

VisiMix LAMINAR. DEFINING KEY PARAMETERS FOR PAINT PRODUCTION. SCALING-UP.

This example shows how to calculate key mixing parameters for homogenizing a mixture and destroying the aggregates in a tank with a tooth-disk agitator. It also shows how to use VisiMix for scaling-up from the laboratory to the production scale.

System Configuration

For your process, the required condition for ensuring the quality of the final product is the complete treatment of all the media in the high stress zone. Not even the smallest part of the material must remain untreated. In the course of your laboratory research, you have found that the required quality is achieved in the following mixing system:

Your laboratory unbaffled flat-bottomed tank has a tooth-disk agitator with tangential teeth. The inside diameter of the tank is 6 in., and the tank height is 6 in. The level of liquid is 4 in., i.e. the volume of the media is about 1.85 l.

The parameters of your laboratory tooth-disk agitator are shown below in Figure 5.

Your media is a suspension of the smallest pigment particles in a viscous solution. It is a highly viscous non-Newtonian fluid with the following properties:

Density	1000 kg/cub. m
Rheological constant, K	15 Pa*s ^{1-m}
Rheological exponent, m	0.3
Yield stress, τ_0	6 N/m ²

The quality of the final product in the laboratory system proves to be satisfactory (that is, the mixture is uniform and no aggregates of the pigment particles remain in the final product) when the rotational velocity of the agitator exceeds 1800 Rpm.

Once this rotational velocity is achieved, the desired quality is ensured. However, the required mixing time was about 8 minutes.

The industrial tank at your disposal has the following characteristics:

Inside diameter	52 in
Total tank volume	1500 l
Volume of media	1200 l

The industrial agitator is of the same type as the laboratory one. Its rotational speed is 800 Rpm, and its characteristics are shown in Figure 11.

The Task

The task is to reproduce this process in the existing industrial system.

This means that you must determine whether it is possible to scale up to the industrial scale with the same product quality in your industrial apparatus. If yes, how long will the process in the industrial apparatus require, and if it requires too long, what can be done to speed it up.

The Solution

The general sequence of operations is as described in Example 1. You create two project files for your case: one for the laboratory system, **saw1-1.vsm**, and another for the industrial one, **saw2-1.vsm**. Let us start with your laboratory system.

Select **Project, New**, enter the project name, **saw1-1.vsm**, and select your flat-bottomed tank from the VisiMix tank selection that appears (Figure 1). Enter the initial data as shown in Figures 3-2—3-6 below – the parameters of the tank, baffle (no baffle option in your case), agitator, and the media properties.

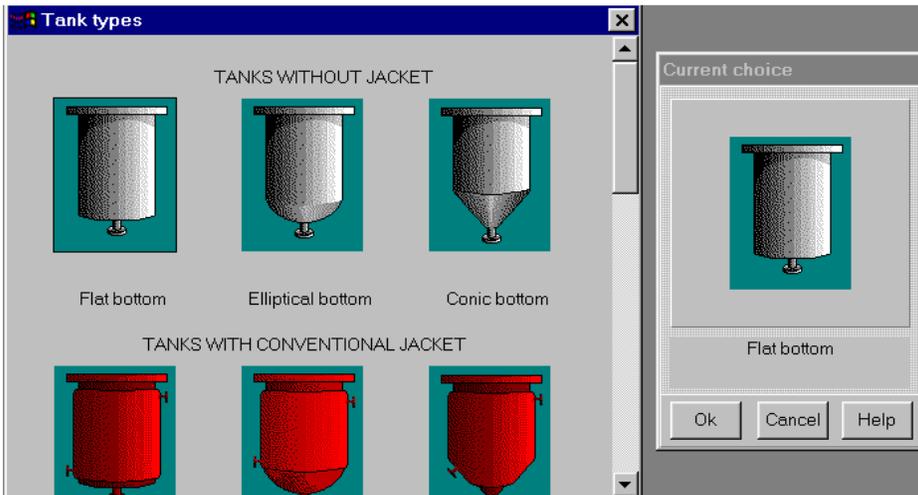


Figure 1. Selecting an unjacketed flat-bottomed tank.

