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Hydrodynamic Study of a Stirred Tank by a Chamfered Blade Agitator

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Hydrodynamic Study of a Stirred Tank by a Chamfered Blade Agitator

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Abstract – *The different steps encountered in the production lines of various industrial processes like food, cosmetic, pharmaceutical, chemical, biochemical, petrochemical, paint, cleaning products, water treatment, textile, etc., appeal to the precepts of agitation, the basics of the rheology of mixed fluids, and are conducted in stirred tanks. Mechanical stirring of the fluid media is designed to promote mixing of these environments in order to obtain a degree of homogeneity of the final product and / or intensify the mass transfer phenomena. A hydrodynamics and mass study is needed to optimize the design of the tanks and the mobile of agitation.*

Initially, a local and global study namely the velocity and number of power on a typical agitation system agitated by a mobile-type two-blade straight (d / D = 0.5) allowed us to test the reliability of the CFD Fluent , the results were compared with those of experimental literature, a very good concordance was observed. This validation will then perform simulations on a configuration such an agitation system in two-dimensional geometry agitated by a two-blade chamfered case of a Newtonian fluid. The velocity profile, the velocity fields and the number of powers are analyzed. It was shown that the hydrodynamics is modified by the effect of the muzzle of the mobile which plays a key role.

When interpreting the results a comparative analysis between the mobile and chamfered right is adopted.

A comparative qualitative study of a mixture of two miscible fluids Newtonian mass transfer analysis was undertaken to test the performance of our proposed mobile.

***Keywords**: Mechanical agitation, Newtonian fluid, Stirred tank, Numerical simulation, CFD, Finite Volume, Laminar, 2D, Two-bladed stirrer Chamfer, Mass transfer, Miscible fluids, Not fractional, Viscous fluids, Rheology.*

I. Introduction

Today human beings have become too demanding as consumers, in terms of the quality food products, cosmetics, pharmaceuticals, chemicals, cleaning products, textiles, etc.

The crude product, the raw material into finished product packaging, the entire production process engineering involves a coordinated series of fundamental operations separate and independent of the process itself is called unitary operation. For each, the engineer must consider the thermodynamic aspect, that is to say, the feasibility of reactions and the energy required to achieve them, some reactions are exothermic, they are accompanied by release of energy, but most are endothermic and therefore require an energy input by mechanical agitation, which is a unit operation that is a big step in a manufacturing process engineering where fluid flows are present.

Our goal is to model and simulate numerically the flow generated by our mobile, to prove its performance in homogenization mixing in a reduced time.

II. Geometric Representation of the System, Mathematical Formulation

This work is a contribution to the study of the difficulties encountered in the field of agitation and a contribution to the study induced mass agitation in laminar incompressible Newtonian fluid in a cylindrical vessel not baffled flat bottom, stirred by a two-blade type mobile chamfered Figure 1. Note that such problems arise in different industrial sectors of great economic importance.

Our goal is to model and simulate numerically the flow generated by our mobile, to prove its performance in homogenization mixing in less time.

The governing equations, the fluid flow are written in dimensionless form, taking into account the following simplifying assumptions:

1. Newtonian fluid,
2. incompressible fluid,
3. the flow is laminar and two-dimensional,
4. The regime is permanent,
5. All solid walls are adiabatic.

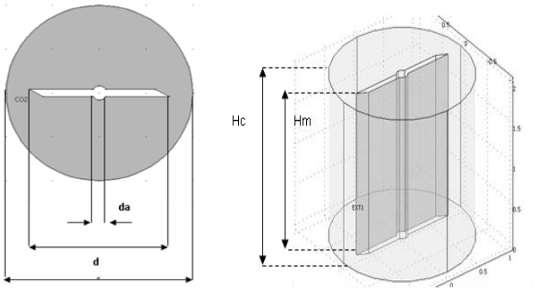


Figure 1. Physical model.

