# Light Metals 2015

## ALUMINA AND BAUXITE

## Digestion

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# A NOVEL SELF-STIRRING TUBULAR REACTOR USED IN BAUXITE DIGESTION PROCESS

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## Abstract

A novel self-stirring tubular reactor driven by pressure energy used in bauxite digestion process is presented originally in this paper. This reactor combines the advantages of autoclaves and conventional tubular digestion equipment, it can restrain scale at high temperature and high pressure and intensify mass and heat transfer. Stirring of the novel reactor only needs the pressure energy of the liquid. Performance of self-stirring reactor driven by pressure energy was studied in this paper. High-speed photography was adopted in the paper to research the effects of various factors on rotating speed in the self-stirring reactor driven by pressure energy. The results demonstrated that fluid pressure has the most outstanding effects on stirring speed of the novel reactor, and the effects of fluid density and viscosity on stirring speed are minor.

## Introduction

Since tubular digestion theory was presented in the early 1930's till now it gradually matures, its technology is extensively applied [1]. Tubular leaching reactors can realize higher temperature and pressure than autoclaves, which is the major development direction of bauxite digestion technology. The pulp presents high-speed turbulence, which intensifies mass and heat transfer, and no backmixing. It can observably cut down the digestion time and improve the utilization rate of equipment [2-5]. Tubular digestion reactors synthesize chemical kinetics and diffusion kinetics, and use high temperature and turbulence to promote the digestion process of aluminum ore. The economic effects are very outstanding. However, tubular digestion equipment has a big disadvantage, i.e. serious scaling problems [6].

Aim at the two problems, improvement of digestion reaction and inhibition of scale, a kind of self-stirring tubular reactor driven by pressure energy is originally presented by Northeastern University [7]. This reactor combines the advantages of autoclaves and traditional tubular reactors, the own energy of high pressure fluid is utilized to drive agitator to rotate, which realizes the stirring action of reaction medium to promote the reaction process. It structurally solves the problem that traditional mechanical agitation reactors are hardly high pressure sealed because of the need for power drive element. It is a novel pressure leaching reactor [8].

High speed photography is adopted to research the effects of various conditions (fluid density, viscosity, pressure) on stirring speed of tubular self-stirring reactor, which provide theoretical basis and technical support to application for alumina industry of the novel reactor.

## Research method and equipment

### Research equipment

On the basis of comparison and research domestic and overseas multiphase leaching reactors for years, around improvement leaching reaction and heat transfer efficiency, Northeastern University presents a tubular self-stirring reactor, design and process the experiment equipment of tubular self-stirring reactor driven by pressure energy, which is shown in Figure 1 and Figure 2.

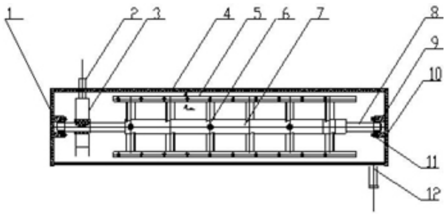



**Figure 1.** Structure of self-stirring reactor driven by pressure energy

1-left end cap 2-inlet 3-drive turbine 4-reactor cylinder 5-flexible scraper blade 6-fixed screw 7-frame agitator, 8-stirring shaft 9-bearing bush 10-right end cap 11-fixed screw 12-outlet

**Figure 2.** Photo of the self-stirring reactor driven by pressure energy

The specific sizes of self-stirring reactor are shown: pipe range is 1000 mm, inner diameter ∅ 198 mm.

When the inlet flow rate is 0.301 $m^3/h$, inlet pressure is 5 MPa, 1/2 height of reactor diameter is taken as the base level, 1/3 and 2/3 heights of diameter are taken as planes of measurement along the base level up and down. The stirring speeds are measured at the liquid levels above. The instrumentation plan of liquid level is shown in Figure 3.

