VISIMIX TURBULENT. GAS-LIQUID MIXING. FERMENTATION.

Calculation of Power, Shear and Gas-liquid mass transfer in reactors for fermentation.

1. Subject of calculations and initial data.

This example demonstrates application of the program VisiMix Turbulent for comparison of **Oxygen dissolution rate** and **maximum shear stress** in fermentation reactors with identical air injection parameters and with two different mixing devices – 2-stage pitch paddle and 2-stage disc (Rushton) turbine.

Subjects of mathematical modeling – Hydrodynamics, Turbulence and Gas dispersion and mass transfer.
Calculated parameters:
Mixing power;
Oxygen mass transfer rate;
Maximum local shear stress;
Relative residence time of suspension in zones of the maximum shear stress.

Description of equipment.

Design characteristics and main dimensions of the equipment are presented below in a form of VisiMix input tables. These tables are presented by the program automatically and must be filled before the start of modeling.
Tank: Jacketed tank with elliptical bottom. The main dimensions are shown in Figure 1.
Baffles: 4 flat radial baffles. The main dimensions are shown in Figure 2.
Mixing devices:
Project PADDLE : 2-stage Pitch paddle.
Project TURBINE: 2 –stage disc turbine.

The main dimensions of impellers, rotation velocity and power of drives are shown in Figures 3a and 3b. Schemes of the reactors corresponding to the two projects are presented in the Figure 4.

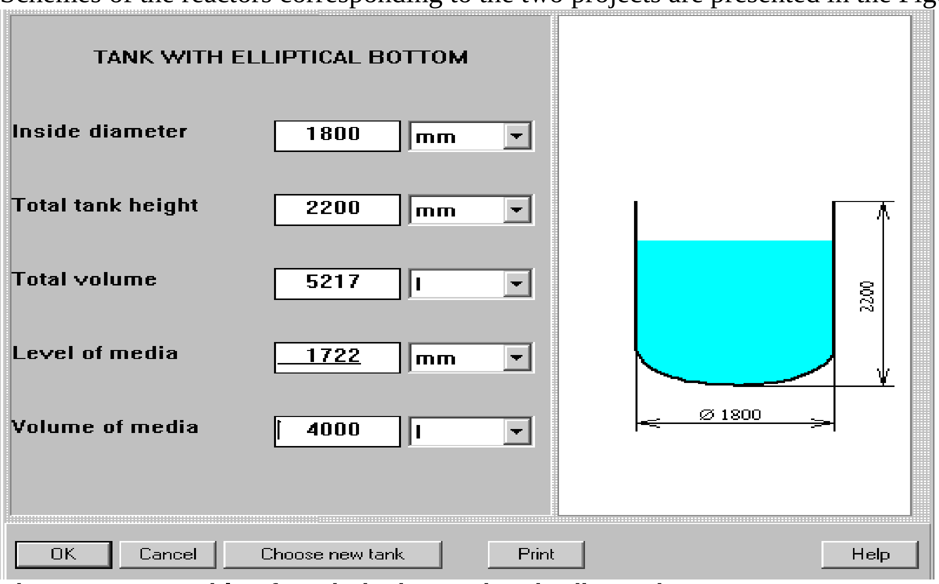


Figure 1. Input table of Tank design and main dimensions.

