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Review Article

PREPARATION OF COAL WATER SLURRY USING AGITATION PARAMETERS INVOLVED AND THEIR INFLUENCE-A REVIEW

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ABSTRACT

Through extensive works conducted on liquid-solid mixing strategies in various industrial applications, many researchers are interested in paying little attention with the use of agitated reactors consisting of ne impeller or multi impellers along with their result on agitation operation. This paper therefore examines the significant variables of solid-liquid mixing with due importance for power inhaled and turbulence. To optimize the transportation yield or output, mixing is to be done which is the combination of solid and liquid phase. In power plants coal is replaced with the slurry prepared by using of coal particles mixed with water for good lubrication to enhance the rheological efficiency and stability. Coal Water Slurry (CWS) preparation and characterization involves coal solid particles in a fluid and particle suspension in an agitation vessel is not more complicated than in slurry pipe flow due to the fact that the average flow in an agitation vessel is not restricted in single direction. Therefore, the current review paper discusses the new methodologies adopted in the preparation of CWS and various parameters involved.
Keywords: Coal water slurry, mixing, solid –liquid mixing, suspension of solid particles, power of agitation, mixing time.

1. INTRODUCTION

Since there is rapid increase in modern economy, energy and environmental conservation are critical global issues. Coal is an important part of contributor to the world's industrial growth as it is primarily used for generating electricity [1]. Energy is the basic component of everyday life, the demand for energy is rising every day in this advanced industrial world [2].

Coal slurry fuels may be classified into different categories based on the liquid type used for the mixture of solid carbon particles, like CGWS (Coal-Gas-Water Slurry), CGOS (Coal-Gas-Oil Slurry), COWS (Coal-Oil-Water Slurry), CMS (Coal-Methanol Slurry) and CMWS (Coal-Methanol-water slurry) [3]. Among these, Coal Water Slurry has the greatest economic viability

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and commercial interest [4]. The Coal Water Slurry is a blend of water-based pulverized carbon that maintains the uniform mixture over time, especially when additives are used. As reported in previous explore and technical documents, the Coal Water Slurry be able to be used for boiler feed, can replace oil as a cause of energy for conversion and be capable of using in diesel engines. This fuel is non-flammable and environmentally friendly, with good combustion efficiency differentiate with traditio nal fuels [5, 6] when store in processes vessels and transfer conditions.

The slurry is prepared by physical processing in dispersion of coal particles in liquid which belongs to the system. Coal-liquid mixtures are widely presented as alternatives because in the markets they are increasing rates of oil. Typical coal - liquid mixture is formed by taking the coal particle ratio of 50 to 75 and water ratio of 25 to 50 based on the application additives will be added around 1 percent [7]. If there is a contact between the solid particles it makes the complex to settle in water and if the ratio of particles in liquid also makes difficult to prepare the coal water slurry when it is static condition.

The Slurry classified into two categories on the basis of coal particles status dispersion in liquid method. In this method it must be stable for some period so it can easily transport when the viscosity is low and the ratio of particles is low, but when the ratio of coal particles increases the viscosity increase so that the transportation will become difficult when the contact particles, strongly collects suspension. In this coal particles will not attract each other but density of coal will be more than water easily settled in water. The disadvantages which are mentioned above can easily rectify by using the external force for the particles not to settle in water by using agitation process which shown in figure 1 [8] [9].

