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THE IMPACT OF THIN DISC MODELING ON MODAL CHARACTERISTICS OF AXIAL STRUCTURES

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ABSTRACT

By using the software I-DEAS Master Series 6, the impact of thin disc modeling on frequencies and modes of vibration of the axial structure were examined. We considered only the case when the disc is mounted in the middle of the shaft. This paper presents the first four flexural modes and frequencies for three sizes of disc diameter and for different ways of modeling.

Key words: modal parameters, disc, axial structure

1. INTRODUCTION

Axially symmetric rotating structures (shafts, machine tool spindles, etc.) usually carry transmission and operating elements such as pulleys, gears, jaw heads, etc. Modeling of these structures, if details and the specificity of each individual aren't necessary, is reduced to the problem of modeling the axial structure with the discs.

Teoretical models of shaft-disc system are usually based on the following four models:

- rigid shaft and rigid disc, [2],
- flexible shaft and rigid disc, [2, 3, 4],
- rigid shaft and flexible disc, [5],
- flexible shaft and flexible disc, [6].

The last model is the most complicated because of the coupling of the shaft vibratory modes with circular and radial disc vibratory modes.

2. MODELING OF THE SHAFT-DISC STRUCTURE

Modeling of the shaft (with diameter d=0.1 mm) will be done by Solid Tetrahedron or Timoshenko beam elements, [1]. The disc (with diameter of 0.2m, 0.3m and 0.5m) will be modeled in three ways:

- by Solid Tetrahedron elements, which can be expected to be the best representation of the actual distribution of inertial and elastic characteristics, and thus to give the best results,
- by Lumped Mass element, which idealizes the disc with dimensionless element with a certain mass and moments of inertia, without flexibility,
- by Timoshenko Beam elements, assuming that they can be good enough for discs with smaller diameters for bending modes of the structure.

Figure 1 shows the discretized models of the analyzed axial structure in free-free condition with a disc in the middle of the shaft.

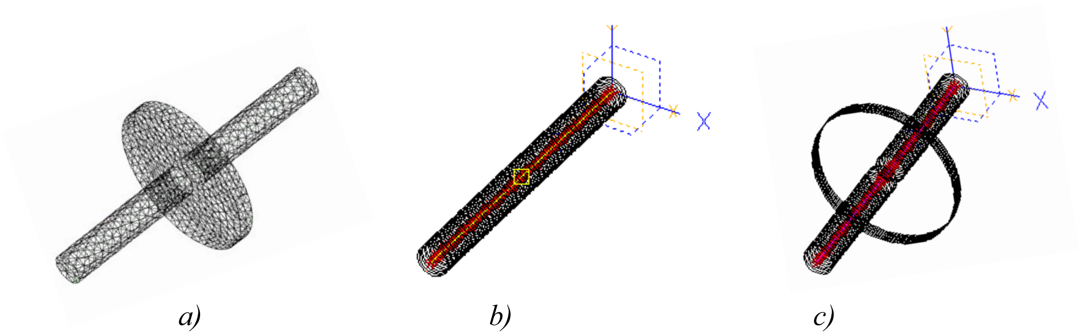
Characteristics of particular modeling of disc are:

- for Solid elements – the disc is modeled by cylinder of thickness h = 0.05 m and an external diameter D, bore diameter was d = 0.1m which corresponds to the diameter of the shaft; shaft of length L = 1 m and diameter d = 0.1m was also modeled by solid elements, Figure 1.a,
- for Lumped Mass - the values of mass and moments of inertia of hollow disc with the thickness of h=0.05 m was entered; these values for the three sizes of the outer disc diameter D are given below in Table 1; the shaft in this case was modeled by beam elements with a diameter d = 0.1m, Figure 1.b,

- for Beam elements – the disc was modeled by ten beam elements of solid section with diameter D and 0.005 mm in length to cover the thickness of the disc h = 0.05m. The rest of the structure that represents the shaft is modeled by beam elements with a diameter d = 0.1m, Figure 1.c.

Table 1. Physical properties of the Lumped Mass element for disc modeling

D, m	**d, m**	**Mass, kg**	**I_{xx}=I_{yy}, kgm^2**	**I_{zz}, kgm^2**
0,2	0,1	9,213	0,03071	0,05758
0,3	0,1	24,57	0,1587	0,03071
0,5	0,1	73,7	1,213	2,395



a) *b)* *c)*

Figure 1. Discretized model of the shaft-disc strukture (for D=0.5 m, L=1m)
a) Solid Tetrahedron elements, b) Lumped Mass element, c) Timoshenko Beam elements

3. THE ANALYSIS OF RESULTS FOR THE FIRST FOUR BENDING MODES

The first four bending mode frequencies for discs of different diameters, modeled in the same way, are shown in Figure 2. Figure 3 shows the frequency of the first four bending modes of the axial structure with a disc of particular diameter for all three ways of modeling.

