

VISI MIX TURBULENT. MECHANICAL CALCULATIONS OF A CONSOLE SHAFT

This example shows how to perform mechanical calculations required to check the shaft reliability, including mechanical strength and vibration resistance.

Problem description:

A single-phase blending process is carried out in a tank with conical bottom. In the basic variant, a single-stage propeller agitator is used. An alternative variant, with 2 pitched paddle impellers on the same shaft is also considered. The task is to compare both variants from the point of view of the shaft reliability.

Initial data

Tank

Inside tank diameter	2000 mm
Cone angle	45°
Cone height	1000 mm
Height of cylindrical part	2000 mm
Media level	2200 mm

Baffles

4 radial flat baffles are attached to the tank wall. They have the following parameters:

width	180 mm
length	2000 mm
distance from the cone edge	0 mm

Impellers

Basic variant:

Impeller type	propeller
Number of impellers on the shaft	1 (single-stage)
Tip diameter	700mm
Distance from bottom	600mm
Rotational speed	160Rpm
Motor power	3000W
Pumping direction	down

Alternative variant:

Impeller type	pitched paddle
Number of impellers	2 (multistage)
Tip diameter	440mm
Number of blades	3
Pitch angle	45°
Width of blade	50mm
Distance from bottom	600mm
Distance between stages	600mm

Rotational speed	160Rpm
Power of drive	3000W
Pumping direction	down

Shaft

Shaft design:

Shaft type	combined
Length	2450mm
Distance from bearing to impeller	2450mm
Length, upper part	600mm
Diameter, upper part	60mm
Outside diameter, lower part	108mm
Inside diameter, lower part	98mm

Shaft material and impeller mass:

Density	7850kg/m ³
Yield strength in tension	6e+08N/m ²
Young's modulus of elasticity	1.93e+11N/m ²
Pull - out factor	2
Impeller mass (basic variant)	70kg
Impeller mass (alternative variant)	25kg

Properties of the media

The media is a Newtonian liquid with the following average properties:

Density	1050 kg/m ³
Dynamic viscosity	0.0017 Pa*s

The task is to evaluate the shaft reliability in both cases and choose the most suitable impeller.

The Solution:

To solve this problem with VisiMix, you should open a new project, enter the initial data for your basic variant, and perform mechanical calculations using the appropriate option of the **Calculate** menu. Then you should create a project for the alternative variant and calculate its mechanical characteristics. You can then compare the results and choose the most suitable variant.

Select **Project – New** in the main VisiMix menu and enter a name for your basic project, for example, **shaft1.vsm**, Figure 8-1.

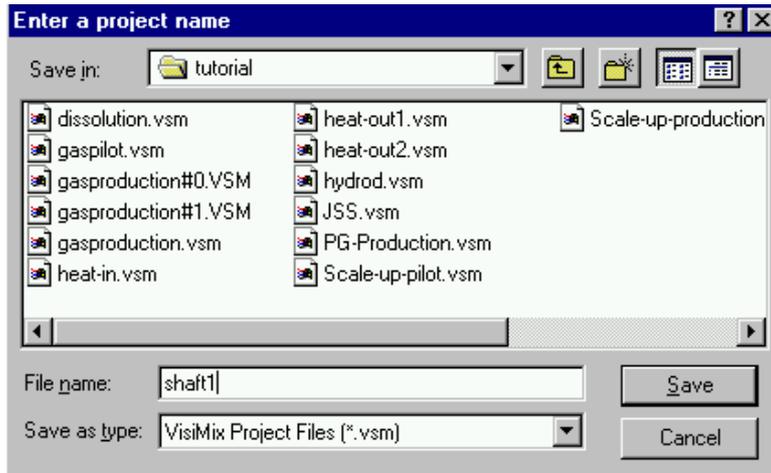


Figure 8-1. Starting a new project.

Click **Save**, and select your tank in the **Tank types** menu that appears (Figure 8-2). The tank you have selected (conical bottom, no heat transfer device) will appear in the **Current choice** window on the right. Click **OK** to confirm your choice.

