VISIMIX LAMINAR.
MODELING OF A STAGNANT ZONE FORMATION AS A RESULT OF INEFFICIENT MIXING.

If your media has a high **Yield stress** value, **Shear stress on the wall** may be lower than **Yield stress**. Stagnant zones may then form on the periphery of the tank, the mixing being limited to a zone around the agitator.

In this case, direct VisiMix calculations are impossible. However, the VisiMix option "Supplement. Approximation of rheology" allows the user to select a proper design and perform simulation of his mixing process even in the case of stagnant zones near the tank walls. This example shows how to use this option.

System configuration:

Your mixing process takes place in an unbaffled flat-bottomed tank with a 2-stage Intermig agitator. The equipment characteristics and properties of the non-Newtonian media are given below.

Tank: unjacketed flat-bottomed
Inside diameter = 220 mm
Total tank height = 350 mm
Volume of media = 9 l
No baffles

Agitator: A 2-stage Intermig Impeller (Radial Turbine-2)
Tip diameter = 116 mm
Agitators number = 2
Distance between stages = 80 mm
Distance from bottom = 30 mm
Number of revolutions = 500 mm

The properties of the media:

Density	1000 kg/cub. m
Rheological constant, K	7.05 Pa*s^{1-m}
Rheological exponent, m	0.5
Yield stress, τ_0	47.2 N/m^2

The Task

The task is to calculate mixing power and determine shear stress near the agitator blades.

The Solution:

The general sequence of operations is as described in Example 1. You create a new project file for your case by clicking on **Project-New**, enter the project name (Example 4 in this case), and select your flat-bottomed unjacketed tank from the VisiMix tank selection that appears (Figure1). Enter the initial data as shown in the Figures 4.2-4.6 below: the parameters of the tank, baffle (no baffle option in your case), agitator and the media properties.

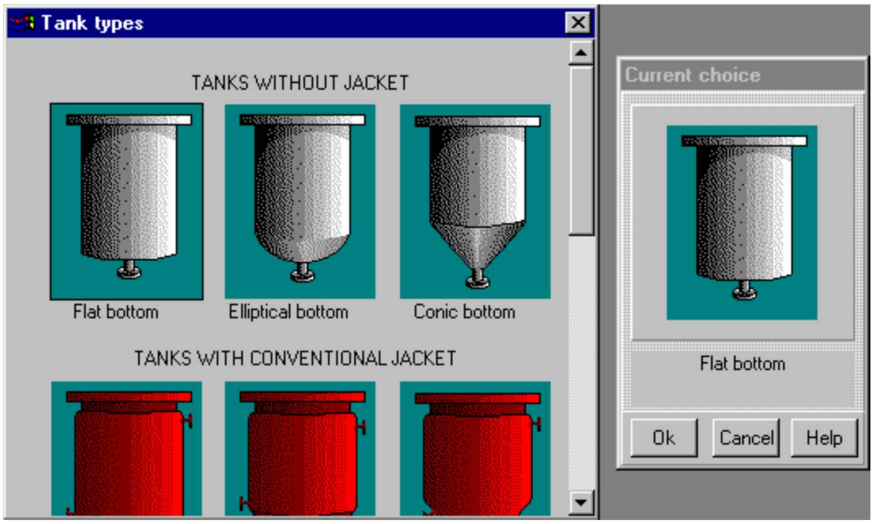


Figure1. VisiMix tanks selection.

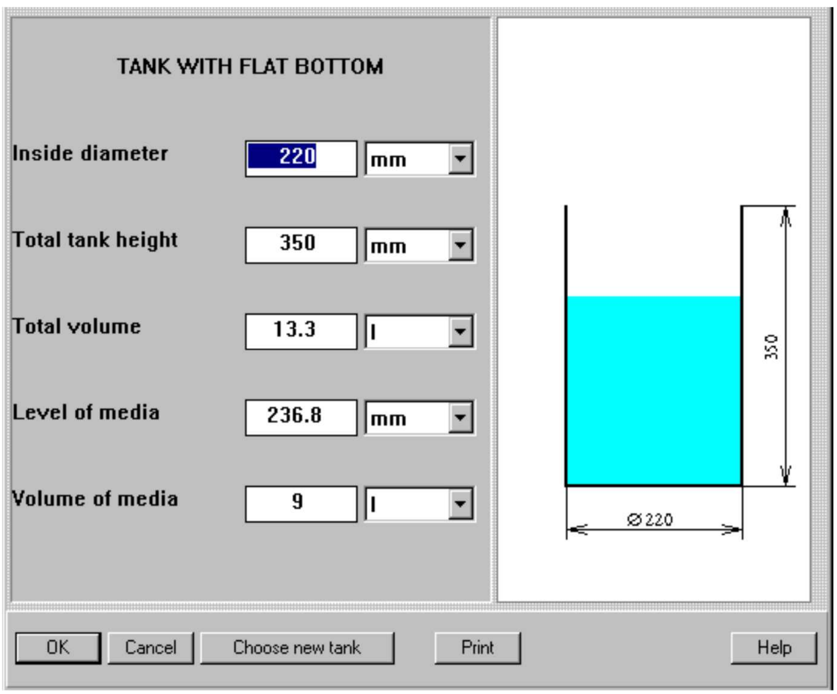


Figure2. Entering the tank data.

