VISIMIX LAMINAR. POWER, CIRCULATION AND MIXING TIME IN TANK WITH ANCHOR AGITATOR.

This example illustrates application of the program VisiMix Laminar for mathematical modeling of mixing of a viscous liquid in reactor with anchor agitator.

Reactor:

Tank with elliptical bottom Internal diameter - 800 mm Total height – 1050 mm

Mixing device:

Anchor agitator Tip diameter – 700 mm Height of blades – 800 mm Width of blade – 55 mm.

Drive:

Rotation velocity - 45 rpm Power – 4 kW.

Media:

Viscous liquid. Volume – 400 l. Density -1300 kg /cub.m. Dynamic viscosity – 50000 cP.

Purpose of mixing: uniform mixing of viscous liquid. **Process regime:** batch.

Step 1. Entering initial data.

1.1. Tank.

As the first step after starting a new project, the program provides a graphic menu for selection of the tank type. In our case a tank with elliptical bottom without jacket is selected (Fig.1), and the program provides input table with the list of necessary dimensions. The filled input table is shown in the Fig.2. If the **Volume of media** is entered, then the **Level of media** is defined by program.



Figure 1. Graphic menu for selecting of the tank design.

TANK WITH ELLIF	PTICAL BOTTOM	
nside diameter	mm	
Total tank height		
Total volume		
Level of media		J
Volume of media		

Figure 2.

TANK WITH E	LLIPTICAL BO	ттом				
Inside diameter	800	mm	•			
Total tank height	1050	mm	•	ĺ.		
Total volume	494.3	1	•			1050
Level of media	862.4	mm	•			
Volume of media	400	1	•	<	Ø 800	>
OK Cancel	Choose new tank	<	Print			Help

Figure 3. Entering dimensions of the tank.

1.2. Baffles.

The program provides a visual menu for selection of baffles. In our case the **'NO BAFFLE'** option has to be selected (Fig.4).



Figure 4.

1.3. Impeller.

The next step – selection of the anchor impeller in a graphic menu provided by the program (Fig.5) and entering of the impeller and drive data into the arriving table (Fig.6).



Figure 5. Graphic menu for selection of impeller (fragment).

AN	ICHOR				
Tip diameter	700	mm	•		П
Number of blades	2			ī	
Height of blade	800	mm	-	Π	
Width of blade	55	mm	•		
Rotational speed	45	Rpm	•		
Motor power	4	кw	-	<	Ø 800

Figure 6. Entering data for impeller and drive.

1.4. Average properties of media.

After input of design data is completed, the program provides tables for entering of average properties of media. For our case, the density is entered, and the media is defined as Newtonian (Fig.7). The table for entering of viscosity is provided by the program (Fig.8). Note, that if the **Dynamic viscosity** is entered, **the Kinematic viscosity** is defined by the program.

	DENSITY AND TYPE	OF MEDIA
Average density	1300 kg/cub.m 💌]
	TYPE OF MED	DIA
Newtoniar	C Power-law non-Newtonian	C Carreau non-Newtonian
τ=μ * γ	$\begin{split} \tau &= \tau_{\bullet} + \mathbf{K} \star \gamma^n \\ \mu &= \tau_{\bullet} \star \gamma^{-1} + \mathbf{K} \star \gamma^{n-1} \end{split}$	$\frac{\mu - \mu_{\min}}{\mu_{\max} - \mu_{\min}} = \left[1 + (\lambda * \gamma)^2\right]^{\frac{n-1}{2}}$

Figure 7. Entering density and type (rheological model) of liquid media.

Dynamic viscosity Kinematic	5e+04	CP	•	$\tau = \mu * \gamma$,
riscosity				 μ - dynamic viscosity, Pa*see γ - shear rate, 1/sec;

Figure 8. Entering viscosity of liquid.

Step 2. Hydrodynamical modeling. Circulation Power.

After the main initial data are entered, simulation can be started.

In order to evaluate general flow conditions in the tank, we start hydrodynamic simulation with pressing one of the **Calculate> Flow characteristics** menu options, for example **Calculate>Flow characteristics> Reynolds number for flow** (Fig.9).

Project	Edit input	Calculate	Supplements	Last menu	Last input table	Window	View	Help
Flow	w characterist	ics		٠	Scheme of main circulation cycles			
Pov	ver and forces	;		•	Impeller tip vel	ocity		
Spe	cific power			•	Average tangential velocity			
She	ar around the	impeller bla	des	•	Circulation flow rate			
She	Shear on the tank wall		Reynolds number for impeller blades		les			
Bler	nding. Uniform	nity of mixin	ig		Impeller Reyno	lds number		

Figure 9. Menu options for hydrodynamic simulation.

Answer to our request based on the results of modeling is shown in the Fig.10. For additional information, we press also Last menu> Scheme of main circulation cycles and Last menu> Circulation flow rate.

REYNOLDS NUM	BER FOR FLOW	
Parameter name	Units	Value
Reynolds number for flow		1.16

Figure 10. Simulation results. Re number value based on calculated flow velocity.



Figure 11. Simulation results. Scheme of circulation cycles.

	CIRCULATION FL	OW RATE	
	Parameter name	Units	Value
Circulation flo	w rate	cub.m/s	0.00769
Index of unifor volume	mity of flow distribution in the tank		1

Figure 12. Simulation results. Main characteristics of axial circulation flow.

