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Determination of Powder-Liquid Mixing Time in A Gyro-Shaker By Experimentally and CFD Method

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***Abstract*— The powder and liquid mixture have important role in many industries such as food industry, chemical industry, pharmaceutical industry etc. The homogeneity of the mixture and time required for mixture to attain homogeneity are the important space for research .This paper is focused on how can enhance the homogeneity of the mixture as well as finding out the critical mixing time for the mixture to attains its homogeneity .The homogeneity of mixing can be enhanced by using gyro-shaker instead of conventional mixer such as single axis stirrers ,in conventional mixing the centripetal force reduce the homogeneity outwards from the impeller ,the dual axis rotation of gyro-shaker solve this problem and provide quality homogeneous mixture .The experiment is conducted on a gyro-shaker ,the simulation is done by the CFD method and verify the results with experiment .The image processing technique is used to find the mixing time , cutting the videos in to frame and by processing MATH LAB code .The Euler multiphase method is used in CFD analysis, The mesh size is calculated by the grid independence theory .**

***Keywords* —homogeneity,Standard deviation, Mixing index**

I. INTRODUCTION

The mixing of powder and liquid is used in wide variety of industries such as pharmaceutical industries ,chemical industries ,food industries etc. The particle size ,shape ,density , moisture ,temperature are the parameters affecting the mobility of the particles. Single axis stirrers are generally used in mixing ,the centripetal force causes inhomogeneity towards the wall of the container . It involves random motion of particles with in the powder bed there by particles change their position relative to another , homogenization of liquids occurs due to molecular diffusion in laminar mixing. Forces of attraction are broken down so that each particles moves on its own between regions of different components and parallel to their surface .In turbulent mixing, the inertial force imparted by the rotation of gyro shaker to the surrounding liquid helps to form eddies. Mixing by eddy diffusion is faster and, therefore, turbulent mixing occurs more rapidly than laminar mixing. The flow of dense solid-liquid suspensions in a mechanically agitated vessel has been successfully modelled by CFD.

The relatively high solid presence coupled with the complexity of the flow at the bottom of the vessel, however, still prevent accurate prediction of the local solid concentration in this region, as the CFD model does not incorporate all of the physics of particle sedimentation and lift .

In various industries mixing of viscous fluid with powder is a major cause of concern. Quality of the blend, mixing time and mixing power are the main problems in hand. Impellers use huge amount of power for mixing viscous liquid and powder still fails to achieve a homogenous mix. For these mixers the mixing is almost complete near the blades but towards the wall mixing is incomplete. Despite consuming huge amount of power these impellers fail to produce enough turbulence towards the wall. Thus the study of mixing time, mixing power and blend quality of various mixers are imperative .Mixing time have important role in mixing, because if the mixing exceeds mixing time it resulted in segregation, power loss, reducing production rate ,increase in unit cost. Blades but towards the wall mixing is incomplete. image that delineates a mixing event. The simplest index is calculated by taking the standard deviation (σ) of the pixel intensities.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(I_i - \langle I \rangle)^2}$$

where Ii shows a local pixel intensity, $\langle I \rangle$ shows the average of the pixel intensities in the cross-section, and N represents the total number of pixels. This index attains the highest value when the fluids are unmixed and 0 if the fluids are homogeneously (completely) mixed.

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Using the standard deviation values, mixing index (MI) of the image is found out. It can be computed by taking the ratio of standard deviation of pixel intensities across a cross section to the standard deviation of the pixel intensities in the unmixed case.

$$MI = 1 - \frac{\sigma}{\sigma_o} = 1 - \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(I_i-\langle I\rangle)^2}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(I_{oi}-\langle I\rangle)^2}}$$

Where σo represents the standard deviation of pixel intensities in the unmixed state and I0i represents the local pixel intensity in the unmixed state. The value of MI varies from 0 to 1 where 0 delineates the unmixed state and 1 as the homogeneously mixed state. The sample is considered homogenous when the value of mixing index attains 99 %.