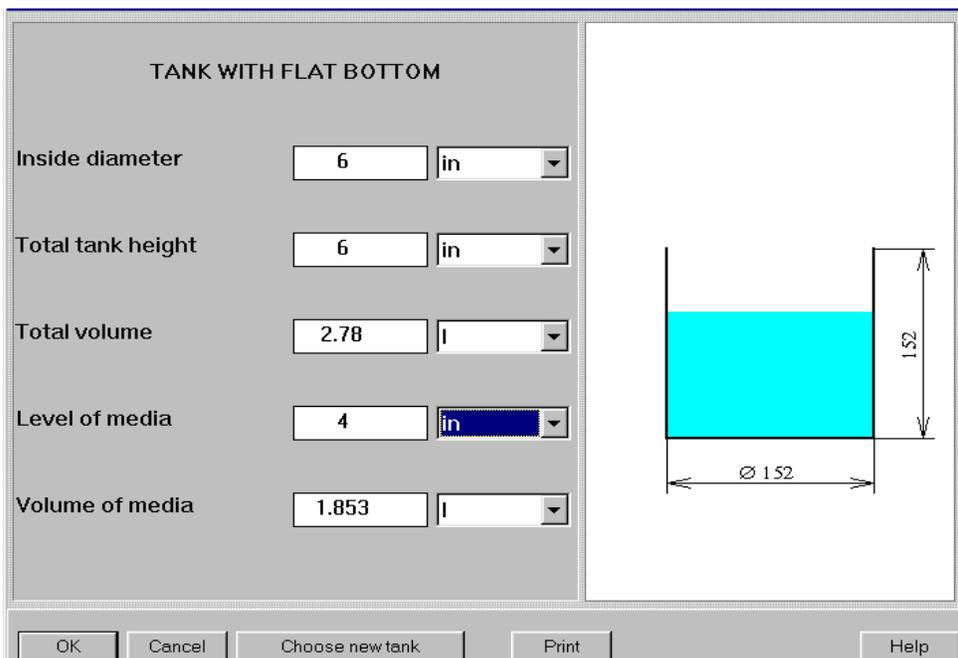


Figure 2. Entering the tank dimensions for your laboratory installation.

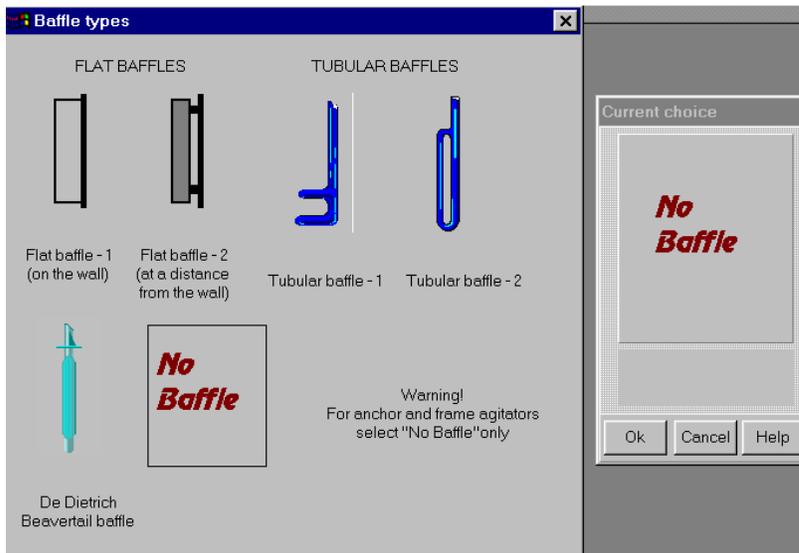


Figure 3. Selecting "No baffle" option.

