Performance of Aerodynamic Baffles in Cylindrical Grinding Analyzed on the Basis of air Layer Pressure and Speed

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Over the years, grinding has been considered one of the most important manufacturing processes. Grinding is a high precision process, and the loss of a single workpiece in this stage of the production is unacceptable, for the value added to the material is very high due to many processes it has already undergone prior to grinding. This study aims to contribute toward the development of an experimental methodology whereby the pressure and speed of the air layer produced by the high rotation of the grinding wheel is evaluated with and without baffles, i.e., in an optimized grinding operation and in a traditional one. Tests were also carried out with steel samples to check the difference in grinding wheel wear with and without the use of baffles.
***Keywords**: grinding, aerodynamic baffle, optimized process*

Introduction

The high competitiveness and quality of products nowadays makes it imperative for the processes used in the manufacture of a workpiece to be as effective and economical as possible. In order to achieve such a goal the study of machining processes, and particularly of grinding, should focus on the constant improvement of manufacturing parameters and methods.

Conventional cutting fluid application systems are relatively inefficient in the grinding process, particularly under conditions of severe application. The energy stored in fluids during their application is insufficient, in most cases, to overcome the centrifugal force of grinding wheel or to penetrate the air barrier surrounding the rotating grinding wheel. According to Guo and Malkin (1992), the effectiveness of conventionally applied cutting fluid ranges from 5 to 30% due to inefficient lubrication and cooling of the grinding wheel-workpiece interface. As a result, the tool requires more frequent sharpening and wears out prematurely. In Brazil, this disadvantage is aggravated by the still widespread use of conventional grinding wheel, whose wear far exceeds that of superabrasive grinding wheels.

These problems must be solved by optimizing the process. Optimization, according to Ebbrell et al. (1999), increases the lubricating and cooling capacity of the fluids, facilitating the removal of chips and generating less dispersion in the cutting region. Several systems have been devised to optimize the grinding process and render it more efficient, including optimized nozzles, cooling bolsters, baffles and baffle systems, which facilitate the penetration of fluid into the grinding wheel-workpiece interface and partially eliminate the damaging air layer that is generated around the grinding wheel (2004).

According to Ramesh et al. (2001), the speed and pressure of the air layer created by the rotation of the grinding wheel is drastically reduced as a function of the radial distance of the grinding wheel perimeter. In other words, the greater the radial distance, the lower the air pressure and speed. The structure of the grinding wheel, topography and the shape of its “jacket” affect the measured results, so they require special care to minimize errors.

The main purpose of this work is to contribute to the study and evaluation of the pressure and speed of the air layer generated by the high rotation of the grinding wheel and of the radial wear of the grinding wheel, comparing the performance with and without the use of baffles.

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Materials and Methods

This research work was carried out using a conventional aluminum oxide grinding wheel, a Pitot tube, a sloping tube manometer, an aerodynamic baffle and a grinding machine.

According to Doebelin (1975), the advantage of the sloping tube manometer is that it operates with greater scales of gradation than vertical manometers under the same pressure variation. Elonka and Parsons (1976) state that sloping tube manometers are normally employed to determine very low pressure differences.

The peripheral velocities of the grinding wheel to be used throughout the tests, the minimum radial distance of the grinding wheel, the radial distance between one pressure measurement and the next, and the most appropriate manometer fluid according to the conditions to be tested were determined during the preliminary tests. A manometer fluid with a relative density of 0.784 at a temperature of 20°C was selected.

It was established that pressure readings would be taken at 0.5 mm intervals, from 0 to 5 mm (starting from the workpiece-grinding wheel interface). These values were recorded for peripheral speeds of the grinding wheel of 30 m/s, 40 m/s, 50 m/s and 60 m/s. Three measurements were taken for each machining condition tested, with and without the aerodynamic baffle.

To analyze the radial wear of the grinding wheel, six samples of VC 131 steel were ground, with half the tests carried out using baffles and the other half without.