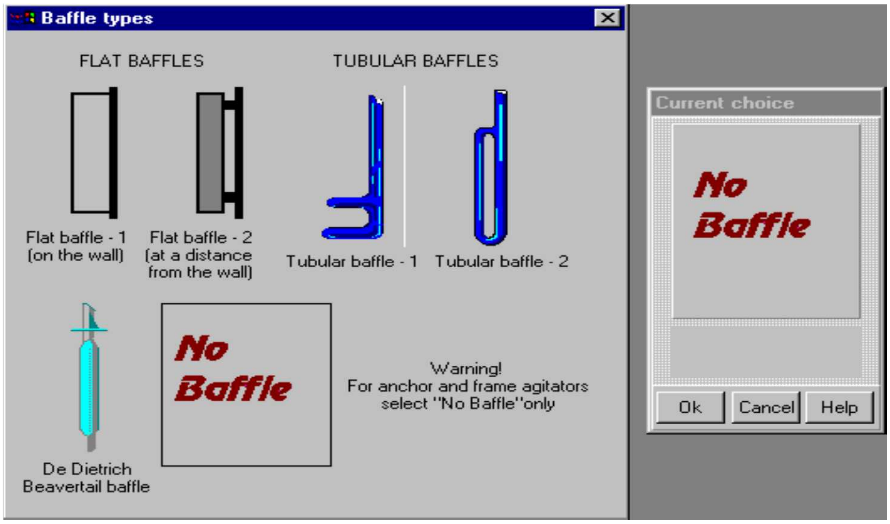


Figure3. Selecting No baffle option.

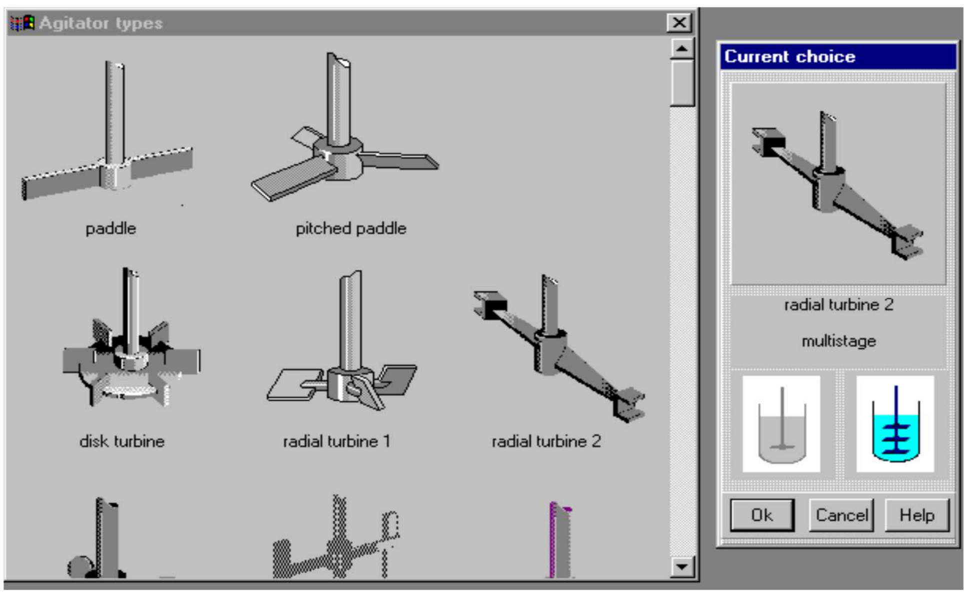


Figure4. Selecting a 2-stage Intermig agitator (radial turbine 2).

The input table for the agitator data (Figure5) allows for entering a number of agitators produced by different manufacturers. Click on the **Help** button in the lower right corner of the table to invoke the following recommendations on the use of **Radial turbine 2** agitator for the approximate simulation of **Intermig** impellers, including typical values and ranges of the main parameters.

For your case, the following values were used:

Pitch angle, **fi** = 26°;
Width of blade, **W** = 12 mm;
Length of blade, **L** = 17 mm.

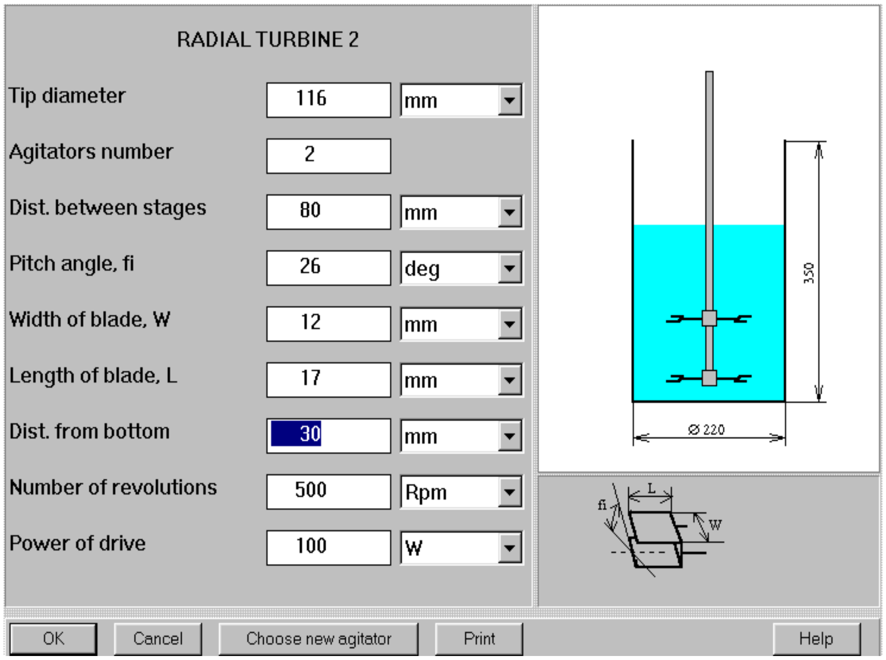
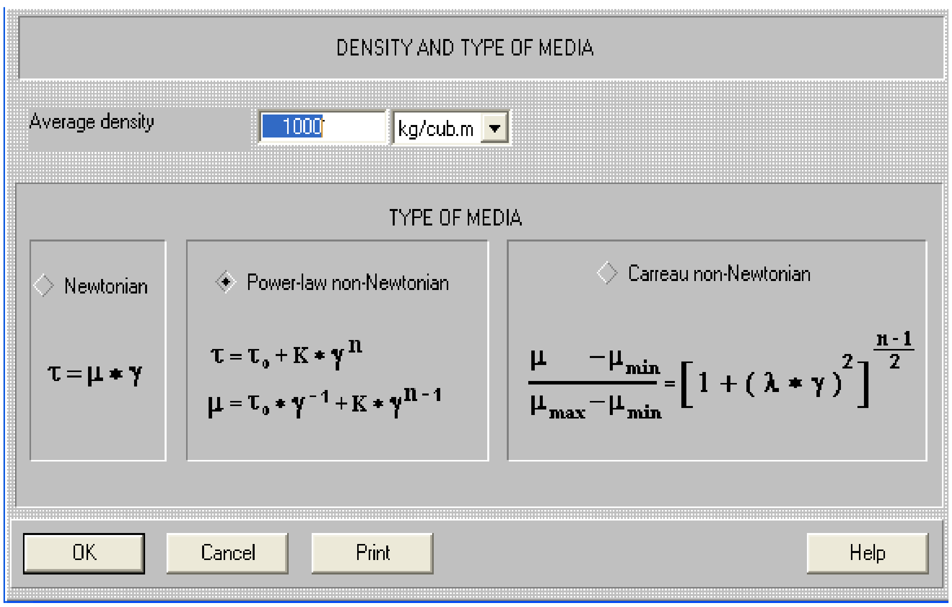