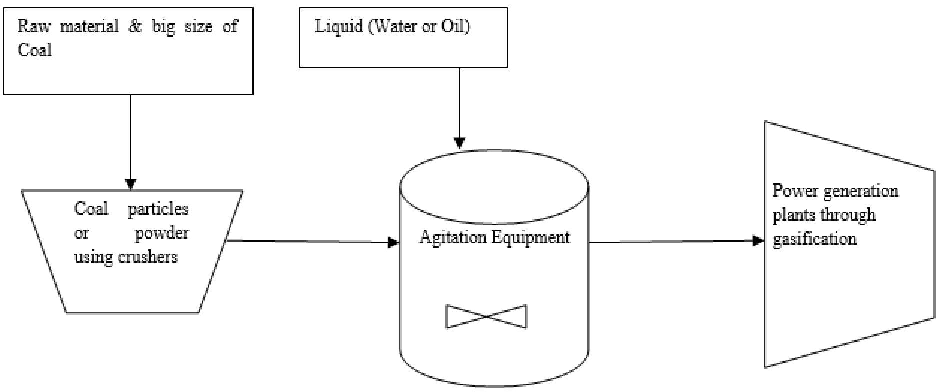


Figure 1. Layout Process of Transport Slurry through Agitation Equipment

From the above literature, agitation process is one of the main factor that influences to produce electricity power generation plants. In this context the latest reports are related to equipment on agitation process for preparation of coal water slurry is discussed. Therefore, agitation process is to be furthered more analysed for better understanding of the parameters and variables in coal water slurry preparation for production of thermal power. The next sessions elaborate how the parameters will effect on mixing of two phases like solid-liquid by using agitation process.

2. AGITATION EQUIPMENT

Agitation provides bulk motion for liquid-liquid, liquid-solid, and solid-gas, which helps the method for transportation. To form into one mixture state, each distinct having different properties like structure, density, or temperature. The mixing reaches the final mass of slurry will reaches more possible uniformity; the molecular diffusion cycle continues until all thermal gradients, pressure and concentration are removed and chemical interactions will not occur. Stirrer tanks or vessels are using in many applications like reactors, crystallizers, and mix tanks a structure of agitated equipment [10].

Table 2. Nomenclature in equipment [11]

S.No	Symbols	Description
1	D	Diameter of impeller
2	DT	Diameter of stirrer tank
3	Z_A	height of the agitator from the base of tank
4	H	Height of stirrer tank
5	W_B	Width of the baffle
6	N	Speed of agitator

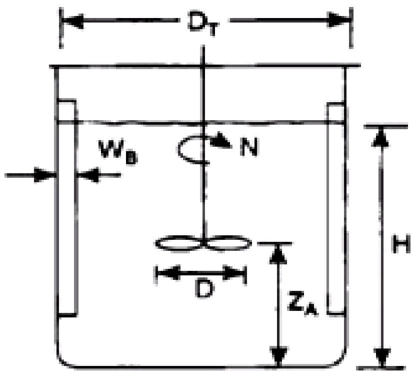


Figure 2. Parameters in equipment [11]

Figure 2 shows different parameters considered to agitation process, the output of agitation equipment it depends on the output variables, if there is any slight change in value parameters that are mentioned above. Diameter and Width of the stirrer tank will help to calculate the volume of the tank for agitation and also it is important for the quantity of the reactor tank to be designed, to consider for gas quantity when it is used for mixing of gas. H/D_T indicates the relation of quantity of liquid height in tank to the inside tank diameter.