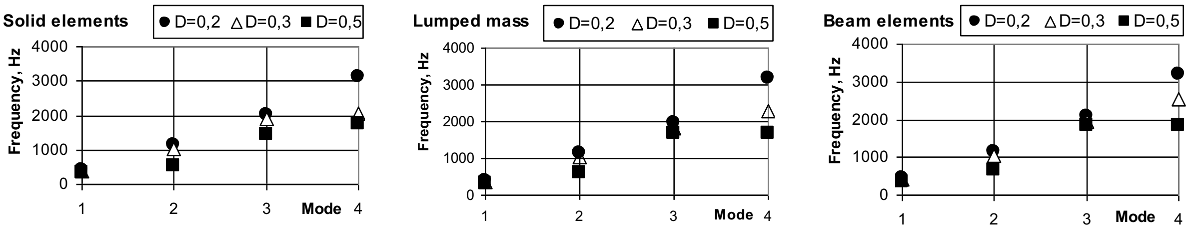


Figure 2. First four bending modes frequencies for discs with different diameters

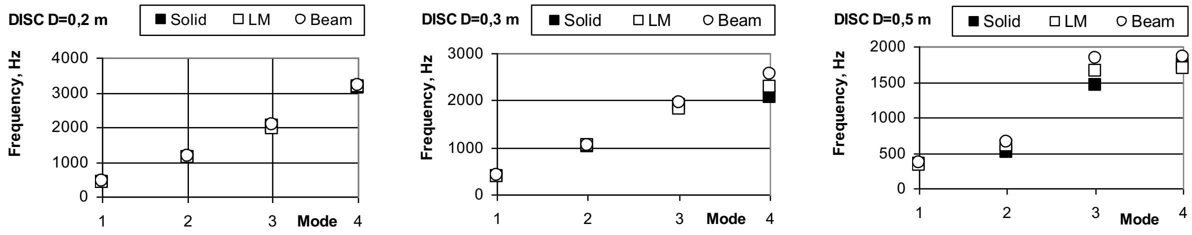
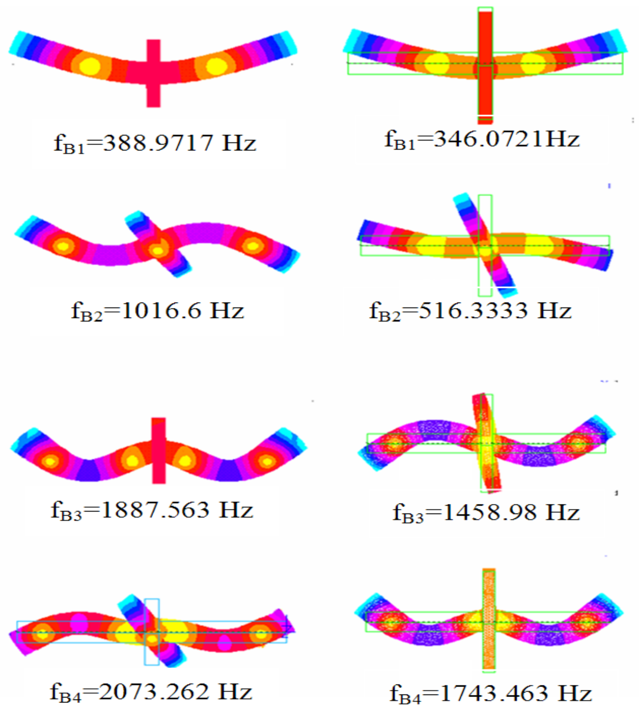


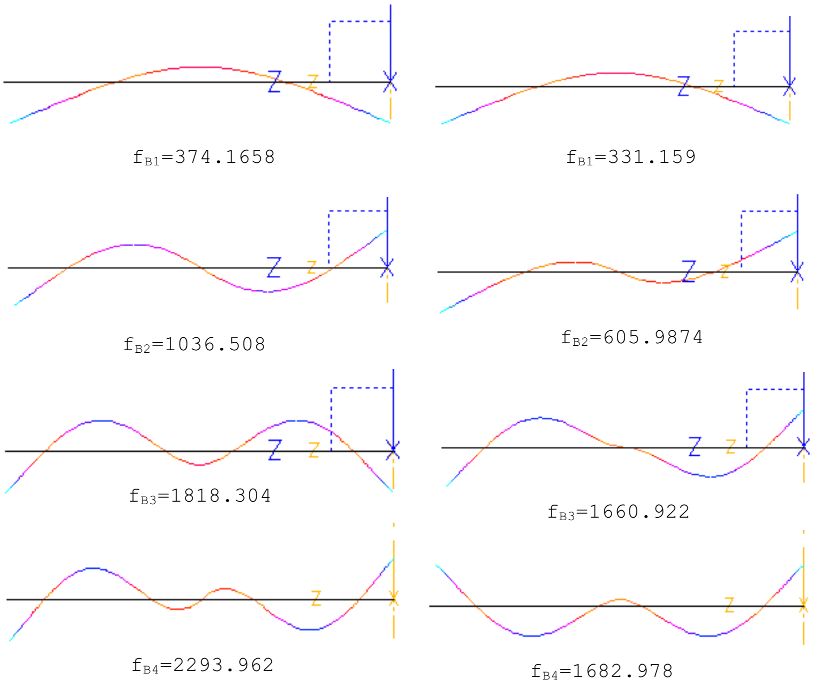
Figure 3. First four bending modes frequencies for discs modeled in three ways

