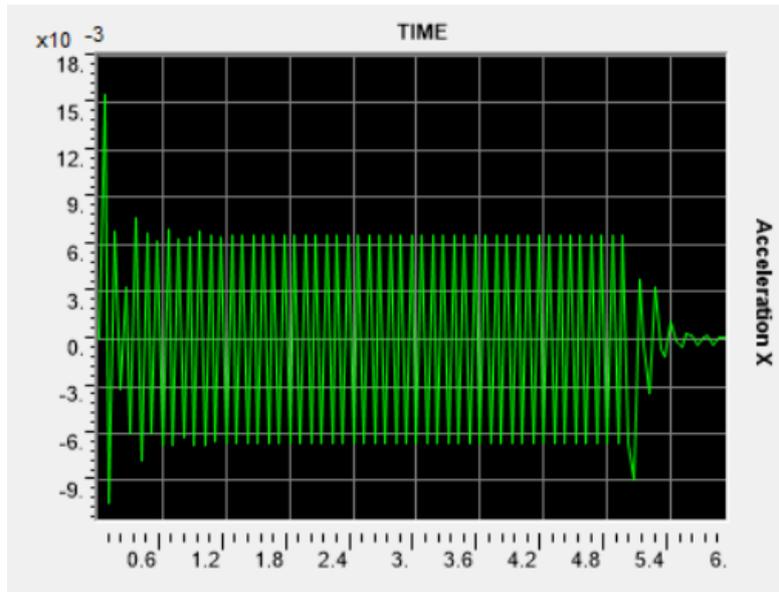


Figure 6 X-direction acceleration of portal structure
Source: Data in Research,2020.

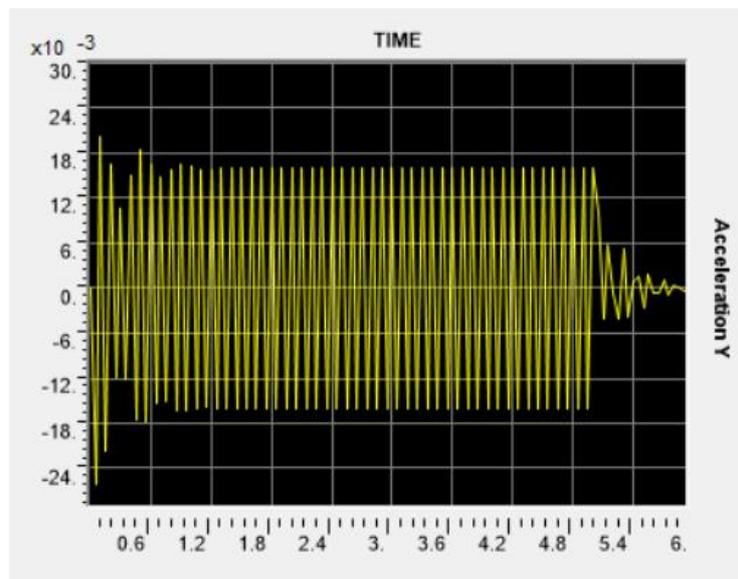


Figure 7 Y-direction acceleration of portal structure
Source: Data in Research,2020.

