IOP Conf. Series: Materials Science and Engineering **124** (2016) 012170 doi:10.1088/1757-899X/124/1/012170

Capturing action of cooling lubricants in grinding and evaluation of its effectiveness

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Abstract. Methods of coolant supply are considered to be aiming at capturing and neutralization of the flare of grinding waste and noxious coolant fumes during flat grinding with a wheel periphery. Study and evaluation of the new coolant functional property – capturing – are presented.

1. Introduction
Recently, in Russia and abroad active researches aimed at improving the methods of lubricating and cooling fluid (coolant) delivery and the use of different types of energy impact on it have been conducted [1]. The features of the coolant application at abrasive processing are related to the specific design of the instrument, mode and method of processing [2]. The main functions of the coolant are: lubricating, cooling, cleaning, dispersant and anti-corrosive. Today, there are more than 2.000 different ways of coolant supplying. Systematizing them, 30 major ways as well as a significant number of their varieties and combinations, have been allocated.

2. A barrage method of coolant supply
In 2002, a new main way of the coolant supply – a barrage one – was designed to fight the waste flare moving from the cutting area, which is a major source of pollution in the grinder's working area (Figure 1).

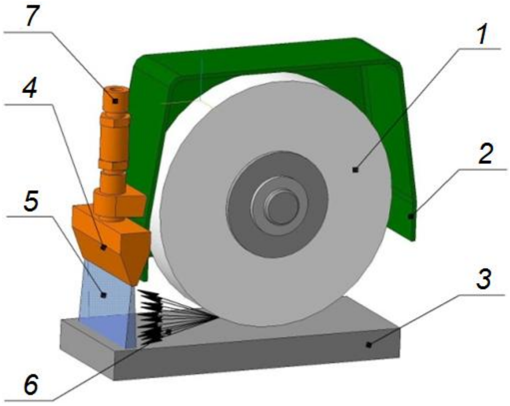


Figure 1. A device of the coolant supply barrage method:
1 – grinder, 2 – protective cover, 3 – workpiece, 4 – nozzle, 5 – coolant jet, 6 – grinding waste torch.

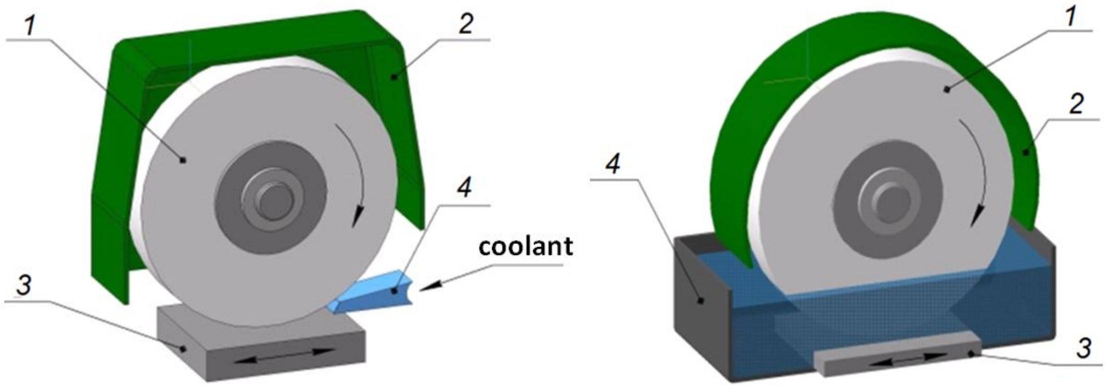
In accordance with GOST 12.1.005-88, the working area is defined as the space bounded by the height of 2 m above the floor or a platform, which is a place of permanent (more than 50 % of the time or more than 2 h continuously) stay of the worker [3].

In the barrage method of coolant supply, the grinding torch capture is of primary importance. The grinding torch capture is resulted from the vertical arrangement of nozzles for coolant supply behind the machining area so that the path of the torch is barraged by a curtain of liquid providing its efficient capture.

However, the barrage method does not ensure the effective implementation by the coolant of its known action that paved the way for the development of the combined technique of coolant supply using the barrage method in 2012.