We have the dimensionless parameters

$$X = \frac{2x}{D} \quad Y = \frac{2y}{D} \quad C^* = \frac{C}{C_0} \quad U = \frac{u}{V_0} \quad V = \frac{v}{V_0}$$

$$V_0 = \pi N D \qquad t^* = 2\pi N t$$

Dimensionless equations are as follows:

II.1. the hydrodynamic study

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0$$

$$\frac{\partial U}{\partial \tau} + U\frac{\partial U}{\partial X} + V\frac{\partial U}{\partial Y} = -\frac{\partial P}{\partial X} + \frac{1}{\mathrm{Re}}.\frac{2}{\pi}.\left(\frac{d}{D}\right)^2.\left(\frac{\partial^2 U}{\partial X^2} + \frac{\partial^2 U}{\partial Y^2}\right)$$

$$\frac{\partial V}{\partial \tau} + U\frac{\partial V}{\partial X} + V\frac{\partial V}{\partial Y} = -\frac{\partial P}{\partial Y} + \frac{1}{\mathrm{Re}}.\frac{2}{\pi}.\left(\frac{d}{D}\right)^2.\left(\frac{\partial^2 V}{\partial X^2} + \frac{\partial^2 V}{\partial Y^2}\right)$$

II.2. the study of mass transfer

$$\frac{\partial C^*}{\partial t^*} + U\frac{\partial C^*}{\partial X} + V\frac{\partial C^*}{\partial Y} = \lambda_2\left[\frac{\partial^2 C^*}{\partial X^2} + \frac{\partial^2 C^*}{\partial Y^2}\right]$$

III. Numerical Solution of Equations

For the numerical solution of equations governing the hydrodynamics flows, we used a CFD code where the finite volume method is integrated; we are to be passed through three steps.

The first step is the pre-processor Gambit CFD code which has constructed the geometry and generated the mesh.

The second step is the solver code where we proceeded to set data, Prescription to initial conditions and limitations, testing and optimization of the convergence of computation, then the calculation and simulation.

The third and final step is the post processing, we used the Tecplot where we operate and our results are viewed.

IV. Results and Discussion

IV.1. Effect of inertia on the evolution of the stream function

Contour of streamlines: d / D = 0.5, 45° chamfer

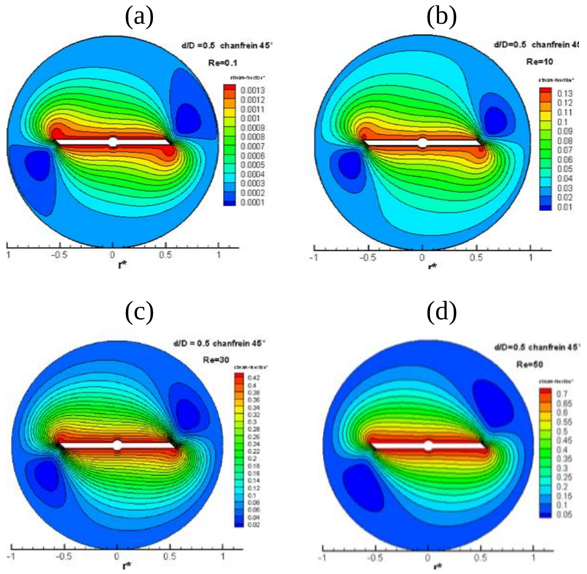


Figure 2. Evolution of the stream function.
(a) *Re*=0.1. (b) *Re*=10. (c) *Re*=30. (d) *Re*=50.

IV.2. Influence of the size of the mobile on the evolution of the stream function

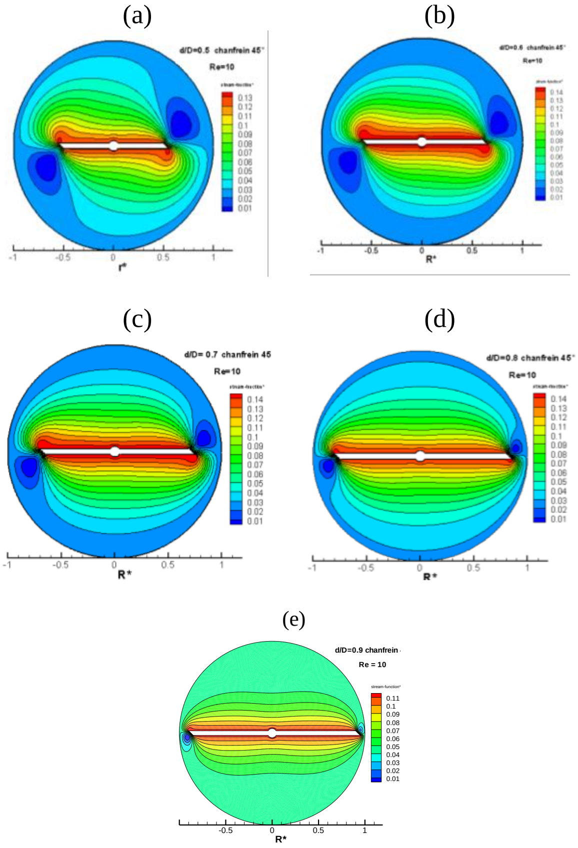


Figure 3. Evolution of the stream function.
(a) *d* / *D*=0.5. (b) *d* / *D*=0.6. (c) *d* / *D*=0.7. (d) *d* / *D*=0.8.
(e) *d* / *D*=0.9.