Figure5. Entering initial data for Radial turbine-2.



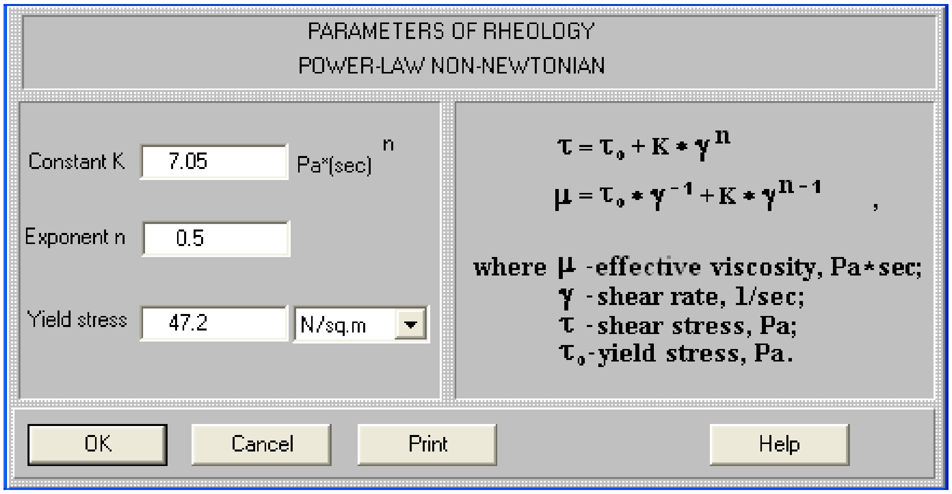


Figure6. Entering average media properties.

After this basic initial data has been entered, a diagram of your system appears (Figure7).

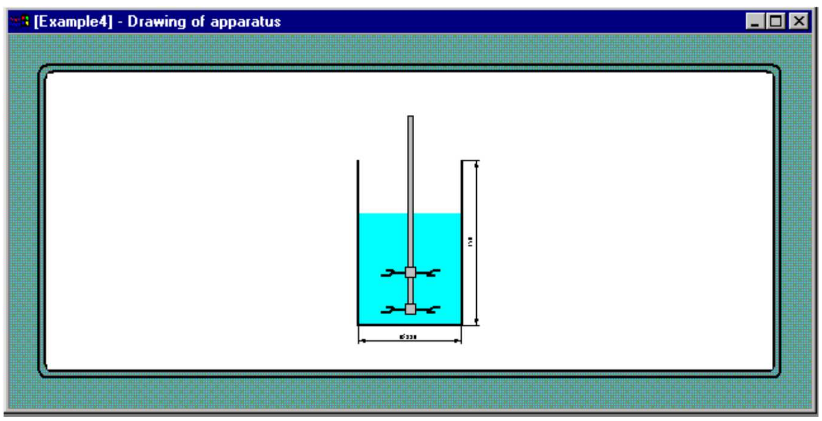


Figure7. The diagram of your system.

Now you can proceed to the calculations. To calculate the mixing power, select **Power and forces**, **Mixing power** in the **Questions by Category** option in the main menu (Figure8).

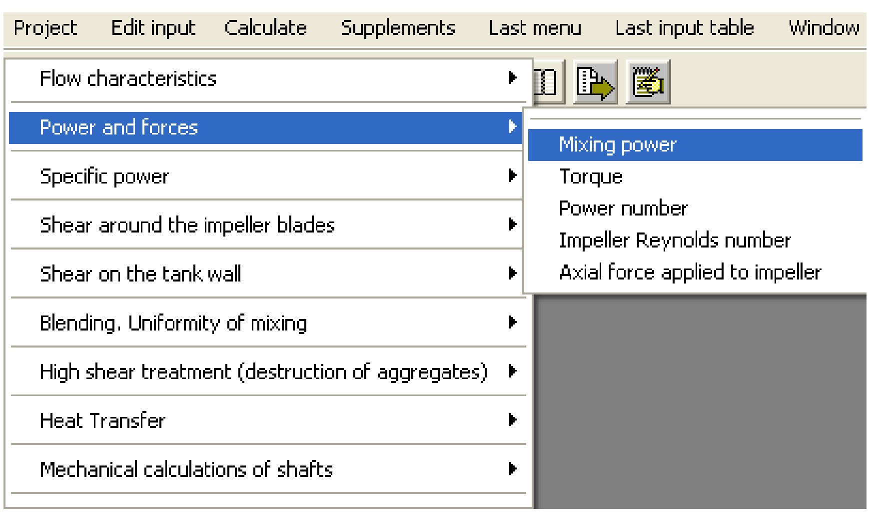


Figure8. Calculating the mixing power

The following message will appear (Figure9):

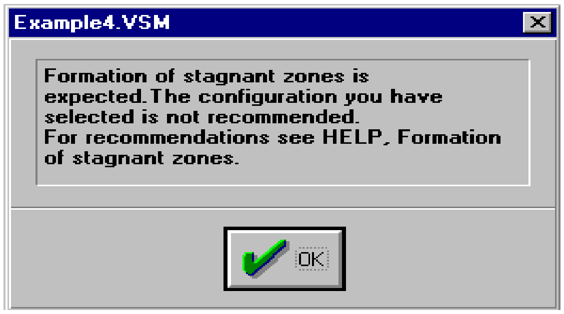


Figure9. The message informing about possible formation of stagnant zones.