A conventional aluminum oxide grinding wheel was used with a 5% emulsion, applied in an optimized way using a 3mm nozzle, since the cutting speed and fluid jet speed were made the same (1995). All the tests were performed with the same parameters, i.e., a plunge velocity of 1.5 mm/min, cutting speed and fluid jet speed of 33 m/s, a flow rate of 14 l/min, 0.5 MPa pressure at the ball gauge entrance and a 5 second spark-out.

Figure 1 illustrates the test bench set-up and the baffle positioned on the cylindrical grinding machine.

Calculation of Air Speed

The air speed was calculated using Bernoulli's equation, which can be applied for any Pitot model, as shown below:

$$\frac{P}{\rho}+\frac{V^2}{2}+g\cdot y=k \tag{1}$$

Where P represents the pressure, □ is the specific mass, V indicates the velocity, y is the height of the fluid, k is the equation's constant and g is the gravity acceleration.

For total pressure (Pt) and static pressure (Pe), which can be measured in the Pitot tube, it follows the equation:

$$\frac{Pe}{\rho}+\frac{V^2}{2}+g\cdot y_1=\frac{Pt}{\rho}+g\cdot y_2 \tag{2}$$

The static pressure was nullified because one of the sides of the manometer was open to the surroundings in which the tests were conducted, thus simplifying the total pressure (Pt), which is the static pressure (Pe) plus the dynamic pressure (Pd), becoming simply the dynamic pressure (Pd). In other words, in these tests, the pressure obtained through the Pitot tube is the dynamic pressure rather than the total pressure normally obtained. Thus, the equation of the velocity is written as:

$$V=\sqrt{\frac{2(Pt-Pe)}{\rho_{ar}}}=\sqrt{\frac{2\cdot Pd}{\rho_{ar}}}=\sqrt{\frac{2\cdot P}{\rho_{ar}}} \tag{3}$$

Where P is the pressure obtained in the sloping tube shown above and ρ is the specific air mass, which was equal to 1.18 kg/m3.

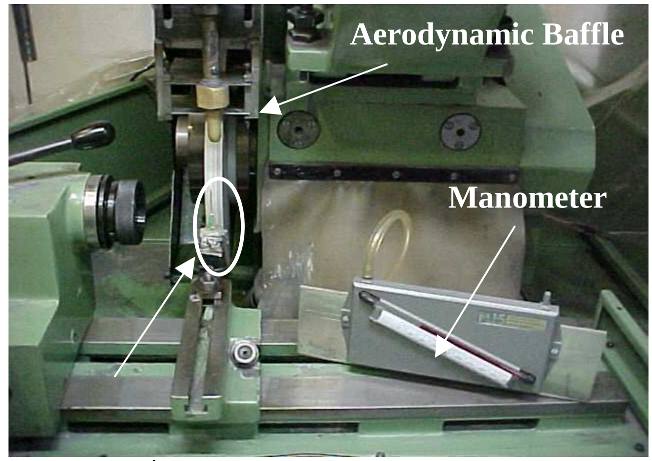


Figure December 2007

1. Test bench set-up.

The uncertainties of the velocity were calculated as follows: [7]

$$V=\sqrt{\frac{2P}{\rho_{ar}}} \quad \Rightarrow \frac{\partial V}{\partial P}=\frac{1}{2}.\sqrt{\frac{2}{\rho_{ar}.P}} \quad \Rightarrow w=\sqrt{\left(\frac{\partial V}{\partial P}.w_P\right)^2}$$

Where the uncertainties are the values of w. Therefore, the values of w are not fixed according to those of wp, because in the derivative of the equation of velocity, the value of P continues being an unknown variable and this is not a constant value.

Results and Discussion

The results obtained for the manometric pressures that the air layer exerted on the cutting region, the speeds this layer attained, and the radial wear of the grinding wheel are shown below will be present in this section.

