Prosimy cytować jako: Inż. Ap. Chem. 2009, 48, 4, 58-59

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Study of erosion wear of pitched blade impellers in a solid-liquid suspension

Introduction

In all areas of particulate technology where solid particles are handled, structures coming into contact with particles exhibit wear. A major constraint of high intensity agitation is the possibility of developing erosion wear of the impeller blades due to the presence of solid particles in the liquid [1, 2]. In some applications, this wear can be so severe as to limit the life of a component, while in others it may be negligible. All particles cause some wear, but in general the harder they are, the more severe the wear will be [3]. The materials used in plants differ in their susceptibility to erosive wear in the mechanism by which such wear occurs.

The erosion of a pitched blade impeller caused by particles of higher hardness (e.g. corundum or sand) can be described by an analytical approximation in exponential form of the profile of the leading edge of the worn blade (Fig. 1).

$$H(R) = 1 - C\exp[k(1 - R)] \quad (1)$$

where the dimensionless transversal coordinate H along the width of the blade is

$$H = y(r)/h \quad (2)$$

and the dimensionless longitudinal (radial) coordinate R along the radius of the blade r is

$$R = 2r/D \quad (3)$$

Parameters h and D characterize the blade width and the diameter of the impeller, respectively.

The values of the parameters of Eq. (1) – the wear rate constant k and the geometric parameter of the worn blade C – were calculated by the least squares method from the experimentally formed profile of the worn blade. While the wear rate constant exhibits a monotonous dependence only on the hardness and shape of the solid particles and on the pitch angle α the geometric parameter of the worn blade is dependent on the pitch angle, hardness and thickness of impeller blades, impeller speed, suspension properties, and, in a linear form, on time [4–6].

$$C = C_t\, t \quad (4)$$

The values of wear rate constant k and the dependence of parameter C_t in Eq. [4] on tested parameters of impeller and suspensions obtained experimentally are listed in [4–6].

Experimental

A pilot plant mixing vessel made from stainless steel was used (Fig. 3), with water as a working liquid (density ρ_l = 1000 kg/m^3, dynamic viscosity μ = 1 mPa.s) and particles of corundum (mean volumetric particle diameter d_p = 0.15, 0.21, 0.29 and 0.34 mm, mean volumetric concentration of particles c_v = 2.5, 5, 7.5 and 10%). Pitched blade impellers (Fig. 4) with four adjustable inclined plane blades made from construction steel or from other metallic materials for their hardness effect investigation (pitch angle α = 30°, impeller diameter D = 100 mm, hub diameter D_0 = 20 mm, width of impeller blade h = 20 mm), pumping downwards were investigated in a fully baffled flat bottomed cylindrical agitated vessel (vessel diameter T = 300 mm, four baffles of width b = 30 mm, impeller off-bottom clearance C = 100 mm).

The impeller speed was held constant n = 900 min^{-1} during an investigation of the influence of the properties of blades or suspension characteristics, and three levels of this quantity (900, 1050 and 1200 min^{-1}) were selected for determining the dependence of the wear rate on the impeller speed. The impeller speed was held within accuracy ±1% and the lowest level of this quantity corresponded for all investigated values of d_p and c_v to complete homogeneity of the suspension under a turbulent regime of flow of an agitated batch. The preliminary experiments were made visually in a perspex mixing vessel under the same conditions as for the erosion wear experiments. It follows from the results that, for all conside-

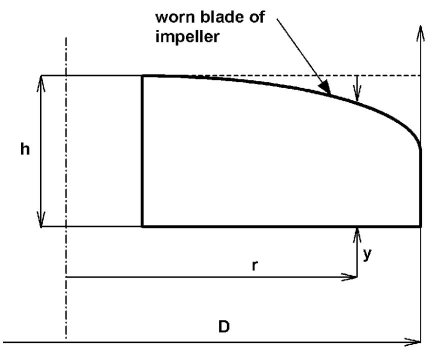

Fig. 1. Radial profile of the leading edge of the worn blade of a pitched blade impeller

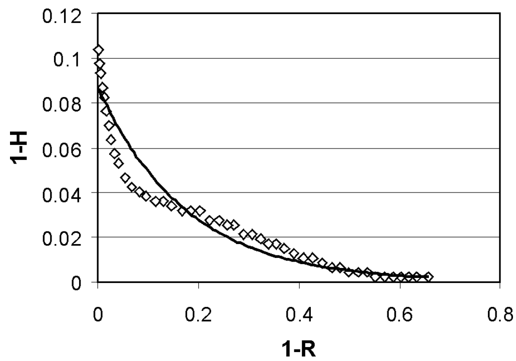

Fig. 2. Example of evaluating of the shape of a worn impeller blade

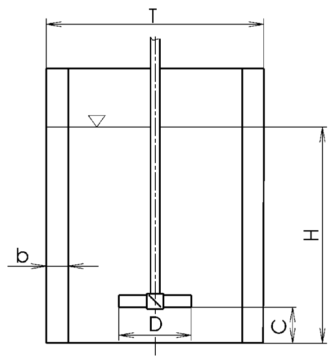

Fig. 3. Geometry of the pilot plant mixing vessel (T = 300 mm, H/T = 1, D/T = 1/3, C/D = 1, b/T = 1/10)