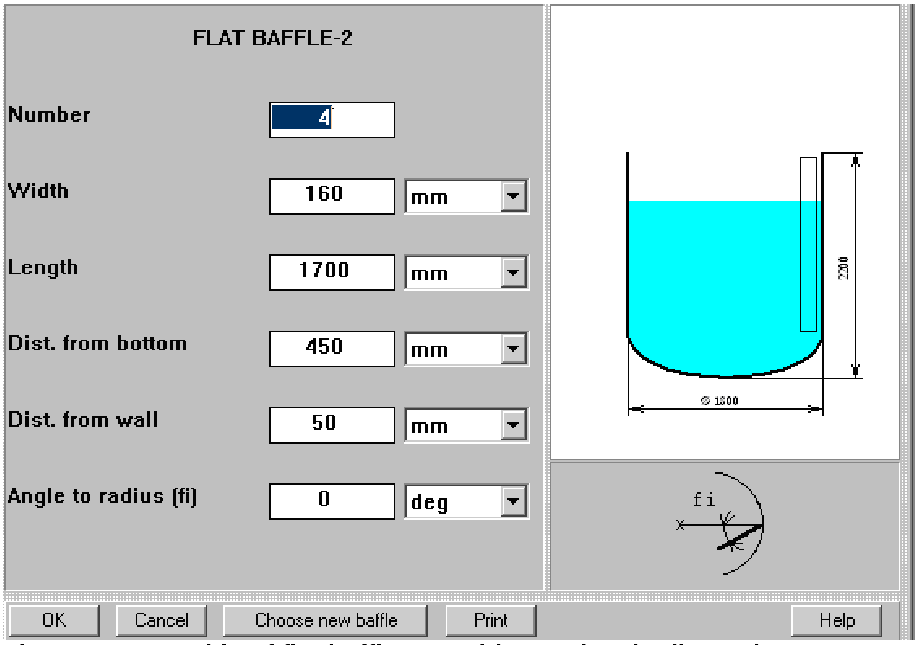


Figure 2.Input table of flat baffles –position and main dimensions.

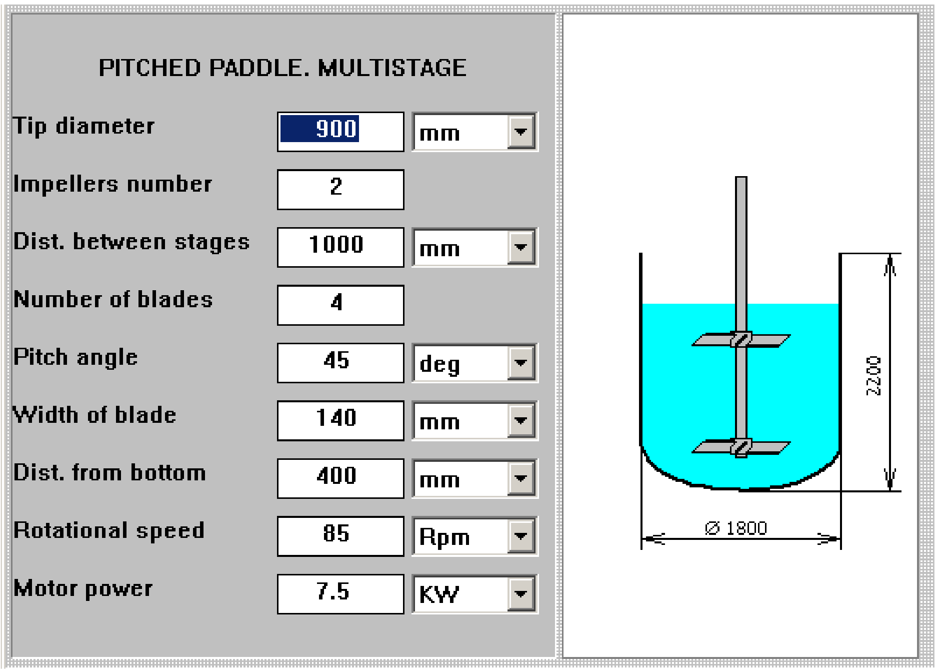


Figure 3a. Characteristics of the Pitch paddle (Project name – PADDLE).

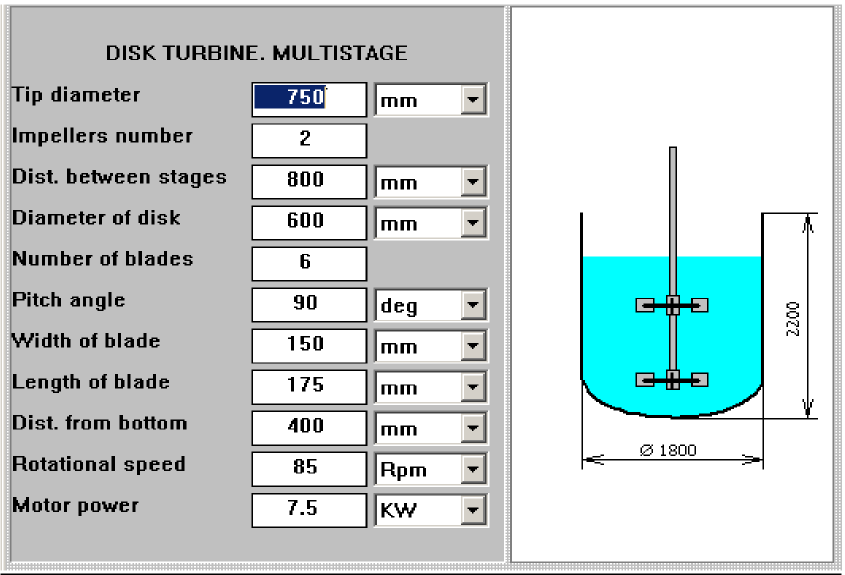


Figure 3b. Characteristics of the Disc turbine (Project name - TURBINE).