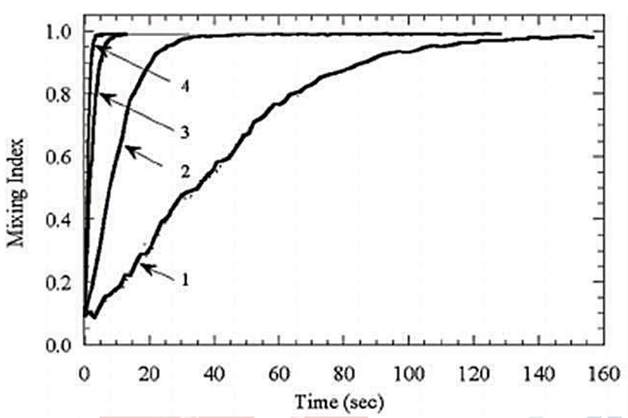

Figure 1: Mixing index vs Time

The mixing time for the mixing of sic and glycerol in gyroshaker is found by CFD analysis and validated by the experiment results .Slight variations are noted ,it is due to the assumptions ,instrumental error etc. But it is negligible at industrial applications The awareness about the mixing time will helps to change the conventional procedure such as long time running ,which cause segregation .So it can reduce the miss consumption of the power ,unit cost and enhance the productivity as well better mixing.

objectives

1. To experimentally study mixing Time of powder and liquid (silicon carbide and glycerol) in a Gyro shaker.
2. To simulate the Mixing time of the fluids using CFD method.
3. Determination of mixing time by the method of image processing.

To verify simulation results with experimental results.

II.EXPERIMENT

The experiment is done in a gyro shaker (dual axis) which makes mixing more homogenous than the conventional mixer gyro shaker has two axis ;gyration axis and spin axis.

Table 1: Physical properties of Glycerol and Silicon carbide

Material	Density (Kg/m^3)	
Glycerol	1259	μ=0.5659 Pas
Silicon Carbide	3217	R=25 μm

The rotational speed along the spin axis is twice as that of the gyration axis. This multi axes high rotational speed is used to create high turbulence inside the container where mixing takes place., auto transformer is used to control the speed of the mixer .By using a 5D camera the mixing in the gyro shaker is recorded ,through the video analysis the time taken for each rotation is noted . After 5 seconds gyro shaker attains constant speed ,and the video is converted into frames and imported to MATHLAB for image processing .A cylindrical vessel made of acrylic with flat bottom is used. The diameter of the vessel is 0.14m and height 0.14m. The vessel is placed in the gyro shaker which is run by a 1Hp 50Hz AC series motor. The speed of the device is controlled by varying input voltage using an auto transformer. The power is calculated with the help of a wattmeter connected in series with the device. The current and voltage readings are also calculated using an ammeter and a voltmeter connected in series and parallel with the device respectively. The circuit diagram is as shown in the figure2.

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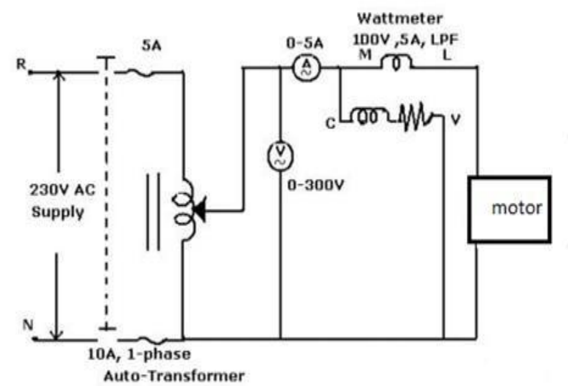

