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Understanding the effect of pressure profile on stirred mill impeller wear

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ABSTRACT

Since about the late-1970s, stirred mills have entered into use in the mineral processing industry. Much work has focused on model developed for power, grinding and performance prediction. However, little effort is cited in the literature related to wear and particularly impeller wear.

In this paper, the focus will be on examining how two pressure profile models might affect stirred mill impeller wear profiles specifically in the gravity induced stirred mill case. The investigation will start with a re-visit of a mechanistic impeller wear model for stirred mills which includes some indications on how impeller wear affects mill power. Subsequently a review of a few pressure profile models analysis will lead to exploring the effect of the pressure profile on impeller wear. The paper will close with a discussion on how the model could be used to illustrate the effect of wear on any impellor design.

1. Introduction

Dating back to 1928 (Stehr, 1988), stirred mills took some 50 more years to before being introduced to the mineral processing industry by the Metso VERTIMILL® (Vertimill, 2015). This was followed by the IsaMill™ (IsaMill, 2013), Metso SMD (SMD, 2015), FLS VXPmill™ (VXPmill, 2014) and most recently Outotec's HIGmill™ (HIGmill, 2012). Since this time, much effort has been made to understand how power, grinding and overall performance can be predicted using models (Radziszewski and Allen, 2014; Radziszewski et al., 2016).

However, in terms of impeller wear in mineral processing applications, there are no references found in the literature for Metso's SMD or for FLS's VXPmill (formerly the Deswik mill). In the case of Metso's Vertimill, only some indication on impeller wear can be found through a paper on VTM maintenance (Allen and Noriega, 2011). More information is produced with respect to the IsaMill disk wear (Jayasundara et al., 2011) which indicates "*…that with increasing wear, impact energy increases…*". Although no data is found in the literature for Outotec's HIGmill, two references have been found. The first of which is corporate literature (Outotec, 2013) indicating that "*…the wear is faster in the bottom part of the mill and typically the lowest discs have to be replaced a few times before the total set is changed…*". This observation tends to be confirmed in a second reference regarding First Quantum Minerals account of HIGmill impeller wear indicating that "*…the grinding discs wore down very fast……every four weeks……FQM and Outotec have been reducing disc wear… …expected to last four to six months… …continuing optimisation work seeks to bring that even further…*" (Moore, 2015).

In an attempt to contribute to filling this void, a stirred mill impeller wear model was proposed (Radziszewski and Moore, 2015) for vertically stirred mills. The proposed model described impeller wear as a function of a hydrostatic pressure profile. The hydrostatic pressure assumption is acceptable for vertically fluidized stirred mills such as Metso's SMD, FLS's VXPmill and Outotec's HIGmill. However, in the case of gravity induced stirred mills such as Metso's Vertimill, the pressure profile is expected to follow a different pressure profile function such as the one defined for silos (Jankovic, 1998, 2001).

In this paper, the focus will be on examining how two pressure profile models might affect stirred mill impeller wear profiles specifically in the gravity induced stirred mill case. The investigation will start with a re-visit of a mechanistic impeller wear model for stirred mills which includes some indications on how impeller wear affects mill power. Subsequently a review of a few pressure profile models analysis will lead to exploring the effect of the pressure profile on impeller wear. The paper will close with a discussion on how the model could be used to illustrate the effect of wear on any impellor design.

2. Background

The model for vertically stirred mill impeller wear, reproduced below, ties the shear power model with an abrasion wear model

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which is a function of a hydrostatic pressure profile in the mill charge.

2.1. Shear power model

Stirred mill power can be estimated using a shear based power model (Radziszewski, 2013) which is a function of the medium (media and slurry) viscosity (η), auger angular speed (ω) and a parameter known as shear volume (V_τ):

$$P = \eta\omega^2 V_\tau \quad (1)$$

Shear volume is determined by first identifying the parallel shear surface pairs in a given mill and then calculating the shear volume for each shear surface pair. In the case illustrated in Fig. 1, there are three shear surface pairs which as the disk circumference and mill shell, the impeller shaft and the mill shell, and the disk and mill bottom.

The resulting shear volume is defined as:

$$V_\tau = A_{disk}\frac{r_{disk}^2}{y_{disk}} + A_{shaft}\frac{r_{shaft}^2}{y_{shaft}} + A_{end}\frac{r_{end}^2}{y_{end}} \quad (2)$$

