CFD Analysis of Pot Tester Impeller to Improve the Performance of Ash Handling Systems

Swapnil Jain[1] Roshan Kumar Dewangan[2] Dr. Deepak Sharma[3]
[1]Associate Professor [2]Student [3]Principal
[1,2]Department of Mechanical Engineering
[1,2]Shri Shankaracharya Engineering College, Junwani, Bhilai, India
[3]Shri Shankaracharya Institute of Engineering and Technology, Junwani, Bhilai, India

Abstract— Impeller deformation is a major problem that constantly affects the operation of the system for hydraulic transportation of solid waste material (such as ash). The design of the impeller with different-different type of material to improve the performance, optimization of slurry flow or strength of the impeller hydraulic transportation pump is analyzed by using Computational fluid dynamics package (ANSYS). CFD are carried out for analyzing of flow effects. The pot tester is designed for study of impact of pressure variation on impeller of slurry/hydraulic transportation system with high concentration. A 3D model generated using commercial software CREO and model is simulated for flow visualization using computational fluid dynamics, which results are closer to experimental result. The pot tester is designed on the accordance of our experimental setup specifications. This paper is based on analyzing the pressure variation impact of slurry on impeller. Computational investigation were conducted on the impeller with the velocity 1.5 m/s to 4 m/s. High kinetic energy is available at the surface of specimen due to high velocity which may causes wear or deformation on blade take place. In this paper, analysis taken the four material (brass, copper, titanium, stainless steel400) to get a suitable material for hydraulic transportation system and also increases the life of the systems.
Key words: Computational Fluid Dynamics, Pot Tester, Slurry Mixture Impeller, Pressure Variation

I. Introduction

A Pot tester is a prototype model of the actual hydraulic transportation system like centrifugal pump or ash hopper. It works on the principle of centrifugal pump. In which the lifting of liquids/slurry enables, from the lower level to higher level by generated dynamic pressure in it. This Pot tester needs critical analysis at highly complex flow, which may turbulent and three dimensional in nature. Computational fluid dynamics simulation visualizes the condition inside the Pot tester and provides valuable information, which may predict the conditions of actual hydraulic transportation system. These results are used to predict the performance of actual transportation system and impact of slurry on impeller. An impeller has highest influence on the performance of the pump among the entire component, since fluid flows in the pump generates energy through it. Therefore improvement in design and material of the impeller must be achieved by CFD analysis.

A. Slurry

Slurry is defined as a mixture of liquid, usually water and oil, and solids such as, sand, coral, sediment, pulverized stone and ash particles. It may also define as a liquid suspension of solids that does not change its characteristics when affected by either temperature and/or pressure. Slurry types have different flow properties that are influenced by the size, shape, density and the concentration of the particles as well as the density and viscosity of the liquid in which the particles are suspended and it have also been depend on the area, work being done. The flow of slurry is generally classified into two categories, one is non-settling slurry and other is settling slurry.

B. Computational Fluid Dynamics

Computational Fluid Dynamics (CFD) is the process of obtaining numerical approximations to the solution of the governing equations. CFD provides a qualitative (and sometimes even quantitative) prediction of fluid flows by means of,

- Mathematical modeling (partial differential equation)
- Numerical method (discretization and solution techniques)
- Software tools (solver, pre-processor and post-processor)

II. Problem Statement

The demand of coal is increasing day by day for both steel plants as well as for power plants. When we use the coal as fuel ash produced as a byproduct. For the transportation of ash many wagon are required. This problem could be avoided by hydraulic transportation system. It is the best way to handle the ash. In present hydraulic transportation system are facing a major problem of impeller deformation or wear that continuously affect the operation of slurry transportation system. During the mixing of ash and liquid (water) , and lifting this mixture (slurry) from lower level to higher level, creates a lot of stress on the impeller which causes wear and deformation take place.an impeller influence the performance of any slurry transportation system and also the cost of this system is too high. This is a serious problem in every work site where the ash transportation system is working or needed.