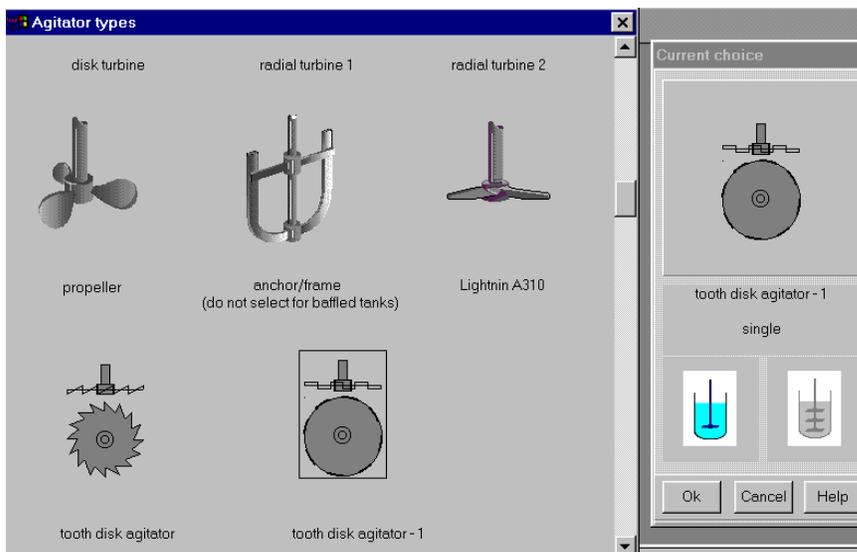


Figure 4. Selecting Tooth disk agitator - 1.

After this basic initial data has been entered, a diagram of your system appears (Figure 7). Save the project by clicking on the **Save** quick access button in the upper screen bar. **Project saved** message appears. Click OK.

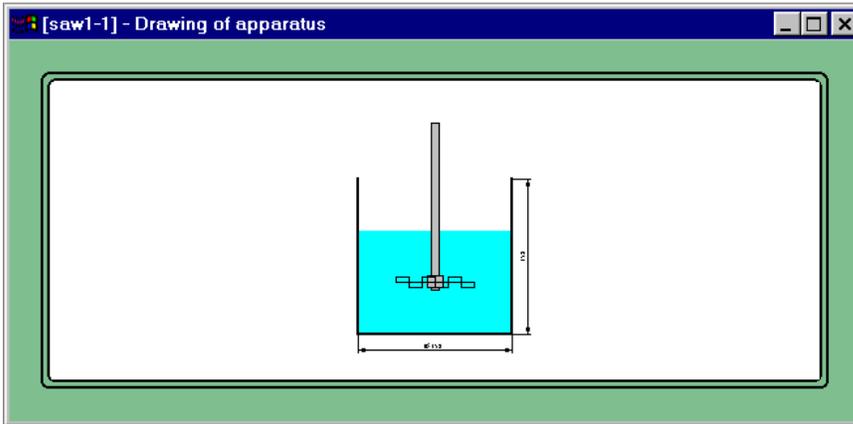


Figure 7. The diagram of the laboratory system.

Now let us create a project for your production scale system. Since we have already entered a lot of initial data, it is advisable to create the second project using the **Save as** option.

Click on **Project, Save as**, enter the name **saw2-1.vsm** for the second project in the dialogue that appears (Figure 8), and click OK.

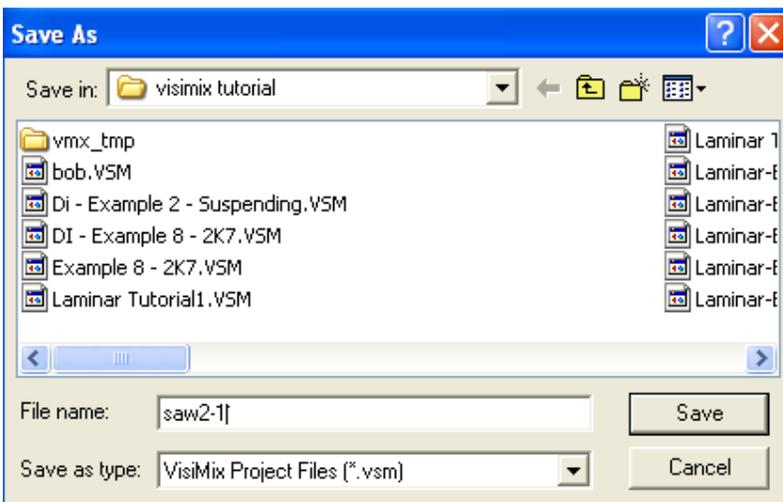


Figure 8. Creating the project for the industrial system through Save as dialogue.

Now you must modify the initial data to suit your industrial system. You can do it through the Edit option, or through the quick access buttons in the upper screen bar. Let us first click on the Tank button (button No. 6 in Figure 9), and the input table with the parameters of your laboratory tank appears (Figure 2).



Figure 9. Quick access buttons.

Click on **Choose new tank button** at the bottom of the screen, and **Tank types** selection shown in Figure 1 appears. Select a tank with an elliptical bottom, and click OK. Enter the dimensions of your industrial tank in the table that appears (Figure 10).