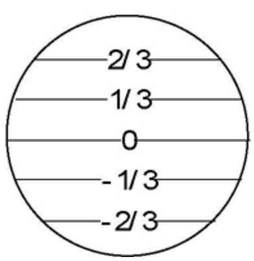



**Figure 3.** Instrumentation plan of liquid level

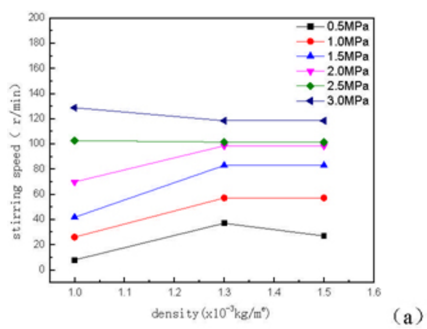
**Research method**

High-speed photography was adopted to measure the rotate speed of self-stirring reactor in the experiment. Drive turbine under the action of high pressure fluid drove the coaxial agitator blade to rotate. The agitator blades in the operation were continuously shot for a time by the high-speed camera to obtain high-definition images of agitator blades in continuously variable positions. MiDAS (software of high-speed camera) was used to get precisely how long the agitator blades rotating n laps took, then the agitation speed was obtained in accordance with N=n/t.

**Research results**

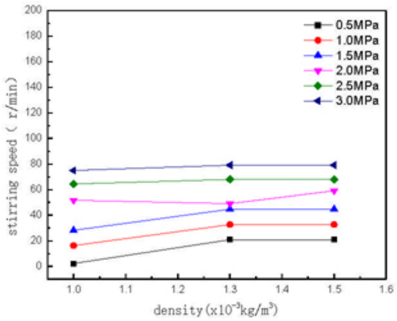
**Effects of fluid density on stirring speed**

The effects of fluid density on stirring speed in the condition of various liquid levels and fluid pressure when calcium chloride solution (viscosity $\mu$=1.0×10$^{-3}$ Pa·s) is the fluid are shown in Figure 4(a)~(e).

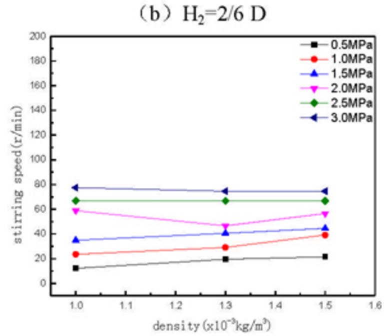



$H_1$=1/6 D

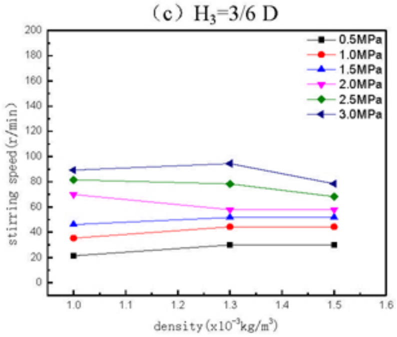
**Figure 4.** Effects of fluid density on stirring speed at different liquid levels and fluid pressures



