ADVANCED DESIGN OF INDUSTRIAL MIXERS FOR FLUID FOODS USING COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT
This work focuses on discontinuous (batch) vertical fluid mixing systems for food fluids with particles. The purpose was to identify the main structural and geometrical parameters that can influence the mixing process, in order to obtain useful indications for the design of mixing systems. The products examined are Newtonian multiphase fluids, with different viscosity values.

A properly designed mixing process has to provide two main results: a satisfactory homogeneity of the product and the preservation of the integrity of solid particles. Different mixer designs were thus analyzed to identify the structural factors which have the greatest impact on the above requirements. In particular, a Computational Fluid Dynamics (CFD) software was used to carry out a series of simulations, from which some Key Performance Indicators (KPI) related to the effectiveness of the different mixer configurations were derived. From those KPIs, some main conclusions were derived, that can be useful to choose the appropriate design solutions for fluid mixers.

Keywords: food fluids, batch mixers, design optimization, computational fluid dynamics

1. INTRODUCTION
Mixing, in many industrial processes, is used for homogenization, i.e. to mix together multiple components into a homogeneous mixture. In particular, when fluids containing suspended particles are processed, the action of the mixer is to transfer a given amount of energy to the material, in order to develop it to an optimum, i.e. to bring it at a uniform inter dispersion of the two phases. The way this energy is transferred is also crucial: in fact, it has to keep the whole internal volume of the mixer in motion, avoiding, at the same time, damages to the solid particles.

Generally speaking, when talking about mixing, it should be noted that there are many different types of mixing systems, which can differ from one another as regards the operation mechanism (continuous or discontinuous), the shape and dimensions of tanks and impellers and their reciprocal orientation (vertical, horizontal or oblique orientation of the impellers axis) and disposition (centered or decentered impellers). In this paper, we focus on the optimization of a batch vertical mixer, and aim to determine whether (and to what extent) the structural characteristics of a mixer may impact on its effectiveness.

Batch mixers are simple discontinuous mixers, consisting of a containing vessel in which the fluid is kept in motion by means of rotating agitators. Batch mixers are very common in food industries, and are often used in different stages of the transformation process. Moreover, in many real industrial processes, homogenization is of paramount importance and may be a limiting factor for the success or failure of processes (Rahimi, 2005). Consider, for instance, the importance of homogeneity of solid and liquid contents for multiphase fluids, in which the solid fraction should be kept as constant as possible. If this does not happen, serious problems may occur during filling. Companies would not be able to ensure the constancy between a container and the other of the bottled product, making the process unsatisfactory.

In the light of the importance of this issue, several studies have been carried out, aimed at analyzing the mixing process from different points of view: mixing efficiency, mixing times, and power consumption have been investigated theoretically and experimentally (Godfrey, 1986; Ottino, 1989; Tanguy et al., 1992, 1996). Moreover, many approaches based on numerical modeling (Alexopoulos et al., 2002, Daskopoulos and Harris, 1996 and Rahimi et al., 2000; Jongen, 2000) and CFD simulation (Patwardhan and Joshi, 1999; Sahu et al., 1999; Rahimi, 2005) have been applied to the study of mixing and have proved successful in predicting the course of homogenization. A better knowledge of the way the fluid is mixed may improve the process outcomes in many ways, e.g., in terms of yield or efficiency of the process. Thus, it would be useful to be able to predict mixing by using modern technologies such as numerical models.

The work builds upon this consideration, and is based on the modelling of mixing through CFD simulation. Nonetheless, we also tried to introduce an innovative method for the evaluation of the effectiveness of mixing plants. Mixers were assessed using four new parameters(that will be detailed later in the paper), trying to take into account all the aspects that may be indicative of a homogeneous mixing and of the preservation of pieces integrity.

2. MATERIALS AND METHODS

2.1. Basic design and structural variables of the mixer

The mixer considered in this study basically consists of a simple cylindrical vessel in which the fluid is kept in motion by means of a vertical impeller. The capacity of the tank has been set at 600 l, and is kept unchanged. Conversely, the tank configuration has been changed during the study. Such a plant is extremely flexible from a design point of view, given the possibility to act on many operating leverages. In order to understand which of these leverages have the greatest impact on the performance of the mixing process, some plant operators were preliminary asked about the importance of some structural characteristics of the mixer and their impact on mixing performance. Therefore, the tests were oriented to the analysis and the comparison of different batch mixers, which differed from each other as regards three main characteristics, related to the geometrical structure or to the properties of the treated product:

1. Rotor disposition inside the tank
2. Aspect Ratio
3. Viscosity of the analyzed fluid.

Each variable has been discretized on two levels (i.e., “high” and “low”), according to the description below, so that a total of 8 configurations was analyzed.

1. In each configuration the rotor is vertically disposed, but it can assume two different dispositions, i.e. centered or eccentric. This means that the impeller can be coaxial with the tank or at a certain distance from the tank axis. In the first case, the eccentricity of the two elements (i.e. the ratio between the radius of the tank and the distance of the axis of tank and rotor) is obviously null, while for all analyzed mixers with decentred impeller, the eccentricity was fixed at about 0.43. Therefore, the “Rotor disposition” variable could score 0 or 0.43.