This message means that either the shear stress near the wall is smaller than the yield stress, or that such situation is expected, for instance due to the properties' fluctuations (see Help, Formation of stagnant zones). Click OK, and the message shown in Figure10 appears.

This message means that you cannot directly perform calculations with the initial data you have entered in the **Average properties of media** table.

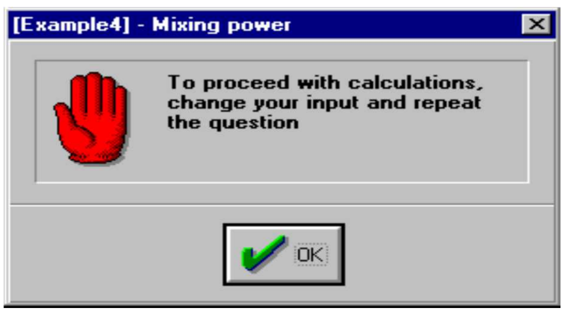


Figure10. The message recommending to adjust input data.

However, it is nevertheless possible to calculate the Mixing power and Shear stresses for your process. A special VisiMix option enables you to enter such equivalent (effective) rheological parameters that the Mixing power, Shear stresses and other flow characteristics near the agitator are the same as with the rheology you have previously entered, but no stagnant zones are formed in the tank. Select **Supplement. Approximation of rheology** in the **Questions by Category** option, then select **Approximate rheological characteristics** (Figure11).

Upper limit of shear rate input table will appear on the screen. This parameter must be selected in such a way that the range of the shear rates corresponding to the value entered in this table includes all possible values of the shear rate for the current project. As the highest values of the shear rate are found in the area near the agitator blades, the **Upper value of shear rate** should differ from the **Shear rate near the agitator blade** by not more than 10-20%. Since the **Upper value of shear rate** is unknown at this stage of the calculations, we will have to determine it by the iteration procedure described below. For example, let us enter 1000 1/s as a reasonable figure for the first approximation of this parameter (Figure12).

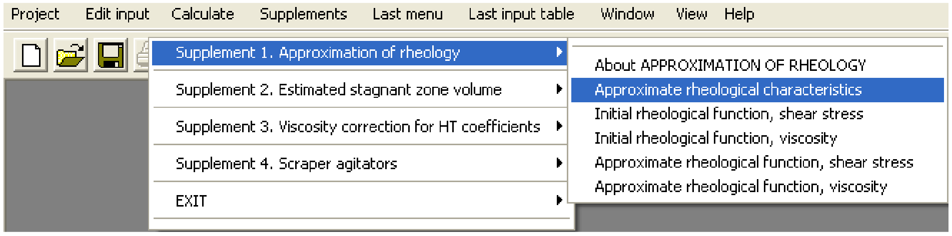


Figure11. Calculating the approximate rheological characteristics.

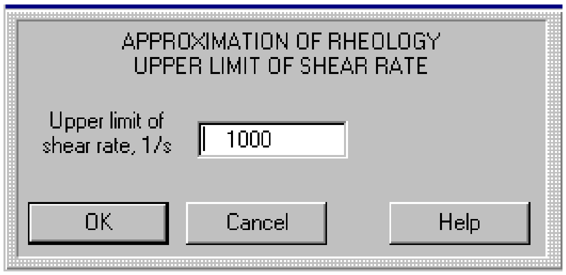


Figure12. Entering upper limit of shear rate (the 1st iteration).

Click OK, and the table of the approximate rheological characteristics appears (Figure13).

The values in this table represent the equivalent rheological characteristics, which approximately describe the curve of shear stress vs. shear rate in the given range of shear rates. They differ from the initial characteristics, in particular, in that the **Yield stress** value is equal to 0**.**

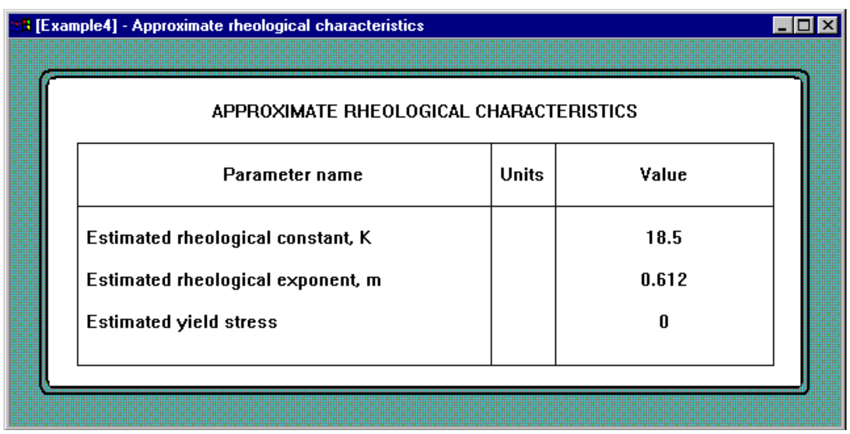


Figure13. Approximate rheological characteristics (the 1st iteration).