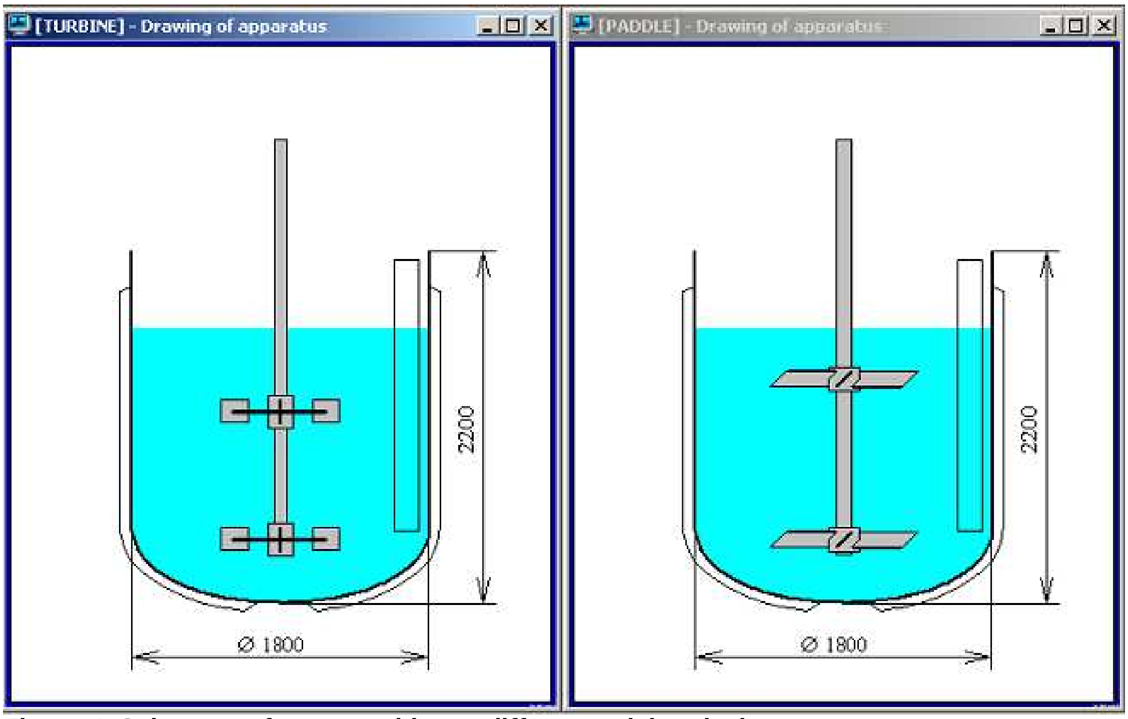


Figure 4. Schemes of reactor with two different mixing devices.

The last input necessary in order to start VisiMix modeling – average properties of media (see Figure 5).

