Figure 1: Debranned Durum wheat

DURUM WHEAT DEBRANNING

Innovative diamond wheels - technical and economic advantages

Debranning has the aim to remove the outer layers of the pericarp from wheat kernels (Figure 1). Increasing number of industrial and research studies reports the advantages of debranning Durum wheat prior to milling:

- It will improve the yield and refinement of semolina in durum wheat milling, as the quantity of bran that contaminates the product will be significantly lower.
- Debranning will ensure a higher chemical safety of the products coming out from milling, as the main contaminants rate is contained in the bran layers (mycotoxins).
- Debranning can lower capital investment because mill flow is shortened (it needs less break and separation phases to reach the desired semolina or flour refinement).
- It speeds up the hydration process of grain prior to the milling phase (without the pericarp layers, the water penetration inside the kernel is faster and more uniform).
- If desired, debranning can allow removing the seed coat layers one by one, separately from the aleurone layer. This offers the opportunity for a products diversification.

The study was carried out as part of a collaboration between the company OCRIM, the Industrial Engineering Department of the University of Parma and the spin-off company of the University of Parma FMB-Eng.In.E.. Ocrim is a worldwide leading plant producer for the milling sector, with particular reference to wheat milling.

Ocrim already produces debranning systems, based on the use of traditional silicon carbide wheels. However the mineral nature of these traditional wheels, can lead to the formation of cracks and crevices after a certain number of production cycles. For this reason, Ocrim proposed an innovative grinding wheel, with a metallic support structure and a thin surface deposition of synthetic diamonds.

Through an experimental campaign and a statistical based data analysis we could demonstrate that innovative wheels are much more reliable, have a longer operating life and are cost-effective compared to the traditional ones.

Diamond VS traditional wheels: performance evaluation

The experimental tests were conducted partially at the Industrial Engineering Department of the University of Parma and partially at a production site, a Durum wheat mill located in U.S.A., whose grinding line was provided by Ocrim. The wheat produced and processed in this area is recognised as one of the toughest in the world, so the wheels have been operating under particularly stressful conditions.

The mill has two parallel debranning lines, each operating at a 4 tons/hour productivity. One of the two debranners has been equipped with a whole grindstone package of silicon carbide wheels. In the other one, the two lower wheels (the sixth and the seventh) have been replaced with diamond wheels (Figure 2).

The diamond wheels have a superficial layer in which syntactic diamonds are partially incorporated. The diamonds have a dimensional distribution around a particular value guaranteed by the producer. The performance of the systems were evaluated using three Key Performance Indicators (KPI). To be conservative, the wear indicators have been calculated on the last wheel of the grindstone package, the one most subject to stresses.

- The first, KPI1, was the debranning ratio. It is the ratio between the overall processed mass of wheat and the relative separated mass of bran. The variation of this KPI over time is an indication that the system is losing its effectiveness.

- The second, KPI2, is an indicator of the wear of the diamonds. At various time steps, the size distribution of the diamonds was determined via image analysis.
- The third, KPI3,is related to the portion of surface of the wheels covered with diamond. During operating cycles, diamonds are not only subject to wear, and therefore to dimensional reduction, but also to detachment. This phenomenon is well described by this indicator, which monitors the percentage variation of the surface covered with diamonds over time.

KPI 1: Trend of debranning rate in time

The experimental campaign was planned to give statistical significance to the results. We chose three measurement points, where we followed a rigorous approach, composed of a series of specified samplings. During the tests, we also varied the power absorption of the machine. At a constant flow rate, it can be assumed it is proportional to the residence time of the wheat inside the debranning machine. The debranning results obtained are collected in Table 1.

From a first analysis of the results, we could draw some important considerations:

- With the diamond wheels, we noticed an important improvement in debranning yield when increasing the absorption of the machine.
- After one year, the yield with diamond wheels is still very good, while with silicon carbide wheels the performance suffered a deterioration.

During experimental tests we also noticed that diamond wheels are certainly much better from a reliability point of view. Their wear is more gradual, and the metal structure, base to the layer of synthetic diamonds, prevents event of sudden rupture, to which are instead subject the traditional grinding wheels, for their mineral nature.


