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# Study on Service Performance Evaluation of Grinding Coolants

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**Abstract.** Grinding coolants have the functions of cooling, lubrication, cleaning and rust prevention in grinding process. To avoid the environment pollution, we should develop environmental protection grinding coolants. So it is important to research the performance evaluation for grinding coolants. In this paper, three different test methods for grinding performance evaluation of grinding coolants are used to investigate the influence of three coolants on grinding process. The three test methods are four balls test, tapping torque test and real grinding test. The test results showed that the mechanism of four balls test is simple, and the test results have good repeatability, but there is a large divagation with real grinding test results. The tapping torque test has a good relativity with cutting process. The real grinding test is the best test method for grinding performance evaluation.

## Introduction

The main feature of grinding process is the large contacting area and the difficulty of supplying grinding coolants to contact area due to the hard friction between grits and workpiece. It leads to thermal damage of ground surface, extra load on grinding wheel and agravate wheel wear. Therefore the function of grinding coolants is very important in grinding process. Generally the functions of grinding coolants are cooling, lubrication, cleaning and rust prevention. With the development of Green Manufacture, the law about environmental protection is more and more strict. The expense correlative with grinding coolants accounts for 16~20 percent of whole manufacture expense [1]. So the research of grinding process using liquid nitrogen, forceful strong cool air as cooling medium is active suddenly. Dry grinding/cutting and quasi dry grinding/cutting are studied widely. Some results have been achieved in study of dry cutting and quasi dry cutting [2].

However to most of machining material and machining method even if it is maybe possible to replace wet grinding and wet cutting by dry machining in the future, there is a long way to go. It is almost impossible to avoid using cutting/grinding coolants in the near future. Thus it is inevitable that the study of green environmental cutting/grinding coolants becomes more and more [3-4].

During the process of developing cutting/grinding coolants, it is significant to evaluate new product correctly. For the technical specification of cutting/grinding coolants, the physical and chemical performances of cutting/grinding coolant are normalized. Most of specifications are lack of service performance item. Only the maximum load capacity ($P_B$) in the specification of synthetical cutting coolant is regarded as equal to service performance. But the $P_B$ is the maximum load capacity that seizure hasn't occurred in four-ball test. It represents the load carrying capacity of lubricant. And the friction mechanism is different between cutting/grinding process and kinematic-pair. It is also shown in engineering practice that the effect of grinding coolants with high $P_B$ value is poor. In order to clarify it, three different grinding coolants are examined in. The results show that $P_B$ and tapping torque can't reflect the service performance of grinding coolants exactly.

## Experimental Study on Service Performance of Grinding Coolants

The performance of grinding coolants is shown through output results of grinding process. The evaluation index about machining quality and efficiency is the most effective reference to show the performance of grinding coolants. The effects accompanying by the grinding process relates closely with grinding results. The effects of grinding coolants on the grinding accompanying effects are great. And the change of the accompanying effects also represents the performance of grinding coolants. In

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the following test, grinding force, material removal rate, surface roughness and burn extent of ground surface are chose to be the examination index of grinding coolants performance.

**Experimental Study on Grinding Force.** Grinding force is the important effect accompanying by grinding process. It leads to not only the displacement of grinding process system but also the residual error on ground surface, which will influence on the whole grinding process and results. To decrease the grinding force is the main function of grinding coolants and is the direct manifestation of lubrication performance of grinding coolants. Refer to the relation between grinding force and grinding coolants, lubrication performance of grinding coolants during the grinding process has a direct effect on the decrease of grinding force.

**Grinding Test Conditions.** Grinding machine: M7120A horizontal spindle surface grinding machine; Grinding manner: Fix-feed grinding, up-cut; Grinding wheel speed: 3000 r/min; Grinding wheel: ZR155, 250×75×25; Dresser: Single-point diamond dresser; Dressing feed speed: $V_d$ =8.3 mm/s; Dressing depth-of-cut: $T_d$=0.01 mm/pass; Specimens: Material 45# steel (240 HBS), Size 10×12.5×80 (grinding width 10 mm).

Table 1 Grinding force in fix-feed surface grinding test

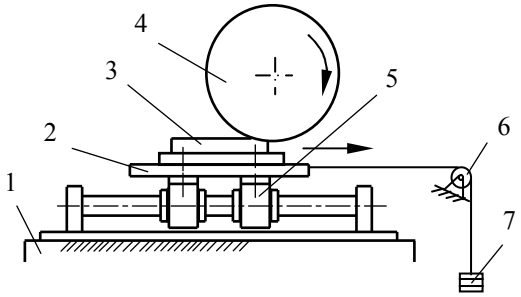
| Grinding coolants | Feed rate $V_w$ [mm/s] | Grinding depth [mm] | Grinding force [N] | |
|---|---|---|---|---|
| | | | Normal | Tangent |
| ECF | 20.5 | 0.05 | 24.5 | 15.7 |
| | | 0.075 | 58.8 | 27.4 |
| | | 0.1 | 61.3 | 29.4 |
| | 45.5 | 0.05 | 31.9 | 31.9 |
| | | 0.075 | 44.1 | 44.1 |
| | | 0.1 | 61.3 | 58.8 |
| ECF2 | 20.5 | 0.05 | 41.2 | 29.4 |
| | | 0.075 | 83.3 | 61.7 |
| | | 0.1 | 117.6 | 70.6 |
| | 45.5 | 0.05 | 116.6 | 61.7 |
| | | 0.075 | 148.0 | 93.1 |
| | | 0.1 | 151.9 | 102.9 |
| EACF | 20.5 | 0.05 | 61.3 | 37.7 |
| | | 0.075 | 122.5 | 63.7 |
| | | 0.1 | 148.1 | 76.2 |
| | 45.5 | 0.05 | 107.8 | 63.7 |
| | | 0.075 | 210.7 | 96.1 |
| | | 0.1 | 333.2 | 137.2 |

In order to measure the grinding force, a force meter and a data acquisition system are installed on the M7120A surface grinding machine. The grinding force is measured on line. There are two kinds of force exist in grinding process, they are normal and tangent grinding force. YDXM-III97 three dimensional piezoelectricity force meter is adopted to measure grinding force. The force meter has the advantage of high rigidity, high sensitivity, and high natural frequency, which meet the request to measure force dynamically. In the test, piezoelectricity force meter is linked with electric charge enlarger, computer data collecting and process system to show the dynamic variety rule of grinding force directly and to save data files of force automatically.