After you click OK, the input table with agitator data appears. Enter the data for your industrial agitator (Figure 11), and click OK. The diagram of your industrial system appears on the screen.

Now open your first project, **saw1-1.vsm**, and click on **Window, Tile**, to obtain both diagrams on the same screen (Figure 12). Note that your current project is now **saw1-1.vsm**, and its name appears in the text box at the bottom of the screen. You may modify initial data, create new output windows, or use any other functions only for the **current project**.

Figure 10. Entering the dimensions of the industrial tank.

Figure 11. Entering the agitator data for your industrial system.

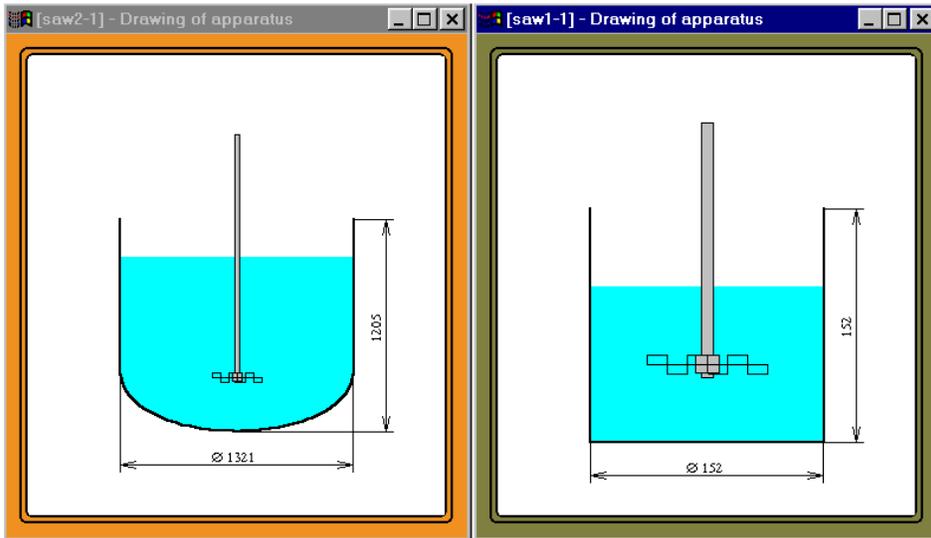


Figure 12. The diagrams of the laboratory and industrial systems.

Now let us return to **saw1-1.vsm** project and simulate our laboratory process in order to determine the key mixing parameters ensuring the desired quality in your laboratory system.

As we know, the aggregates of the pigment particles in your mixture were not destroyed at rpm values lower than 1800. This means that at these velocities, the required shear stress value in the vicinity of the agitator blades was not ensured. Let us now determine the value for the required shear stress by selecting **Shear around the agitator blades**, **Shear stress near the agitator blades** in the **Calculcate** option (Figure 13).

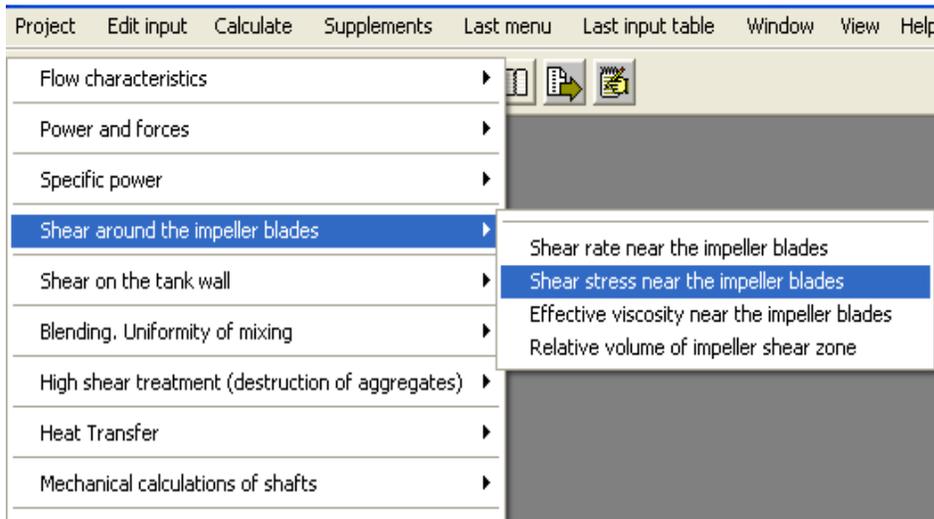


Figure 13. Calculating the shear stress value.