IV.3. Influence of a-degree chamfer on the evolution of the stream function

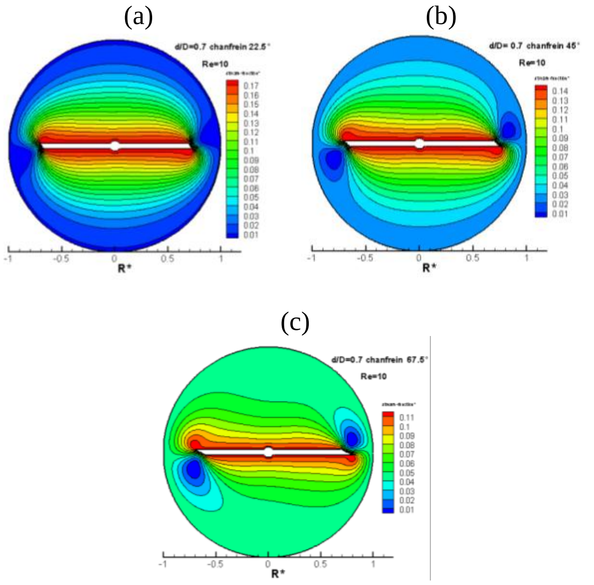


Figure 4. Evolution of the stream function.
(a) chamfer 22.5°. (b) chamfer 45°. (c) chamfer 67.5°.

IV.4. Comparison between the right and chamfered

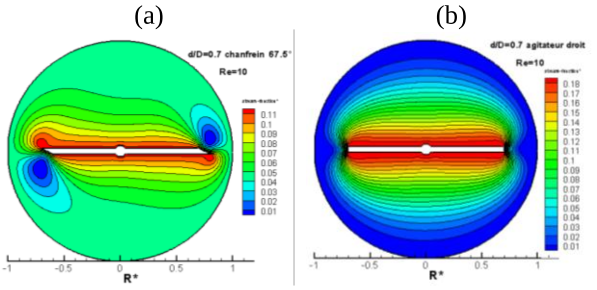
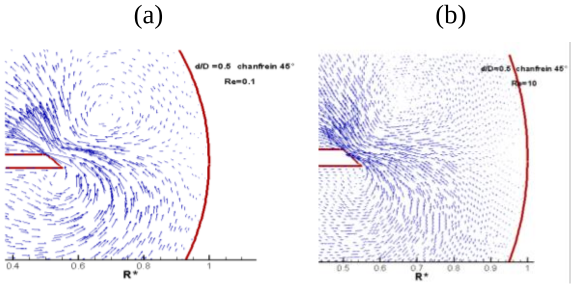


Figure 5. Comparison between the right and the chamfered. (a) the chamfered. (b) the right.

IV.5. Influence of inertia on the evolution of velocity fields



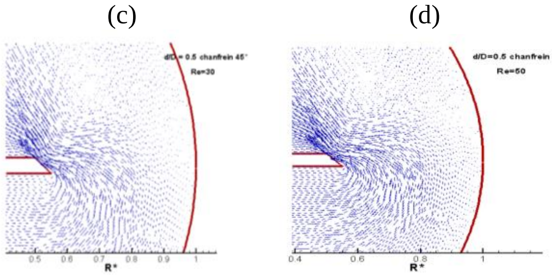


Figure 6. Evolution of the velocity fields.
(a) Re=0.1. (b) Re=10. (c) Re=30. (d) Re=50.