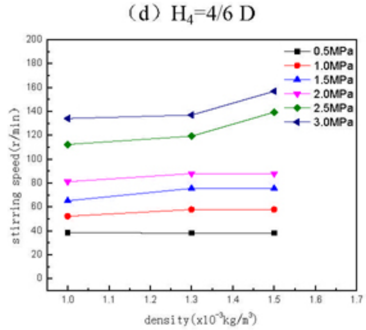

（b） $H_2$=2/6 D




（c） $H_3$=3/6 D




（d） $H_4$=4/6 D



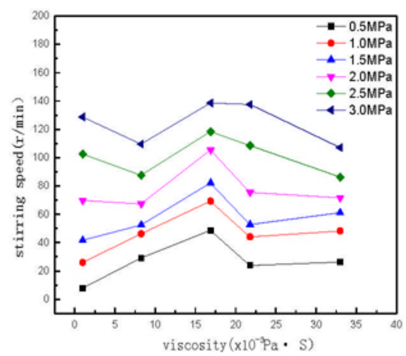

（e） $H_5$=5/6 D

**Figure 4.** Effects of fluid density on stirring speed at different liquid levels and fluid pressures

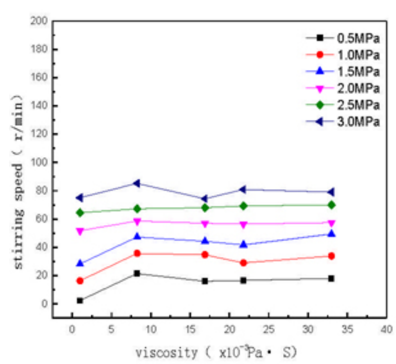
At various liquid levels, when the fluid pressure $P_1$=0.5 MPa, $P_2$=1.0 MPa, $P_3$=1.5 MPa, the stirring speed of self-stirring reactor first magnifies then goes smooth with the increasing of fluid density. At the liquid level of $H_1$=1/6 D、$H_2$=2/6 D, when the densities are in the $1.0\times10^{-3}$ kg/m$^3$~$1.31\times10^{-3}$ kg/m$^3$ range, the effects of density on stirring speed are obvious. When $P_5$=2.5 MPa, $P_6$=3.0 MPa, at low liquid levels ($H_1$=1/6 D~$H_3$=3/6 D), the effects of density on speed are minor. At the liquid level of $H_4$=4/6 D, the stirring speed decreases obviously with the increasing of density. At $H_5$=5/6 D, the speed increases markedly with the increasing of density.

**Effect of fluid viscosity on stirring speed**

Figure 5(a)~(e) show that when the syrup aqueous solution is the fluid (density $\rho=1.0\times10^{-3}$ kg/m$^3$), at different liquid levels and fluid pressures, the effects of fluid viscosity on agitation speed are researched.

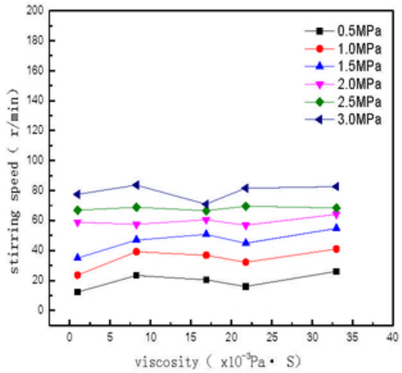



（a） $H_1$=1/6 D

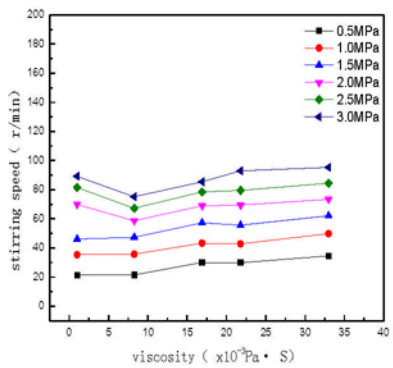



（b） $H_2$=2/6 D

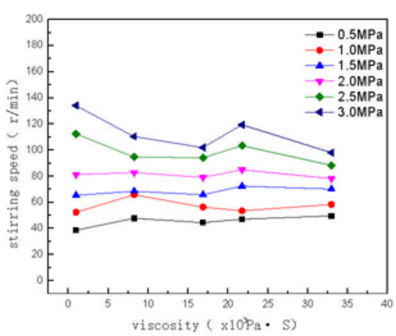
**Figure 5.** Effects of fluid viscosity on stirring speed at different liquid levels and fluid pressures




(c) $H_3$=3/6 D




(d) $H_4$=4/6 D



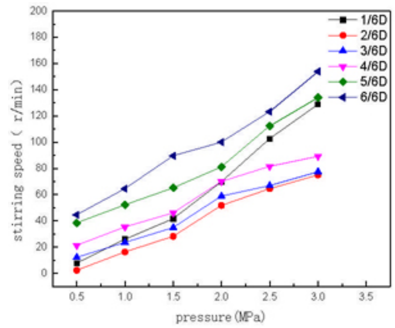

(e) $H_5$=5/6 D

**Figure 5.** Effects of fluid viscosity on stirring speed at different liquid levels and fluid pressures

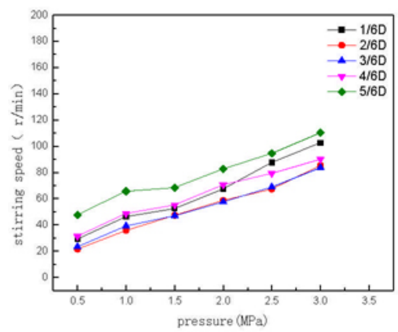
The effects of viscosity on stirring speed are minor. At liquid level of 1/6D, stirring speed fluctuates greatly with the variation of viscosity, in other conditions, the viscosity has small effects on stirring speed.