3. A combined method of coolant supply

By the hierarchy analysis method, the main ways of coolant supply were analyzed and the methods, by means of which the process fluid carries out its functions most effectively, were identified: freely falling jet, pressure jet, hydroaerodynamics in the coolant environment. The most important ones are: freely falling jet and the coolant environment (Figure 2a, b), which formed the basis for a new combined method of coolant supply (Figure 3).



a *b*

Figure 2. The most important ways of coolant supply during flat grinding:
a – irrigation, *b* – grinding in the coolant environment
1 – grinding wheel, 2 – protective cover, 3 – workpiece, 4 – coolant nozzle

The essence of the method is that the treatment zone perimeter is completely surrounded by the coolant curtains, and due to inclination of these curtains, a bath of processing liquid is created in the cutting area. Consequently, the entire sludge departing from the cutting area is fully captured by protective curtains of the coolant, and in the cutting zone there is a process liquid bath. The captured sludge particles are washed away to the coolant cleaning system of the machine.

4. New device of combined coolant supply

As shown by the experimental operation, the device of combined coolant supply presented above has several disadvantages:

– increased consumption of the coolant;
– low efficiency in the grinding spatial detail;
– increased energy consumption by the machine coolant system.

To eliminate these drawbacks, the method is amended taking into account the application of a hydroaerodynamic way of coolant supply, and a new device of combined coolant supply is developed (Figure 4). The device is a piece fixed to protective cover 2 of the machine; it is joined by pipes 1

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providing coolant supply. The liquid itself forms protecting circuit 5 of a smaller perimeter than in the prior device.

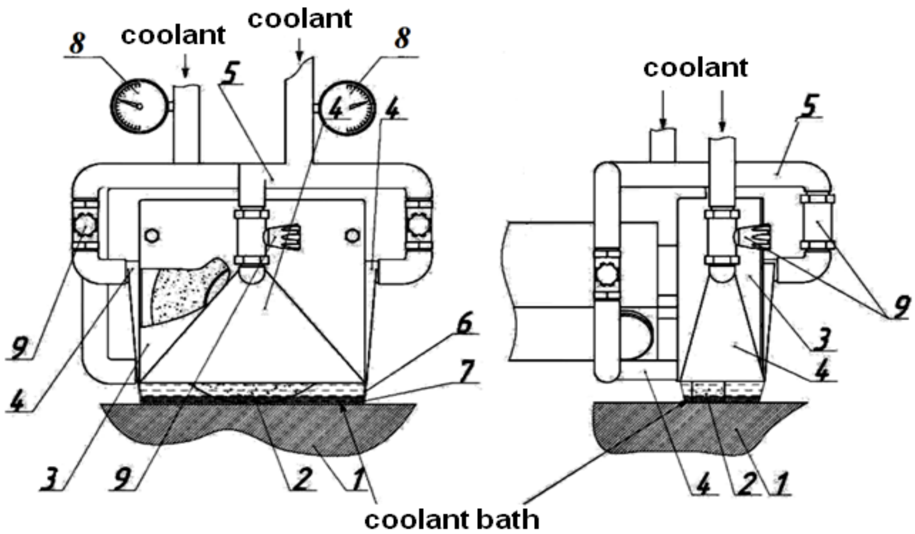

Figure 3. A device of combined coolant supply:
1 – workpiece, 2 – grinding wheel, 3 – protective cover, 4 – nozzles, 5 – pipe, 6 – coolant curtain, 7 – coolant bath, 8 – manometers, 9 – valves.

