SCIENTIFIC
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Durability analysis of rotor mill working components during the micronisation of oat seed coats

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ABSTRACT:

The paper presents the results of operational tests aimed at verifying the durability of a rotor mill's working components. Its rotor and beaters were made of heat-treated 40HM steel. The material subjected to micronisation was oat grain seed coats with a moisture content not exceeding 8%. Micronisation process efficiency was assumed as the parameter determining equipment wear. Its decrease by 30% was set as the process profitability limit and the moment when the working components, beaters, should be replaced. Conducted research allowed the working time of beaters without a significant efficiency loss to be determined – 50 h for the tested parameters and materials.

Analiza trwałości elementów roboczych młyna wirnikowego przy mikronizacji okrywy nasiennej ziarna owsa

Słowa kluczowe: trwałości, zużycie, mikronizacja

STRESZCZENIE:

W pracy przedstawiono wyniki badań eksploatacyjnych dotyczących trwałości elementów roboczych młyna wirnikowego. Jego tarcza i bijaki zostały wykonane ze stali 40HM ulepszanej cieplnie. Materiałem poddanym mikronizacji była okrywa nasienna ziarna owsa o wilgotności nie przekraczającej 8%. Jako parametr określający zużycie przyjęto wydajność procesu mikronizacji. Jego spadek o 30% przyjęto za granicę opłacalności procesu i moment, w którym należy wymienić elementy robocze w postaci bijaków. Na podstawie badań wyznaczono czas pracy bijaków nie powodujący istotnego zmniejszenia wydajności, który wynosi dla badanych parametrów i materiałów 50 h.

1. INTRODUCTION

Comminuted materials are used in many processes in various industries. They are obtained through the use of mills of various types [1, 7]. They differ in structure, efficiency [4] and the obtained comminution level [1]. The food industry is one of those in which certain raw materials with grain sizes below 100 µm are used in large quantities, which necessitates high-performance mills. Mill components demonstrating high durability will result in a cheaper milling process, while a smaller number of particles generated through wear will be introduced into the final product.

The comminution process [4, 9] consists in breaking down solids into smaller parts using external forces that destroy the internal cohesion of the said solids' structure. In accordance with the PN-72/C-47270 standard, comminution can be divided into two processes: crushing and milling. The criterion for the division is a larger or smaller proportion of grains above or below 1 mm in size. Various mill designs have been developed to meet efficiency and fineness requirements for the product. It is important to define the method and conditions of the energy transfer to the milled material by the mill's working components. According to literature on the subject [4, 7], the basic methods of milling in mills are crushing, impact force, grinding or breaking. Actually, all these processes occur simultaneously, but one dominates depending on the employed design solution. Therefore, appropriate selection of the technical and technological parameters of the mill for the specific type of milled material is of such importance [6].

Aside from its design, the selection of a material intended for the working elements of the mill is an important issue. It will affect the structure's reliability, the product quality, as well as the device's operational costs [3, 5]. This requires knowledge of the wear processes occurring when performing comminution of a particular raw material in a mill of a given type. In the food industry, it is important for wear products to not contaminate the milled material.

Rotor mills ensure high efficiency while allowing comminution to a size below 100 µm. Milling in them is the result of dynamic contact of a particle with the mill rotor beater and the chamber wall (Fig. 1). The material's particle breaks up and changes shape, while the mill beater erodes [5]. Both processes are interdependent. Once broken up, the particles are routed to a classifier, which allows those of the right size to pass and returns those of excessive size to the milling chamber [1].

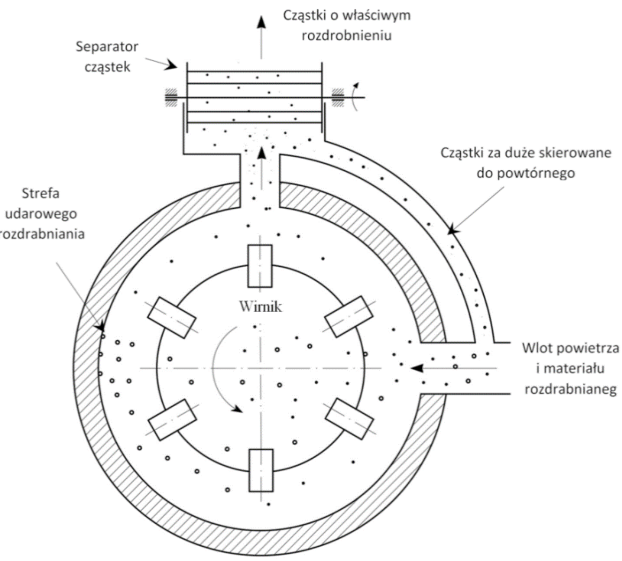

Figure 1 Operational diagram of a rotor mill with particle separation

In rotor mills the erosive wear of the beaters and rotor material occurs in a stream of solid particles (e.g. cocoa husk, oat husk, etc.). This wear is the result of the action of a mixture of loose grains suspended in gas, hitting the beater surface at high velocity. The impact's effects depend on the kinetic energy of the grains and apply to both the milled grains and the impacted material [2, 4]. Under set operating conditions the erosive wear of materials depends largely on their mechanical properties [3, 5, 8].