Figure 2 - 3D rendering of the grindstone package with two diamond wheels

The wear of the grindstone package, after 12 working months, was evident especially from a visual standpoint. We could observe an important thinning of the debranning material layer, along with a shape deformation. For this reason, the company decided to replace the wheels after a few weeks from the measurement intervention, therefore after about 1 year from the installation.

KPI 2 & 3: Wear indicators for the diamond wheels

To determine the surface wear of the diamond wheels over time we used, as mentioned, an Image Analysis tool. The software was developed by FMB Eng.In.E., spin-off company of the University of Parma. We took a series of 150 photographs randomly on all the surface of the diamond wheel. This operation was conducted on the new wheel and after one year of operation, and we observed the variations.

To extrapolate the first KPI, we measured all the diamonds on the pictures and calculated their dimensional distribution.


THE PEAK IN PRODUCTION
You are at peak production with our turnkey solutions in sustainable grain milling technology.
Milleral
25 YEARS
INTEGRATED MILLING SYSTEMS

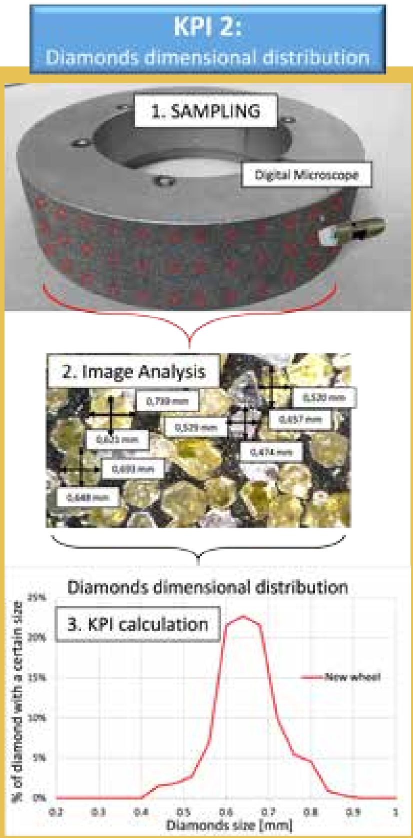


Figure 3 - Diagram of the procedure used to calculate the KPI2. Another important aspect that influence the debranning

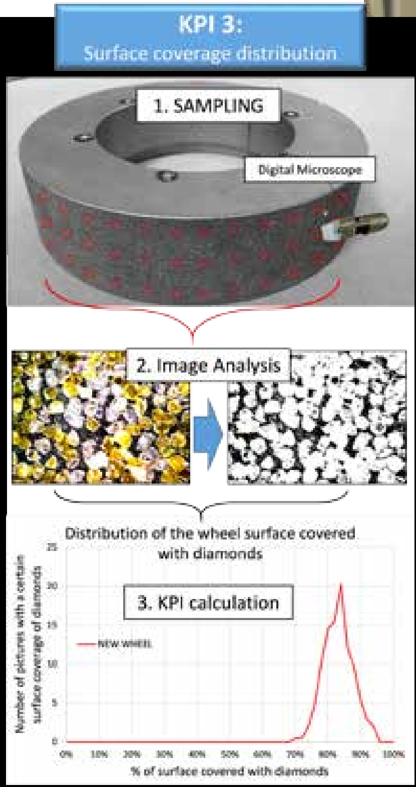


Figure 4 - Diagram of the procedure used to calculate the KPI3. The indicators were very important to quantify the wear process of the diamond wheels over time

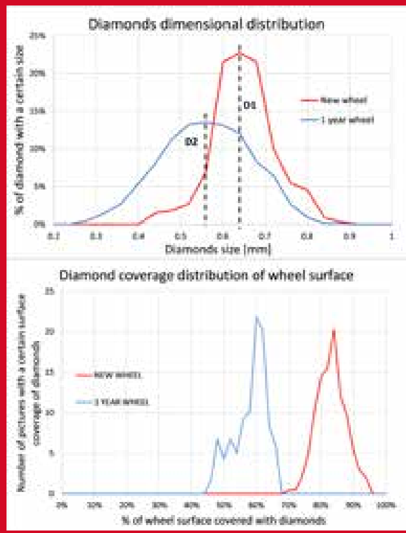


Figure 6 - Diamonds dimensional distributions obtained with Image Analysis (top) and distribution of the area covered with diamonds (bottom)