Let us now compare the initial and approximate rheological characteristics to make sure that the approximation performed by VisiMix is satisfactory. Click on **Initial rheological function** and **Approximate rheological function** in the **Supplement. Approximation of rheology** submenu, and the following graphs appear (Figures 4-14, 4-15).

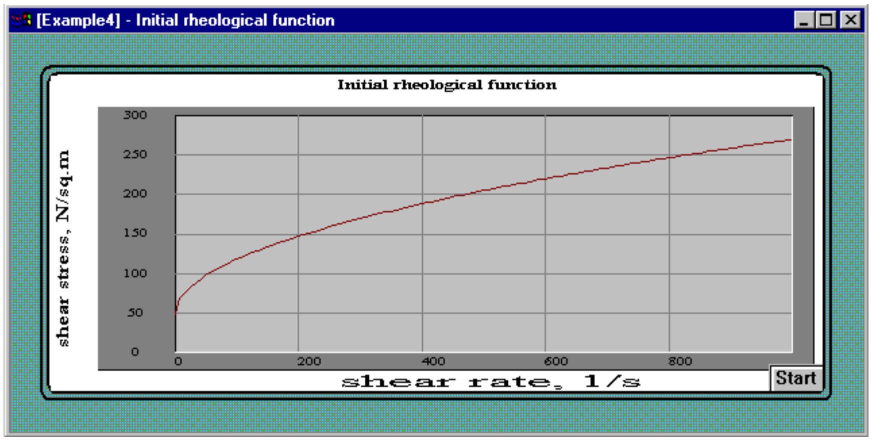


Figure14. Initial rheological function.

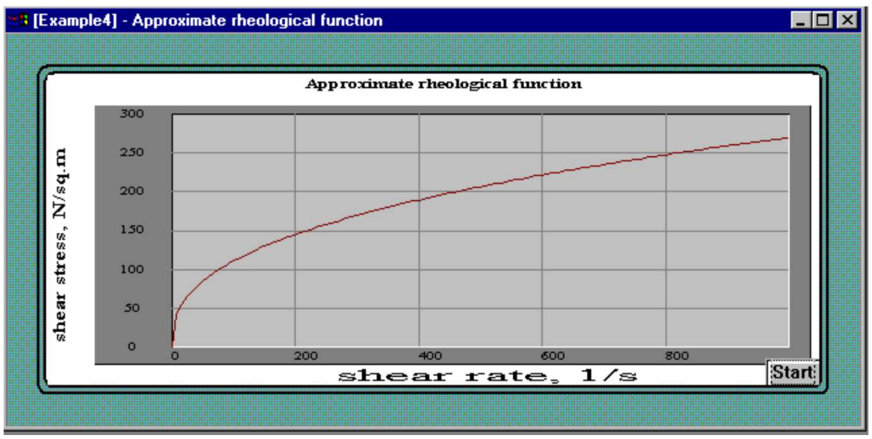


Figure15. Approximate rheological function.

These functions are quite similar. You can see that the difference between the initial and approximate rheological functions is noticeable for shear rate values smaller than about 200 1/s. This range of comparatively small shear rates is characteristic for close-to-wall regions only and not for the agitator area you are interested in.

To enable the calculations, these approximate characteristics must be entered as average properties of your non-Newtonian media. Let's go to the **Edit** option in the main menu and select **Properties & regime**, **Average properties of media**. The **Average properties of media** input table appears (Figure16). Enter the calculated values of rheological parameters (Figure17).

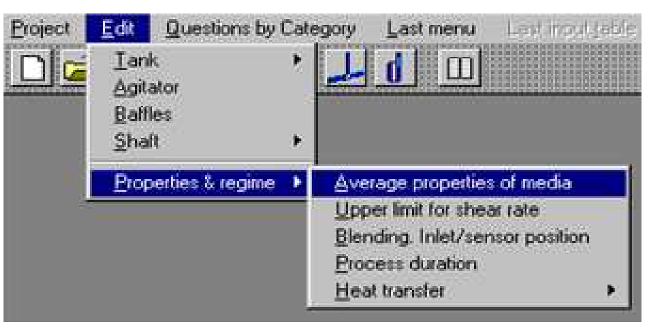


Figure16. Returning to the Average properties of media input table.

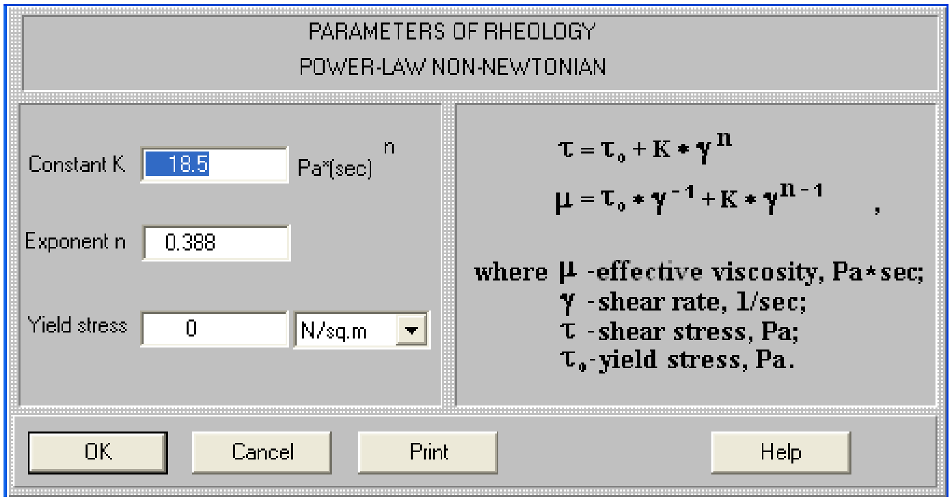


Figure17. Adjusted average properties of the media (the 1st iteration).