Results of simulation presented in the Figs 10-12 show that:

- Accordingly to the data of the Fig. 8, Re number is low and corresponds to laminar regime. So, flow in the tank is laminar.
- The scheme in the Fig.9 shows that, along with evident tangential flow, liquid in the tank is involved in axial circulation cycle that provides axial and radial exchange necessary for mixing.
- Accordingly to data of the Fig 12, rate of the axial flow is about 450 liter per min (compare it with the volume of media 400 l).
- An important parameter in this table is the **Index of uniformity of flow distribution in the tank volume.** The higher this index is, the higher is the uniformity of the flow distribution, and the smaller part of flow is "short circuited" in vicinity of the impeller. Value '1' is the maximum value, it shows that circulation cycle involves 100% of the liquid.

For defining power, let us use menu option Calculate>Power and forces>Mixing power (Fig.13).

Project	Edit input	Calculate	Supplements	Last men	u	Last input table	Window	View	Help
Flor	w <mark>chara</mark> cterist	ics		÷	51				
Pov	ver and forces	5		•		Mixing power			1
Spe	cific power			•		Torque			
She	ar around the	impeller bla	des	•		Power number			
She	ar on the tank	k wall		•		Axial force app	lds number lied to impe	ller	

Figure 13. Menu options for calculation of power.

Accordingly to the obtained results (Fig.14), power of the drive is high enough for mixing and provides necessary reservation.

MIXING POWE	R	
Parameter name	Units	Value
Mixing power	w	2550

Figure 14. Simulation results. Power consumption of impeller.

Step 3. Mathematical modeling of macro-mixing. Mixing uniformity. Mixing time.

For a simple evaluation of mixing dynamics let us use the menu option **Calculate> Blending. Uniformity** of mixing>Mixing time (Fig.15)

Project Edit input Calculate Supplements Last	menu	Last input table Window View Help
Flow characteristics	· 6	
Power and forces		-
Specific power		
Shear around the impeller blades	•	
Shear on the tank wall		
Blending. Uniformity of mixing		Unmixed part of media vs.time (%)
High shear treatment (destruction of aggregates)	•	Unmixed part of media (%), final value
Heat Transfer	•	Mean circulation time
Mechanical calculations of shafts		Mixing time
		Time for unmixed part of media to reach 1% Characteristic function of tracer distribution Dynamics of mixing/blending Dynamics of mixing/blending. Double - impeller system.

Figure 15. Menu options for mathematical modeling of macro-mixing.

MIXING T	IME		
Parameter name	Units	Value	
Mixing time necessary to attain 5% non-uniformity	s	225	
Mixing time necessary to attain 2% non-uniformity	s	357	

Figure 16. Simulation results. Mixing time values for different degrees of uniformity.

Significance of this information is clear from the text below that is extracted from the **Help** section of the program (see also **User's Guide**).

Output Parameters Blending. Uniformity of mixing. Mixing time The required duration of the mixing process depends on the desired degree of non-uniformity of the final mixture, i.e. ± 5% or 2 % of the final change in concentration.

As follows from the obtained simulation results, during the first 5-6 minutes of mixing the media is quite non-uniform, and time necessary for a uniform mixing must be a few times longer. In order to define the necessary time, let us use menu option **Calculate>Blending. Uniformity of mixing>Unmixed part of media (%), final value** (see Fig.15).

After we press the corresponding menu line, the program provides request for estimated process duration (Fig 17). Let us start with 20 minutes.



Fig. 15. Entering of process duration.

UNMIXED PART OF MEDIA	(%), FINAL	VALUE
Parameter name	Units	Value
Process duration	s	1200
Unmixed part of media (%), final value		0.0990

Figure 18. Simulation results. Achieved degree of uniformity.

Result of modeling presented in the Fig.18 shows that after 20 min of mixing composition of about 0.1% of media is not exactly equal to composition of the another 99.9%. In the most practical cases this can be considered insignificant.

Project	Edit input	Calculate	Supplement	s Last menu	Last input table	Windo
	Tank Impell Baffles Shaft	er s)))		1	
	Prope	rties & regime	•	Average prop Upper limit fo Blending, Inle	erties of media r shear rate t/sensor position	•
				Process durat	ion	
				Heat transfer		•

Figure 17. Menu option for changing process parameters.

In order to define possibility of further reduction of this value, we can select the menu option **Edit input** > **Properties & regime>Process duration** (Fig.17) and increase the **Process duration** value up to 30 min. The program repeats the modeling automatically and provides the new result (see Fig.18).

s Value
1800
0.0660

Figure 19. Simulation results. Achieved degree of uniformity.

In order to define possibility of further reduction of this value, we can select the menu **option Edit input** > **Properties & regime** > **Process duration** (Fig.19) and increase the **Process duration** value up to 30 min. The program repeats the modeling automatically and provides the new result (see Fig.20).

UNMIXED PART OF MEDIA	(%), FINA	LVALUE
Parameter name	Units	Value
Process duration Unmixed part of media (%), final value	s	1800 0.0660
		For HEI Pore

Figure 20.

As follows from the obtained data, on this stage effect of increase of mixing duration is not too significant.

Degree of uniformity achieved in the tank looks acceptable, and process duration may be limited to 20-30 min.