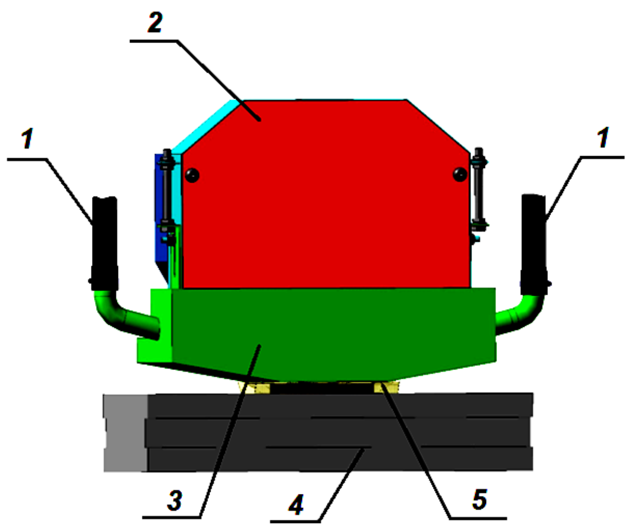

Figure 4. A new device of combined coolant supply for flat grinding with the wheel periphery:
1 – pipeline, 2 – protective cover of the machine, 3 – device of combined coolant supply, 4 – magnetic table, 5 – coolant curtain.

At the bottom, the device is provided with a number of non-regulated nozzles 1…7 positioned as shown in Figure 5, due to which a continuous barrage of the coolant curtain is formed around the cutting zone capturing all grinding waste and the coolant fume. Due to a combination of at least six major ways of supply (treatment zone irrigation, irrigation of the wheel periphery and the workpiece beyond the treatment zone, grinding in the coolant environment, hydroaerodynamic and barrage methods) a negative influence of peripheral air flows on the coolant action is neutralized. During the contact of the wheel with the workpiece, a running dynamic spatial bath of processing liquid is instantaneously formed in the cutting zone.

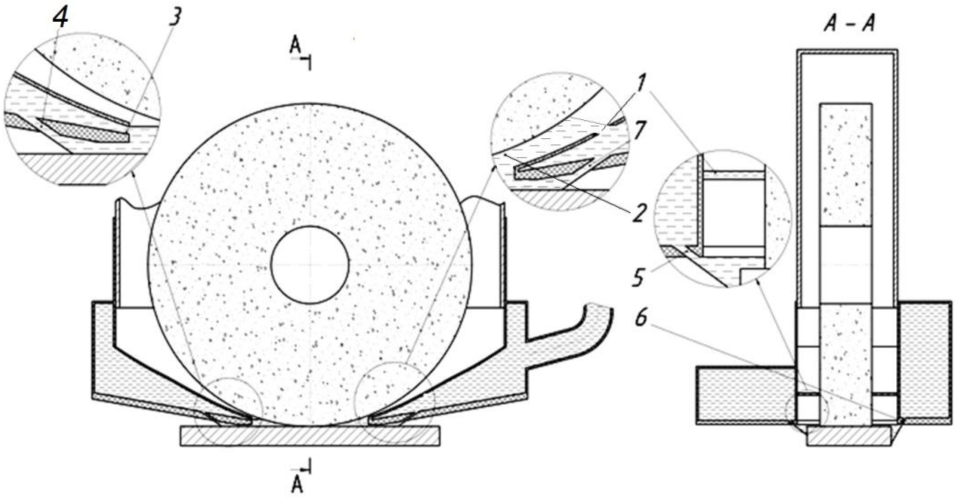

Figure 5. Design features of the new device of combined coolant supply:
1 – rear nozzle, 2 – constructive nozzle, 3 – frontal nozzle, 4…7 – contour nozzles.

The device is equipped with screws 1 (Figure 6) providing the adjustment of the device position when the grinding wheel is worn.

It is generally known that grinding is accompanied by dust emission, the intensity of which depends on the processed material, abrasive tools used and techniques of the coolant supply.

5. Background and evaluation of the coolant capturing effectiveness

The grinding dust is an aerodisperse system, in which the dispersion environment is the air of the working area, and the dispersed phase consists of suspended solids of the material being treated, abrasive and ligaments of the grinding wheel and the atomized coolant.