Eccentricity is a very important factor for mixers, because it is connected with the shape of the impeller blades and with the presence of stators on the inner wall of the tank. In particular, with centered rotor, the tank was considered equipped with stators, while in the case of decentralized impeller, stators were not inserted in the geometry. Stators are fixed metal parts inside the tank, which should deflect the flow of product in order to create relative motions that help the mixing process. The position of the rotor inside the tank also affects the shape of blades. Figure 1 shows and compares two possible configurations of the mixer (i.e., with axial and decentralized rotor).

With eccentric impeller, mixers are equipped with 5 superposed propellers, all equal in shape, and whose dimensions are limited by the proximity of the wall. The task of creating recirculation motion inside the system is executed thanks to the asymmetry of the geometry. On the other hand with centered rotor the design of the blades is more complex: there are only 4 propeller, equal in pairs.

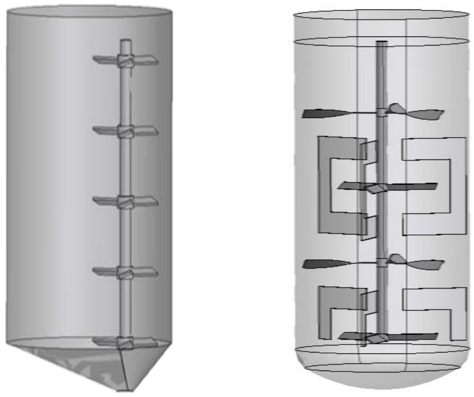


Figure 1 - The two configurations analyzed: axial rotor and stators (a) and decentralized rotor (b)

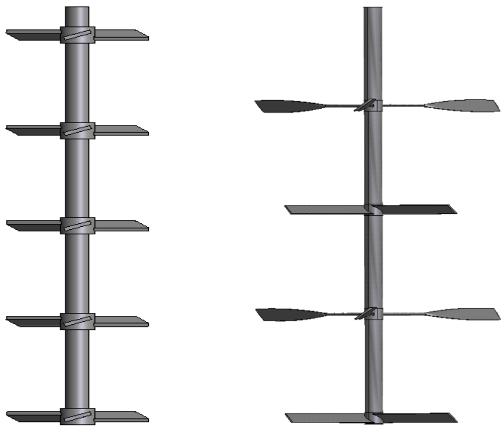


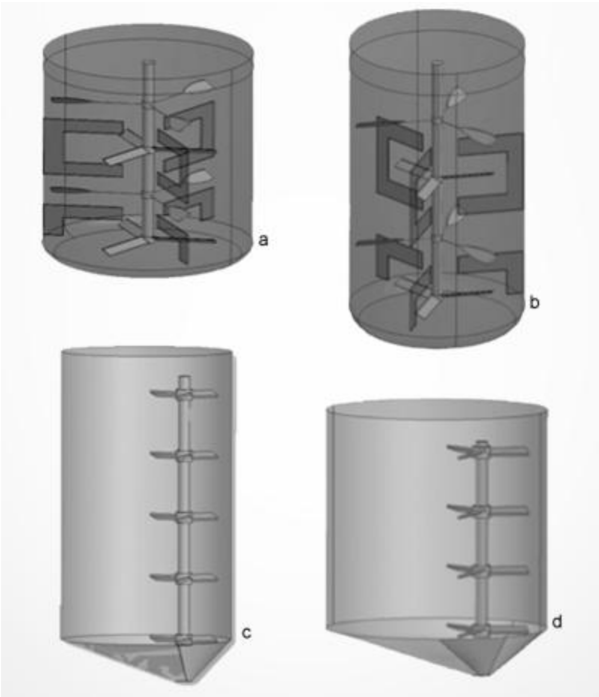
Figure 2 - Detail of the two different impellers of mixers with axial and decentralized rotor

Two of them are simple propeller, while the others are constituted by a kind of oars disposed radially. The internal blades should create a down flow, the external ones an up flow, in order to facilitate the recirculation.

2. The Aspect Ratio is a coefficient which describes the shape of the tank, and is computed by dividing its height by its diameter. An Aspect Ratio greater than 1 means that the tank is higher than wide and vice versa. Two configurations, having Aspect Ratio of respectively 0.9 and 1.55, were taken into account in this study. In the first one, the tank has a diameter of 931 mm and an height of 838 mm; in the second one, the diameter is 776 mm and height 1200 mm (Figure 3).