Figure 2: Circuit diagram of experimental set up

The viscosity of the Glycerol is measured using Brookfield DV 2T Extra Viscometer and was found to be 0.5659 PaS at 340C which is the room temperature at the lab where the experiment is conducted. The density of glycerine is measured using Density Meter DMA 35 Anton Paar instrument and found to be 1259 kg/m3 at a temperature of 22.40C and the same is used for simulation by neglecting the very small deviation for the room temperature of 340C. density of silicon carbide 3217kg/m3. The cylindrical vessel is then filled with glycerol and siicon carbide in the ratio 80:20 by volume respectively. It is then placed in the gyro shaker and locked properly. Power supply is now switched on and video of the mixing process is captured.it is noted that for the first 5 seconds the gyro shaker rotates at 1.256 rad/sec , due to the inertial forces and the load of the container and liquids, and after 5seconds , the gyro shaker rotates at a constant speed of 6.28rad/sec. The video is captured and converted to frames. Then these images are imported to image processing software Mat lab version 16. Image samples with size 75mm*75mm and 200dpi resolution are cut. Standard deviations of these samples are found out for each second frame images. Also the standard deviation of the non-mix image is also taken. The movement of silicon carbide particles depends on particle size, shape, temperature, density etc. The mixing index is calculated from the value of standard deviation of each images. The time corresponding to Mixing index value of 99 % is taken as the mixing time and the mix is considered homogeneous.

Figure3: Acrylic Container filled with glycerol and silicon carbide in the ratio 80:20 by volume fraction

III. SIMULATION

Computational fluid dynamics (CFD) technique is used for solving the numerical model of this problem. Computational fluid dynamics (CFD) is the use of computers and numerical methods to solve problems involving fluid flow. CFD has been successfully applied in many areas of fluid mechanics. The main stages in a CFD simulation are: preprocessing which involves formulation of problem and construction of computational mesh. Solving, which involves discretization of governing equations and solution of resulting algebraic equations? Post processing, which involves visualization and analysis of results. Realizable k-Ɛ model is selected. The realizable k- model has the same model equation for turbulent kinetic energy (k) as in the standard k- model, It solves a set of momentum and continuity equations for each phase. Coupling is achieved through the pressure and interphase exchange coefficients. The manner in which this coupling is handled depends upon the type of phases involved; granular (fluid-solid) flows are handled. For granular flows , the properties are obtained from application of kinetic theory. Momentum exchange between the phases is also dependent upon the type of mixture being modeled. ANSYS FLUENT's user-defined functions allow you to customize the calculation of the momentum exchange.

Applications of the Eulerian multiphase model include bubble columns , risers , particle suspension, and fluidized beds description of multiphase flow as interpenetrating continua incorporates the concept of phasic volume fractions , denoted here by Volume fractions represent the space occupied by each phase, and the laws of conservation of mass and momentum are satisfied by each phase individually. The derivation of the conservation equations can be done by ensemble averaging the local instantaneous balance for each of the phases or by using the mixture theory approach.

Mesh	No. of cells	Min. Orthogonal Quality	Max. Aspects Ratio
Tetrahedron	91436	0.30	14.94
	223734	0.19	22.33
	553622	0.22	18.2
Polyhedron	16707	0.50	7.88
	42657	0.53	8.34
	108859	0.52	8.22