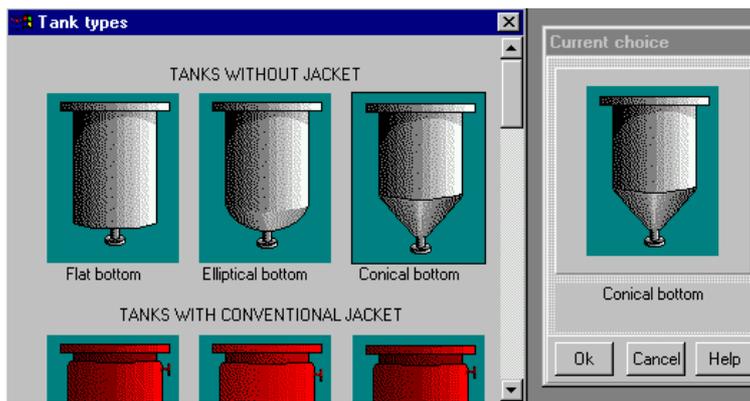


Figure 8-2. VisiMix graphic tanks selection.

Now you will be requested to enter basic initial data for your project. After you confirm your tank choice, TANK WITH CONICAL BOTTOM input table with the selected tank diagram appears. Supply the internal dimensions of your tank. Enter **Inside diameter**, **Cone angle**, **Cone height**, **Height of cylindrical part**, and **Level of media**, and **Total volume** and **Volume of media** will be calculated by the program and entered automatically. After the table has been completed (Figure 8-3), click anywhere on the field of the window, and the tank diagram on the screen will change to reflect your input. Click **OK** to confirm your input.

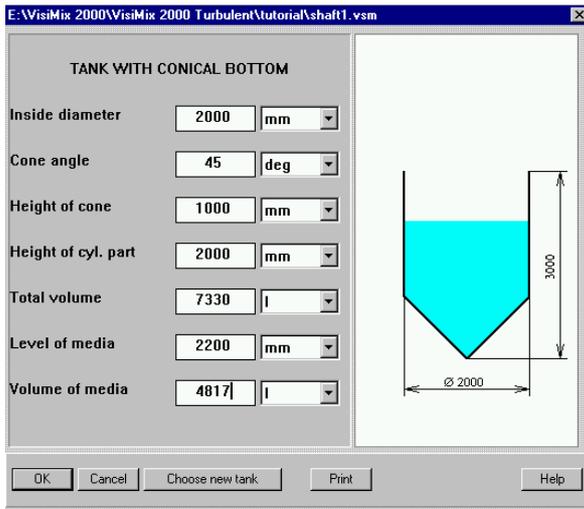


Figure 8-3. Entering tank data.

The **Baffle types** menu will now appear. Click on the diagram of Flat baffle – 1 , and it will appear in the **Current choice** window on the right (Figure 8-4). Click **OK** to confirm your choice.

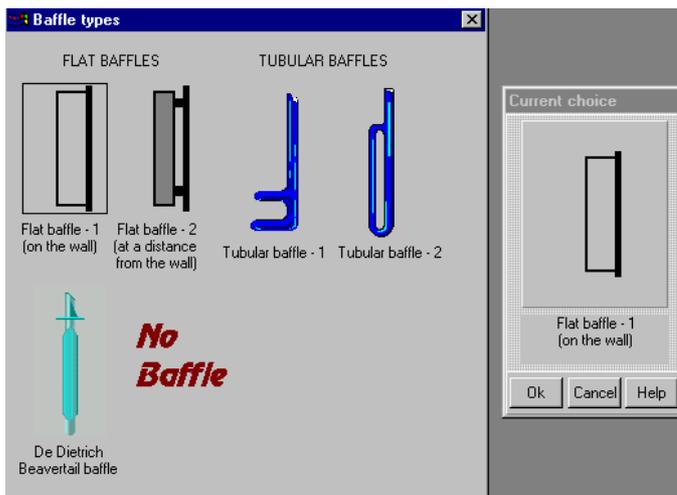


Figure 8-4. VisiMix graphic baffle selection.