III. Methodology

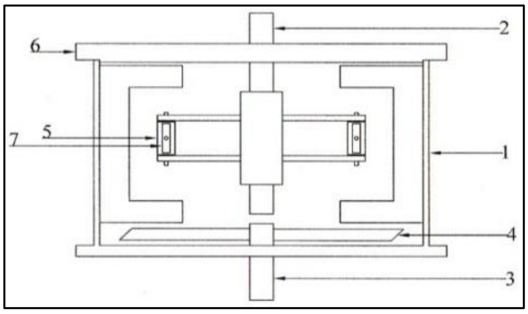

Fig. 1: Geometry of "Pot Tester"

Fig. 2: Experimental setup of pot tester

According to the problem identifies, to overcome this, we design a "Pot Tester" to select the best material for impeller. All the parts of the pot tester designed in CREO and simulation is done on ANSYS to identify the best material for impeller.

Sr. No.	Name of Parts	Specifications(mm)
1	Cylindrical tank	dia- 263, height-180
2	Test fixture shaft	dia- 20
3	Shaft of propeller	dia- 20
4	Propeller	2 blade, Bend at 45°(from Centre)
5	Test fixture	33.4×14.9×5
6	Transparent acrylic sheet	Dia-313, thickness-150
7	Test specimen	27.8×6.4×2.12

Table 1: Specification of "Pot Tester"

A. *Mesh Generation*

Mesh generation is the process of subdividing a region to be modeled into a set of small control volumes. In each control volume there will be one or more value of the dependent variable (e.g. velocity, temperature, pressure etc.). Meshing is a method to define and break up the model into small elements.

The quality of mesh is dependent on orthogonal quality and aspect ratio. Orthogonal quality ranges from 0 to 1.

- Minimum Orthogonal Quality = 1.22915e-01
- Maximum Aspect Ratio = 3.35101e+01

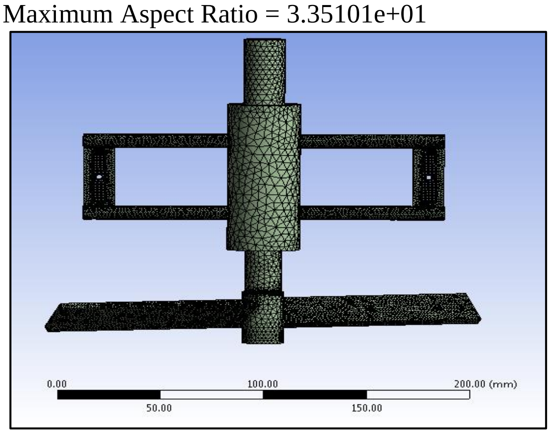

Fig. 3: Meshing of blade

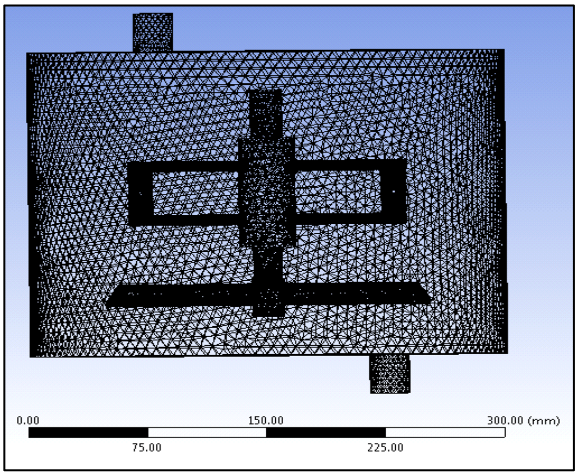

Fig. 4: Meshing of model

No. of Nodes	471824
No. of Elements	2428601

Table 2: Mesh Statistics

B. *Pre-Processing*

In pre-processing material properties, cell zone conditions and boundary conditions are applied on the model. The particle size is 20µm. applied cell zone conditions are

- At inlet- velocity inlet
- At outlet- pressure outlet

C. *K-Epsilon Turbulence model*

The k-epsilon (k- ε) model proposed by Lounder and Spalding (1974) makes use of two model equation, one for the turbulent kinetic energy k and one for the rate of dissipation of turbulent kinetic energy per unit mass ε. These equations are:

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial t}(\rho k v_i)=\frac{\partial}{\partial t}\left[\frac{\mu_j}{\sigma_k}\frac{\partial k}{\partial x_j}\right]+2\mu_T S_{ij}S_{ij}-\rho\varepsilon \quad (1)$$