IV.6. Influence of the size of the mobile on the evolution of velocity fields

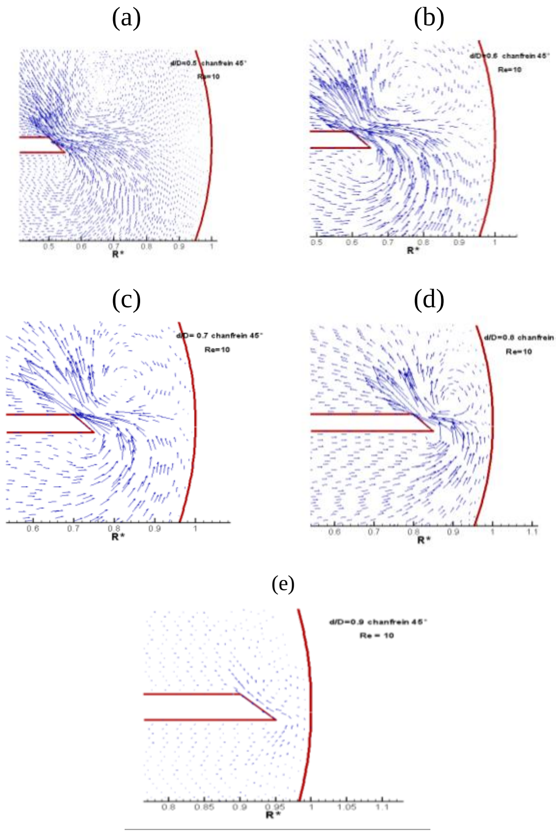
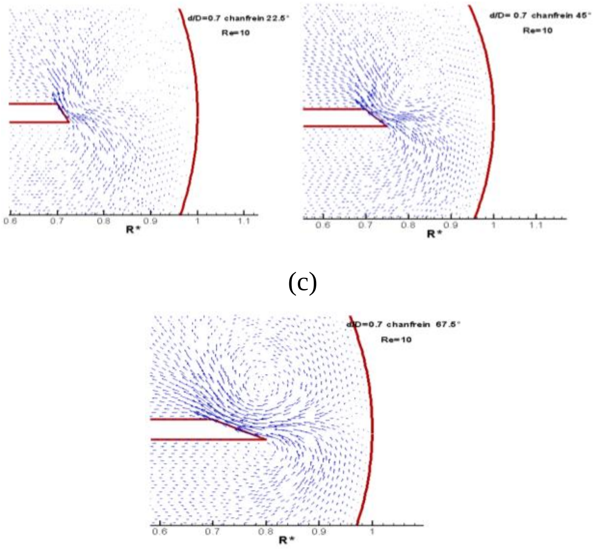


Figure 7. Evolution of the velocity fields.
(a) $d\,/\,D$=0.5. (b) $d\,/\,D$=0.6. (c) $d\,/\,D$=0.7. (d) $d\,/\,D$=0.8.
(e) $d\,/\,D$=0.9.

IV.7. Influence of the degree of chamfering on the evolution of velocity fields

(a) (b)



(c)

Figure 8. Evolution of the velocity fields.
(a) chamfer 22.5°. (b) chamfer 45°. (c) chamfer 67.5°.

IV.8. Comparison between the right and chamfered

(a) (b)

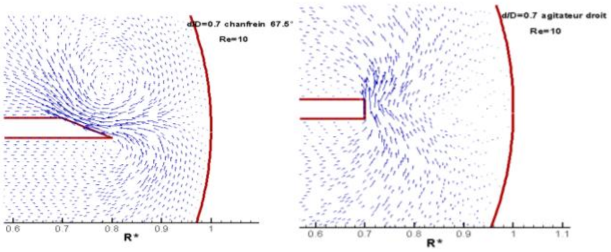


Figure 9. Comparison between the right and the chamfered. (a) the chamfered. (b) the right.

IV.9. Evolution of the stream function depending on the size

(a) (b)

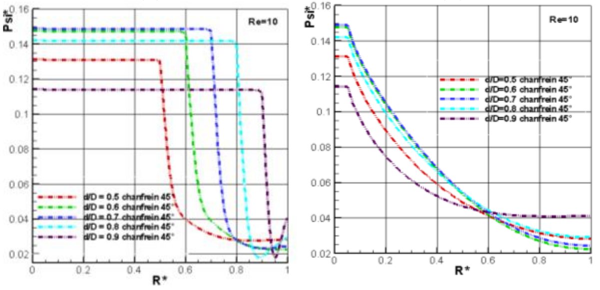


Figure 10. Evolution of the stream function depending on the size.

V. Interpretation of the Results

A. The maximum value of the current function is at the level of the agitator (moving frame), this value is proportional to the number of *Re* (Figure 2).

The maximum value of the current function is at the level of the agitator (moving frame).