Results of the Manometric Pressures Exerted by the Air Layer

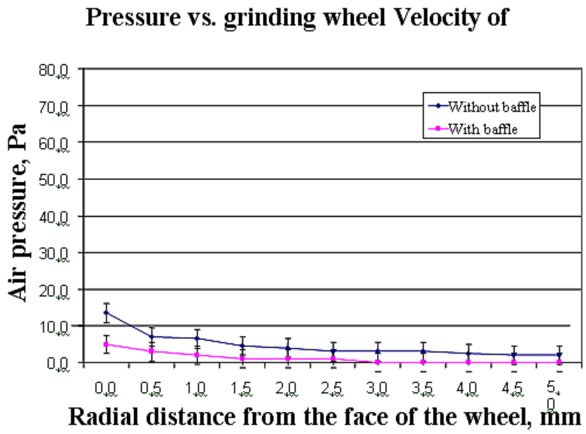
For a more in-depth analysis of the results with and without the aerodynamic baffle, graphs were plotted comparing the pressures for the same grinding wheel peripheral speed, as illustrated in Figure 2. According to Holman (7), the uncertainties of the pressures (wp) that appear in the graphs below are constant and equal to 2.5 Pa, i.e., half of the unit of the scale on the manometer used in the tests.

It should be pointed out that, for each point on the graph in Fig. 2, an arithmetic mean was calculated from the values obtained from the three repetitions of the tests.

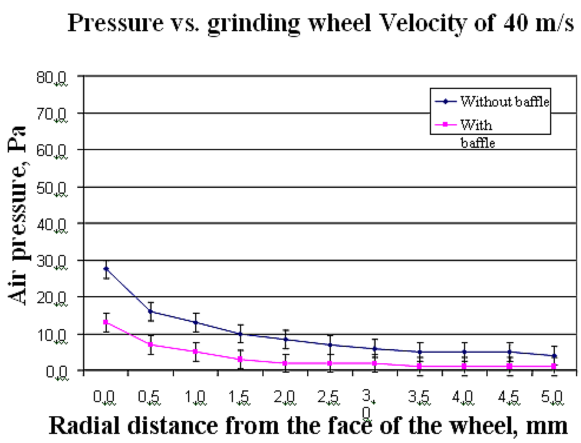
The use of the aerodynamic baffle resulted in a reduction of approximately 74.5% to 64.5% of the air pressure for tangential grinding wheel velocities of 30 m/s and 40 m/s, respectively. Air pressure was reduced by an average of 59.6% at a peripheral grinding wheel velocity of 50 m/s, and by about 54.5% at a velocity of 60 m/s.

It can be concluded, based on the analysis of Figure 2, the pressures obtained in each case were lower when aerodynamic baffle was used, demonstrating that this device can partially eliminate the air layer generated by the rotation of the grindiwheel, thereby facilitating the application of the cutting fluid at the workpiece-grinding wheel interface, as proposed by Ebbrell et al. (1999) and Catai et al. (2004).

Note, also, that the higher the peripheral velocity of the grinding wheel, the greater the difference between the results achieved with and without the baffle system at the grinding wheel-workpiece interface (point 0). In other words, in machining operations requiring high cutting speeds, the use of the baffle will provide a substantial drop in the air pressure generated by the high rotation of the grinding wheel at that point.

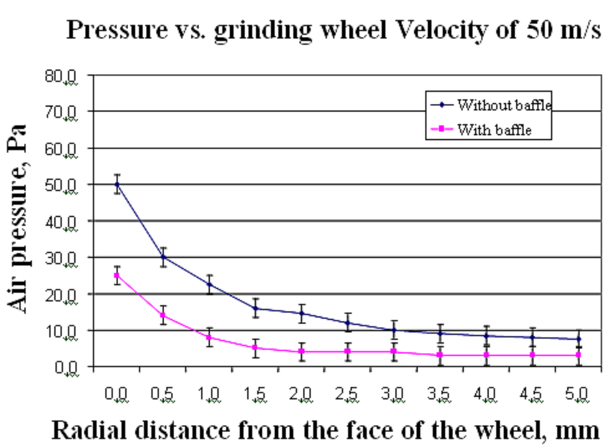


(a)