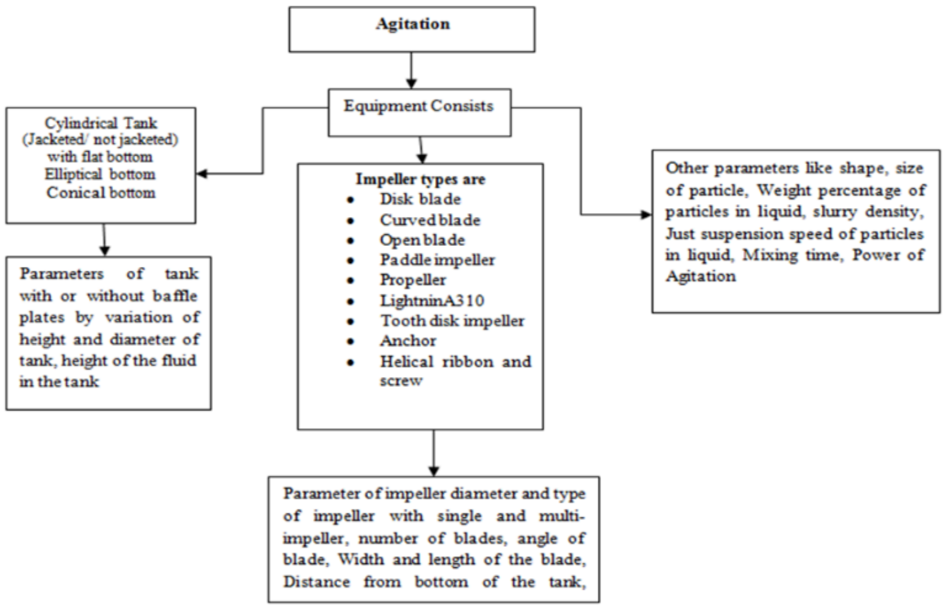


Figure 3. Parameters influenced on Agitation

This ratio plays a key role on the engine and drive system in agitation equipment. The other important parameter is selection of impeller. It has only one agitator in figure 2 which is near to the bottom of agitation tank. In addition, more than one agitator easily mounted based on the solid and liquid properties, ratio of quantity of liquid height in tank to the inside tank diameter and the available power of agitator. In the impeller selection mixing of solid phase and liquid phase the flow distribution is one of the criteria. In figure 3 it shows complete information related to agitation Parameters [12]. The coming section discussed about different researcher's works associated with the parameters which influence on the mixing of solid-liquid in agitation equipment for various applications.

3. EFFECT OF MECHANICALLY STIRRER VESSEL ON AGITATION

The reactors, are used in the industries which are related to the chemical industries are stirred reactors in which impellers are produce flow while mixing inside the reactor. Stirred reactors have an unprecedented versatility and manage the transport processes within the reactor. Parameters like geometrical measurements of the reactor, ratio of impeller also consider with respective the ratio of inside tank diameter, the number, type, geometrical measurements of the impeller and the degree of confusion provide effectively varies the output from agitation equipment. A standard tank it should be like a vessel which is fitted with movable impeller [13]. The base shape and place is in form of vertical agitator tank. A mechanically agitator vessel can be operated in three different systems (i.e., laminar flow, turbulent flow, and transition flow). Turbulence is a major mixing phenomenon which affects all typical processes, such as mass transmission, transmission of heat, distribution of liquid -liquid, gas-liquid dispersion and solid suspension in liquid**.**

Turbulence is a dynamic movement state in which time and all three dimensions fluctuate. The complex structure and interactions of a range of form and size of small and large structural elements such as vortexes, boards, ejections and sweeps, reflect these fluctuations. The important parameters are tank inside diameter and height of the tank, type of tank, with baffles and without baffles by different authors shown in below table 1

Table 1. Some of the authors worked by varying the tank dimensions and types

S.no	Author Name	Tank Type/ratio	Type of baffles/ ratio of baffles length and width	Parameters effected
1	PanZhang et.al[14]	Flatbase cylindrical tank with ratio of Height of the tank and diameter of the tank is equal to 1	Un-Baffled	Mixing time increases initial speed when speed [rpm] increases the time reduced.
2	G. G. Roy et.al[15]	Cylindrical tank with cross section of conical by taking the ratio Height of the tank and diameter of the tank is varies to 1 to 3	Draught tube type baffles is used	Reduces the gas bubbles in making of slurry, and gas hold up.
3	MartaMajor-Godlewska et.al[16]	Inner vessel diameter D=0.6m is taken by varying the height	Baffles are used by changing the ratio of length of baffles with the height of the tank ratio values are 0.17,0.33,0.5,0.67,1	Power consumption is observed.
4	JolantaSzoplik et.al[17]	Bottom flat surface of agitated vessel where H=D	Tubular types baffles 4 number surrounded the tank	Power number varies because of tubular baffles effect on the power number.
5	A. Debab.et.al[18]	agitated jacketed vessel, on to determine film heat transfer coefficient, temperature varies	With 4 flat baffled and un-baffled plates	For heat transfer process by using the baffle plates giving better result
6.	Emily T. Mitchell [19]	Flat-bottom square tank. Tank diameter is taken as T=0.38mchanging the impeller diameter with Tank diameter ratio D/T=0.25,0.40,055	With baffle and un-baffle	By using of baffle in square tank is necessary. Square tank results compare with the cylindrical tank giving almost results are nearer Suspension speed of solids will varies based on the volume of the tank
7.	HouariAmeur[20]	Flat bottomed dished, bottomed cylindrical vessel ,closed spherical vessel by taking ratio of Height	Without baffles	Less energy is required when the flow is uniform. By comparing the three vessels the spherical vessel

		of the tank and diameter of tank equal to 1D=400mm		having more volume.
8	Youcef Kamla.et.al[21]	flat bottomed cylindrical tank, D equal to its height (D = H = 150 mm)	With 4 baffles, a width w/D = 1/10 and a thickness t/D = 1/75.Inclination angles of 25^0,32.50, 450, 70^0 and 90^0	When increase of the baffle angles the upper vortex. When increase the angle the impeller speed also increases, the impeller speed increases the power consumption increases.
9	K. J. Bittorf[22]	Flat bottom with different tank diameters of 240 and 140	With baffles and by varying the impeller diameter with tank diameter	Mixing time varies according with baffles

