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Analysis of the different forms of application and types of cutting fluid used in plunge cylindrical grinding using conventional and superabrasive CBN grinding wheels

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Abstract

The work reported here involved an investigation into the grinding process, one of the last finishing processes carried out on a production line. Although several input parameters are involved in this process, attention today focuses strongly on the form and amount of cutting fluid employed, since these substances may be seriously pernicious to human health and to the environment, and involve high purchasing and maintenance costs when utilized and stored incorrectly. The type and amount of cutting fluid used directly affect some of the main output variables of the grinding process which are analyzed here, such as tangential cutting force, specific grinding energy, acoustic emission, diametrical wear, roughness, residual stress and scanning electron microscopy. To analyze the influence of these variables, an optimised fluid application methodology was developed (involving rounded 5, 4 and 3 mm diameter nozzles and high fluid application pressures) to reduce the amount of fluid used in the grinding process and improve its performance in comparison with the conventional fluid application method (of diffuser nozzles and lower fluid application pressure). To this end, two types of cutting fluid (a 5% synthetic emulsion and neat oil) and two abrasive tools (an aluminium oxide and a superabrasive CBN grinding wheel) were used. The results revealed that, in every situation, the optimised application of cutting fluid significantly improved the efficiency of the process, particularly the combined use of neat oil and CBN grinding wheel.

Keywords: Optimised application; CBN grinding wheel; Cutting fluid; Grinding

1. Introduction

The worldwide tendency is to produce ever more sophisticated pieces with high geometrical, dimensional and surface finish tolerances, at low cost and without polluting the environment [1]. Thus, the efficient application of cutting fluid in the cutting region is crucial.

According to Ebbrell et al. [2], cutting fluid benefits the industrial sector in several ways, but it is often utilized incorrectly, thus generating substantial losses. Lubrication and cooling depend on the effective entrance of fluid into the cutting region between the workpiece and the tool, which allows high volumes of fluid to be reduced.

According to Webster et al. [3], in the grinding process a jet of fluid directly hitting the cutting region can significantly reduce the temperature in this region, but high fluid jet velocities are needed to enable the fluid to penetrate the cutting region effectively. A marked drop in the cutting region temperature was recorded when a circular shaped nozzle was used instead of the conventional jet, which normally disperses the fluid widely. These authors also stated that, because of their low density, water-based fluids should be used carefully. A great deal of dispersion may occur if they are applied with conventional nozzles, so

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efficient nozzles should be used to prevent this kind of situation.

In the present project, an appropriate methodology was employed to analyze the quantity of cutting fluid applied in the process and its consequences. Based on this analysis, we investigated a new form of applying cutting fluid aimed at improving the performance of the process with regard to the main output variables, such as tangential force, total specific grinding energy, acoustic emission, diametrical wear of the grinding wheel, roughness, and residual stress, using scanning electron microscopy (SEM).

2. The grinding process and the material removal mechanism

Fig. 1 illustrates the plunge cylindrical grinding and chip removal processes. Fig. 1(a) gives an overall view of the process and the main parameters that influence it, i.e., grinding depth, ‘a’, grinding wheel diameter, ‘d_s’, surface speed of the grinding wheel, ‘v_s’, surface speed of the workpiece, ‘v_w’, diameter of the piece, ‘d_w’, length of the chip, ‘l_c’, and flux of heat generated by the cut, ‘q’. Fig. 1(b) depicts the mechanism whereby the chip is formed, from its plastic strain up to the formation of the chip itself, in the plane tangential grinding operation, which is similar to the chip forming process that occurs in the plunge cylindrical grinding operation.

According to Malkin [4], in a great many cases, cutting fluid does not substantially reduce the temperature in the grinding zone owing to the difficulties it encounters in penetrating that region, the small length of contact, and often due to the aerodynamic barrier generated by the grinding wheel surface, which has a V_s velocity. The velocity at which the jet of cutting fluid should penetrate the region of contact should be equal to the peripheral velocity of the grinding wheel so that the aerodynamic barrier is effectively breached, thereby enabling the cutting fluid to perform its function in an optimised way [5].

Guo and Malkin [6] found that cooling in the cutting zone is only effective in creep-feed operations, in which the high penetration and low velocity of the piece generate long contact lengths, as indicated in Fig. 1(b), allowing the fluid to be drawn toward the cutting region and providing considerable cooling. However, when correctly applied, cutting fluids allow for cooling of the workpiece as a whole (except in the instantaneous position of the cutting region), helping control dimensional and shape errors by subjecting the piece to lower thermal forces.

Minke [7] stated that cutting fluids reduce the temperature in the cutting region, diminishing the occurrence of surface thermal damage of the workpiece. Through their lubricating properties, cutting fluids reduce friction, thus reducing the wear on the top of the grains of the grinding wheel, generating less heat by decreasing the energy spent in sliding and ‘plowing’.

The mechanism of wear of the top of abrasive grains is illustrated in Fig. 2, which shows that excessive wear of the cutting edges of the abrasive grains increases the contact surface considerably, leading to increased tangential cutting force, specific grinding energy, temperature, residual stress, etc.

It is important to mention that because CBN grains are much harder than aluminium oxide and silicon carbide grains, CBN wheels have greater wear resistance than conventional wheels. Consequently, a CBN wheel usually gives better size holding and longer wheel redress life. In addition, the mechanical strength of vitreous bonds for CBN abrasives is usually much higher compared to conventional wheels of the same grain size. This is because CBN wheels are designed to have a lower wear rate and it is important that the grains are not easily lost by breaking away from the bond [8].

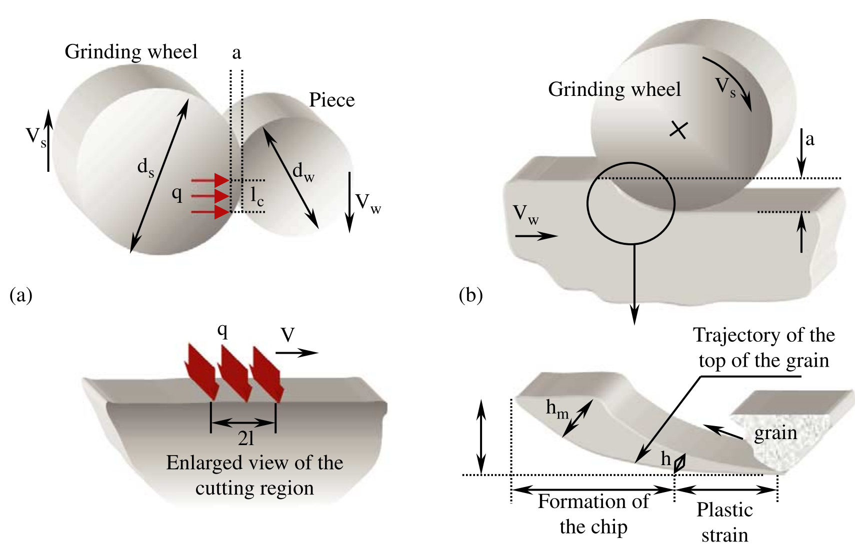

Fig. 1. (a) Parameters involved in the plunge cylindrical grinding process, (b) general chip formation mechanism (adapted from MALKIN, 1989).