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial t}(\rho\varepsilon\overline{v}_j)=\frac{\partial}{\partial t}\left[\frac{\mu_T}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}2\mu_T S_{ij}S_{ij}-2C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \quad (2)$$

Transport equation (1) and (2) are solved iteratively along with Reynolds averaged Navier-Stokes equation. Using k and ε, velocity and length scales are defined as follows:

$$q=\sqrt{k}, \qquad L=\frac{k^{\frac{3}{2}}}{\varepsilon}$$

IV. RESULTS AND DISCUSSIONS

The impact of slurry on the impeller of different kind of material for same working conditions (i.e. velocity 4m/s, density 1440kg/m^3 and boundary condition etc.) displayed in the form of pressure variation (static, dynamic, absolute and total pressure) are as:

A. *For Titanium*

- Dynamic pressure-6.56bar
- Total pressure -6.299 bar

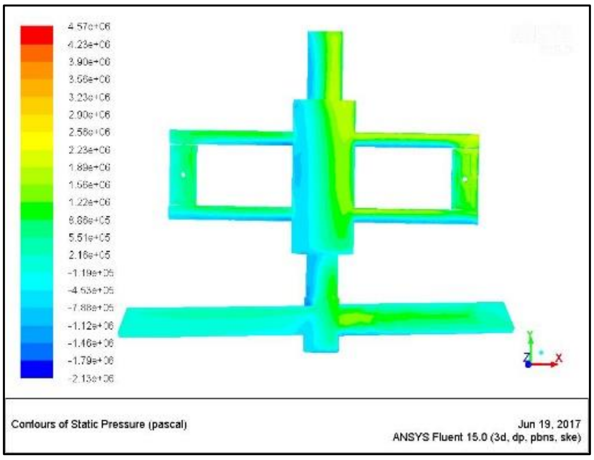

Fig. 5: Contour of static pressure

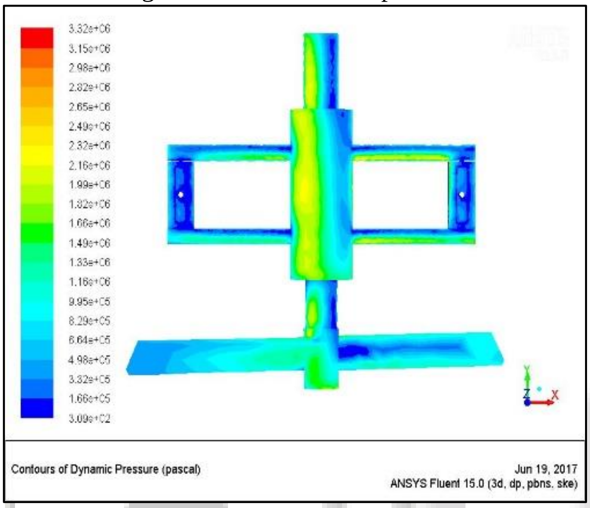

Fig. 6: Contour of dynamic pressure