4. INFLUENCE OF AGITATOR TYPE AND ITS PARAMETERS

Dissipation of power by the impeller rotations is the main source of energy in an agitated vessel. In both the pumping and down-pumping mode, the researchers have focused on the energy it is one of the main in an agitated vessel is when mixing of two phase. The flows are classified into two type laminar, turbulent flow, but usually only to demonstrate a specific range of traditional behaviour. The impellers are divided into two categories, based on axial and radial flow, such as the Rushton turbine (radial), blade corners, propellers (axial) and blade pitched turbines choosing an effective drive that fulfils suspension requirements is important because different drives generate various stream patterns that affect energy efficiency and hydrodynamics. Shown in table 2.

Table 2. Some of the authors worked by varying the impeller parameters and types

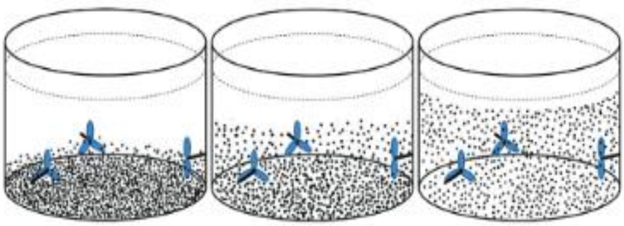
S.no	Author name	Impeller type	Ratios of impellers	Parameters observed
1	HouariAmeur et.al[23]	6-blade Rushton ,6-paddle type blade is used	By taking the height of the blade and diameter ratio 0.1	Reynolds number is increases the power number will be constant
2	A. Debab.et.al[18]	Flat blade disc turbine	Ratio of impeller diameter with tank diameter 0.33 to 1, Varying the impeller speed of 250 to 600	Shear rate near impeller increases when the temperature at 30,40, 50 ,60 degrees centigrade of agitated jacket vessel
3	A Benmoussa.et.al [24]	anchor impeller	Circular gate impeller of diameter d positioned at the centre of the tank rotating around shaft of diameter(da), with clearance to the wall w=0.02, tank diameter D, L indicates height of the tank The geometrical ratios used are d/D=0.96, da/D=0.023, and L/D=0.067	Thermal behaviours, power number varies along with Reynolds number. Nusselt number, Tangential velocity is also varies with respective the mixing time

4	Mohammad-Reza Ashory. et.al[25]	six-blade turbine Rushton	Clearance from bottom of the tank is equal to the impeller diameter. Diameter of the impeller is d=D/3(D is the tank diameter) length and height of the impeller is D/12 and D/15 thickness of the blade 3mm width of the blade is D/4. Blade angle varies 45^0,60^0,75^0,90^0	Angle of blade changes the power number and Reynolds number increases. The power consumption decreases when angle decreases of the blade. When tip of the blade increases the radial velocity value increases first and then decreases When angle is varies from 90 degrees to 45 degrees it will pump into the bottom of vessel
5	Houari Ameur.et.al.,[26]	Paddle Impeller	Blade curvature with respective tank diameter ratios of b_c/D= 0, 0.016, 0.033, 0.05, 0.066 and 0.116 Ratio of blade diameter with tank diameter ratios of b/D= 0.5, 0.66, 0.82 and 0.98, also change in number of lades,2,3,4,5b,6,8	Curvature of blade is more affected than remaining parameters. When curvature increases compare to straight blade Reynolds number is almost same but the power consumption is low. It based on curvature of blade
6	D.Chitra.et.al,[27]	Rushton turbine blade,6-paddle turbine, curvature blade	Diameter is same for three impellers, the clearance of impeller from the bottom of the tank is varies 30mm 58mm,87mm, 102mm 116mm ,131mm, 147mm	Power consumption is varies for different impellers
7.	Mohammed Foukrach[28]	Rushton turbine with flat blades	diameter is considered: d = D/2.5 and D/3.Curvature radius 3mm and 5mmblade height h = d/5, blade length l = d/4 thickness of blade is 3mm	Flat blade is more suitable in terms of enhancement of the axial circulation of fluid. Increase in blade height generates stronger tangential flow and enhanced axial movement of fluid particles
8	J. Karcz.et.al.,[29]	Propeller impeller	Diameter of impeller is equal to 0.33 of diameter of tank Shown the difference between	Reynold's number value varies, tangential flow is also varies with distance of