3. Two different fluids were considered, one with a high viscosity value and the other with a significant

lower one. To get practical feedbacks, the more viscous fluid owns approximately the viscosity of apricot puree, while the fluid with lower viscosity is similar to water at 30°C.



a = Aspect Ratio 0.9, centered impeller with stators
b = Aspect Ratio 1.55, centered impeller with stators
c = Aspect Ratio 1.55, eccentrical impeller
d = Aspect Ratio 0.9, eccentrical impeller

Figure 3 - The four geometrical configuration analyzed for a tank with a constant capacity of 600 l

As said previously, the study consists of eight simulations which were performed by varying 3 input variables on 2 levels:

- Aspect ratio: Level 1: 0.9; Level 2: 1.55;
- Rotor position: Level 1: 0 (centered) Level 2: 0.66 (eccentric)
- Viscosity: Level 1: 8.6e-4 Pa·s; Level 2: 10 Pa·s.

2.2. Simulation settings

The most relevant part of a simulation model for a mixing process is the impeller modelling. In this study, the CFD simulations were carried out by means of the commercial software Tdyn Multiphysics. It has a mesh deformation module that includes all the necessary capabilities to solve problems with mesh updating techniques. This module includes several mesh updating techniques and arbitrary Lagrangean Eurelian Algorithms (ALE) for solving systems of equations. In order to solve problems with moving parts, it exploits the "sliding mesh" or "sliding grid" method: the flow domain is divided into two cylindrical, non-overlapping sub-domains, each gridded as a separate block. The grid in the impeller region rotates together with the impeller, while the grid in the tank remains stationary. the two mesh crawl over one another at the cylindrical interface. Brucato et al. (1998) demonstrate that the sliding-mesh method provided good agreement with experimental data for the mean flow field.

At the sliding interface, a conservative interpolation is used for both the mass and momentum equations, using a set of fictitious control volumes. In order to reduce the errors related to the interpolation and thus to obtain good convergence of the simulation, it is necessary that the grid on the interface surface is sufficiently fine. In this study, by setting a maximum size of the elements in this area of 2 cm, good convergences of the simulation were obtained.

Another critical area is the region close to the impeller, where transfers of motion from the mechanical organ to the fluid take place. It is therefore necessary to set a condition of no-slip wall on impeller surfaces and produce a dense mesh in order to reconstruct the fluid boundary layer. To achieve this, a maximum size of the elements of 2 mm is assigned to these surfaces. Moreover, the elements size is further reduced in the direction normal to the surface (0.1 mm), in order to drop at least two layers of the grid inside the boundary layer. No-slip boundary conditions are also used on the tank walls and on the baffles. No experimental data is prescribed in the outflow of the impeller. All fluid motion strictly arises from the rotation of the impeller blades.

Spalart-Allmaras turbulence model was used during the simulation. This model solves directly a transport equation for the eddy viscosity and it is quite popular because of its reasonable results for a wide range of flow problems and its numerical properties (Deck et al., 2002). It is a one equation model for turbulent flows with integration to the wall. The aim of this model is to improve the predictions obtained with algebraic mixing-length models to develop a local model for complex flows, and to provide a simpler alternative to two-equations turbulence models. Contrarily to two-equations turbulence models, it does not require an excessively fine grid resolution in wall-bounded flows, and it shows good convergence in simpler flows (Tdyn Turbulence Handbook). Those characteristics allow to reach a good compromise between the precision of the results and the computation time, even in large size contexts as the industrial ones.

Time dependent simulations were performed with a characteristic time of the simulations of $5 \cdot 10^{-3}$ s.

The purpose of this work is to develop a method that can give indications on the performance of the mixing process, in terms of homogeneity, effectiveness and damage of the particles. However, the behaviour of solid-liquid mixtures is very complex, as well as their simulation through CFD software. In this work we will develop an innovative method for evaluate the performance of a mixer without including within the simulation the solid particles: the fluid dynamic simulations were conducted considering fluid without particles, and the results were investigated in order to provide hypotheses on the behaviour of the mixer in the presence of particles. Obviously, the lower is the solid phase concentration the more reliable are the results obtained.

2.3. Performance measurement

The final objective of a mixer for fluids with particles is to obtain a homogeneous dispersion of the solid phase within the liquid phase . To achieve that, the mixer must grant the following actions:

- Avoid the stratification of the solid phase;
- Ensure the suspension of the solid phase within the liquid medium.
- Ensure the homogeneity of the suspension of the solid phase inside the tank;
- Avoid damage of suspended particles.

To have an indication about the overall performance of a mixer, all the above factors should be taken into account. A Global Performance Index (GPI) was then introduced to include four main KPIs of the mixer, namely:

- Velocity index;
- Mixing homogeneity index;
- Particles damage index;
- Mixing efficacy index.

To ensure comparability of various aspects, each KPI was expressed in percentage. In particular:

- Velocity index: calculated as the percentage of nodes (i.e. the volume) where the speed is greater than a threshold value.
- Mixing homogeneity index:
$$MHI = \frac{\sigma}{\sigma_{max}}$$
The maximum standard deviation value (σ_{max}) was calculated assuming a fictitious distribution in which half the nodes has zero velocity and remaining ones have the maximum speed detected inside the tank.
- Particles damage index: calculated as the percentage of nodes where the impact coefficient is lower than a threshold value.
- Mixing efficacy index: calculated as the percentage of vertical kinetic energy to the total energy supplied to the fluid.