The value for the **Shear stress near the agitator blades** is shown in Figure 14.

SHEAR STRESS NEAR THE AGITATOR BLADES		
Parameter name	Units	Value
Shear stress near the agitator blades	N/sq.m	6200

Figure 14. Shear stress near the agitator blades for the laboratory system.

This is the first key parameter required for your scaling up procedure.

We know that this value of the shear stress is sufficient for destroying the aggregates. However, to ensure the desired quality, all the media in the tank must undergo treatment in the high shear stress area near the agitator during the process. This condition is checked by the following two VisiMix parameters:

- 1) **Unmixed part of media (%), final value**
- 2) **Untreated fraction of media**

These are the second and third key parameters required for your scaling up procedure.

Unmixed part of media (%), final value is calculated as part of the media that has not passed through the mixing zone near the agitator even once during the process time. The rest of the media, which is “mixed”, is treated in the high shear zone, but it may remain partly “untreated” in the given process time.

Untreated fraction of media represents the relative quantity of the “mixed” media, which underwent high shear treatment less than 1 - 5 times during the process time. It indicates the degree of the media treatment in the high shear zone.

Both **Unmixed part of media** and **Untreated fraction of media** are small compared to the total media volume, but their quantities are important for estimating the quality of the final product.

Let us check the value of **Unmixed part of media**. Select this parameter in the **Blending. Uniformity of mixing** menu in the **Questions by Category** (Figure 15).

Since this value is calculated for a specific process time, VisiMix asks you to specify your process time by invoking the appropriate input table. Enter the time for your laboratory process, which is 8 minutes (Figure 16).

Click OK, and VisiMix calculates the **Unmixed part of media**. Its value is shown in Figure 17.

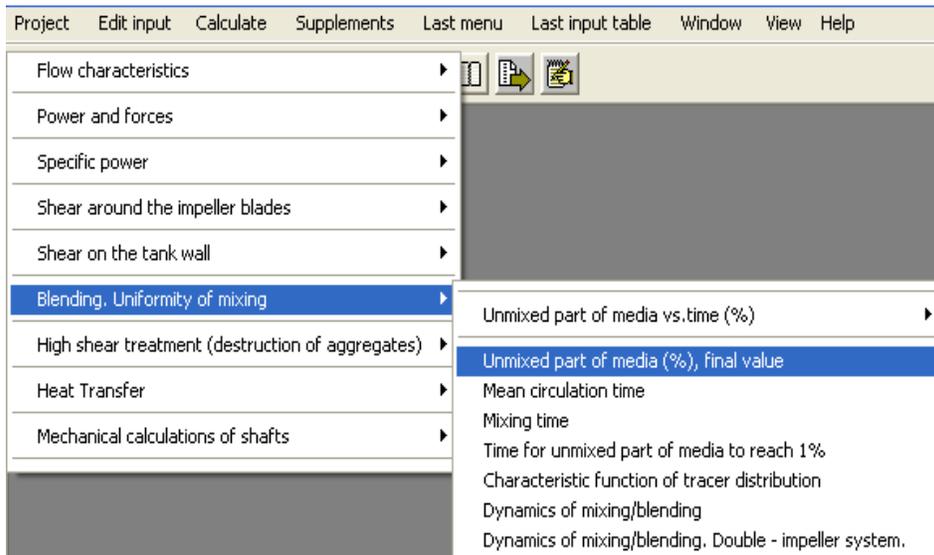


Figure 15. Calculating unmixed part of media for the laboratory system.

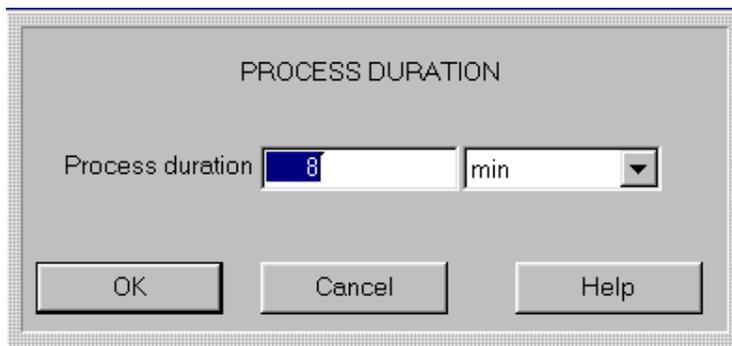


Figure 16. Entering the process duration.