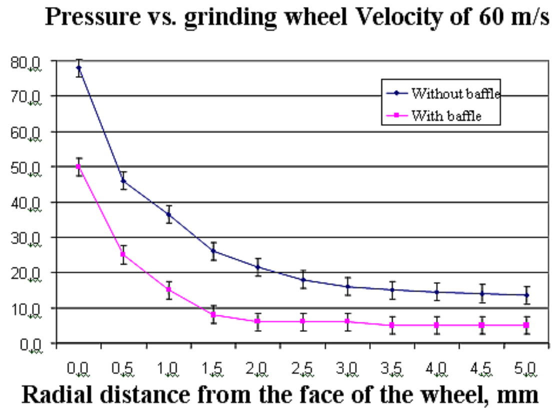
(b)

Figure 2. Air pressure at the following peripheral grinding wheel velocities: (a) 30 m/s; (b) 40 m/s; (c) 50 m/s; (d) 60 m/s.



(c)

Figure 2. Air pressure at the following peripheral grinding wheel velocities: (a) 30 m/s; (b) 40 m/s; (c) 50 m/s; (d) 60 m/s.



(d)

Figure 2. (Continued).

Results of the Speeds Attained by the Air

Graphs were plotted comparing the air layer speeds for a more detailed analysis of the results achieved with and without the baffle system, as shown in Fig. 3.

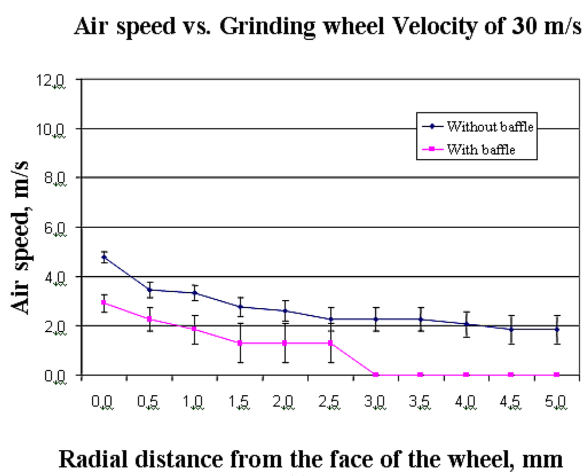
Each point on the graph in Figure 3 is the result of a pressure value obtained from the arithmetic average of the values of the three tests. Note that the use of the aerodynamic baffle reduced the air speed by approximately 62.9%, 43.6%, 38.1% and 35.9% at the peripheral grinding wheel velocities of 30 m/s, 40 m/s, 50 m/s and 60 m/s, respectively.

The uncertainties increase as the distance from the face of the grinding wheel increases. This is because the pressure is in the denominator of equation (4), which was used for this calculation, and when the distance from the grinding zone increases, the pressure decreases.

Based on the analysis of the results, it can be stated that the baffle is effective, i.e., it reduces the speed and pressure of the air that reaches the cutting region.

It should be noted that the uncertainties shown in the graphs were disregarded in calculating the percentile decrease.

An analysis of Fig. 3 (a) reveals that the air speed takes on a null value starting from a distance of 3.0 mm from the grinding wheel-workpiece interface at a grinding wheel velocity of 30 m/s. This means that the air that passes through a region further than 3.0 mm from the face of the grinding wheel exerts no effect when grind at velocities of less than 30 m/s.



(a)

Figure 3. Air speed at the following peripheral grinding wheel velocities: (a) 30 m/s; (b) 40 m/s; (c) 50 m/s; (d) 60 m/s.