The four KPIs were then reported on a Kiviat (or radar) chart; this is a graphical method to display data relate to multiple variables in the form of a two-dimensional graph of several (4 variables in this case), represented on multiple axes with the same origin. In Figure 4 the radar chart for the above KPIs is represented: clockwise, the axes show the Mixing homogeneity index, the Particles damage index, the Velocity index, and the Mixing efficacy index.

By joining the four points obtained by plotting the KPI values on the axes, a rhombus is obtained. The ratio between the area of the rhombus divided and the maximum achievable area corresponds to the GPI.

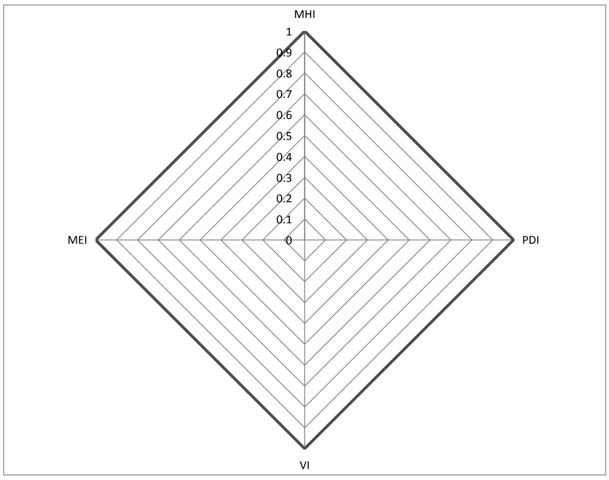


Figure 4: Kiviat chart used to represent the global performance of the mixers

3. RESULTS AND DISCUSSIONS

3.1.1. Velocity distribution

This index, as previously stated, represent the fraction of the internal volume of a mixer, whose velocity absolute value is higher than a certain threshold value. Such a threshold value must be calibrated so that it is representative of the minimum speed required at each point of the fluid so that it may be considered in a good state of mixing. The chart in Figure 5 shows the velocity distribution in the eight cases considered.

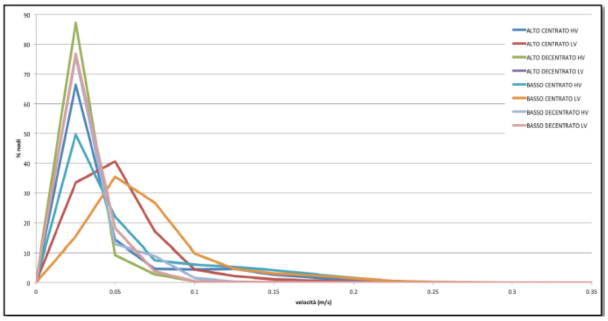


Figure 5: velocity distributions for the configurations analyzed

A better speed distribution can be observed for the mixers with centered rotor; in fact, the curves related to these configurations are particularly shifted to the right, i.e. towards higher values of speed.

In mixers with decentralized rotor, most of the fluid (75-85%) moves with very low speed values. Greater values are observed for mixers with centered rotors and in particular for the configuration characterized by low viscous product ($8.6 \cdot 10^{-4}$ Pa·s).

Table 1 shows the percentages of volume with a fluid velocities higher than a reference value (v_{ref}).

Table 1: percentages of volume with $v>v_{ref}$

Aspect ratio	**high**	**high**	**high**	**high**	**low**	**low**	**low**	**low**
Rotor position	**centered**	**centered**	**decentered**	**decentered**	**centered**	**centered**	**decentered**	**decentered**
Viscosity	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**
VI (v_{ref}=0,025 m/s)	33.52%	66.54%	12.75%	23.12%	50.36%	84.65%	24.03%	23.12%
VI (v_{ref}=0,05 m/s)	19.28%	25.99%	3.55%	5.05%	28.45%	49.22%	11.34%	5.05%
VI (v_{ref}=0,1 m/s)	10.21%	4.57%	0.34%	0.75%	14.85%	12.77%	0.86%	0.75%

Speed reference values (v_{ref}) in Table 1 were chosen for illustrative purposes in order to make a comparison between the different mixer configurations. In practical cases, the designer will refer to the minimum speed which the fluid must have in order to maintain the particles in suspension and will choose the configuration where the whole fluid moves with a speed higher than the reference one (percentage 100%).

Table 1 shows that mixers with the rotors in centered position guarantee a better motion of the fluid.