Now when you have entered the approximate data, let us first check if the selected value for the **Upper limit of shear rate** was correct, and if not, adjust it. As already mentioned, the **Upper limit of shear rate** should differ from the shear rate near the agitator by not more than 10-20%. To check the shear rate near the agitator blade, select **Questions by Category, Shear around the agitator blade, Shear rate near the agitator blades** as shown in Figure18. The appropriate output table appears (Figure19).

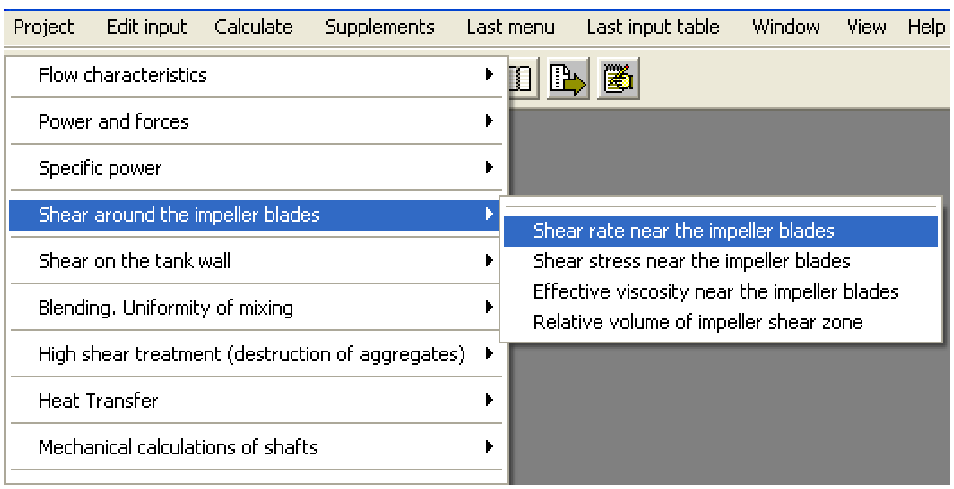


Figure18. Calculating the Shear rate near the agitator blades.

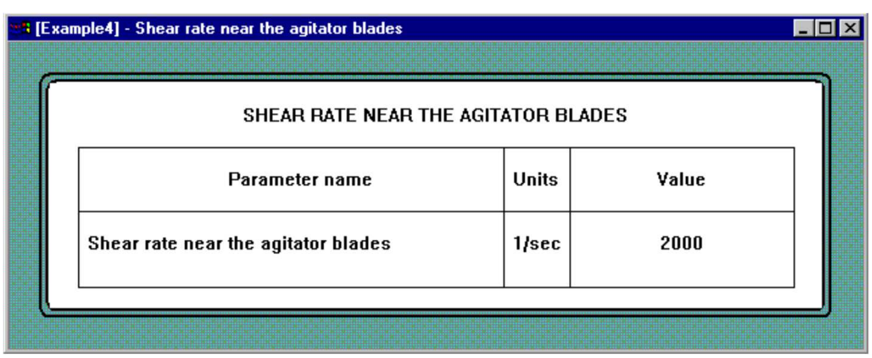


Figure19. Shear rate near the agitator blades (the 1st iteration).

As previously mentioned, the **Upper limit of shear rate** should differ from this calculated value by maximum 10 – 20%. For your first approximation, you have entered 1000 1/s for the **Upper limit of shear rate** and obtained 2000 1/s for the shear rate near the agitator blades. This means it is necessary to correct the **Upper limit of shear rate**. First of all, through the **Edit** option, invoke the **Average properties of media** input table and restore the initial rheological parameters (Figure6). Then change the **Upper limit of shear rate** value, entering 2000 1/s for the second iteration (Figure20).

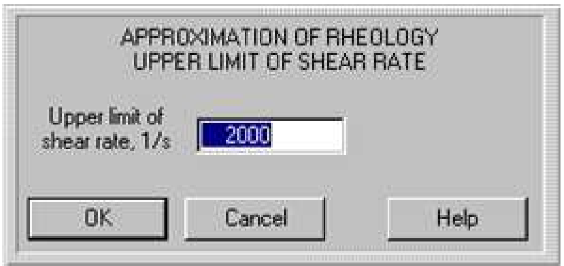
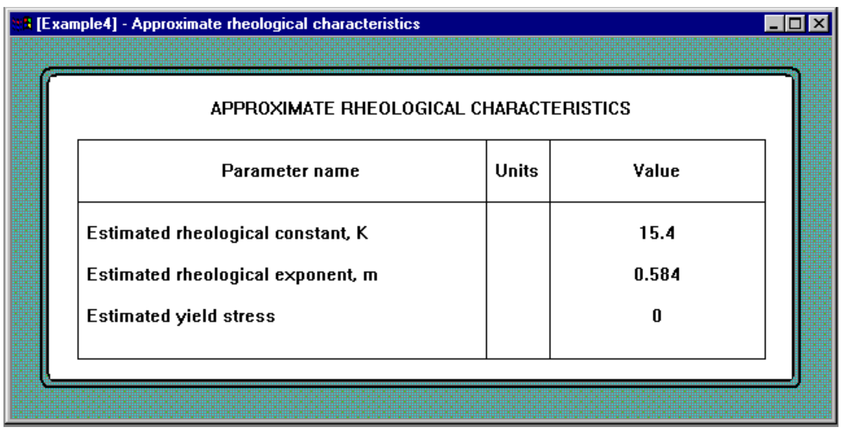


Figure20. The adjusted value for the Upper limit of shear rate.

Now let's calculate the approximate rheological characteristics as we have already done for the first iteration. Click on **Supplement. Approximation of rheology** in the **Questions by Category** option, then select **Approximate rheological characteristics**. The results of the calculation are shown in Figure21. You can also compare the initial and approximate rheological characteristics shown in Figures 4-22 and 4-23, respectively.



[Example4] - Approximate rheological characteristics

APPROXIMATE RHEOLOGICAL CHARACTERISTICS

Parameter name	Units	Value
Estimated rheological constant, K		15.4
Estimated rheological exponent, m		0.584
Estimated yield stress		0

Figure21. Approximate rheological characteristics (the 2nd iteration).

