FEA Analysis for Frequency Behavior of Industrial Robot's Mechanical Elements

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Abstract. The dynamic behavior of the mechanical elements used in Industrial Robots is extremely important for defining the overall performance. From this perspective, the material used for these elements is very important. This study shows the overall difference between using a composite material and the traditional aluminum for the design of the robot elements.

Keywords: Industrial Robot, Materials, Modal Behaviour

1. Present and future materials used in robots

In terms of materials being used for designing and manufacturing of industrial robots, aluminium is widely used, because of its good mechanical properties. For industrial robots design, a material with low density and high stiffness is always preferred [3]. Aluminium meets these properties, in comparison with Steel or other metals. Composite materials, although harder to manufacture, can provide superior properties regarding stiffness and density. The table below shows a comparison between aluminium and a carbon fibre composite.

Table 1. Material comparison [1]

Material	Mechanical properties	
	Density (kg/m3)	*Elastic Modulus (GPa)*
Aluminum 6063 – T6	2700	70
Carbon Fiber (70%) Composite	1600	140

As seen in the table above, the composite material has a lower density and a higher stiffness. The composite material stiffness is given just on one direction, for a unidirectional type of carbon fibre composite. On the other two directions, the E modulus is 10GPa, like shown in [1] and [2]. Given that the composite material stiffness is not the same on all three directions, a study is made for a simple beam, of 20x100x400mm, for both aluminium and carbon fibre composite, to see the difference in terms of the first 40 natural frequencies seen by the FEA analysis made in Ansys. The E modulus of 140GPa was considered along the length of 400mm. the dimensions of the beam have been considered after looking at the most used sizes for industrial robots, in terms of their mechanical elements. The chosen dimensions are a rough average estimated based on these mentioned general sizes of the existing industrial robots that can be found on the market. The carbon fibre composite used in the simulation has a 70% Fibre with 30% resin volumetric ratio.

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2. FEA Analysis and Results

2.1. The analysis setup

As mentioned before, Ansys simulation environment has been used for a Modal analysis of the beam, for both materials. The general setup can be seen in the figure below.
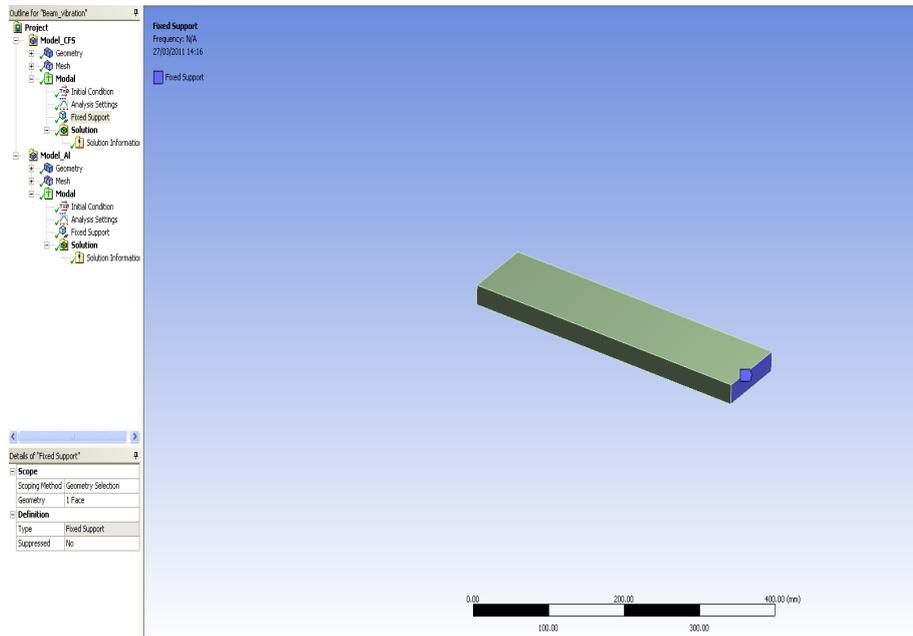

Fig. 1: FEA analysis setup.

The beam was constrained with a fixed support at one end. The analysis was run for the first 40 modes, for both cases using the two earlier mentioned materials.