			single impeller and double impeller. Also change the liquid height Z/T=0.2,0.7,1.By changing the eccentric distance from the axis line	eccentricity and number of impellers
9	K.J. Bittorf[22]	Paddle blade,Helical,A310 types of impeller is used	Varying of diameter impeller with the ratio D/T=0.19,0.33,0.50,0.58,0.43 Clearance ratio with tank diameter C/T varies for different impeller	Observed the mixing time varies with the clearance of impeller and diameter of impeller

5. SUSPENSION SPEED EFFECTED OF SLURRY DENSITY AND PARTICLE DIAMETER

Efficient contact with solid-liquids is necessary for many chemical processes to be optimised. An external force is necessary in this scenario to lift the solids and keep them suspended. On-bottom movement is only appropriate for high solubility solids. If impeller reached for particular speed the solid particles will not settle in bottom of the tank they will in continuous motion. The bottom-up movement will help the uniform suspension helps the solid particles that settled in tank before leaving from equipment. In a solid-liquid mixing system, the level of suspension is critical and can be divided into three stages shown in figure 4[30].



(a) **(b)** **(c)**

(a)-1st cylinder the solid particles Partial suspension when the N< Njs,
(b)-2nd cylinder the solid particles Complete suspension when N= Njs,
(c)-3rd cylinder the solid particles Uniform suspension when N>Njs.

Figure 4. Settlement of solid particles for suspension speeds [30]

In first level of a cylindrical tank is not required since solid particles can be deposited on the base of the tank at a low speed and not all surface area of the particles are effectively used for chemical reacting, mass and heat transfer. An increase in impeller speed leads to a complete phase of suspension during which no solid particle stays on the base of the tank over 1 or 2 seconds, and the maximum particular surface area for chemical reactions, mass and heat transfer is exposed to liquid. The Njs, defined as the minimum impeller speed at which the particles all enter complete suspension, is most commonly used for off-bottom suspension. The pioneering study by Zwietering [31] established a correlation shown in eq. (1)) to relate the crucial speed of suspension to process parameters and physical properties of fluid and solid to the highly invasive stirred method.

$$\boldsymbol{Nj_s = s.\vartheta^{0.1}.\ (g.\ \frac{\Delta p}{\rho_L}).X^{0.13}.d_p^{0.2}.D^{-0.85}} \tag{1}$$

Here, *Njs* is just suspension speed of solid particles in liquid, S is Zwietering constant for a given system geometry,ϑ,g,Δp, , $\rho_{L,}$X, dp, and D terms indicates kinematic viscosity of slurry, gravitational of force, densities difference of solid and liquid, weight fraction, particle diameter, and impeller diameter.

Nienow [32], Nagamine [33] and VanderWesthuizen along with Deglon[34] extended their connection to density of solid particles suspension system with an average concentration of particles over 5wt. percent could give rise to the formulation of a clearly defined clear liquid layer in the top part of the tank and the process operating conditions were shown in the workshop to be two main drivers of Njs for the stirred tank with constant geometry parameters. As a result, the principle of cloud height, h, which means the height of this interface from the bottom of the tank, was used as an alternative measure of the strong suspension degree. Also described the cloud height as 90% of the liquid height when the speed of the turbine was equal to Njs in the top-enter tank. A cloud height model based on the average flow assumption for the solid fully suspension at low clearance and wide sprocket diameter was developed. Scaling up or changing from one system to another, power or specific energy at just-suspension has been commonly used to compare the efficiency of different systems. Ochieng and Lewis [35] stressed that while bulk fluid flow represented by impeller tip speed may trigger particle suspension at low solid loads, turbulence strength is what regulates particle suspension at high loads, and therefore it is recommended that power be used per unit volume as a scale up factor. Various types of solid particles have been studied by, such as, sand particles by Ali Alouache.et.al [36] slurry density is also significance on the suspension by varying the solid particle concentration weight percentage. Based on the equation 2, a graph is plotted between the slurry differences between solid –fluid particles and shown in figure 5. It can be observed that higher density increases the Njs rotary limit needed to achieve full suspension within the limits of the solution by observation and simulation gradually increases.