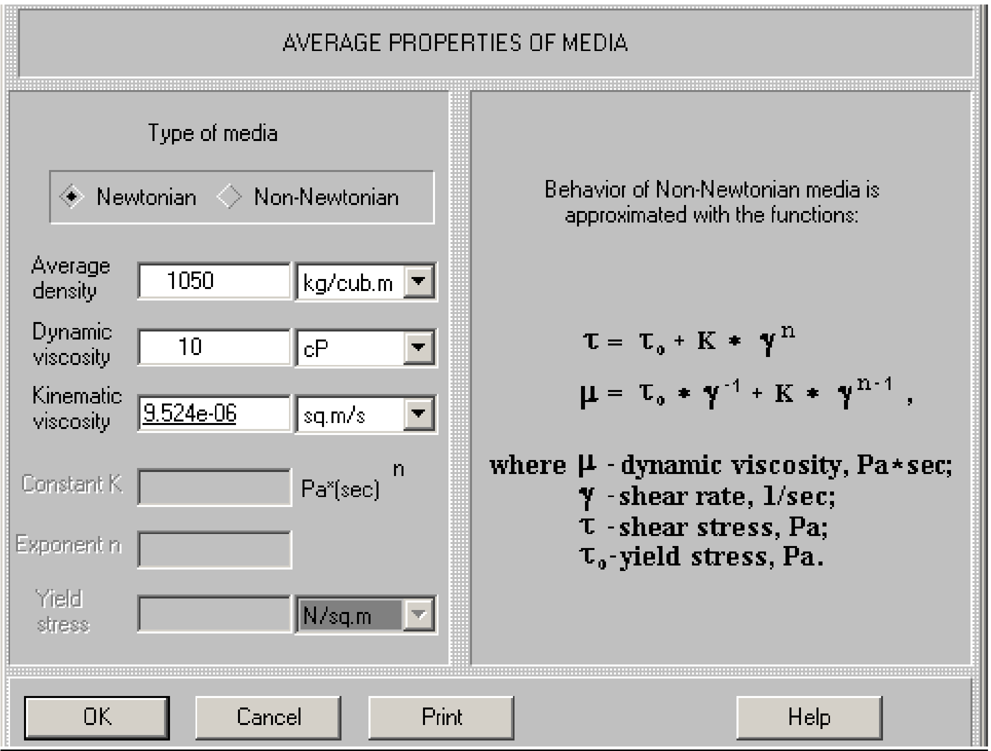


Figure 5. Input table of Average properties of media.

2. Defining of mixing power and shear characteristics..

The first stage of mathematical modeling – Hydrodynamics- is performed by selecting one of the options of **HYDRODYNAMICS** sub-Menu (Figure 6).
The calculated values of the selected parameters or functions are displayed as tables or graphs. In this example we select the parameter **Mixing power** (see Figure 6), and the program returns the calculated value. Output tables of **Mixing power** for the both projects are shown in the Figure 7.

Defining of the shear stresses in turbulent flow is based on mathematical modeling of micro-scale turbulence. In this example we are interested in evaluation and comparison of shear stresses, and in particular – of the maximum local shear stress values in the two reactors. Locations of the maximum values of shear stress correspond to zones of the maximum local turbulent dissipation rate in vicinity of the impeller blades. So, in the sub-Menu **TURBULENCE** (Figure 8) we select parameters **TURBULENT SHEAR RATES IN DIFFERENT ZONES**, **Turbulent shear stress near the impeller blade** and **RESIDENCE TIME IN ZONES WITH DIFFERENT TURBULENCE.** The corresponding VisiMix outputs for the compared projects are presented in the Figures 9, 10 and 11.

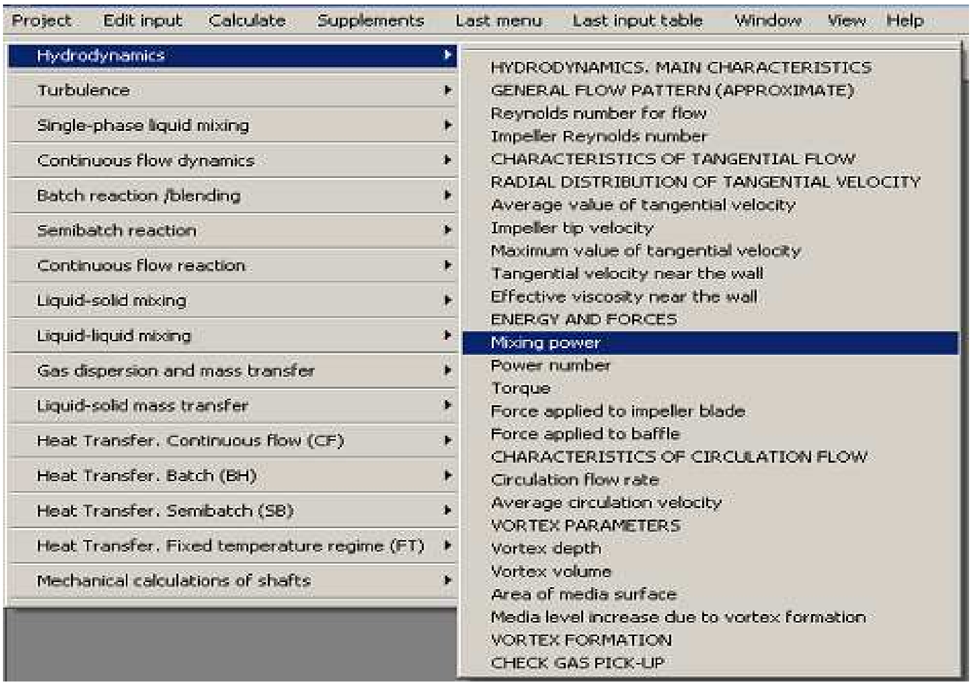
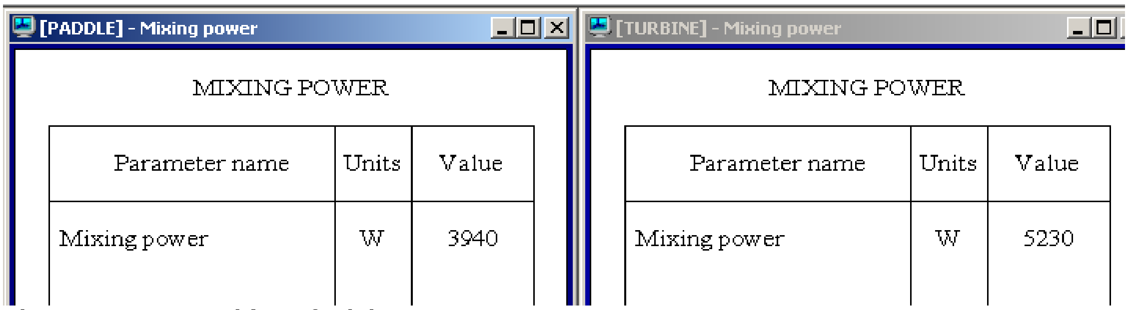