2.2. Discussion of the results

After running the model, the first 40 natural frequencies for each case have been obtained. All of these have been plotted on the same graph that can be seen below.

Carbon Fibre Composite

$$y = -0.1985x^3 + 12.49x^2 + 355.85x$$

$$y = -0.1689x^3 + 6.034x^2 + 369.76x$$

Legend:
- Carbon Fibre Composite
- Aluminium Alloy
- Poly. (Aluminium Alloy)
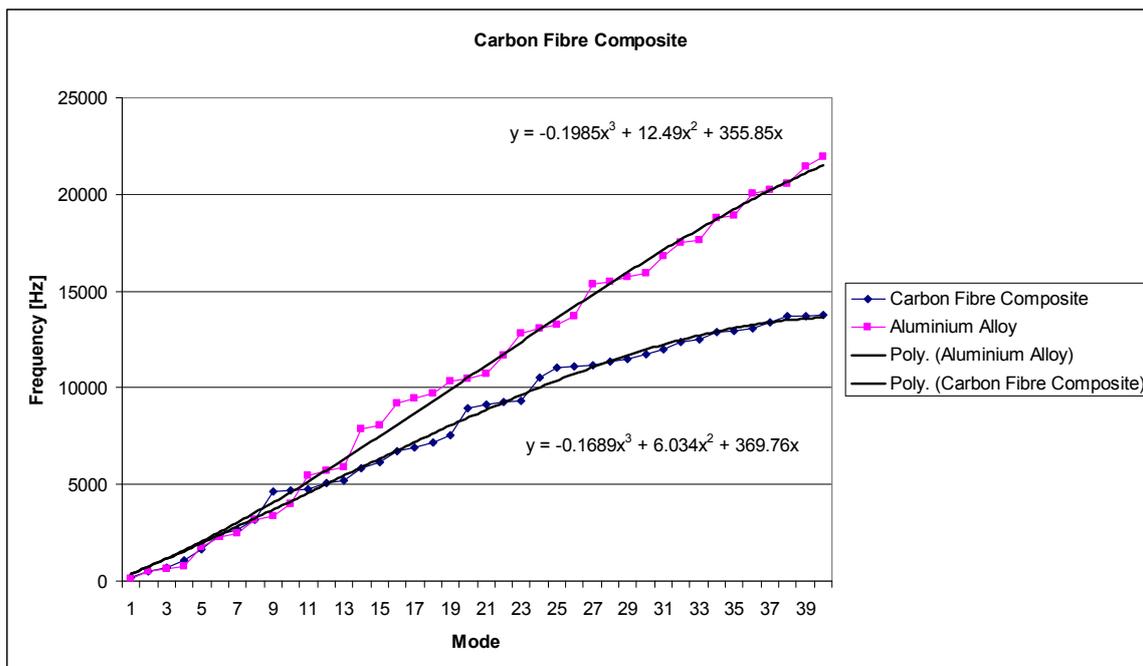- Poly. (Carbon Fibre Composite)

Fig. 2: Modal analysis results.

The modes have been plotted on the X axis, while the Y axis shows the frequency in Hertz. The results have been approximated by a curve fitting with a third degree polynomial, for each one of the cases, as follows:

- For the carbon fiber composite case, the relation is:

$$y = -0.1689x^3 + 6.034x^2 + 369.76x \qquad (1)$$

- For the aluminum case, we have:

$$y = -0.1985x^3 + 12.49x^2 + 355.85x \qquad (2)$$

The result is expressed as the difference between the two expressions, as:

$$y = -0.0296x^3 + 6.46x^2 - 13.91x \qquad (3)$$

2.3. Conclusion

The present study was made to establish a general rule for de difference in the dynamic behaviour between the same mechanical element made of aluminium and carbon fibre composite material. The difference is expressed in Hertz, by relation 3. The simulation for the carbon fibre composite was made by applying orthotropic material properties. It was seen that even if the carbon fibre has lower stiffness across both secondary axes, generally the natural frequencies for the first 40 modes are higher in the carbon fibre composite material.

3. Acknowledgements

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4. References

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