**Effects of fluid pressure on stirring speed**

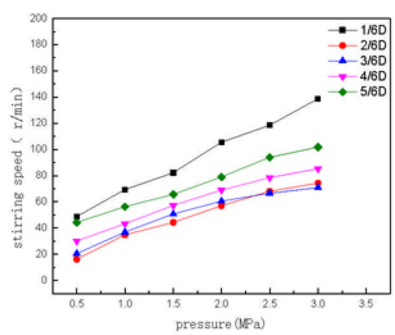
Figure 6(a)~(e) show that the effects of fluid pressure on stirring speed with the fluid (density $\rho$=1.0×10$^{-3}$ kg/m$^3$) at different viscosities and liquid levels.




(a) $\mu$=1×10$^{-3}$ Pa·s

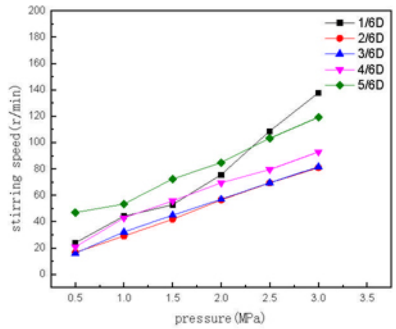



(b) $\mu$=8.3×10$^{-3}$ Pa·s

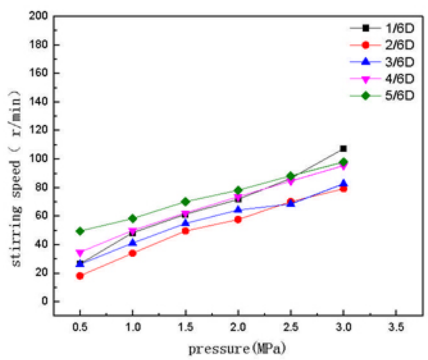



(c) $\mu$=16.9×10$^{-3}$ Pa·s

**Figure 6.** Effects of fluid pressure on stirring speed at different fluid viscosities and liquid levels



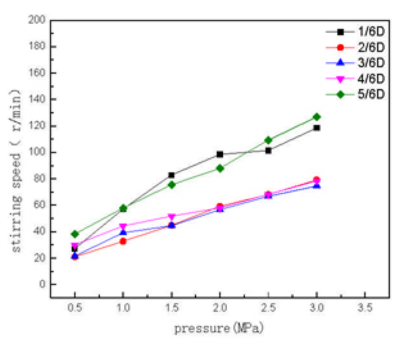

（d）$\mu$=21.8×10$^{-3}$ Pa·s



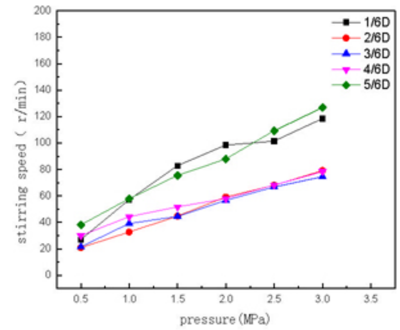

（e）$\mu$=33×10$^{-3}$ Pa·s

**Figure 6.** Effects of fluid pressure on stirring speed at different fluid viscosities and liquid levels

Figure 7 (a)~(b) show that the effects of fluid pressure on stirring speed with the fluid (viscosity $\mu$=1.0×10$^{-3}$ Pa·s) at different densities and liquid levels.




（a）$\rho$=1.3×10$^{-3}$ kg/m




（b）$\rho$=1.5×10$^{-3}$ kg/m$^3$

**Figure 7.** Effects of fluid pressure on stirring speed at different fluid densities and liquid levels

As shown in the figures above, in various conditions of viscosities and densities, the stirring speed increases with the increasing of fluid pressure, and the range of increase magnifies with the rise of liquid level.

## Conclusions

Effect of various conditions on stirring speed of tubular self-stirring reactor driven by pressure energy is researched in this paper. The main conclusions are as follows:

(1) Fluid pressure is the biggest of various factors which has effects on stirring speed, the stirring speed goes higher with the increasing of fluid pressure.

(2) The effects of density and viscosity on stirring speed are minor. Overall, when pressure is low, stirring speed slightly increases with the increasing of density, when the pressure exceeds 2.5Mpa, stirring speed instead slightly decreases with the increasing of fluid density. At liquid level of 1/6D, stirring speed fluctuates greatly with the variation of viscosity, in other conditions, the effects of viscosity on stirring speed are minor.

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