Enter parameters of your baffle in the table that appears (Figure 8-5).

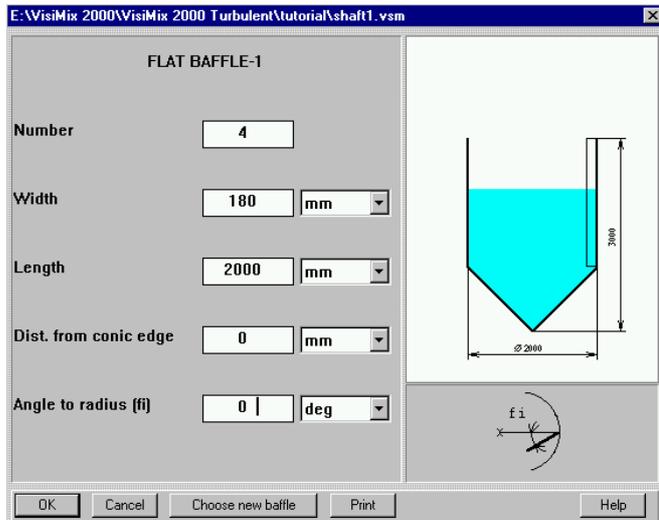


Figure 8-5. Entering baffle data.

Now select your impeller in the **Impeller types** menu, and it will appear in the **Current choice** window on the right (Figure 8-6). In the same window, the **single** option for your single-stage mixing system is already selected.

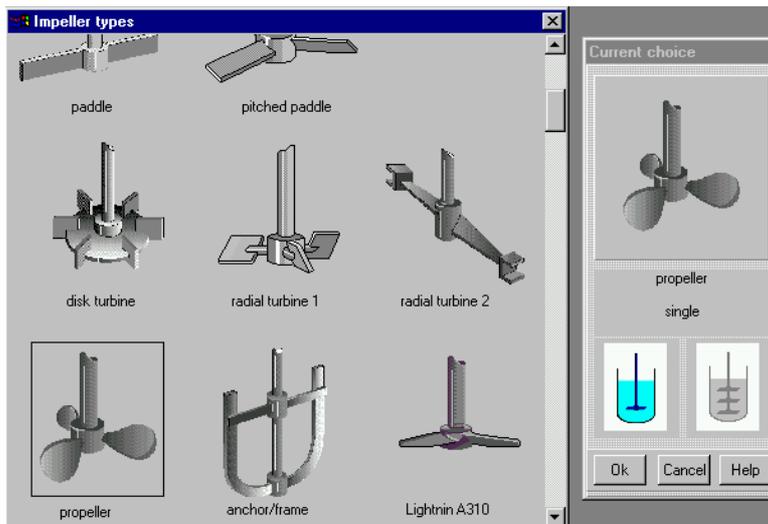


Figure 8-6. Selecting the impeller.

Enter the impeller parameters in the input table that appears (Figure 8-7), and click **OK** to confirm your input.

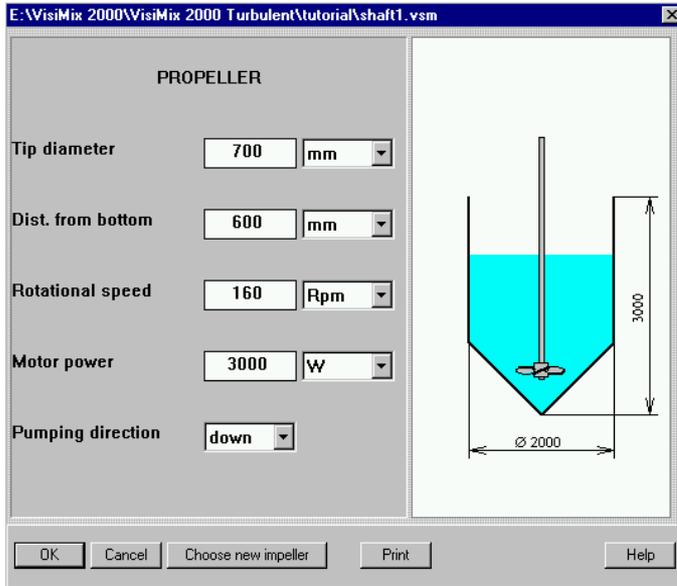


Figure 8-7. Entering impeller data (basic variant).