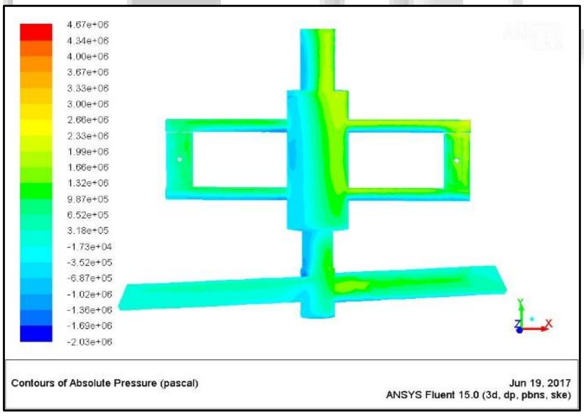

Fig. 7: Contour of absolute pressure

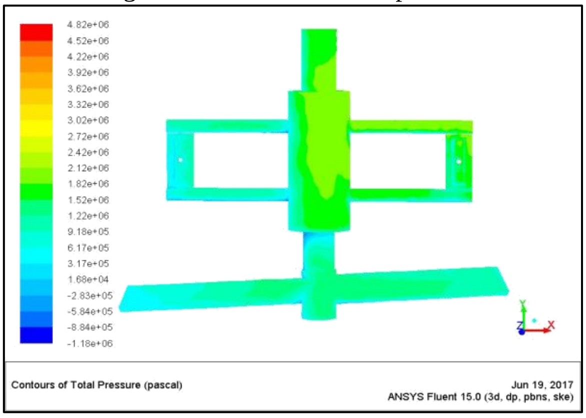

Fig. 8: Contour of total pressure

B. For Copper

- Dynamic pressur-9.46 bar
- Total pressure-6.88bar

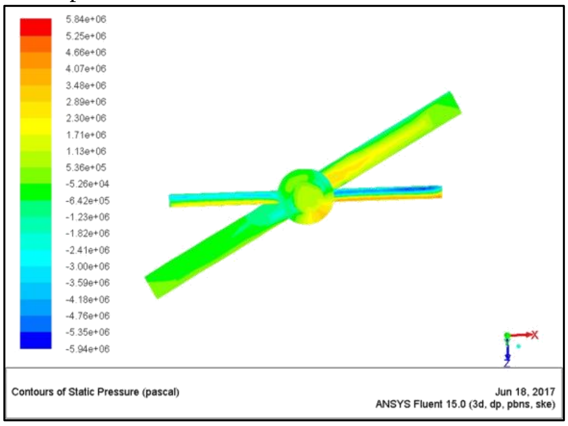

Fig. 9: Contour of static pressure

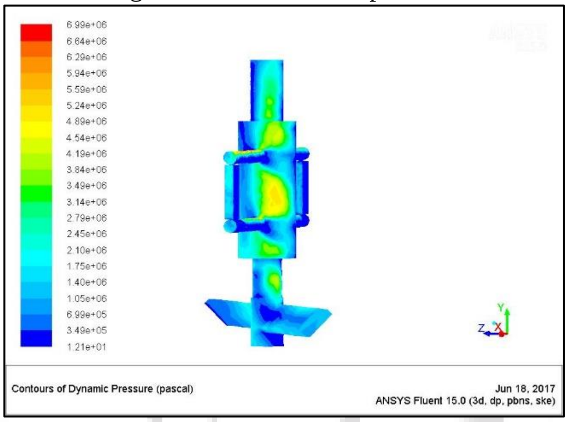

Fig. 10: Contour of dynamic pressure

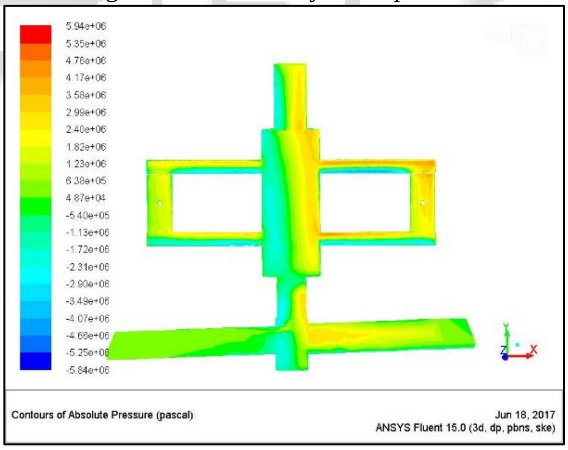

Fig. 11: Contour of absolute pressure

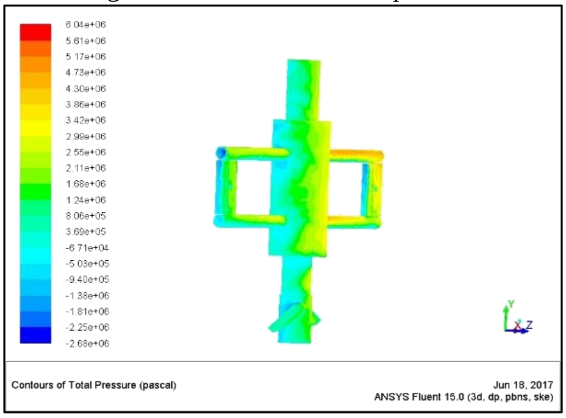

Fig. 12: Contour of total pressure

C. For Brass

- Dynamic pressure-9.43bar
- Total pressre-7.26bar

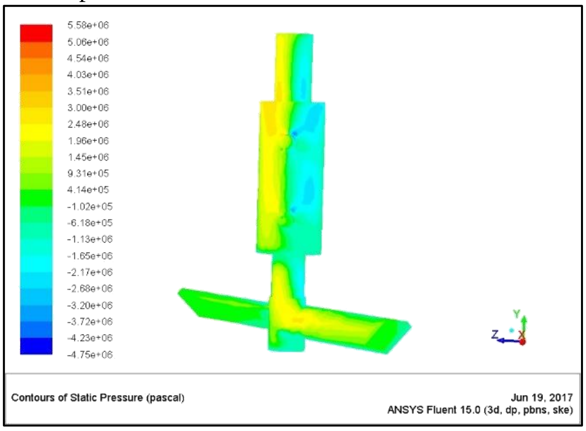

Fig. 13: Contour of static pressure

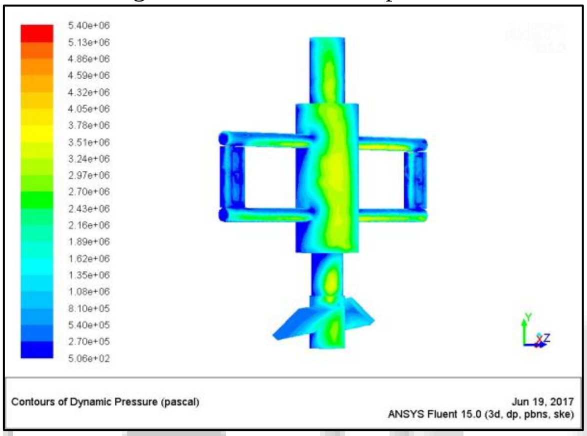

Fig. 14: Contour of dynamic pressure

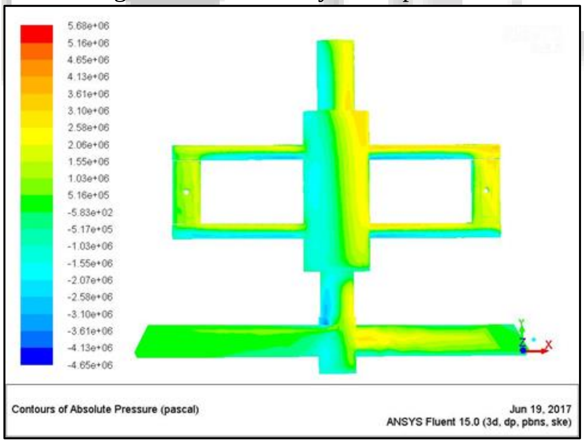

Fig. 15: Contour of absolute pressure

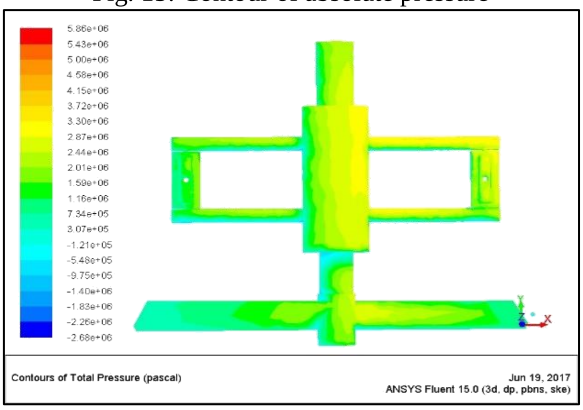

Fig. 16: Contour of total pressure

D. For Stainless Steel 400

- dynamic pressure- 8.33bar
- Total pressure- 6.94 bar

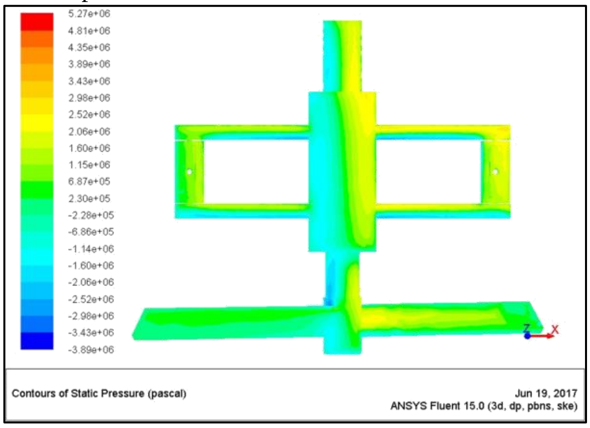