2. RESEARCH SUBJECT

The study analysed the working components of a rotor mill, worn out during the micronisation of oat seed coats. This is a grain fraction obtained in the dehusking process. The micronised raw material had a moisture content of less than 8%.

The rotor mill was part of the fibre micronisation line. Its operating parameters are given in Table 1.

Table 1 Rotary mill operating parameters

Parameter	Value
Rotor rotation speed	3710 rpm
Classifier rotor speed	2890 rpm
Mill capacity	500 kg/h
Air flow	2 m^3/s

Working components in the form of the mill's beaters and rotor (Fig. 2) were made of 40HM steel and heat treated.

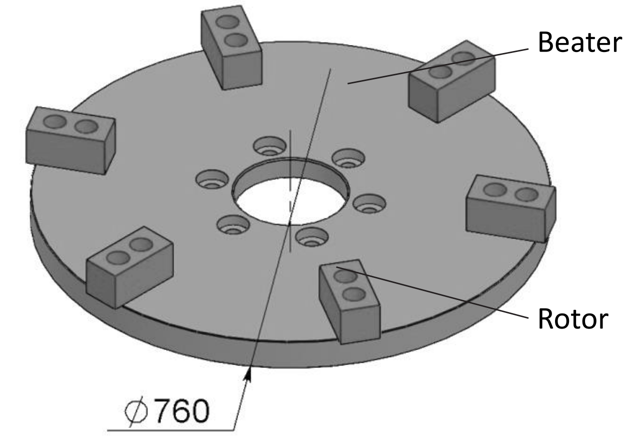

Figure 2 Working components – beaters and rotor

3. RESEARCH RESULTS AND DISCUSSION

The durability of working components during the micronisation of the oat seed cover was tested experimentally, by weighing the micronised material every hour. A 30% drop in efficiency was assumed to indicate excessive wear of the mill's working components. The total test time was 60 hours. The obtained result is shown in Figure 3.

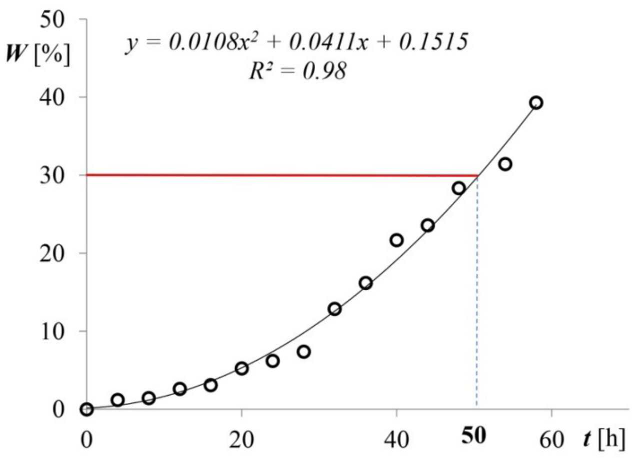

Figure 3 Decrease of efficiency *W* depending on the micronisation time *t*

The obtained results served as the basis for a polynomial describing the micronisation process efficiency decrease due to mill working component wear over time, which has the following form:

$$W = 0.0108x^2 + 0.0411x \mp 0.1515.$$

Working components in the form of rotors and beaters showed clear signs of wear after 60 hours of operation (Fig. 4).

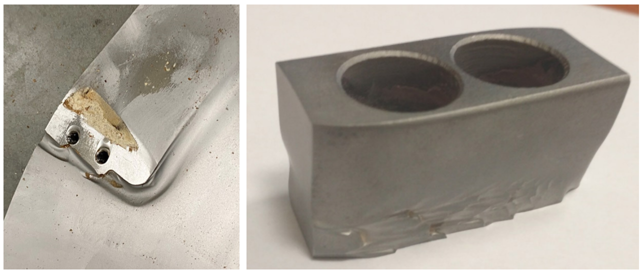

Figure 4 View of the rotor mill's working components after 60 hours of operation (micronised material – oat seed coats, humidity <8%)

4. CONCLUSIONS

The conducted operational tests made it possible to determine the durability of the rotor-jet mill's working components. The obtained results can be related to the material (40HM steel) and the operational parameters used. If the device's operating parameters change or a different raw material is used, the durability of the components may differ from those determined in the experiment.

Analysing the obtained results, it can be concluded that:

• a 30% decrease in efficiency occurs after approximately 50 hours of microniser operation,
• 60 h of micronisation of the oat seed covers leads to a process efficiency decrease of approximately 40%,
• the durability of the microniser's working components allows about 18 tonnes of oat seed covers to be micronised,
• the following polynomial can be used to predict the durability of the microniser's working components:.

Conflict of Interest:

The authors declare no conflict of interest.

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