$$\boldsymbol{N_{js}} = \propto (\Delta\boldsymbol{\rho}/\boldsymbol{\rho})^{\boldsymbol{\beta}} \quad (2)$$

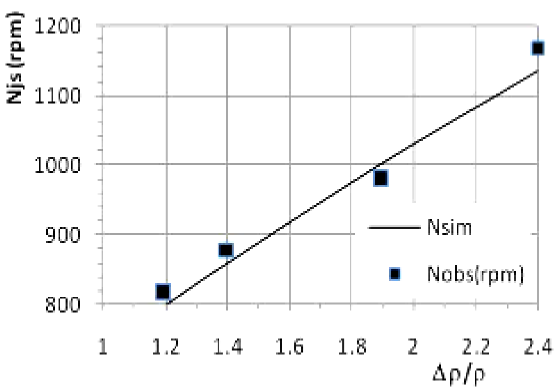


Figure 5. Plotted between difference of density and Njs

6. POWER CONSUMPTION

In the design and operation of solid liquid mixing phases, the amounts of energy dissipated in the vessel by the impeller are an important parameter. The above mentioned parameters like type, size and shape of stirrer cylindrical tanks. Impeller is the one most important parameter based on the diameter, width, length and impeller types, impeller speed, slurry density such as concentration of solid particles, shape diameter. The power number for the Low Solidity

Hydrofoil Impeller was determined by Bujalski et al [37] showed that the number increases by increasing the solid loading power. Measurements for solid concentration loading by weight were made in that study around 40 percent. The variance of the power number showed different patterns at solid loading greater than 20 per cent. When impeller speed is less than 200 rpm the power number is lower value for single phase. Bujalski et al [37] and Wu et al., [38] observed the power rating by using different types of impellers like pitched blade turbine, Rushton Turbine, disk with 6 blade turbine at extreme strong concentrations greater than 50 per cent. As reported in their study, the Pitched blade turbine's power number increases at high solid concentrations whilst that of Rushton turbine decreases. But a reduction in the power number of Rushton Turbine was linked to the fact that damping at high solid loading suppresses the dead flow zones at the back of the disk with 6 blade turbine leading to drag reduction.

The power number must be characterized in order to estimate energy consumption and proper scale up procedures which very important to choose. Intense blending in smaller reactors is simple, whereas in larger reactors, different flow patterns, turbulence structures are encountered. The non-homogeneous distribution of dissolved solids in most solid-liquid multi-phase reactants provides strength large scale operating efficiency leads to significant industrial disadvantage. Exhaustive knowledge on the effects of various factors for perfect design and process of transportation of liquid-solid is mainly focused on physical properties, dimensional parameters, and operational parameters. It is important to develop more reliable techniques for the design of turbulent concentric systems, especially for processes in which conventional techniques characterize the suspension speed of solid particles. Moreover, the process evaluation needs to be conducted with detailed knowledge of solid vessel concentration distribution and active reactor volume in order to accurately predict reactor selectivity and reactor output.

7. CONCLUSION

This paper reviews the preparation of coal water slurry mixing methods and process parameters in the recent times. The agitation equipment parameters have great influence on solid – liquid mixing procedures. Several authors made attempts with different ratios of tank dimensions, tank types such as elliptical base and flat base maximum authors and given their best in uniform mixing. Liquid to tank diameter ratio, Suspension velocity seems to be affected by particle diameter and solid concentration by weight. The future directions of agitation process may include research on changes in each tank parameter, the volume of the liquid, with and without the number of baffles, the impeller diameter, the clearance distance, the difference in the size of the particles, the concentration weight in the liquid, suspension speed of solid particles in liquid and various parameters for industrial advantage.

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