IV. SIMULATION PROCEDURE

1) Model is created first. A cylinder of diameter and height of 140 mm is modelled.
2) The simulation of fluid was performed on Fluid Flow (Fluent) on ANSYS Workbench 16.0.Inside the Fluid Flow (Fluent), geometry was created on Design Modeler and mesh generation was performed on Mesh stage in Fluid Flow (Fluent).
3) Mesh is generated.Meshing is an important stage in fluid simulation. Open the Mesh stage of ANSYS Workbench.Tetrahedral mesh having 619899, 223734, 91436 elements are generated.
4) Modelling fluid flow using Ansys fluent. Mesh quality is checked and reported. Tetrahedron meshes are converted to polyhedral mesh.
5) Euler model is selected for mixing of liquids.
6) Simulation is performed by selecting RNG K-epsilon model from the Viscous Model dialog box. Enhanced wall treatment is selected.
7) Two materials Glycerol and Silicon Carbide are created and glycerol is defined as primary phase and castor oil is defined as secondary phase.
8) Frame motion is defined about Z axis as 15 rpm for first 4 seconds and 60 rpm for the remaining time.Wall motion is then defined about Y axis (spin axis) likewise. The rotational speed along this axis is 2.03times as that of Gyration axis.
9) Solution parameters is set.Standard deviation and power is plotted in surface monitors and volume monitors respectivelySolution is then initialized and 20% of the volume is patched with secondary phase.
10) Calculation is then done for a time step size of 01 and number of time steps as 400(first 4 seconds at 15 rpm) and then 2000 timesteps(remaining time at 60 rpm).
11) The resulting simulation pictures is cut into a grid size of 75mm*75mm with 200dpi resolution and is image processed to find the mixing time.

V.IMAGEPROCESSING

Image processing is processing of images using mathematical operations by using any form of signal processing for which the input is an image, a series of images, or a video, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image. Image processing is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image. Image processing basically includes the following three steps:

- Importing the image via image acquisition tools;
- Analysing and manipulating the image;
- Output in which result can be altered image or report that is based on image analysis.

There are two types of methods used for image processing namely, analogue and digital image processing. Analogue image processing can be used for the hard copies like printouts and photographs. Digital image processing techniques help in manipulation of the digital images by

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using computers.An image may be defined as two dimensional function F(x,y) where x and y are special coordinates and amplitude of f at any pair of coordinates x,y is called intensity or gray level of that image at that point. Digital images possess finite number of elements which has a particular location and value. These elements are known as pixels. Image is processed using MAT LAB version 16 to find out the standard deviation values. From this, the mixing index is found out. The time corresponding to mixing index value of 99 % is taken as the mixing time.

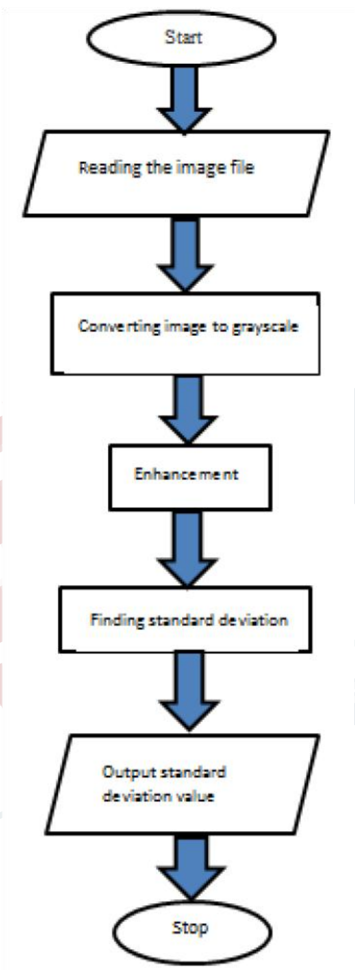

Figure 4:stages in image processing

VI.RESULT AND DISCUSSION

The results from experiment and analysis were duly noted and necessary calculations were made to obtain desired results. Mixing time was calculated experimentally and by numerical simulation using image processing method. The best results were then obtained by grid convergence method. Experiment and numerical simulations results are then compared for validation of simulation results.