3.1.2. Mixing homogeneity index

The velocity distribution standard deviation (σ) indicates how velocity is homogeneous inside the mixer and then indicates how homogeneous the mixing process is. Table 2 shows the standard deviation values calculated:

Table 2: velocity distribution variance for each configuration

Aspect ratio	**high**	**high**	**high**	**high**	**low**	**low**	**low**	**low**
Rotor position	**centered**	**centered**	**decentered**	**decentered**	**centered**	**centered**	**decentered**	**decentered**
Viscosity	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**
σ [m/s]	0.041	0.030	0.016	0.013	0.048	0.041	0.023	0.018
σ_{max} [m/s]	0.101	0.095	0.049	0.044	0.113	0.114	0.067	0.064
MHI	59.54%	68.02%	68.06%	71.16%	57.86%	64.08%	65.94%	71.74%

The configurations with the rotors in decentered position guarantee a more homogeneous process. This result can be also inferred observing Figure 5: the velocity distributions in the mixers with a decentralized rotor position is highly concentrated around very low values. Thus, the homogeneity looks very good. In the case the system performance are examined from a more global point of view, it can be seen that this is due to the fact that almost all the liquid is at a standstill; this is why this kind of geometry with these speeds of rotation (10 rpm) is not able to adequately put the product in motion .

The above considerations suggest that the process homogeneity cannot be taken as the unique parameter in the choice of a mixer; conversely, a more detailed evaluation is required.

3.1.3. Particles' damage index

The mixing process of a fluid containing solid particles (i.e pieces of fruit, sacs, etc.) can lead to damage of the suspended particles due to possible collisions between the particles themselves or between the particles and the moving parts. In order to estimate the probability of having particles' damage, an Impact Coefficient was introduced. This coefficient was calculated at each node of the geometry of each mixer, applying the following formula:

$$C_{Impact} = \left|\frac{\partial v_x}{\partial x}\right| + \left|\frac{\partial v_y}{\partial y}\right| + \left|\frac{\partial v_z}{\partial z}\right| \qquad (1)$$

It describes the acceleration imparted, in the three normal directions x, y and z, to a hypothetical solid particle which is located in a certain node at a certain time instant. The higher is this acceleration (or deceleration), the stronger will be the force acting instantaneously on the particle to change its state of motion, with a corresponding increase in its damage probability. In fact, it is supposed that a strong velocity variation can occur as a consequence of an impact. Figure 6 represents the trend of the Impact coefficient for the different mixer geometries:

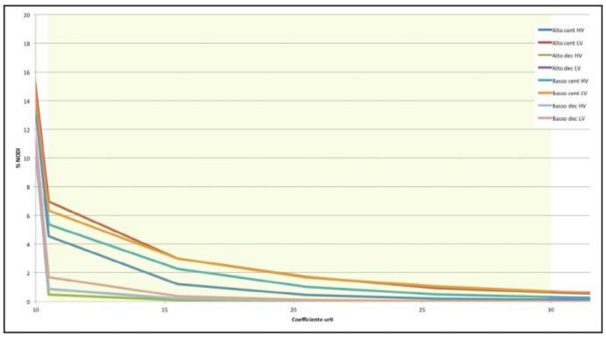


Figure 6: distribution of impact coefficient for the configurations analyzed

On the basis of this Impact coefficient, a proper KPI, named *Particles Damage Index (PDI)* was then computed, as already mentioned, as the percentage of nodes (i.e. volume) with a value of Impact Coefficient lower than a threshold value. In this study, the threshold value was set at 10 s-1; this value was chosen for illustrative purposes in order to make a comparison between the different configurations. In practical cases, the designer will choose this parameter as a function of the fragility of the particles contained in the liquid phase.

The mixer configurations with a centered rotor position show higher PDI, because of the higher diameter and then the higher peripheral speed of the rotor.

3.1.4. Mixing efficacy index

Mixing efficacy is related to the ability of the mixer to prevent stratification of the particles that, in doing so, would tend to deposit to the bottom or to float on the free surface. To avoid stratification, it is necessary that most of the energy supplied to the fluid is directed vertically. The Mixing Efficacy Index (MEI), therefore, assesses the percentage of vertical kinetic energy against the total energy supplied to the fluid.

$$MEI = \sum_{i=1}^{n} v_{y;i}^2 / \sum_{i=1}^{n} (v_{x;i}^2 + v_{y;1}^2 + v_{z;1}^2) \qquad (2)$$

Where $v_{x;i}$, $v_{y;i}$ and $v_{z;i}$ are the three components of the velocity at each point *i* of the geometry. In particular $v_{y;i}$ is the vertical component of the velocity

Figure 7 represents the sharing of the kinetic energy among the horizontal and vertical components, for different mixer configurations.

A first analysis shows that the centered position of the rotor allows increasing the vertical component of the velocity, since the aspect ratio and the viscosity have less impact on the MEI.

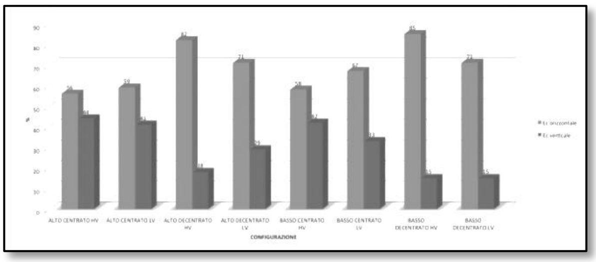


Figure 7: sharing of the kinetic energy among the horizontal and vertical components

From the results obtained, the radar charts for each configuration was derived as shown in Figure 8.