Figure 6. Menu HYDRODYNAMICS.



MIXING POWER

Parameter name	Units	Value
Mixing power	W	3940

MIXING POWER

Parameter name	Units	Value
Mixing power	W	5230

Figure 7. Output tables of Mixing power.

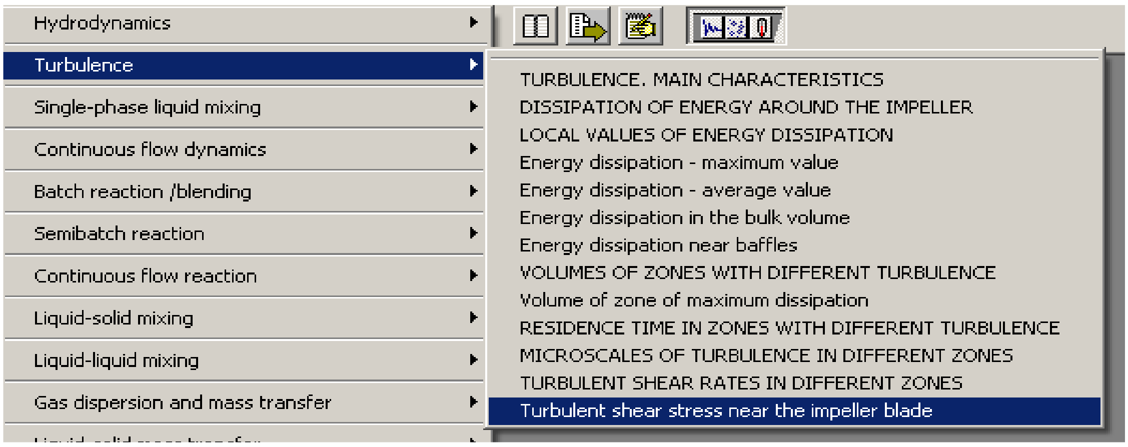


Figure 8. Menu TURBULENCE.

[PADDLE] - TURBULENT SHEAR RATES IN DIFFERE...

TURBULENT SHEAR RATES IN DIFFERENT ZONES

Parameter name	Units	Value
Turbulent shear rate near the impeller blade	1/s	1810
Turbulent shear rate near the baffle	1/s	257
Turbulent shear rate in the bulk volume	1/s	220

[TURBINE] - TURBULENT SHEAR RATES IN DIFFERE...

TURBULENT SHEAR RATES IN DIFFERENT ZONES

Parameter name	Units	Value
Turbulent shear rate near the impeller blade	1/s	3170
Turbulent shear rate near the baffle	1/s	364
Turbulent shear rate in the bulk volume	1/s	224

Figure 9. Output tables of Turbulent shear rates in different zones.

[PADDLE] - Turbulent shear stress near the impe...