You will now be requested to enter properties of the media in AVERAGE PROPERTIES OF MEDIA input table (Figure 8-8).

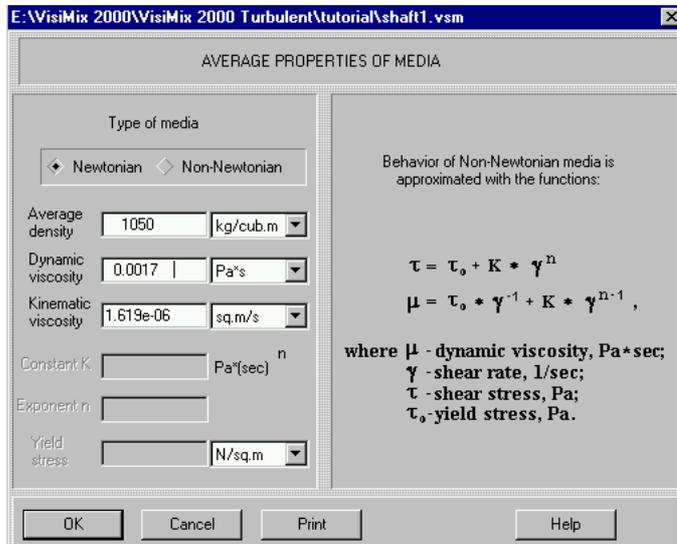


Figure 8-8. Entering average media properties.

Now you have entered basic data for your basic variant, and a corresponding diagram of your apparatus appears (Figure 8-9). From now on, you will be asked to enter only the data required for calculating the parameters you will select in the **Calculate** option.

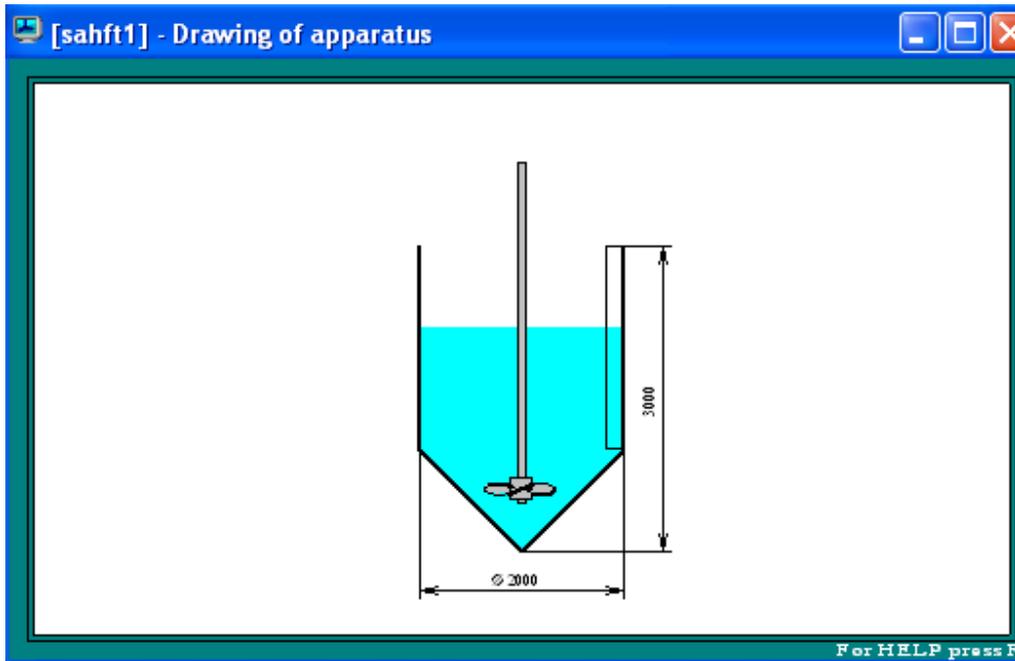


Figure 8-9. Drawing of apparatus (basic variant).