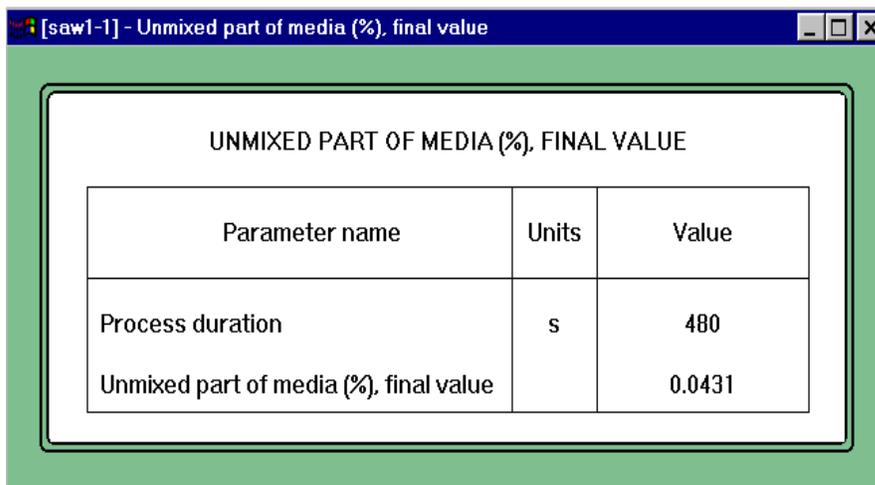


Figure 17. Unmixed part of media for the laboratory system.

Now let us check the second scaling-up parameter, the **Untreated fraction of media**. Select the appropriate item in the **High shear treatment** option (Figure 18). The output table is shown in Figure 19.

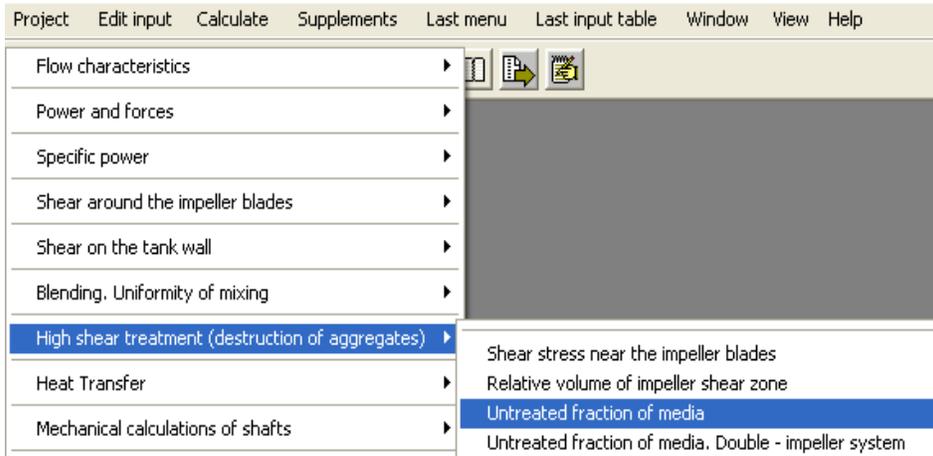


Figure 18. Calculating untreated fraction of media for the laboratory system.

UNTREATED FRACTION OF MEDIA		
Parameter name	Units	Value
Process duration	s	480
Untreated fraction of media (%), less than 1 cycle of treatment		1.09e-06
Untreated fraction of media (%), less than 2 cycles of treatment		2.1e-05
Untreated fraction of media (%), less than 5 cycles of treatment		0.00643

Figure 19. Untreated fraction of media for the laboratory system.

Figure 17 shows that about 0.05% of the media remain unmixed during the process time, and Figure 19 shows that practically all mixed part of the media is completely treated in the high shear stress zone during the process time. Since the quality of the product obtained in your laboratory system is satisfactory, it means that 0.05% is a permissible value for the untreated fraction of the media. This is the value we want to reproduce in our industrial plant.

Now let us return to the project created for the industrial system, make sure that the **Shear stress rate** is not smaller than 6200 N/sq. m obtained in the laboratory system, and if yes, determine the time needed to provide the same value for the **Untreated fraction of media**, i.e. 0.05%.