TURBULENT SHEAR STRESS NEAR THE IMPELLER BLADE

Parameter name	Units	Value
Turbulent shear stress near the impeller blade	N/sq.m	18.1

[TURBINE] - Turbulent shear stress near the imp...

TURBULENT SHEAR STRESS NEAR THE IMPELLER BLADE

Parameter name	Units	Value
Turbulent shear stress near the impeller blade	N/sq.m	31.7

Figure 10. Output tables for Maximum shear stress.

[PADDLE] - RESIDENCE TIME IN ZONES WITH DIFFE...

RESIDENCE TIME IN ZONES WITH DIFFERENT TURBULENCE

Parameter name	Units	Value
Relative residence time in zone of maximum dissipation		0.00882
Relative residence time in zone of baffles		0.0163
Relative residence time in the bulk volume		0.833

[TURBINE] - RESIDENCE TIME IN ZONES WITH DIFF...

RESIDENCE TIME IN ZONES WITH DIFFERENT TURBULENCE

Parameter name	Units	Value
Relative residence time in zone of maximum dissipation		0.00591
Relative residence time in zone of baffles		0.0163
Relative residence time in the bulk volume		0.741

Figure 11. Output tables for RESIDENCE TIME IN ZONES WITH DIFFERENT TURBULENCE.

3. Evaluation of the Oxygen consumption rate.

The last stage of modeling – comparison of Oxygen mass transfer rates. In our example it is based on approximately assumed initial data.

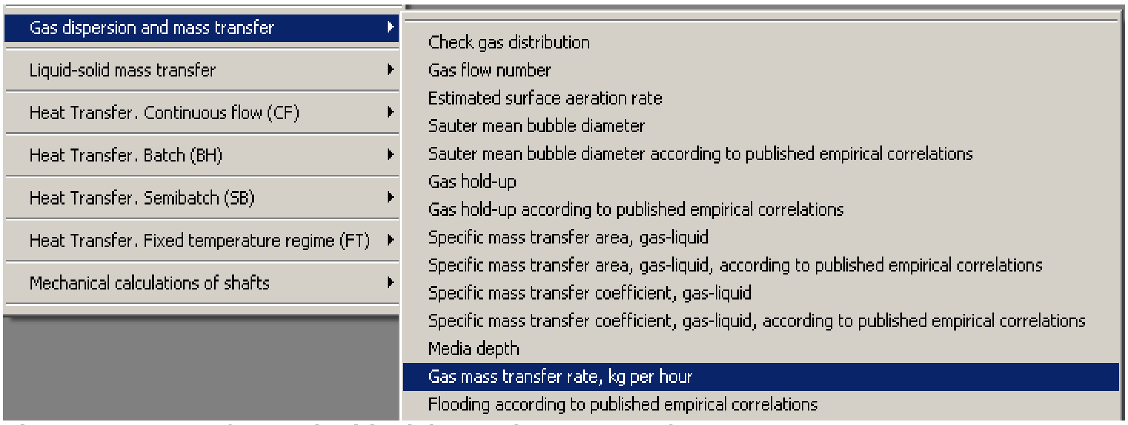


Figure 12. Menu of Gas-Liquid mixing and mass transfer.

In order to perform modeling, we must select one of the options in sub-Menu GAS DISPERSION AND MASS TRANSFER.. Let us select **Gas mass transfer rate** (Figure 11).

As a response to this action, the program will display a few input tables for entering additional data that are necessary for mass transfer calculations – the data on air injection and physical properties of phases (Figures13-16).

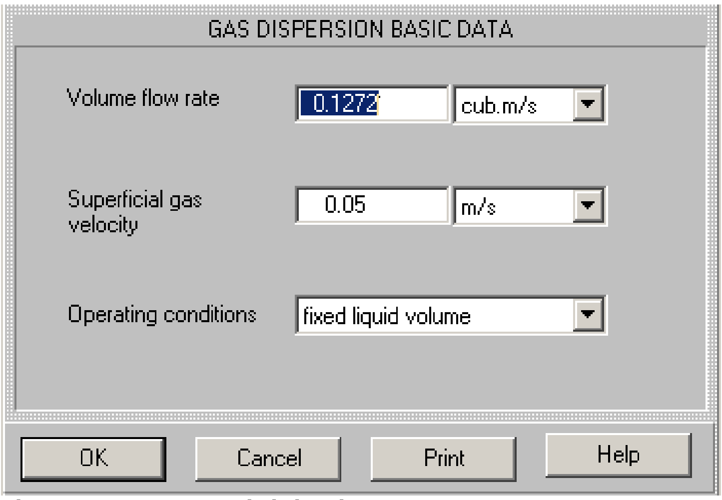


Figure 13. Data on air injection.