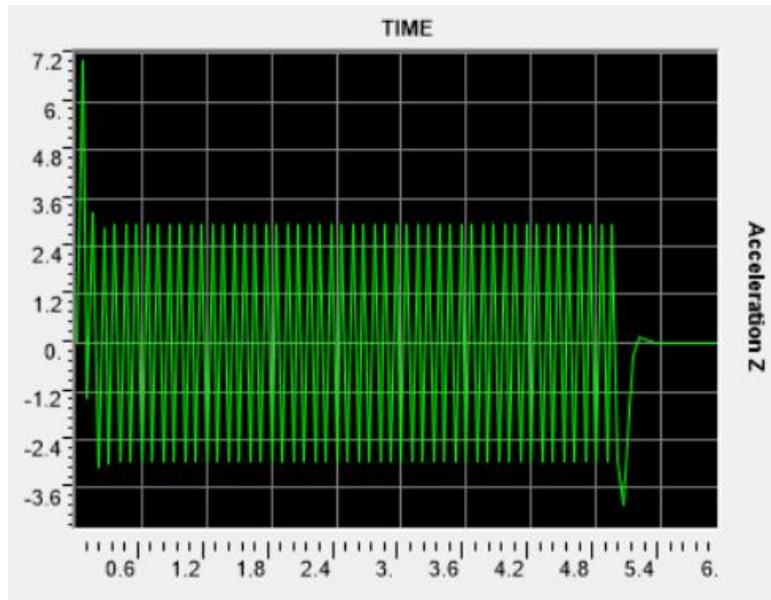


Figure 8 Z-direction acceleration of portal structure
Source: Data in Research,2020.

Table 4 Acceleration of Portal structure

Direction	Transient (m/s^2)	Steady State (m/s^2)
X	$1,55 \times 10^{-2}$	$6,58 \times 10^{-3}$
Y	$2,05 \times 10^{-2}$	$1,59 \times 10^{-2}$
Z	6,99	2,95

Source: Data in Research,2020.

From the results of the review and seen from the graph, the maximum acceleration obtained from the transient acceleration, this happens when the engine just starts up or starts operating and causes a large acceleration so that the maximum acceleration is obtained is the transient acceleration, although at the next second the engine returns to balanced acceleration.

3.3. Acceptance criteria

Acceptance criteria are the requirements that must be met in each structure so that the structure is safe and comfortable. There are 3 structural acceptance criteria to support a rotating machine based on the highest value limit or amplitude, namely the displacement amplitude, velocity amplitude and acceleration amplitude caused by the vibration of the machine that is operating against the structure.

a. Displacement Amplitude

Limitation of structural displacement amplitude that is used based on [4] after the process of running on the portal structure is obtained:

Table 5 Criteria for acceptance of displacement

Joint	Displacement		Acceptance Criteria		Explanation
	(mm)	(inch)	(mm)	(inch)	
30	0,054725	0,00215453	0 - 0,2	0 - 0,00787402	Easily noticeable to person.

Source: Data in Research,2020.

b. Velocity Amplitude

The amplitude limit of the calculated structural velocity is at the center of gravity of the portal structure. In [6] issued speed limits for various types of machines.

Table 6 Criteria for acceptance of velocity

Velocity (mm/s)	Acceptance Criteria (mm/s)	Explanation
24,6	2,8 - 11,2	Zone D

Source: Data in Research,2020.

c. Acceleration Amplitude

Limitation of structural acceleration amplitude used is based on [5]:

Table 7 Criteria for Acceptance of WBV Acceleration

Direction	Acceleration (m/s ²)	Period (s)	Acceptance Criteria (m/s ²)	Explanation
X	$6,58 \times 10^{-3}$	60	50	SAFE
Y	$1,59 \times 10^{-2}$	60	50	SAFE
Z	2,95	60	50	SAFE

Source: Data in Research,2020.

4. Conclusion

The natural frequency of all modes except the third mode is far with dynamic frequencies, according to the determination then it can be said that the structure is far from resonance. The result of this displacement amplitude is 0.054725 mm and entry into the category easily noticeable to person or the deflection received is safe for the portal structure. The results of the acceleration amplitude criteria from all directions according to the acceptance criteria can be said to be safe from vibrations due to machines operating and not causing (WBV) Whole Body Vibration or vibrations in the whole body for workers around the machine. Velocity amplitude itself is obtained at 24.6 mm/s which enters the danger limit which can cause damage to the engine from that speed. Preferably for the dimensions or quality of the structure to be changed so that the value of velocity can be entered into criteria. Or it can be given a so as to dampen the excess vibration of the machine so that the speed amplitude value can be entered in the acceptance criteria.

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