We recommend closing this window before proceeding to calculations.

To start calculations, select **Calculate** in the main menu, click on **Mechanical calculations of shafts**, and then on any of the items in this submenu, for instance, on **Combined torsion and bending**. SHAFT DESIGN input table will then appear (Figure 8-10). Enter the initial data for the shaft.

After this table has been completed, you will be asked to fill another input table, SHAFT MATERIAL AND IMPELLER MASS (Figure 8-11).

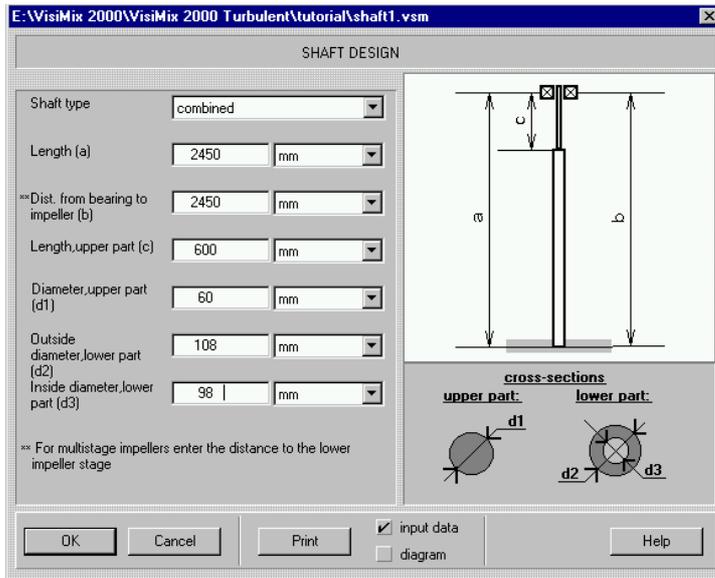


Figure 8-10. Shaft design.

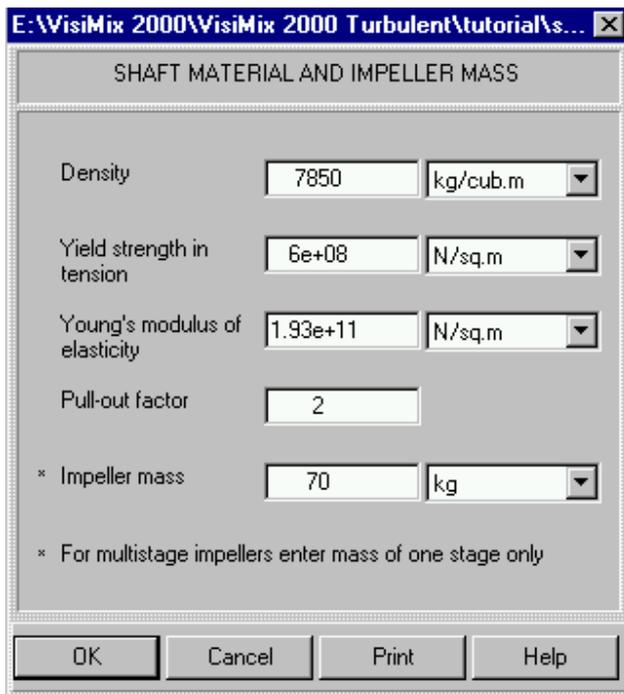


Figure 8-11. Shaft material and impeller mass (basic variant).

Now, after all the data for your basic variant has been entered, VisiMix starts the calculations. In a few seconds, a warning message appears (Figure 8-12), informing you that the rotational frequency of the shaft is too close to its critical frequency, and vibrations are possible. In addition, the message recommends checking another set of output parameters, **Shaft vibration characteristics**.