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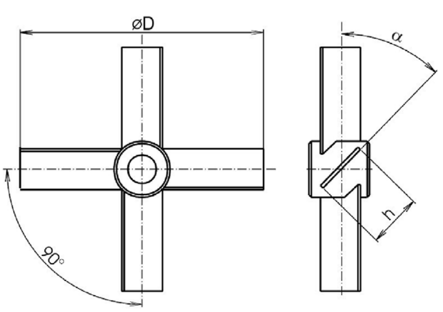

Fig. 4. Design of a pitched blade impeller with four inclined plane blades (D = 100 mm, D_0/D = 0.2, h/D = 0.2, α = 30°)

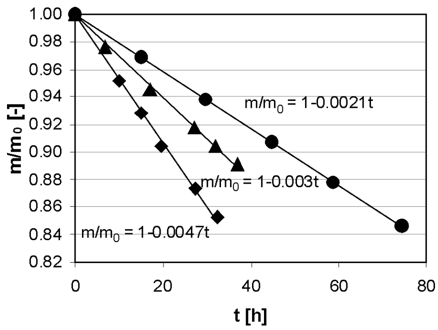

Fig. 5. Time dependence of the relative weight of the impeller blade for different levels of impeller blade thickness: ♦ s = 0.6 mm, ▲ s = 1 mm, ● s = 1.3 mm

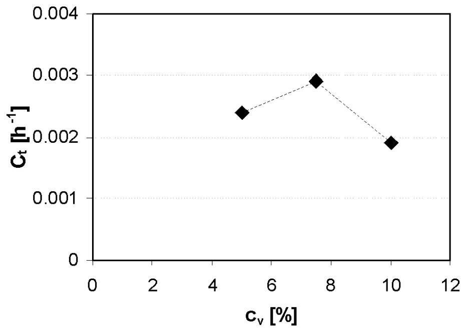

Fig. 6. Dependence of parameter C_t on the average volumetric particle concentration c_v (d_p = 0.15 mm)

red sizes and concentrations of the particles of corundum, there was 90% homogeneity of the suspension at impeller speed n = 700 min^{-1}.

During the experiments, the shape of the blade profile was determined from magnified copies of the worn impeller blades scanned to a PC. The parameters of the blade profile for the given time of the erosion process were determined from each curve of four individual worn impeller blades. The selected time interval from the very beginning of each experiment was not to exceed the moment where the impeller diameter began to shorten. Then the values of the parameters of Eq. (1) – the wear rate constant k and the geometric parameter of the worn blade C – were calculated by the least squares method from the experimentally found profile of each worn blade at the given time interval t of the erosion process. Each curve was calculated from at least 30 points (H, R) with a regression coefficient better than R = 0.970 (see example in Fig. 2). The resulting values of parameters k and C were the average values calculated from all individual values of these parameters for each blade. It can be mentioned that the chosen shape of the regression curve $H = f(R)$ fits best to the experimental data among other possible two-parameter equations (e.g. an arbitrary power function or the second power parabola).

After the investigation of the shape of the worn blade, the weight of the blade was measured. All four blades were weighed on a scale with an accuracy ±5 mg, and the weight of the blade m related to its initial weight m_0 (relative weight) was calculated at a given time (period) of the erosion process. The average value of the weight of the blade was calculated as the mean from all measured weights of the four individual blades. In this way the dependence of quantity m/m_0 on time t was obtained in linear form

$$\frac{m}{m_0} = 1 - C_m t \tag{5}$$

where the values of parameter C_m are listed in [4–6].

Hardness and thickness of impeller blades

The metallic blades of tested impeller [5] were made from various materials of different hardness (*Vickers* hardness *HV*), i.e. aluminium alloy Al 99.8 (HV10 = 34), aluminium alloy Al 99.5 (HV10 = 40), rolled brass Cu Zn 37 (HV10 = 74), construction steel C 10E (HV10 = 112), stainless steel X5CrNi18-10 (HV10 = 194). A two parameter equation Eq. (1) describing the shape of a worn blade during the erosion process of a pitched blade impeller in solid-liquid suspension was investigated. It follows from the experiments made in this study that the wear rate constant k is independent of both time and blade material hardness, while the worn blade geometric parameter C increases linearly with time and decreases almost hyperbolically with increasing blade hardness.

Figure 5 illustrates the time dependences of the relative weight of a worn impeller m/m_0 at three tested levels of blade thickness s (s = 0.6, 1 and 1.3 mm). The erosion wear rate of the impeller blades practically lineary increases with decreasing relative thickness of the impeller blade.

Impeller speed

The results of impeller speed effect investigation [6] confirm that the wear rate of a pitched blade impeller depends significantly on the impeller speed. This dependence is expressed in $C_m \approx n^{2.7}$ and $C_t \approx n^{2.4}$, while the wear rate constant k does not exhibit any change within the tested impeller speed interval. The power at both dependences $C_m = f(n)$ and $C_t = f(n)$ exceeds two, so it does not depend only on the square of the velocity of the solid particles in a suspension, i.e. not only on their kinetic energy [3]. For metals, the value of the exponent at n can be considered within the interval 2.3–3 [7].

Suspension characteristics

The erosion wear rate of the impeller blades increases with increasing size of the particles [6]. However, the erosion rate of the pitched blade impeller increases up to a certain critical level of the average particle concentration, and then it decreases with increasing c_v (see example on Fig. 6). This finding is in accordance with the general observation [7] that above some critical particle concentration the mutual interaction between striking and reflecting particles reduces their kinetic energy, and their influence on the metal surface of the impeller blade is reduced.

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