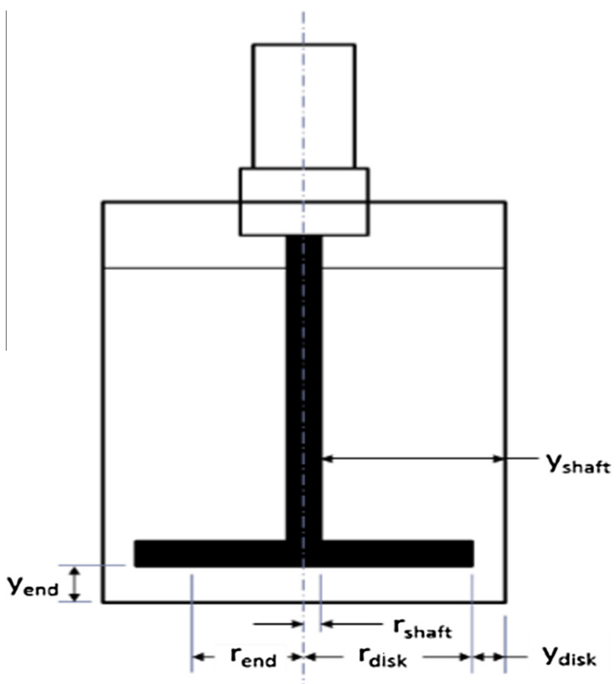

Fig. 1. Parallel shear surface pairs on a single disk impeller (Radziszewski, 2013).

where A_{disk}, A_{shaft}, A_{end} are the areas of disk circumference, the impeller shaft, and the disk bottom, and r_{disk}, r_{shaft}, r_{end} and y_{disk}, y_{shaft}, y_{end} are defined in Fig. 1.

After determining the shear volume and the viscosity of the medium, it is possible to estimate the power consumption of lab scale and of industrial scale mills (see Fig. 2).

It is noted that a generalised definition of the shear volume is found in Martins and Radziszewski (2015). However, this generalise definition can be approximated by dividing any impeller into a series of discrete disks as illustrated in Fig. 3 and calculating the shear volume of each individual disk "i" and summing the shear volumes as follows:

$$V_\tau = \sum_{i=0}^{n} A_i \frac{r_i^2}{y_i} \quad (3)$$

2.2. Abrasive wear model

Archard's abrasive wear model (1953) is at the centre of a number of abrasion wear model formulations. Essentially, volume wear rate ($\dot{V}_w$) is a function applied load (F), sliding speed ($\dot{x}$) and a material wear constant (K). If applied to a particular discrete disk "i" (Fig. 3), the volume worn would be defined as:

$$\dot{V}_{w_i} = K F_i \dot{x}_i \quad (4)$$

2.3. Hydrostatic pressure profile

Thus the pressure (p_i) acting on the impeller at any given point i down into the charge is a function of the charge depth (h_i), gravity (g) and the medium density (ρ_{med}):

$$p_i = \rho_{med} g h_i \quad (5)$$

Therefore, the applied force (F_i) in wear would then be a function of the surface area (A_i) of that the shearing surface at that charge depth such that:

$$F_i = A_i p_i \quad (6)$$

Furthermore, if "any given point down the charge" equates to "any given disk" described in the shear volume approximation described in Fig. 3, it will be possible to associate pressure acting on any given discrete disk slice and therefore the applied force acting on that discrete slice too.

2.4. Vertimill auger wear profile estimate

Knowing the applied force acting on the impeller at any given charge depth, it then becomes possible to use the wear model to

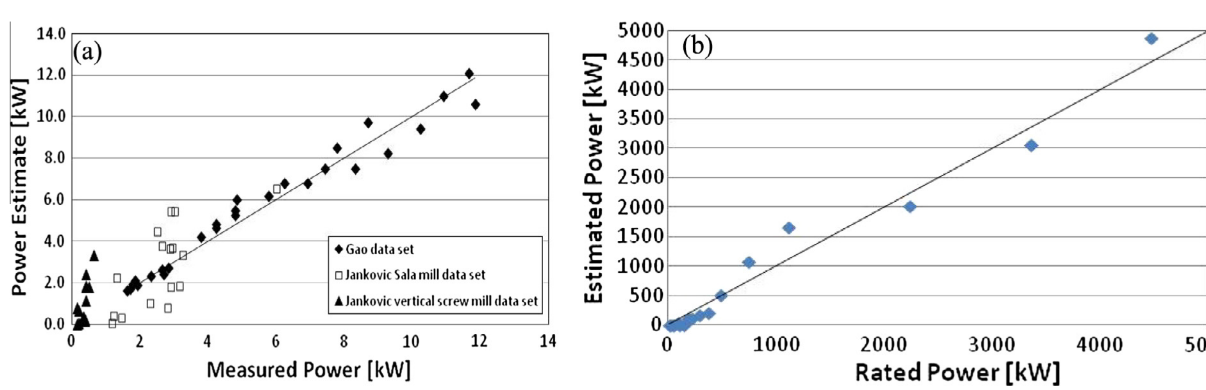

Fig. 2. Stirred mill shear power correlation. (a) Lab scale correlation (Radziszewski, 2013). (b) Industrial scale correlation with Vertimill installed power (Radziszewski and Allen, 2014).

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