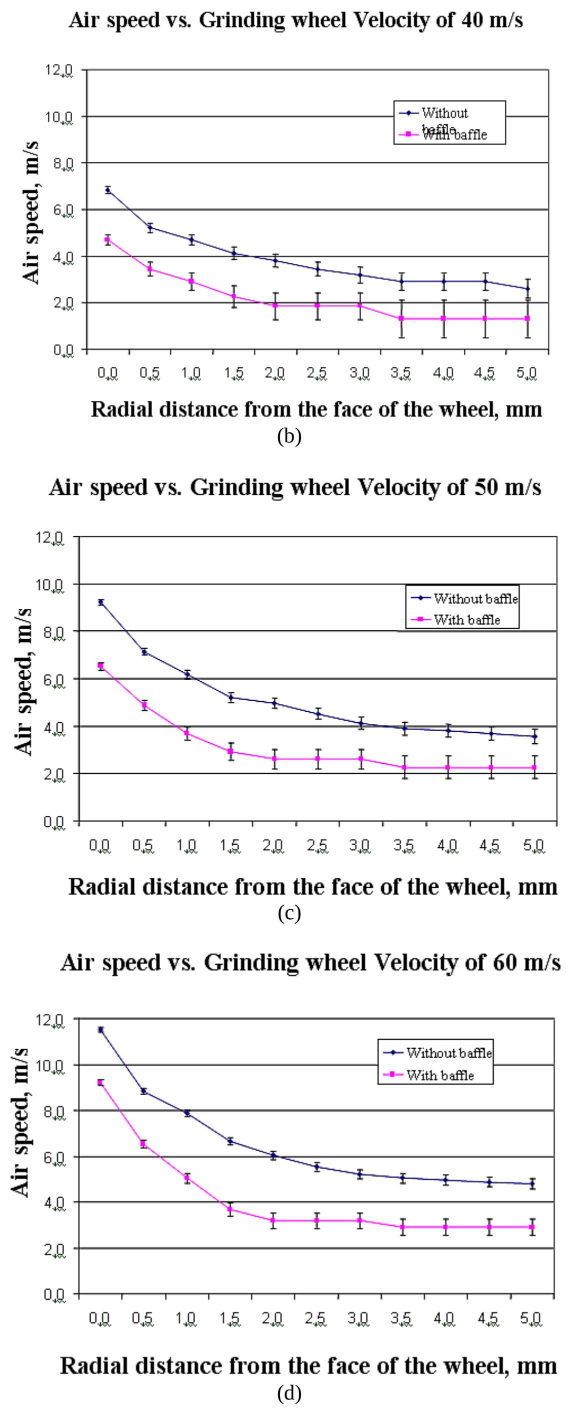


Figure 3. Air speed at the following peripheral grinding wheel velocities: (a) 30 m/s; (b) 40 m/s; (c) 50 m/s; (d) 60 m/s.

Radial Wear Results

The radial wear values were acquired by marking the grinding wheel wear on a SAE 1020 steel workpiece after each test. In this way, the profile of the grinding wheel was passed onto the workpiece, which was then used to measure the unevenness (micrometric degree) between its worn and unworn regions, thus identifying the radial wear of the grinding wheel.

Figure 4 shows the average radial wear for the tests carried out with and without the baffle system.

As can be seen in the Figure 4, the use of the baffle system led to 5.5% lower in radial wear; in other words, the baffle system prolonged the service life of the tool.

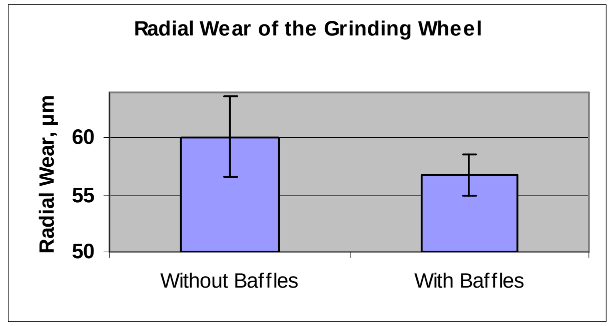


Figure 4. Radial wear of the grinding wheel with and without the use of the baffle system.

Conclusions

This study revealed the behavior of the air layer created by the high rotation of the grinding wheel in plunge cylindrical grinding, with and without the use of the proposed baffle system.

The simulation of an optimized grinding process (with the baffle) consistently proved to be a better alternative to reduce the effect of the air flow, allowing for more effective cooling and lubrication of the workpiece. In addition, the graphs show that the use of baffles allowed for a 5.5% reduction of grinding wheel radial wear.

Therefore, the best alternative is actually to use a baffle system in the cutting region to minimize the effects of the air layers originating from the high rotation velocity of the grinding wheel, which causes the jet of fluid to dissipate during grinding. The baffle system considerably reduces the speed and pressure exerted by this air layer, facilitating lubrication and cooling.

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