1. Results from experiment

The experiment is done and the video is captured and converted to images of size 75*75 mm with 200dpi resolution. The images are then processed in Mat lab and the standard deviation is found out. From the standard deviation value, the mixing index is found out for each second. The time corresponding to the mixing index value of 99% is taken as the mixing time and the blend becomes

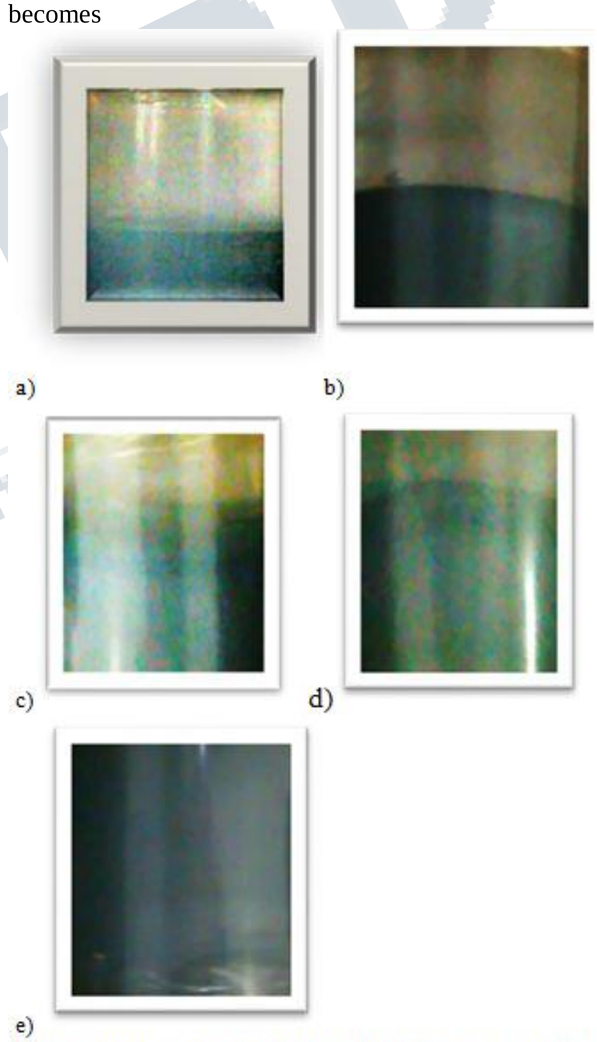

Figure 5: Images at a)non mix condition (b) after 2 sec (c)

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after 5 sec (d) after 8 sec (e) after 11 sec

The images are processed and the standard deviation of images at different time intervals is found out. From this value The mixing index is calculated using the formula .the values of mixing index for 2 sec, 5sec, 8sec ,11sec are tabulated in the table MI = 1 – (SD of the image at particular time/ SD of non-mix condition)

Table 3: Mixing Time

Sl no:	Time in seconds	Mixing index (percentage)
1	2	38
2	5	66
3	8	90
4	11, 12	99

From the table, It's clear that Mixing index value attains 99% when the time is 10 seconds. Hence the mixing time is taken to be 10 seconds.

2. Results from Numerical Analysis

Simulation is carried out using athe above mentioned 3 meshes and mixing time is found out. The images at different time intervals are taken and is processed to find out the standard deviation. From the standard deviation values, the mixing index is found out and hence the mixing time. Grid convergence study was carried out to obtain the best result.

Table 4: Calculation of Grid Convergence Index and Mixing Power for Torque method

mixing time (mesh 1)	mixing time (mesh 2)	mixing time(mesh 3)	R	GCI 21	GCI3 2	Mixing time
9.92	9.61	9.11	.37	.019	.049	9.92

The Grid Convergence Index (GCI) is a measure of convergence for grid refinement studies. It determines how much the solution approaches the asymptotic value. The GCI value less than 5% is an acceptable measure of grid independent converged solution. The GCI is in the required range and convergence ratio R between 0 and 1 depicts monotonic convergence. Hence the third mesh is selected. The images at each time step is converted to grayscale images and the standard deviation is found out using image processing software. From the standard deviation value , Mixing index is found out .From that , the mixing time is