As to one approach the wall of the value of the function of current decreases until it becomes zero (phenomenon of adhesion with the wall fixed frame).

The two vortexes located between the two ends of the blade and the wall are important in the low Reynolds number.

The size of the area surrounding the two-blade is less important in the *Re* = 0.1, is growing in *Re* (10 and 30), then decreases in volume in the *Re* = 50.

B. The maximum value of the current function is at the stirrer.

The closer the value of the wall of the stream function decreases until it becomes zero (Figure 3).

The size of the vortex is inversely proportional to that of the agitator, as and as one increases the size of the agitator, the volume of the vortex decreases.

C. the maximum value of the function of current is inversely proportional to the degree of chamfering. Figure 4).

The value of the stream function in the remote area of the two-blade approaching the wall increases with increasing degree of chamfer of two-bladed.

The maximum value of the function of current is always at the stirrer.

The volume of the recirculation zone grows progressively as one increases the degree of chamfering,

D. The shape of the streamlines in the two-bladed right is concentric and symmetrical about the blade (Figure 5).

Compared to the agitator right (90°), the recirculation zone (the vortex) is less important, with respect to three degrees of chamfering.

The function value of current in the area close to the wall is important in the case of the chamfered.

E. The Figure 6 confirms the evolution of the vortex inversely proportional with respect to the inertia.

F. The Figure 7 confirms the evolution of the vortex inversely proportional to the relative size of the two-bladed.

G. The size of the vortex is proportional to the degree of chamfering, Figure 8.

H. the difference between the two blades chamfered and the right is remarkable.

A good shear of the fluid at the chamfered, pumping the fluid inwardly beyond tank, the swept volume is important (Figure 9.a).

Unlike the two-bladed right, the shear is low, the swept volume is low, fluid is pumped to the wall (Figure 9.b).

I. Figure 10 confirms what was mentioned above, the maximum value of the stream function is at the agitator (moving frame), and that as and when we approach the wall of the value of the current function decreases to values close to that of the wall (wall adhesion phenomenon fixed frame), We also note that the value of the current function is constant at the blade for the different sizes, and then from the right end of the blade decreases the function of current to the wall by taking an exponential form.

Figure 10.b shows that the curves of the two blade sizes have an exponential shape and intersect at point $R^* = 0.6$.

VI. Validation

To test the reliability of our simulations and the conformity of our results we have compared with previous work on a two-blade paddle agitator straight ($d / D = 0.5$ $da / D = 0.05$) [Youcefi 1993] and [Bertrand 1983].

We validated our work according to two parameters the local and global.

Depending on the locale that is the tangential velocity on the blade and its extension, we have validated with the experimental study [Youcefi 1993], as shown in Figure 11 good agreement is demonstrated.

Following the global setting that is the power number *Np*, we have validated with the experimental study [Bertrand 1983], as shown in Figure 12, good agreement is clearly confirmed.

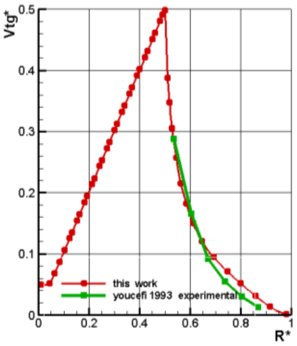


Figure 11.
Comparison with Youcefi.

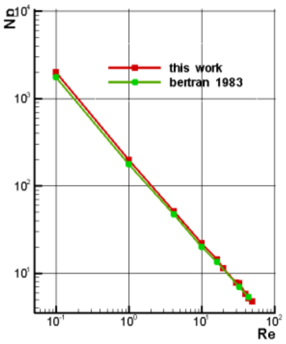


Figure 12.
Comparison with Bertran.

VII. Conclusion

Our work is a form of contribution to the study of the difficulties encountered in the phenomena of agitation in tanks environments Newtonian rheology.

Note that such problems arise in different industrial sectors of great economic, industrial plastics, inks and paints, cosmetics and beauty products, food industries, bio industries, etc.

A 2D simulation was undertaken studying the hydrodynamics and mass transfer of incompressible flow around a two-blade chamfered.

Then the results on a two-bladed hydrodynamic chamfered were presented, by making changes in the degree chamfer 22.5°, 45° and 67.5°, the Reynolds number and size of mobile.

It was shown that the hydrodynamic effect is modified by the muzzle of the mobile which plays a key role.

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