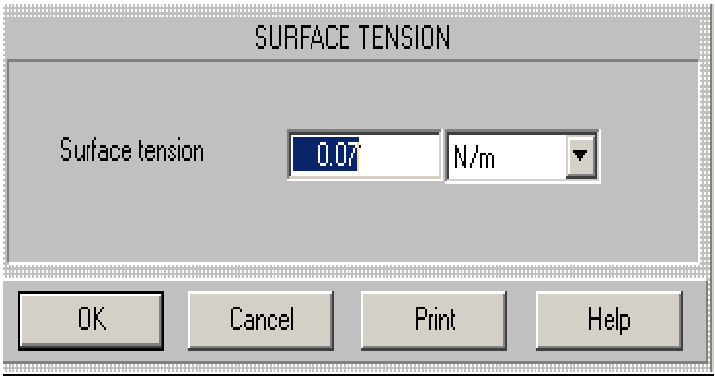


Figure 14. Input table of Surface tension.

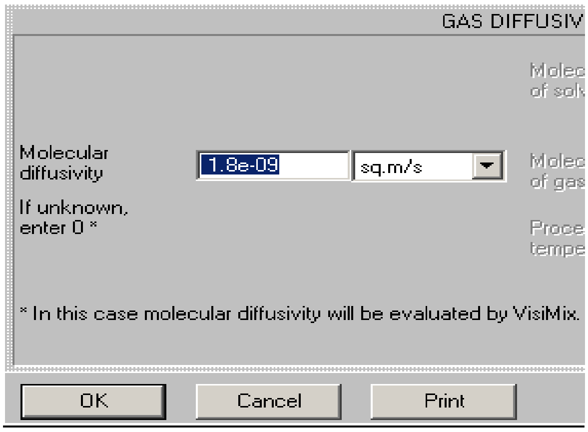


Figure 15. Input table of Oxygen diffusivity.

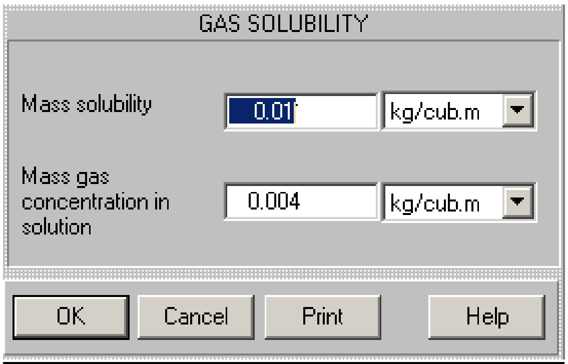


Figure 16. Input table of Oxygen solubility.

After the last of the tables is filled, the output table for the corresponding project is displayed by the program. Comparison of the mass transfer rates in the two reactors with different mixing devices is shown in the Figure 17.

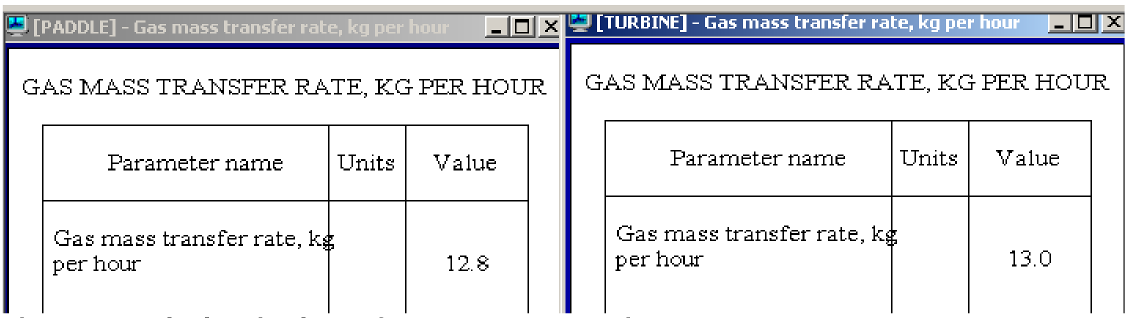


Figure 17. Calculated values of Oxygen consumption rate.