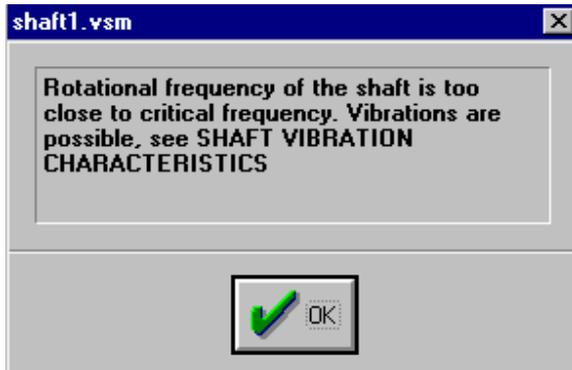


Figure 8-12. The message warning about shaft vibrations.

Click **OK**, and the table **Combined torsion and bending** containing the results of the calculations, appears (Figure 8-13).

COMBINED TORSION AND BENDING		
Parameter name	Units	Value
Allowable combined stress	N/sq.m	6e+08
Max. combined stress in upper section of the shaft	N/sq.m	1.59e+08
Max. combined stress in lower section of the shaft	N/sq.m	6.46e+07

Figure 8-13. Combined torsion and bending (basic variant).

Let us now check **Shaft vibration characteristics** as recommended by the message. Select **Last menu, Shaft vibration characteristics**, and the table shown in Figure 8-14 appears.

SHAFT VIBRATION CHARACTERISTICS		
Parameter name	Units	Value
Critical frequency	1/s	2.99
Rotational frequency	Rps	2.67
Rotational to critical frequency ratio		0.893

Figure 8-14. Shaft vibration characteristics (basic variant).

You can see that the shaft rotational frequency is too close to its critical frequency, and that the ratio of these frequencies, i.e. the harmonic ratio is close to 1. The warning message and the calculated results show that your basic variant with a single-stage propeller is unacceptable because of possible vibrations. Let us now check the alternative variant, replacing a single-stage propeller with a double-stage pitched paddle impeller.

Save your current project, and then create a new project for the alternative variant, using **Save as** or **Clone** options, and saving the new project under a new name, for example **shaft2.vsm**. Enter the data for the alternative variant through the **Edit input** option.

You must first change your impeller and its parameters. Select **Edit input -Impeller** and then **Choose new impeller** at the bottom of the **Propeller** input table that appears. Now select **pitched paddle** impeller and click on **multistage** icon in the **Current choice** window (Figure 8-15).

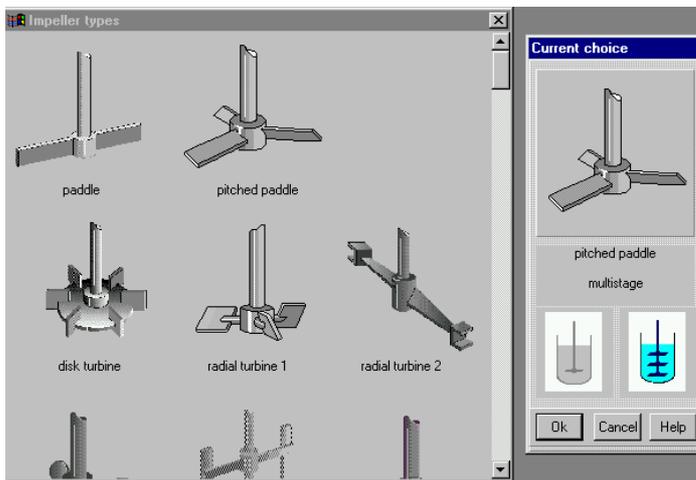


Figure 8-15. Selecting impeller for the alternative variant.

Enter the parameters of **Pitched paddle** double-stage impeller in the input table that appears (Figure 8-16).