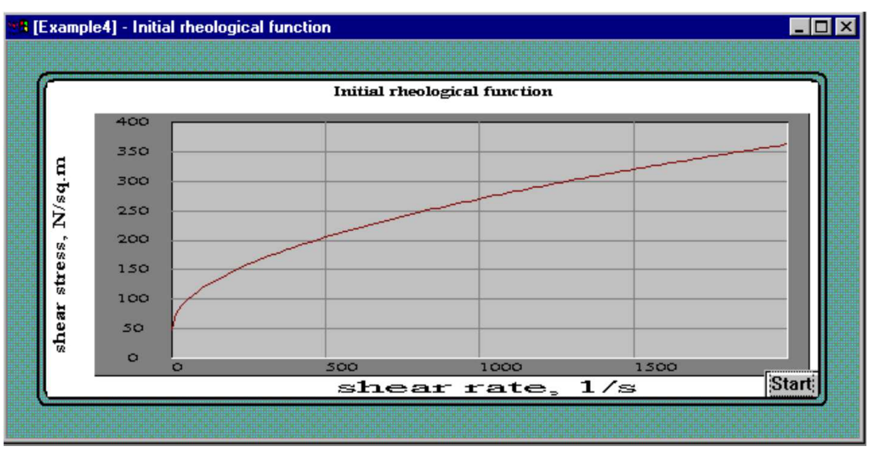


Figure22. Initial rheological function.

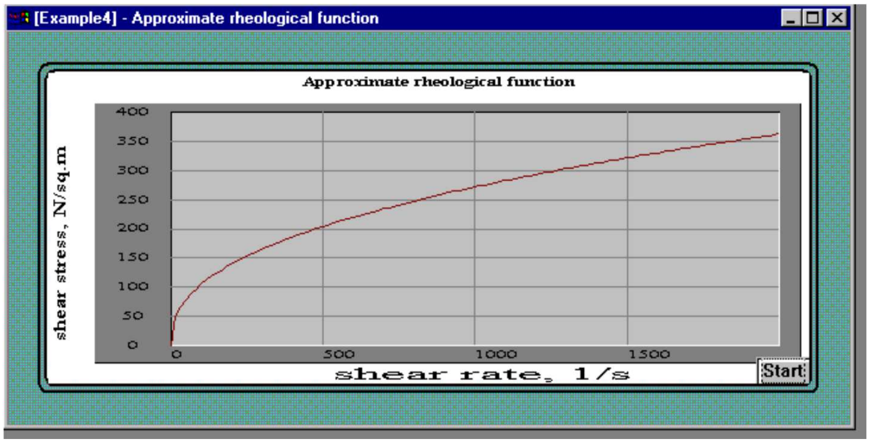


Figure23. Approximate rheological function.

The approximation proved to be quite acceptable, as in the first case.

Now enter the approximate rheological characteristics (Figure21) in the **Average properties of media** input table, through **Edit- Properties & regime - Average properties of media** (Figure24).

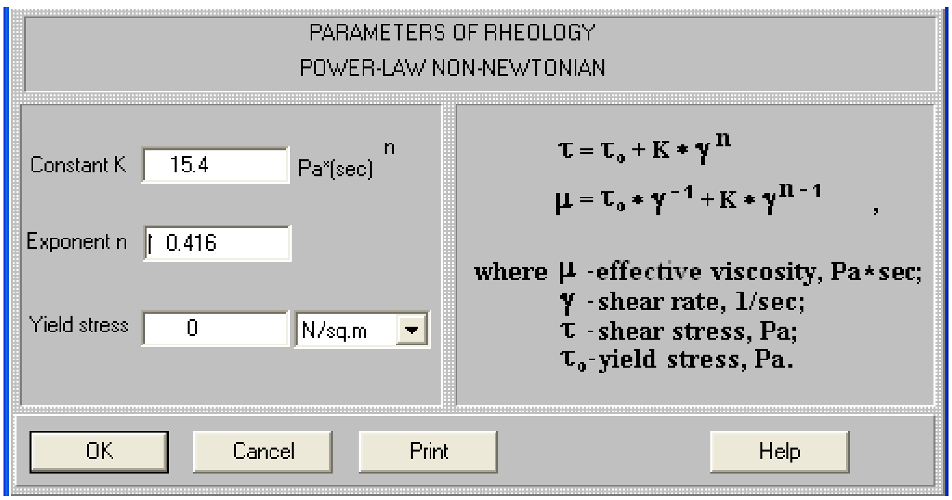
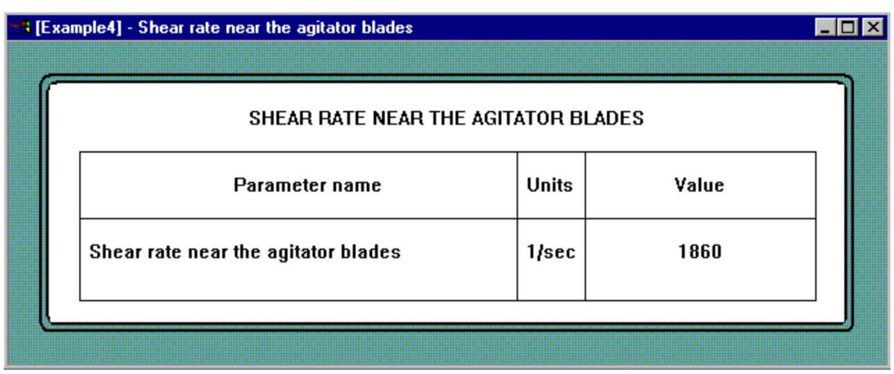


Figure24. Entering approximate rheological characteristics (the 2nd iteration).