Table 3: KPIs of the configurations analyzed (8.33 rpm)

Aspect Ratio	**high**	**high**	**high**	**high**	**low**	**low**	**low**	**low**
Rotor position	**centered**	**centered**	**decentered**	**decentered**	**centered**	**centered**	**decentered**	**decentered**
Viscosity	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**
MHI	59.54%	68.02%	68.06%	71.16%	57.86%	64.08%	65.94%	71.74%
PDI	97.73%	96.33%	99.88%	99.45%	95.20%	91.59%	99.73%	99.77%
VI	33.51%	66.54%	12.75%	23.13%	50.36%	84.65%	24.03%	23.13%
MEI	41.12%	43.66%	17.86%	29.08%	41.78%	33.19%	14.67%	29.08%
GPI	**32.30%**	**47.09%**	**23.79%**	**30.30%**	**37.06%**	**46.39%**	**25.73%**	**30.56%**

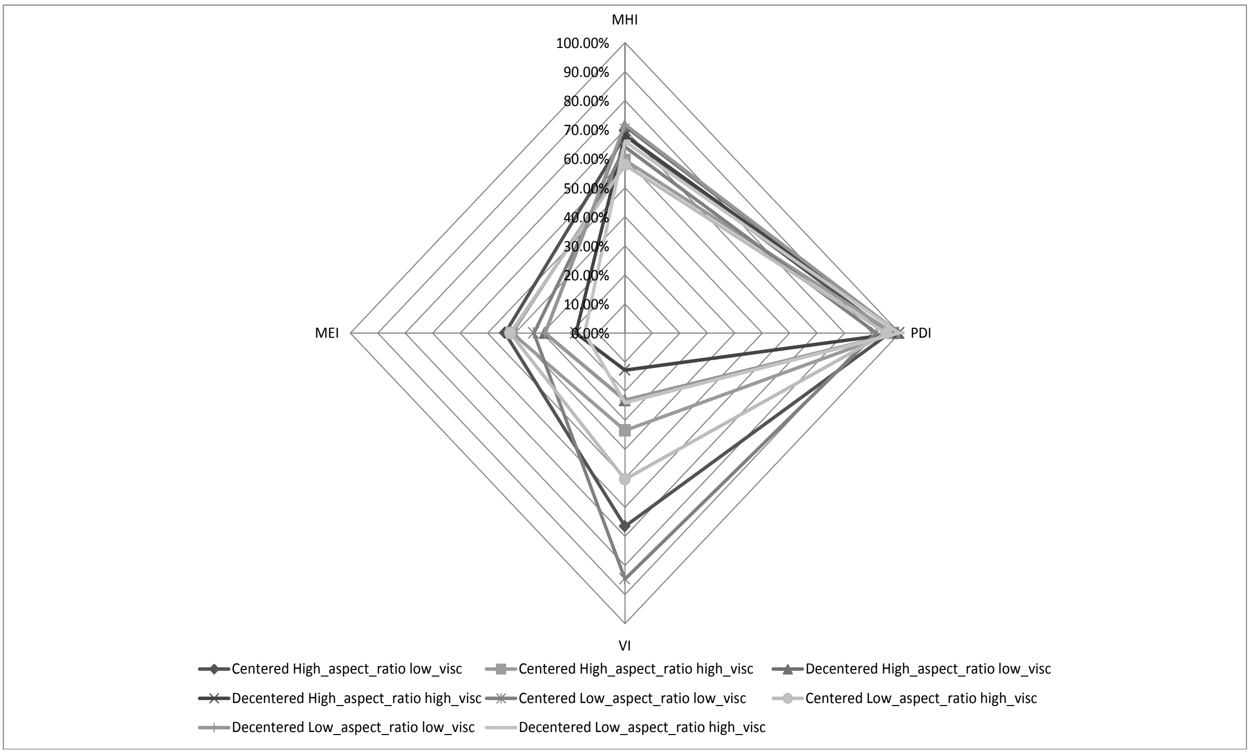


Figure 8: Kiviat chart for the different configurations analyzed

From the results obtained, it emerges that, in the configurations with a decentered rotor, a blade speed rotation of 50 degrees per second (i.e. 8.33 rpm) produces a velocity distribution within the fluid. In the best configuration (i.e., low aspect ratio and high viscosity fluid), only 24% of nodes exceeds 0.025 m/s, while in the worst configuration (high aspect ratio and high viscosity fluid), this percentage drops to 12.7%. In these configurations, in fact, the diameters of the rotors are much lower than those set in the configurations with centered rotor; consequently, the power involved and the energy supplied to the fluid are significantly lower. **Errore. L'origine riferimento non è stata trovata.** shows a comparison between the power required on the rotor shaft in decentered configurations and in the centered ones.

In order to improve the comparison between the performances of the mixers with decentered rotors, and those of the mixers with centered rotors, it is necessary that the energy supplied to the fluid is approximately the same. For this reason, the four analyses related to the mixers with decentered rotor were repeated with a different value of speed (25rpm).