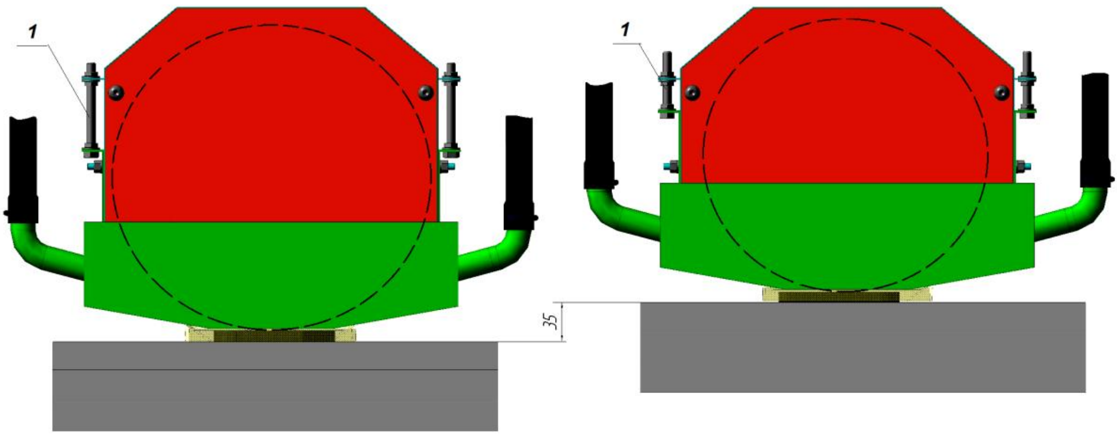

Figure 6. Adjusting the new device of the combined coolant supply height.

The grinding machine releases up to 30 g/h per 1 kW of dust with the dispersion of 0.1 to 200 microns. Due to the relatively rapid subsidence of large dust particles (10 mcm or more), the air of production areas contains mainly dust particles of up to 10 microns, 70 ÷ 90 % of which consist of particles larger than 5 microns.

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One of the most common hazardous substances released during grinding is silicon dioxide (SiO_2) coming from the cutting zone in the form of condensation and disintegration aerosols and amounting to 70 % of the total weight of the dust. Silica refers to the third class of danger; its MPC is 2 mg/m^3.

On the basis of the coolant supply technology, we may speak of allocating a new functional action (property) of the coolant – the capturing one, which is to reduce the concentration of hazardous substances in the working area of the machine operator by neutralizing the flare of grinding waste and disintegration and condensation aerosols in the cutting zone by their physical capture and removal by the process fluid.

Numerically the capturing effect of the coolant can be evaluated through dimensionless capture coefficient μ by the following formula:

$$\mu = \frac{K}{MPC}, \tag{1}$$

where K is the concentration of harmful emissions in the working area, mg/m^3; MPC is maximum permissible concentration of harmful substances in the working area, mg/m^3.

The capturing action of the coolant can be considered satisfactory if coefficient $\mu \leq 1$, and the less is this value, the better is the coolant capturing effect. It should be taken into account that the hot waste intensive penetration to the coolant in the cutting zone intensifies evaporation and heating being able to dramatically alter its composition and structure, so in each case the capturing process requires a balanced approach.

The results of discussed ways of the coolant supply test are presented in Figure 7.

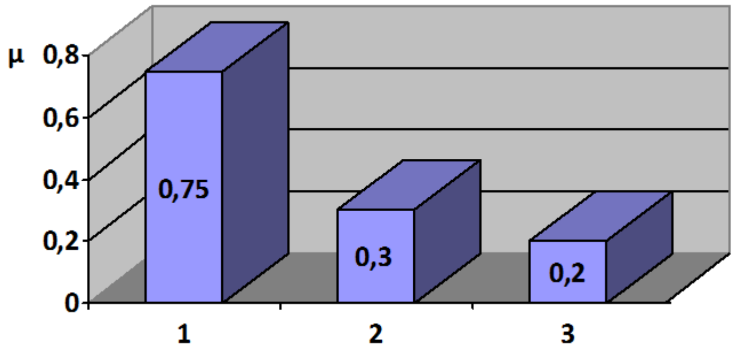

Figure 7. Evaluation of the coolant capturing action for the developed methods:
1 – barrage, 2 – combined, 3 – new combined (predicted value).

6. Conclusion

Analyzing the data obtained it can be concluded that the most effective device in terms of capturing and neutralization of the grinding waste flare, disintegration and condensation aerosols in the cutting zone is a recently developed device of the combined coolant supply. This device also provides the cutting zone with a dynamic spatial bath of the coolant that allows processing flat workpiece surfaces of any form factor.

References

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