Click OK and repeat the question by selecting **Shear rate near the agitator blade** in **Shear near the agitator blades** in **Questions by Category**. The results of the calculation are shown in Figure25.


[Example4] - Shear rate near the agitator blades

SHEAR RATE NEAR THE AGITATOR BLADES

Parameter name	Units	Value
Shear rate near the agitator blades	1/sec	1860

Figure25. Shear rate near the agitator blade (the 2nd iteration).

As you can see, the **Upper limit of shear rate** (2000 1/s) exceeds the **Shear rate near the agitator blades** (1860 1/s) by about 7% which is less then 10-20% specified above as the allowed deviation between these parameters.

Now we can return to calculating the mixing power. The result of the calculations is presented in Figure26.

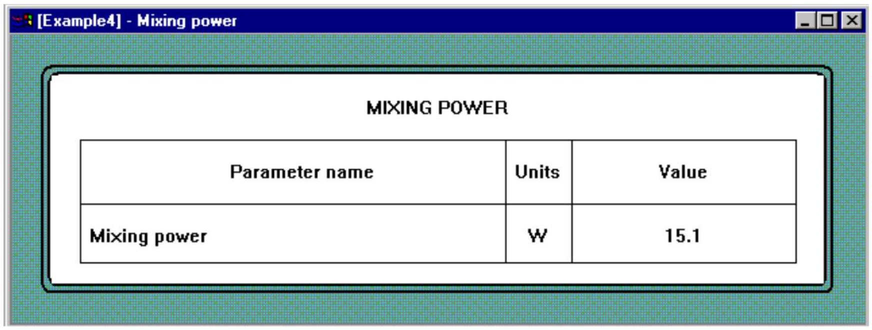


Figure26. Mixing power.

We have thus obtained the **Mixing power** value, which is essential for selecting the drive, performing mechanical calculations for the shaft, etc.

In addition to the **Mixing power**, you have also calculated the **Shear rate** (Figure 25), one of the key parameters describing the processing of the media, destruction of aggregates, etc. The task has thus been fulfilled.

Now let us examine the reasons for the formation of stagnant zones in your tank. The **Yield stress**, i.e. the minimum shear stress value ensuring the flow of the media, is 47.2 N/sq. m for your media (Figure 6). Now let us check this value near the tank wall. Select **Shear on the tank wall**, **Average shear stress near the tank wall** in the **Questions by Category** (Figure 27). The calculated value is shown in Figure28.

We see that the shear stress near the wall is lower than the Yield stress. It is now clear why the media near the wall does not move, and stagnant zones form on the tank periphery.

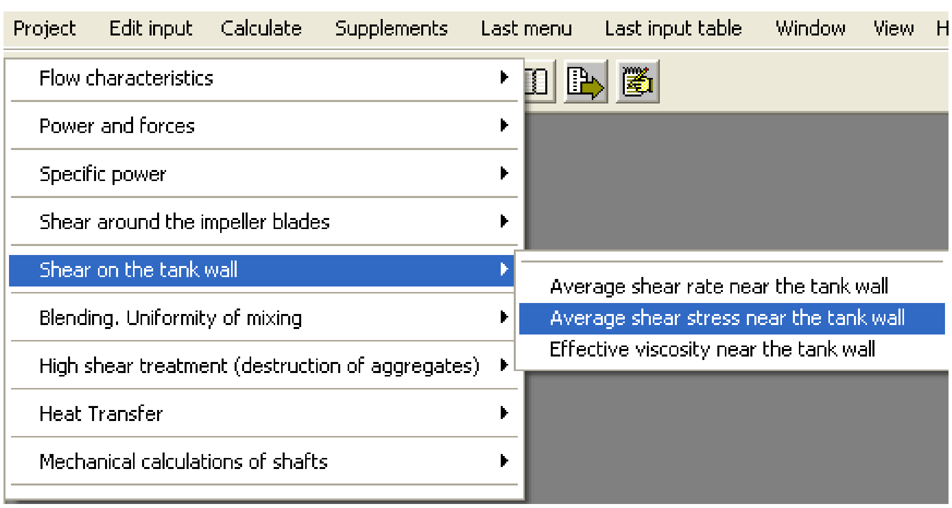
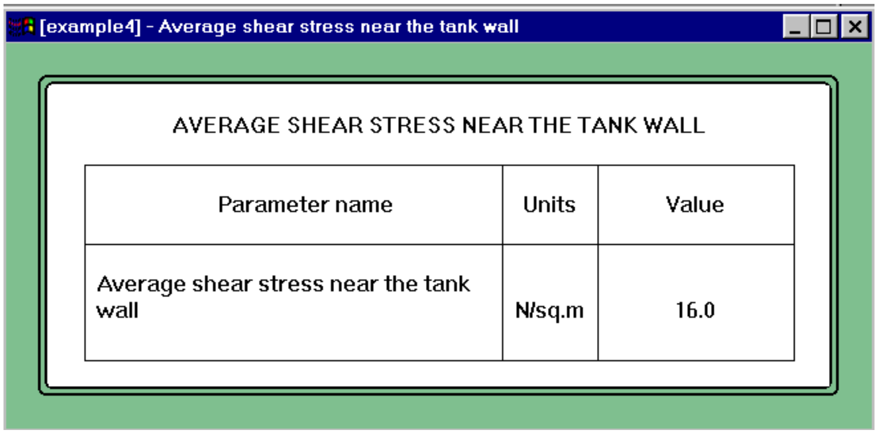


Figure27. Calculating the Average shear stress near the tank wall.



Parameter name	Units	Value
Average shear stress near the tank wall	N/sq.m	16.0

Figure28. Average shear stress near the tank wall.

As you can see, the VisiMix option for approximating the rheological characteristics enables the user to perform the required calculations, and find the most important process characteristics in spite of the fact that the complete mixing is impossible, or the situation is very close to it. The accuracy of the calculations based on the approximate rheological properties is identical to that achieved with the real properties and the calculations completely reflect the main features of the process.