The results of these analysis are summarized in Table 4.

Table 4: KPIs of the configurations with the rotors in decentered positions (25 rpm)

	Decentered High_Aspect_Ratio Low_Visc_25rpm	**Decentered High_Aspect_Ratio High_Visc_25rpm**	**Decentered Low_Aspect_Ratio Low_Visc_25rpm**	**Decentered Low_Aspect_Ratio High_Visc_25rpm**
PDI	98.13%	98.22%	95.91%	96.70%
VI	60.21%	34.38%	80.29%	53.29%
MEI	28.22%	14.21%	33.42%	12.87%
MHI	70.81%	68.62%	72.75%	66.77%
GPI	**41.39%**	**28.95%**	**49.48%**	**32.89%**

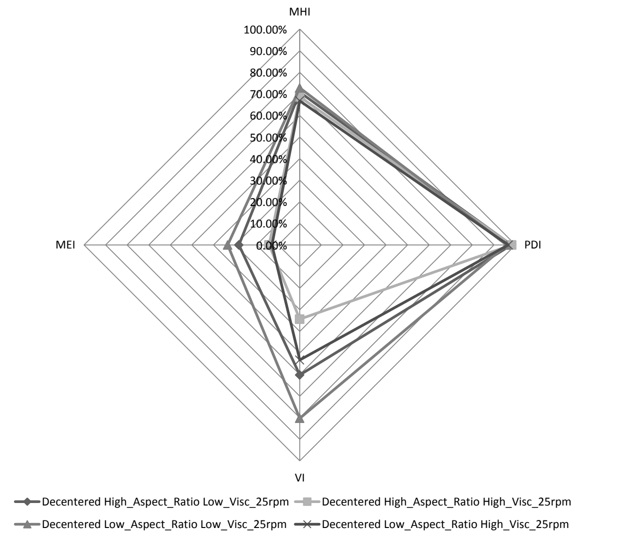


Figure 9: Kiviat chart for the four configurations analyzed with decentered rotors.

The highest GPIs is obtained when the product has low viscosity (8.6 e-4 Pa*s); the aspect ratio turns out to have a limited influence on the GPI.

This kind of configuration, however, provides inadequate performance when mixing high viscosity fluids .

Finally, it should be noted that to achieve the same performance realized by the mixer with the rotor in centered position using a mixer with the rotor in decentered position, the rotation speed should be increased of a factor of 3.

3.2. Factorial analysis

A full factorial analysis was conducted on the results obtained, in order to assess the significance of the influence of the three input variables (position of the rotor, viscosity, aspect ratio), on the overall performance index (GPI) and on the individual KPIs.

A commercial software (Design Expert®) was used to carry out the factorial analysis. The results, in terms of the effect of individual factors on the GPI and on the other KPIs, are reported below.