Fig. 17: Contour of static pressure

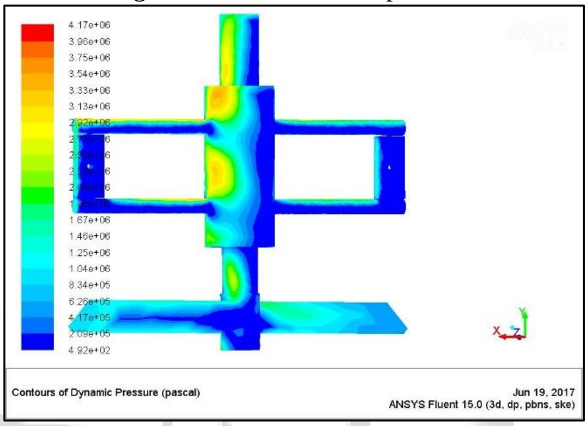

Fig. 18: Contour of dynamic pressure

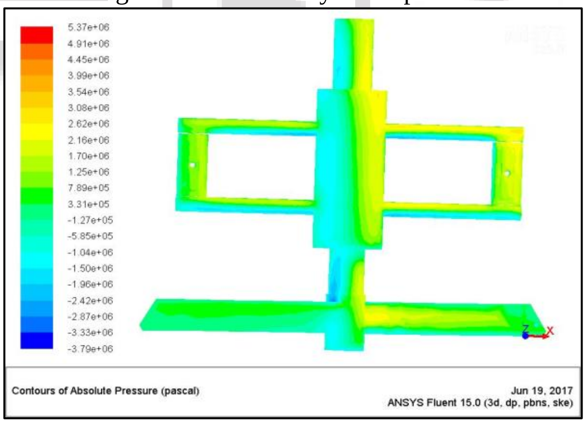

Fig. 19: Contour of absolute pressure

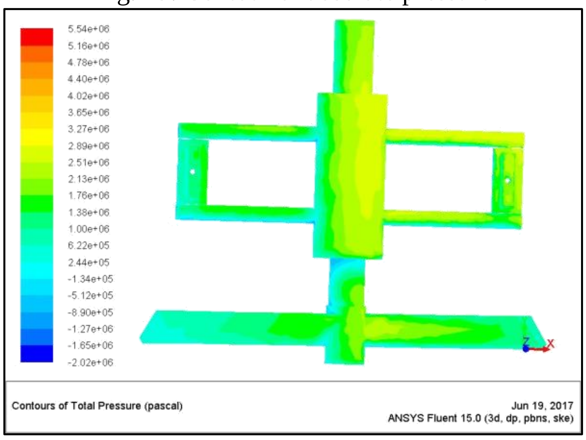

Fig. 20: Contour of total pressure

V. CONCLUSION

The pot tester is modeled by using CREO software and this model is simulated in ANSYS software in the term of pressure variation. In this paper we simulate the impeller of the pot tester, for four different type of material. Simulation is taken out and we found the dynamic pressure on titanium, copper, brass and SS400 are 6.56bar, 9.46bar, 9.43bar, 8.33bar and total pressure are 6.29bar, 6.88bar, 7.26bar, 6.94bar respectively at velocity 4m/s. As we further increases the velocity and slurry concentration (density more than 1440kg/m3), the pressure also increases in same manner, and at a stage when pressure will be maximum there is a chance of deformation.

So that from this paper, result we can conclude that we need a material for impeller which resist the maximum pressure. On the basis of simulation of four different materials in this paper, we can suggest "Titanium" for impeller design. To improve the performance, reduce deformation and get longer life of impeller.

VI. FUTURE SCOPE

There are lots of scope and work to do in this field. The following suggestions for further work are as:

1) The material selected for impeller, in this work are titanium, copper, ss400 and brass. So those different materials which possess better properties can be selected for future work.
2) The experimental setup can be used for similar work in different working conditions.
3) The test fixture can be fix at different-different angle. So that it is possible to analysis in future work.
4) The computational approach can be used to simulate the similar work, with different working conditions.
5) The computational approach can be used to simulate the work for curved blade.
6) The similar work can be extended by using other type of "Pot Tester" and slurry concentration.

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