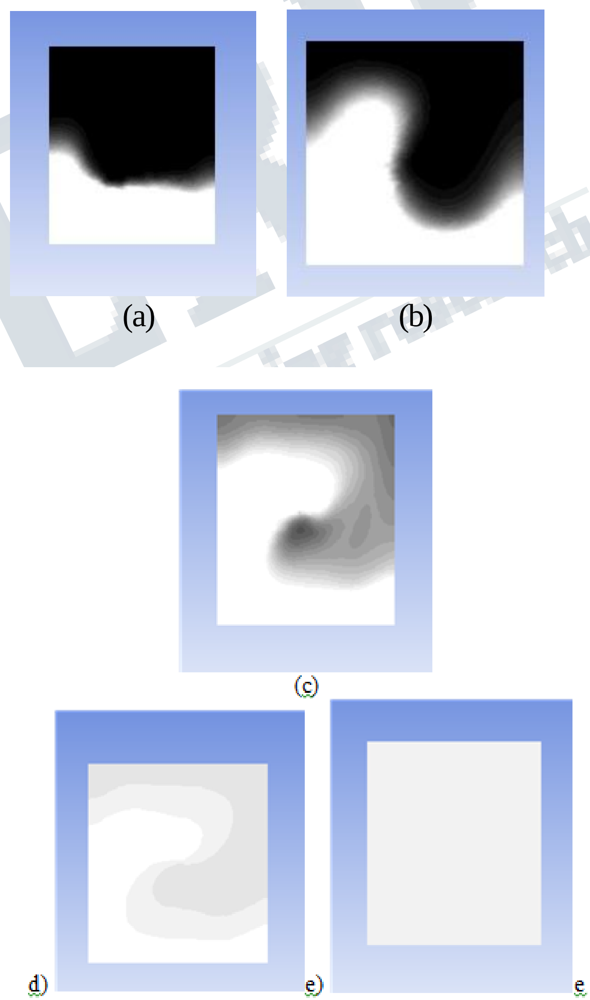

Figure 6: greyscale images at(a)2 sec(b) 4 sec (c)6sec (d)8 sec (e)9.92 sec

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The mixing index values are found out for each second till maximum homogeneity is attained. That is, the time corresponding to 99% mixing index value is takes as mixing time.

Table 5: Mixing index

Sl no:	Time in seconds	Mixing index (percentage)
1	2	25
2	4	66
3	6	81
4	8	96
5	9	99

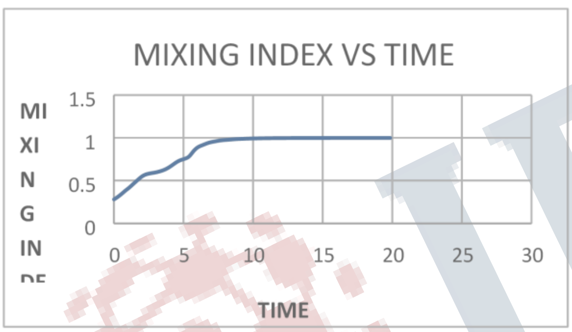

Fig 7:Mixing index vs mixing time

The mixing time obtained for experimental and numerical simulation are tabulated in table:6

Table 6 : comparison

Experimental mixing time	11-12 seconds
Simulation mixing time	9-10 seconds

VII.CONCLUSION

The mixing time of Silicon Carbide and glycerol is estimated by CFD simulation and validated with the experiment result .therefore a CFD model is generated VIII.

IX.REFERENCES

[1] Hong-liang., Yan LIU 2013 Experimental and CFD studies of solid−liquid slurry tank stirred with an improved Intermig impeller Research and Design, 89,280-290.

[2] Li Liu, Mostafa Barigou 2013. Numerical modelling of velocity field and phase distribution in dense monodisperse solid–liquid suspensions under different regimes of agitation: CFD and PEPT experimentser

[3] C. Andre, J.F. Demeyre,2014,Derivation of dimensionless relationships for the agitation of powders of different flow behaviours in a planetary mixer