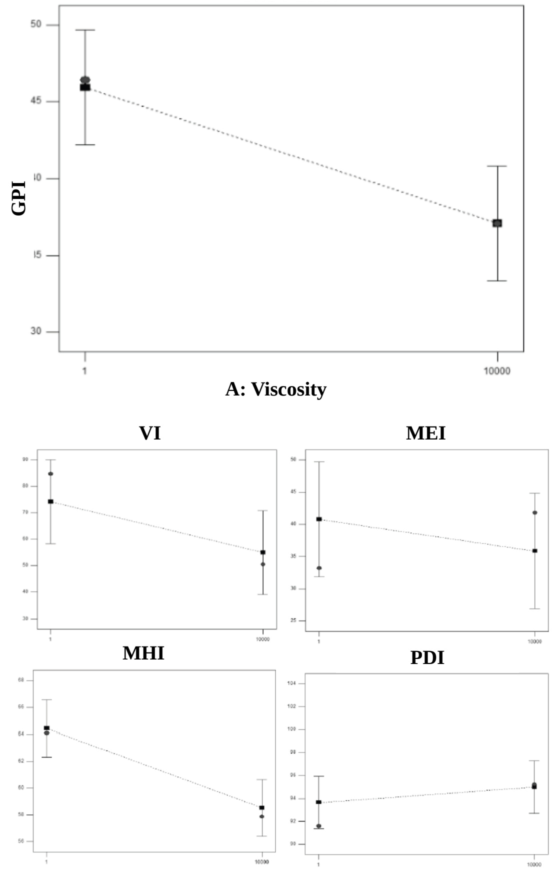


Figure 10: influence of viscosity on process KPIs

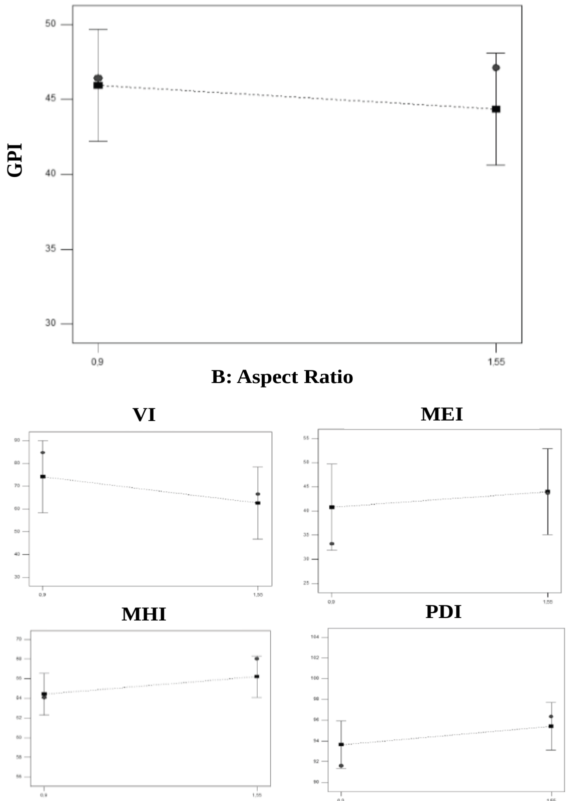


Figure 11: influence of aspect ratio on process KPIs

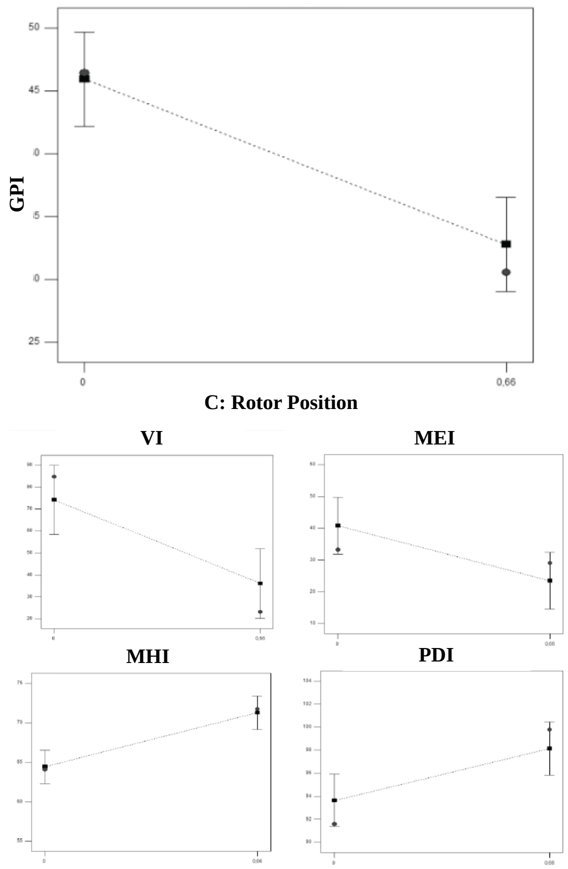


Figure 12: influence of rotor position on process KPIs

Through the observation and the analysis of the graphs, the influence of each variable on the KPIs could be evaluated. In particular, the higher the slope of the line, the higher the influence of the variable on the KPI measured.

It can be seen that PDI is influenced to a limited extent by all the factors. Conversely, MHI and VI seem to be very influenced by both rotor position and viscosity, while the influence of aspect ratio seems to be lower. Overall, the aspect ratio turned out to be a parameter with little influence on all response variables. Conversely, MEI resulted to be significantly influenced by the rotor position.

Finally, the ANOVA analysis performed on the results confirmed that the GPI was significantly influenced by both the viscosity and the rotor position, while the influence of aspect ratio turned out not to be significant

Table 5 - Results of the ANOVA analysis to understand what are the factors that impact more on KPIs considered

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**
Model significant	506.6	3	168.87	23.18	0.0054
A-Viscosity	*156.56*	*1*	*156.56*	*21.49*	*0.0098* ***SIGNIFICANT***
B-Aspect Ratio	*5.02*	*1*	*5.02*	*0.69*	*0.4532 NOT SIGNIFICANT*
C-Rotor position	*345.03*	*1*	*345.03*	*47.36*	*0.0023* ***SIGNIFICANT***

4. CONCLUSIONS

In this study an innovative approach for the evaluation of the performances of discontinuous vertical fluid mixing systems for food fluids containing particles was developed. In particular four KPI's were introduced in order to evaluate the capability of the mixer to prevent both particles stratification and damage and to guarantee a homogeneous process. The stochasticity linked to the shape of the particles, their distribution, and their interactions, prevents from conducting a reliable CFD simulation of the real process conditions. Some approximation is therefore necessary. In this study it was decided to neglect the solid phase and the CFD simulation were conducted considering only the liquid phase; the results obtained were then analyzed in order to provide hypothesis on the behavior of the particles. The results will be the more reliable the lower the concentration of the solid phase is; a validation phase is already planned in order to verify the accuracy of the results obtained.
This new method was applied to the analysis of different configurations. It was demonstrate how it can be useful in the design phase of a new mixing plants or in the optimization of an existing one.

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