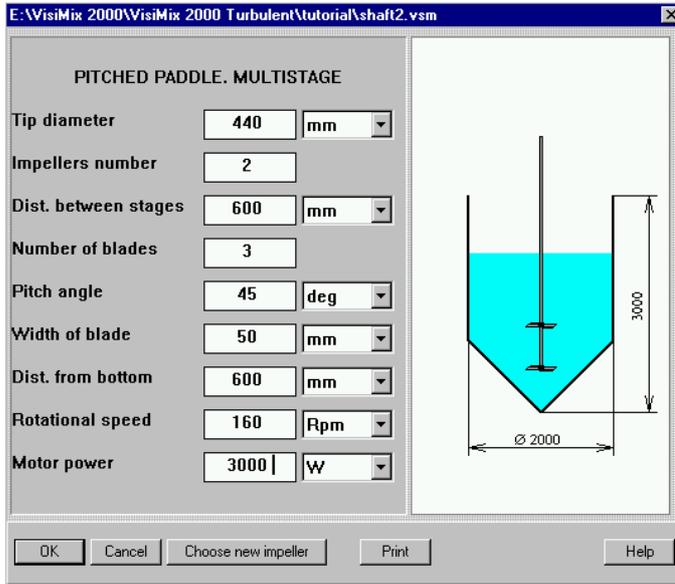


Figure 8-16. Entering data for pitched paddle impeller (alternative variant).

You must also enter the mass of the alternative impeller in the input table **Shaft material and impeller mass**. Select **Edit input - Shaft - Shaft material and impeller mass**, and change **Impeller mass** from 70kg to 25kg in the table that appears (Figure 8-17). Note that in this table, the mass for a single impeller stage is entered.

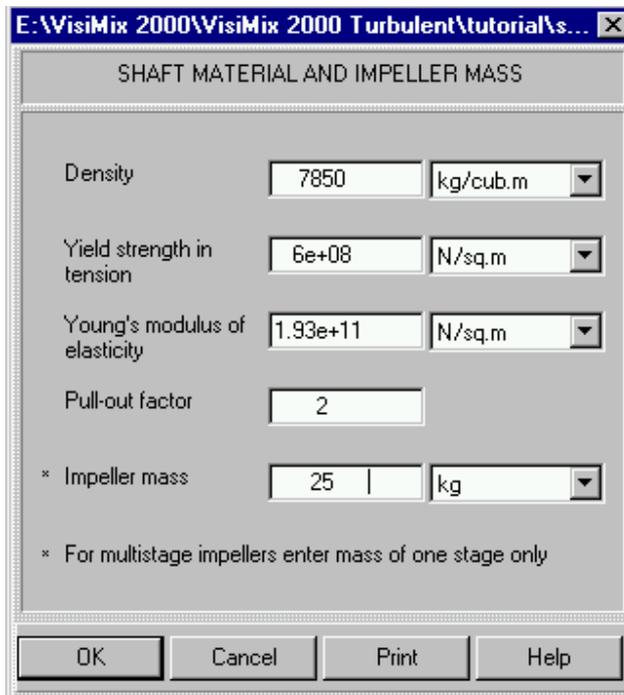


Figure 8-17. Shaft material and impeller mass (alternative variant).

All initial data for the alternative variant has now been entered. Select **Last menu**, then **Combined torsion and bending**, and the table shown in Figure 8-18 appears.

COMBINED TORSION AND BENDING		
Parameter name	Units	Value
Allowable combined stress	N/sq.m	6e+08
Max. combined stress in upper section of the shaft	N/sq.m	2.52e+08
Max. combined stress in lower section of the shaft	N/sq.m	1.02e+08

Figure 8-18. Combined torsion and bending (alternative variant).

Now click **Last menu, Shaft vibration characteristics**, and the table shown in Figure 8-19 appears.

SHAFT VIBRATION CHARACTERISTICS		
Parameter name	Units	Value
Critical frequency	1/s	3.96
Rotational frequency	Rps	2.67
Rotational to critical frequency ratio		0.673

Figure 8-19. Shaft vibration characteristics (alternative variant).

Note that in this case there were no warning messages. This means that in the alternative configuration, no vibrations are expected, and your 2-stage pitch paddle impeller is acceptable with regard to its mechanical characteristics.