**Test Results.** Under the above test conditions grinding test are carried in surface grinding machine using three different grinding coolants. Average surface grinding force under different condition is shown in Table 1. Every value in Table 1 is obtained through three or more tests. Evidently, under the experimental condition normal and tangent grinding force is the lowest when using ECF grinding coolant that is developed by us.

**Experimental Study on Material Removal Rate.** Material removal rate is removal volume of

ground specimen per unit time. It is influenced greatly by grinding coolants. Grinding mode of fix-force feed is adopted to investigate material removal rate.




1. Magnetic platform; 2. Moving platform; 3. Specimen;
4. Grinding wheel; 5. Line bearing; 6. Pulley; 7. Poise.
Fig.1 Fix-force feed equipment

Table 2 Influence of grinding coolants on material removal rate

| Grinding coolants | Grinding time [s] | Material removal rate [$mm^3/s$] | Burn extent |
|---|---|---|---|
| ECF | 3.9 | 10.3 | light |
| ECF2 | 4.6 | 8.7 | serious |
| EACF | 2.9 | 13.8 | moderate |

**Fix-force Feed Equipment.** Principal of fix-force feed equipment is shown in Fig.1. The equipment can be fixed on magnetic platform of surface grinding machine and depends on poise to load. The structure is simple and there is no change taken place on grinding machine. The grinding mode is surface grinding.

**Test Results.** On the above test conditions, fix-force feed grinding tests are carried out. The main aim of the test is to investigate material removal rate of specimen. Specimen is ground in the same grinding depth 0.1mm under the condition of a fix feed force. Once material removal volume is $40mm^3$. Record the grinding time the material removal rate can be obtained. The test results are shown in Table 2. On the view of material removal rate EACF is the most perfect grinding coolant. Its burn extent is moderate compared with the other ones.

**Surface Roughness of Ground Specimens.** The specimen surface ground at different grinding condition and using different grinding coolants is measured using 2205 surface roughness meter off-line. The measuring results are shown in Table 3. Coolant ECF is the best one for decrease of surface roughness value to fix-force feed surface grinding, and ECF2 is the best one to fix-feed surface grinding.

## Experimental Results of Four Balls Test and Tapping Torque Test

**Results of Four Balls Test.** Using the MRS-10A four balls test machine (a standard test machine), the maximum load capacity ($P_B$) is measured. The test results of $P_B$ are shown in Table 4. Under the recommend concentration, oil film load carrying capacity of EACF is the highest.

**Results of Tapping Torque Test.** Tapping operations are considered one of the most difficult of all metal-removing operations. Falex tapping torque test machine could be used to evaluate the efficacy of coolants and to determine tool life, as well as qualifying the efficiency of taps. It could also be used to rate the machinability characteristics of materials [5]. Tapping torque, during a tapping operation, is affected by coolants, taps and the machinability of the materials. In this paper, the Falex test machine is used to evaluate the performance of coolants.

The test results using Falex test machine are shown in Table 4. The test mode is cutting. Axial

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rotate speed is 243 r/min. Material of specimen nut blank is 20Cr. Standard No. 4 tap is used. Many tests proved that the repeatability and reproducibility of test results are good. The test can distinguish small difference of machining performance between different grinding coolants.

Table 3 Influence of grinding coolants on surface roughness of specimen (Grinding depth=0.1 mm)

| Grinding coolants | Fix-feed | | Fix-force feed |
|---|---|---|---|
| | Feed rate $V_w$ [mm/s] | Roughness $R_a$ [μm] | Roughness $R_a$ [μm] |
| ECF | 20.5 | 0.273 | 0.235 |
| | 45.5 | 0.361 | |
| ECF2 | 20.5 | 0.144 | 0.278 |
| | 45.5 | 0.221 | |
| EACF | 20.5 | 0.224 | 0.379 |
| | 45.5 | 0.338 | |

Table 4 Load capacity ($P_B$) and tapping torque of grinding coolants（27℃）

| Grinding coolants | Concentration [%] | $P_B$ [N] | Tapping torque [Nm] |
|---|---|---|---|
| ECF | 4.0 | 313.6 | 9.308 |
| EACF | 2.0 | 833 | 8.514 |
| ECF2 | 2.0 | 450.8 | 8.96 |

## Conclusions

Repeatability of four balls test result is better. But its disadvantage is to use film oil load capacity of sliding friction contact surface to evaluate grinding coolant performance. Tapping torque test is real cutting test, the correlativity between the test and cutting is close. But there is little changeable test condition. The real grinding test is the perfect testing method to evaluate grinding coolant performance. However the influencing factor of this test is too many, such as grinding wheel dressing condition, grinding coolants supply method, feed rate, grinding depth, precision of data collecting system. Through the investigation of grinding force, material removal rate, ground surface roughness and burn extent, it is easy to draw a conclusion that there is no grinding coolant perfect in every aspect. That is, the above indexes can't evaluate performance of grinding coolants individually. It is necessary to establish a standard real grinding test method.

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