Various types of centrifugal pumps are used for handling solid–liquid mixtures, which are characterized by their ability to convey solid particles of different size, hardness, concentration and speed. This multitude of factors, which influences pump selection, leads us to suggest that the best option for the construction of pumps is where the angular speed and the properties of the mixture are ideally related to the transport system. Centrifugal pumps for handling mixtures are usually designed for specific applications. When this involves transporting large solids and/or high concentrations, component wear will be a major factor and must be considered in the pump selection and the pump installation configuration. The major erosive mechanisms inside a pump that is conveying mixtures are sliding abrasion and particle impact. This article also studies the influence of wear on the operating parameters of these pumps.

Solid–liquid slurries are transported over short and medium distances via pipelines in many mining, industrial and fossil-fuel related processes. In a centrifugal slurry pump transport system, a critical component encounters some of the most erosive environments, resulting in high wear and short life. Wear inside the pump casing is a function of the operating conditions, the geometry of the casing collector and the wear-resistant properties of the material. The transport of abrasive mixtures causes rapid wear of the pump parts, especially at the exit of the impeller, due to the hardness of the solid particles, which negatively affects the pump's performance.

The reduction in the impeller diameter and, consequently, the efficiency causes an increase in the associated energy costs. The wear of the pump parts increases as the concentration of the mixture increases.

Statistics show that:
- 50% of spare parts are impellers,
- 25% are volute casings,
- 25% are distributors and other parts.

Modelling wear
A numerical model was developed by Roco and Addie to obtain speed, concentration and erosive wear in the...
erosion rate using the following relationship \( \text{Erosion rate} = K \cdot d \cdot V^m \cdot \mu^n \)

where \( d \) = particle diameter,

\( V \) = speed,

\( \mu \) = viscosity,

and \( K, l, m, n \) are coefficients to be determined experimentally.

However, these attempts did not lead to useful results.

Abrasion occurs when the solid particles are forced between two surfaces that are moving with respect to the other. For the centrifugal pump, this may occur anywhere where there is relative movement and narrow gaps.

### Wear of rotary parts

To predict the erosion, one requires knowledge of the two-phase flow field, so that the wear coefficients \( K_1, l, m, n \) can be determined experimentally. Many efforts have been made over more than 20 years with the aim of formulating calculations for the weak points of the impeller blade, the erosion speed, and the influences of concentration and particle size. Firstly, these methods still present severe limitations and none makes it possible to answer all the problems arising unless they are simple cases. Moreover, these methods demand significant computing power to solve the Navier-Stokes equations describing the fluid flow. Secondly, the method involves evaluating the removal of material from what is known as an erosion experimental origin model and which constitutes the basis of the method. The magnitudes obtained by calculation become input values in the erosion model.

### Constructing the erosion model

The erosion rate is a function of the speed, direction, size, form, particle density, material nature, etc. Wear decreases with the decrease in size of the solid particles as well as of their concentration. Hunt and Faddick \( \text{show that the relationship between the concentration and wear is linear for a concentration of about 10% by volume.} \)

We carried out experiments on a Russian centrifugal pump of type 5.P8, which show the change in the head and efficiency characteristics after transporting 220, 960 and 990 tonnes of a typical mixture (in this case, a phosphate mixture of density, \( \rho_s = 2.8 \text{ t/m}^3 \) and particle diameter, \( d_p \leq 0.3 \text{ mm} \)). It can be observed that the head decreases by 25% at 990 tonnes (see Figures 1 and 2).

### Operating variables

#### Impeller type

Currently, a definition of abrasiveness does not exist but it is related to the hardness of the solid, to the nature of the contact between the solid particles and the pump parts and to the characteristics of the materials from which the pump is constructed. Table 1 shows some of the most common pump construction materials as a function of the hardness of the transported rock particles.

It is observed that the impeller shape influences the characteristics of a pump working with solid–liquid mixtures. For an open pump impeller handling a mixture of a given concentration, efficiency (\( \eta \)) decreases by 4–6% and power (\( P \)) increases by 5–8% from the values for the same impeller pumping water. In comparison, for a closed impeller pump, efficiency decreases by 20–30% and power increases by 20–30% for the same mixture concentration. According to the results obtained (Table 2), it can be seen that open impellers are better adapted to the transportation of solid–liquid mixtures.

#### Pump selection

The parameters that influence the selection of pumps for handling mixtures are:

- The density of the solid
- Mixture concentration
- Particle size
- Abrasiveness

The appropriate selection depends mainly on the application. Each case will have its own design parameters, and the principal ones are: flow, head, maximum particle dimensions and the abrasiveness of the
mixture. For the transport of mixtures, single-stage centrifugal pumps are used.

Speed/wear interaction

The majority of centrifugal pumps are conventionally designed for precise hydraulic performances with maximum efficiency and minimum operating cost. No manufacturer’s limit is imposed as regards pump configuration, since conventional materials such as cast iron, bronze and steel alloys are used. The highest specific speed is generally selected because wear is not taken into account as being a significant factor.

In contrast, when considering pumps for transporting mixtures, the factors with the greatest influence on the design are the wear and the material, whereas the efficiency is less important. To achieve these goals, pumps must function at a lower angular speed, and the impeller must be designed for radial flow. The impeller wear is proportional to the operating time (see Figure 3). It can be confirmed according to our tests that the particle size affects the deterioration of the impellers considerably. Therefore, it can be deduced that, in order to prolong the lifespan, the selection of the impeller material will mainly depend on the size of the transported particles.

Conclusions

The conclusions illustrated by this case study are:

- For centrifugal pumps handling mixtures, it is recommended that open impellers are used. This will facilitate the circulation of the mixture and hence reduce the blade wear and increase the flow.

- The wear of the centrifugal pump’s impellers is directly related to the concentration and size of the solid particles.

- In order to increase the lifespan when conveying solid-liquid mixtures it is rational to drive the pumps at a low angular speed. Wear is related to the relative velocity between the pumped liquid and the pump parts. A large variety of metals are used for slurry pumps, due to the diverse range of applications. A given mixture can be erosive, abrasive, or erosive and abrasive. Proper material selection depends both on knowledge of the properties of the mixture to be pumped and on the pump design.

Table 2. Comparison of the centrifugal pump results for different impellers*

| No. of | Speed | | Percentage to | | |
| Pump | diameter | passages | type | (rpm) | with respect to | water |
| type | (mm) | | | | | |
| 1 | 24 | 5 | Open | 860–1600 | –4 to –6 | +5 to +8 |
| 2 | 24 | 2 | Closed | 950–1550 | –20 to –30 | +20 to +35 |
| 3 | 30 | 2 | Closed | 850–1160 | –5 | +7.5 |
| 4 | 25 | 2 | Closed | 1000–1600 | –4 to –6 | +1 to +3 |

*Data from Ref. 10.

References


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