Using the attached displays in Figure 2 it can be concluded that the increase in disc diameter reduce the first four bending frequencies, which is understandable because the increase in disc diameter increases in a larger amount the structural mass than stiffness. Also, it should be noticed that larger differences in frequencies with different diameters of discs occur in modes with inclined disc (modes 2 and 4).



a) *b)*

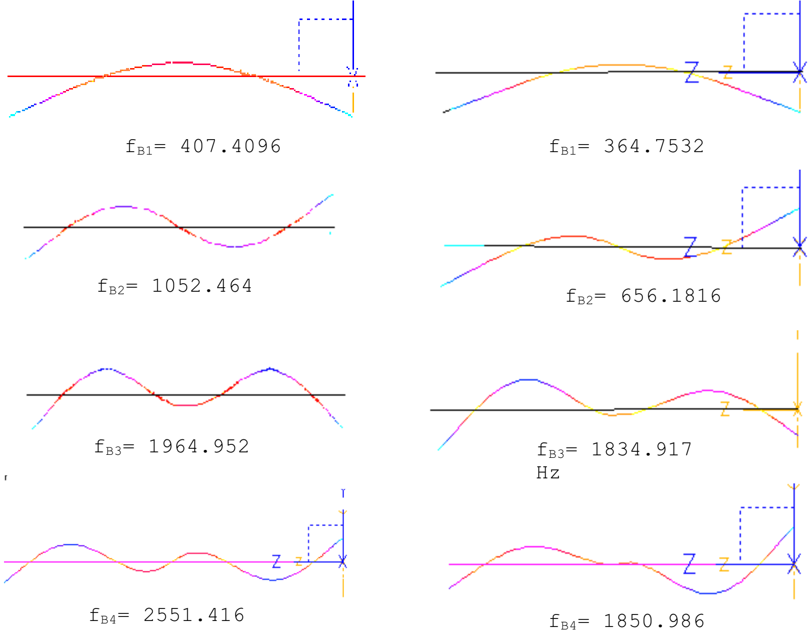
Figure 4. First four bending modes for modeling with Solid Tetrahedron elementima: a) disc diameter D=0.3 m, b) disc diameter D=0.5 m



a) *b)*

Figure 5. First four bending modes for disc modeling with Lumped Mass: a) disc diameter D=0.3 m, b) disc diameter D=0.5 m

It can be concluded from Figure 3 that the lowest frequencies are calculated by modeling with solid elements and the highest with beam elements. If it is considered that the solid elements are the best interpretation of mass and stiffness distribution, then it means that beam elements modeling gives maximum frequency deviation. For beam elements in fact, at the very beginning, it could be presumed that they could be satisfactory choice only in cases of small diameter discs (up to D=0,2 m in this analysis), because as such meet initial assumptions of the beam theory. Disc modeling by Lumped Mass element gives satisfactory results that differ little from those obtained by solid elements.



a) *b)*

Figure 6. First four bending modes for disc modeling with Timoshenko Beam elements: a) disc diameter D=0.3 m, b) disc diameter D=0.5 m

It's interesting that calculated frequencies of modes with vertical disc (symmetrical ones) are lower when Lumped Mass element represents the disc in relation to the disc modeling by solid elements, and higher frequencies are obtained for modes with inclined disc (anti symmetric). The reason for this can be certainly found in introduction of stiffness distribution when the disc is modeled by solid elements.

Also, it should be noted that in case of larger diameter discs higher vibration modes with inclined disc appears earlier than the mode with vertical disc. This is not the case for modeling with beam elements, which once again shows that they are not acceptable for disc modeling especially for larger disc diameter.

4. CONCLUSIONS

From the above numerical analysis it can be concluded that modeling of shaft-thin disc system gives satisfactory results when Lumped Mass represents the disc, because it gives the frequency values and mode shapes almost as solid elements, but the time required for modeling and calculation is much less. Contrary, the use of beam elements for disc modeling should be avoided because the results are not accurate enough.

5. REFERENCES

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