Click on **Projects list** button in the upper screen bar (quick access button 9 in Figure 9), and **Change current project** dialogue appears. Select **saw2-1.vsm**, and click OK (Figure 20).

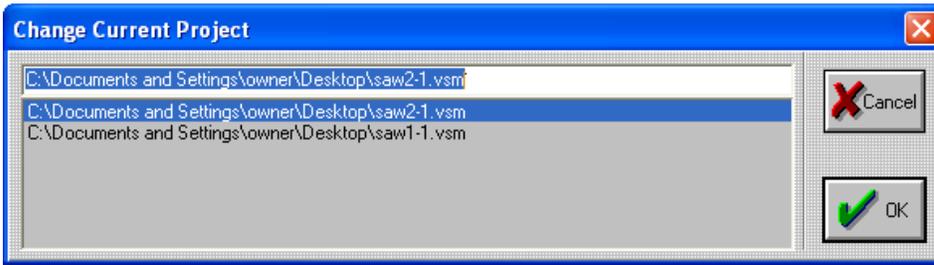


Figure 20. Changing the current project.

The project you have created for your industrial system becomes your **current project**, and the diagram of the industrial system appears on the screen.

Let us now determine the shear stress value. Select **Shear around the agitator blades, Shear stress near the agitator blades** in the **Calculate** (Figure 13). The calculated value of the shear stress is shown in Figure 21.

SHEAR STRESS NEAR THE AGITATOR BLADES		
Parameter name	Units	Value
Shear stress near the agitator blades	N/sq.m	7720

Figure 21. Shear stress value for the industrial system.

This value is even greater than the one obtained in the laboratory system. This means that your industrial system is satisfactory in this regard.

Now let us enter a preliminary value for the process time in the **Process duration** input table, for example, one hour, and check these two parameters again. The value for the **Unmixed part of media, final value** is shown in Figure 22, and the values for the **Untreated fraction of media** are shown in Figure 23.

UNMIXED PART OF MEDIA (%), FINAL VALUE		
Parameter name	Units	Value
Process duration	s	3600
Unmixed part of media (%). final value		0.0408

Figure 22. Unmixed part of media for the industrial system. The process time is 1 hour.

UNTREATED FRACTION OF MEDIA		
Parameter name	Units	Value
Process duration	s	3600
Untreated fraction of media (%), less than 1 cycle of treatment		0.149
Untreated fraction of media (%), less than 2 cycles of treatment		1.12
Untreated fraction of media (%), less than 5 cycles of treatment		22.3

Figure 23. Untreated fraction of media for the industrial system. The process time is 1 hour.

You can see that though the value for the unmixed part of the media is satisfactory, the untreated fraction of media is much greater than the permissible value of 0.05%. In the laboratory conditions, 8 minutes were enough to ensure the required quality, while in the industrial system, one hour is far from enough. This is a typical situation for a lot of industrial processes that require much longer than analogous processes in laboratory and pilot conditions.

To ensure the required quality, we will have to increase the process time. Increasing the process time to 2 hours results in the following values for the untreated fraction of media (Figure 24). You see that at least one value in the table does not meet the requirement to the quality of the mixture that you have set in your laboratory tests. Let us now increase the process time to 2.5 hours, and check the **Untreated fraction of media** again (Figure 25) to see if this process time is sufficient.

UNTREATED FRACTION OF MEDIA		
Parameter name	Units	Value
Process duration	s	7200
Untreated fraction of media (%), less than 1 cycle of treatment		0.000218
Untreated fraction of media (%), less than 2 cycles of treatment		0.00306
Untreated fraction of media (%), less than 5 cycles of treatment		0.365

Figure 24. Untreated fraction of media for the industrial system. The process time is 2 hours.

UNTREATED FRACTION OF MEDIA		
Parameter name	Units	Value
Process duration	s	9000
Untreated fraction of media (%), less than 1 cycle of treatment		8.55e-06
Untreated fraction of media (%), less than 2 cycles of treatment		0.000148
Untreated fraction of media (%), less than 5 cycles of treatment		0.0325

Figure 25. Untreated fraction of media for the industrial system. The process time is 2.5 hours.

The values in this table show that in 2.5 hours, the mixture's quality as described by the key parameters we have selected becomes satisfactory.

You have thus found out that the industrial mixing system currently at your disposal is suitable to your homogenization process, and that the process time required to achieve the desired results is 2.5 hours.