Figure 3 shows exactly the procedure used calculate the second KPI: the graph at the bottom refers to the dimensional distribution of the diamond on the new wheel.

effectiveness is the overall percentage of surface covered with diamonds, expressed by KPI3. The software was able to recognise, analysing the colours, the portion of the image consisting of diamonds and the portion consisting of free metallic surface. The procedure was repeated on each image, in order to define a coverage mean level and a coverage distribution of the wheel. This operation is represented in Figure 4. The graph at the bottom indicates the diamonds coverage distribution on the new wheel. It was constructed from the coverage index extrapolated from each of the 150 pictures.

Comparing the data obtained during the two experimental campaign (on the new wheels and after one year), the results obtained can be observed in Figure 6. After one year there is a clear decrease in the average diamonds size and a spread of the distribution. The upper graph represents the dimensional distribution of diamonds: after one year there was an average size reduction of about 15 percent. The lower graph, instead, shows the distribution of the percentage of surface covered with diamonds on the 150 pictures analysed. After 12 months, the average value passed from 80 to 60 perent, as shown in Figure 6 (bottom).

Table 1 - Debranning yields obtained from the experimental tests on the two debranning machines

DHB North	Diamond	Silicon Carbide
Time 0- installation		
65 [A]	7.4%	8.1%
75 [A]	9.5%	9.0%
85 [A]	11.7%	9.3%
Time 1-3 months		
65 [A]	7.6%	8.3%
75 [A]	9.2%	9.0%
85 [A]	11.0%	9.3%
Time 2-12 months		
65 [A]	7.7%	7.9%
75 [A]	9.1%	8.5%
85 [A]	10.9%	8.7%

Considering all these aspects, we could observe three main deterioration mechanisms:

1. Reduction of the average size of diamonds.
2. Variance increase of the dimensional distribution of the diamonds: wear is not a regular and controlled phenomena, therefore its effect are not always the same.
3. Reduction in the average number of diamonds per unit surface: in some cases, wear can lead to a sudden detachment of the diamonds.

All these phenomena alter the functionality of the debranner. To ensure the same performance with a worse wheels condition, the power absorption of the machine must be increased. However, after a certain useful life, the wheels must be replaced. Useful life, anyway, resulted much higher than the one of traditional wheels.

Life-cycle of diamond wheels

Traditional silicon carbide wheels have an average useful life of about one year, which can vary as a function of the processed product. After this period usually the conditions of the devices are too compromised and they need replacement.

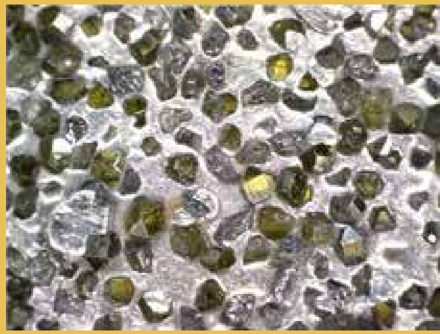
Since after one year the diamond wheels resulted still functional, we had to develop a predictive model, to extrapolate their behaviour over time. We used the three KPIs, regarding debranning rate and surface wear, to find out the relationship between diamonds conditions and the obtainable decortication yield over time. This in order to define a plausible useful life of the devices.

The life-cycle curve obtained is represented in Figure 7. The performance shown by the curve remains constant for about 12 months, despite diamonds wear has already begun. Later the wear becomes too heavy and the debranning rate starts to decline. Moreover, the performance drop is not expected to be linear, as the wear is not constant. It worsens more than linearly with time. In the last months, hence, the process will be faster. This trend is different from that of the traditional wheels, for which the debranning yield stars to decrease from the beginning.

Results indicated an expected life period of about 28 months for diamond wheels. This value refers to the wheel located in the most stressful position, namely the last one of the grindstone package. It represents a considerably better result if compared to the average duration of one year of the silicon carbide wheels. In addition, diamond wheels wear is a much more controllable process as the diamonds are embedded in a resistant metallic substrate.

Ultimately, the diamond wheels resulted much more durable and reliable than the silicon carbide ones.

Surface detail of a new wheel



Surface detail after 12 months

Figure 5 is a clear example of the surface deterioration of the wheels

Economic considerations

We considered a series of costs connected with the functioning of the machine. Obviously, the overall cost of a certain solution comes not only from the initial investment, but also from various operating costs. In our analysis, we concentrated on differential costs, which are mainly connected with the maintenance interventions, as the traditional and the diamond wheels machines are supposed to ensure the same debranning performance.
For instance, we considered costs resulting from maintenance interventions (downtime and workings), but also opportunity costs and product discarded. The incidence of these variables is inversely proportional to the useful life of the grinding wheels: a longer life will result in lower operating costs.

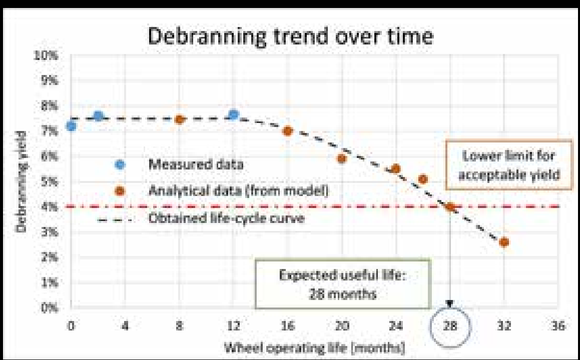


Figure 7 - Graph of the debranning trend over time for a diamond wheels debranning machine.

Figure 8 - Annual equivalent cost of the grinding wheels VS duration of the package: determination of the temporal break-even point for two diamond wheels solutions

As said, a grindstone package is composed by seven wheels. The experimental tests described, used a package with only two diamond wheels. This number could however be increased, up to a grindstone package entirely composed by diamond wheels. For this reason, we applied the differential economic approach to the different scenarios.

Considering a useful life of one year for the silicon carbide wheels, they gave a certain operating annual cost. This level was compared with the annual cost of a grindstone package with diamond wheels, which was calculated as a function of the lifetime of the devices. The aim of this analysis was to find out a break-even point between the plant solutions, i.e. the duration of the diamond wheels that ensures the same level of operating costs of the traditional ones.

The plant solutions with two diamond wheels gave a break-even point of about 15-16 months (see Figure 8), while with seven diamond wheels the break-even point is at 23-24 months. Obviously, the intermediate solutions gave a break-even point between 16 and 24 months. Anyway, all the different cases involving diamond wheels ensured better economical results compared to the silicon carbide grindstone package, as their duration was estimated to be at least 28 months. This means that the difference in the initial investment cost is more than offset by the improved performance of diamond grindstones.

Conclusions

The study highlights a series of advantages connected with the substitution of traditional silicon carbide wheels with diamond wheels for the wheat debranning process. The analysis focused on both operational and economic evaluations, and allowed to obtain some important conclusions:

- Data show a slower decrease of the debranning yield over time using diamond wheels compared to the traditional ones.
- After 12 months of working, despite a certain superficial wear, diamond wheels still maintained their debranning performance.
- The useful life of a diamond wheel was estimated to be at least of 28 months, thus more than twice in comparison to the 12 months duration of the traditional wheels. Moreover, diamond wheels, thanks to their metallic and not mineral structure, have a much higher reliability, and ensure a superior stability.
- Despite a superior initial investment cost, a grindstone package that includes diamond wheels has a break-even point between 15 and 24 months (depending on the number of diamond wheels desired) if compared to a traditional grindstone package. For example, with two diamond wheels, after 15 months the system will begin to work more cost effectively. Therefore, the choice of diamond wheels is convenient also from an economic point of view.