Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7765986

ENHANCEMENT OF GRINDING PROCESS USING BORIC ACID AS SOLID LUBRICANT

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Abstract.

The most commonly used technique grinding which is extensively applied for surface finishing that extracts unwanted parts of the material in the form of small pieces to attain required accuracy and precision. It has numerous uses in the manufacturing sector. Unfortunately, it demands a lot of energy and raises the temperature, which causes significant residual tensions, microscopic cracks, and burn. Coolants are typically used to mitigate these negative effects because they lower friction and effectively cool the work-wheel interface. Traditional coolant applications frequently fail because the fluid cannot reach the grinding zone and the film is boiling. Several conventional coolants are hazardous to health and contribute to the greenhouse effect. In order to reduce friction and, in turn, eliminate any negative thermal effects on the grinding process, this study discusses the use of solid lubricant, namely boric acid transported in the appropriate medium to the grinding zone. The demonstrative results shows that the important use of boric acid is to decrease the surface roughness, grinding force, and grinding energy, rather than to wettest grinding with standard cooling agents and dried grinding.

Keywords: Coolant, Boric acid, Grinding, Lubricant, Taguchi method.

Introduction

The displacement of spare and excess material separated as scrapes in small pieces in the grinding process. The act of grinding is the removal of material in the form of tiny chips with the use of an abrasive wheel and mechanical action of bound abrasive particles. It is essentially a finishing technique used to produce precise geometrical and dimensional surfaces with a smooth finish. Nonetheless, the grinding process is sometimes used for faster rates of material removal and is sometimes known as abrasive machining [1]. Aspects including tool geometry, a large contact area, significant friction between the tool and the workpiece, and a high specific energy requirement set it apart from many other machining processes. Heat is produced during the grinding process due to the high specific energy used. Heat is primarily conveyed to the workpiece [2]. The workpiece quality is impacted by the intense heat input. Burns, residual tensile strains, outside texture as surface and subsurface cracks, metallurgical state variations, dimensional defects, and various other negative effects are examples of heat degradation that can occur [3-5]. The unfavorable results of heat produced are to be bound by using cooling agents. This process normally completed by grinding technique at the carving area that ensures the property of the workpiece. in grinding processes Grinding fluids are utilized to minimize and transfer heat, lubricate during chip produce, neat the grinding wheel of detached chips and cuttings, analytically support the grinding operation, or maintain the machine. There are five popular categories of grinding fluids.

These cutting oils include mineral or petroleum bases, are water soluble, contain additives including rust inhibitors, water treatments, and deformers, and are synthetic or semi-synthetic. Many studies on coolant type, content, and supply characteristics have been conducted [6]. Unfortunately, the grinding arc has rather limited access to coolants while grinding. As a result, it frequently just provides general cooling of the work piece and is unsuccessful at lowering the temperature of the grinding zone. The fluid can't enter the grinding zone because of the stiff boundary layer that is formed around the rotating grinding wheel [7, 8].

The efficiency of the grinding fluid is impacted by conventional coolants' loss of cooling qualities during film boiling and their lower film boiling temperature [9]. However, the elimination of grinding swarf, which is necessary for grinding, is made possible by flooded coolant operation. Traditional grinding fluids are a source of environmental risks, and usage and disposal guidelines are becoming more stringent [10]. These fluids are expensive as well. Several different coolants and lubricants are attempted as alternatives to conventional fluids. Solid lubricants have been used in certain efforts as a replacement and have demonstrated to significantly improve the technique [11]. Additionally, these elements sparked research on the usage of biodegradable cooling agents, minimal coolant amounts, and cooling agents free grinding [12].

Although, any experiment to reduce or destroy the cooling agents must be addressed by finding a different way to do the tasks that would typically be performed by the coolant. Other methods for achieving this goal include grinding with liquid nitrogen cryogenic cooling and minimum quantity lubrication (MQL) using ester oil provided as a spot jet or spray mist. In order to improve the process, the impact of graphite nanoplatelets in solid lubrication grinding is also investigated [13]. The results are quite positive, but the cost has been dramatically raised by the amount of nonmaterial needed. In order to boundary the heat produced at the grinding area and analyse the process functioning, the current research will use boric acid, a high temperature solid lubricant.

An experimental arrangement is constructed and fabricated for the design of comparing the effectiveness of boric acid-supported grinding with dry and standard flooded cooling liquid grinding.

Experimental Arrangement

To satisfy suitable carry of the solid lubricant and carrier to the grinding zone, an experimental setup is created. This was created using a cylinder that was loaded with dead weight. The cylinder is filled with the boric acid and carrier oil mixture. With the assist of a piston, which is in spin loaded by the dead weight connected on the piston rod as depicted in Figure 1, constant pressure is maintained on this mixture. The flow control valve is used to regulate the flow of the mixture.

Via a nozzle with a 1 mm * 25 mm aperture, the compound is impinged on the grinding zone. The size of the opening matches the size of the grinding wheel. The soft rubber wheel, which can freely move and is kept in continuous contact with the grinding wheel, receives the mix first. In the end, the paste is applied to the grinding wheel and consequently to the grinding area, where it works as a lubricant.

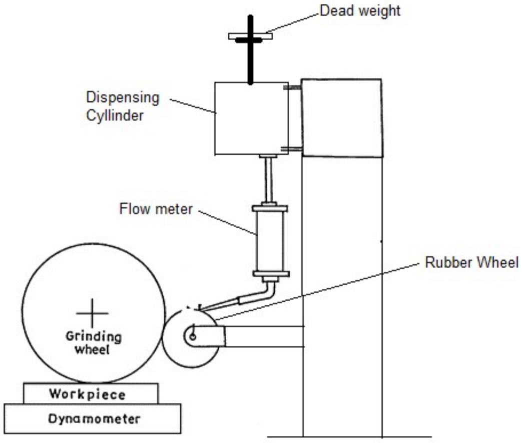

Fig. 1. Schematics Designs of Experimental Arrangement

Initial research and development

With a surface grinding machine with a horizontal reciprocating table, the grinding action is performed. For the experiment, a test specimen with the dimensions of 100 mm x 50 mm x 10 mm thick is used. Throughout the length of the workpiece, grinding is ended. The grade of surface conclude achieved using the process and the quantity of energy applied for the action are the final effects in which industry is particularly interested. Hence, the following factors are maintained constant during first investigations. This is described in further detail in below Chart 1.

Chart 1. Elements maintained constant in grinding.

Elements	**Particulars**
Workpiece substance	Compound steel AISI 4140

Grinding Device	Horizontal axle surface grinding, machine, PMT make, Model SG 42, 5.5 kw
Grinding Roll (Wheel)	A60L5V10, Diameter 300 millimetre, width 25 millimetre.
Roll (Wheel) velocity	30m per minute
Chart feed value	10m per minute
Dressing situation	With single point diamond dresser, 1 carat, in dry situation

AISI 4140 alloy steel is used for the initial experiments so that the effects of the use of solid lubricants on the process may be seen. Chart 2 lists the experimentation's findings.

Chart 2. Observations for preliminary experimentation.

Depth of Reduce (µm) ↓	**Dry Grinding**		**Wet Grinding**		**Boric Acid**	
	Force (N)	**Ra (µ)**	**Force (N)**	**Ra (µ)**	**Force (N)**	**Ra (µ)**
5	217.21	0.23	201.58	0.23	100.01	0.205
10	253.41	0.235	235.175	0.235	116.675	0.205
15	289.605	0.235	268.77	0.235	133.345	0.21
20	325.81	0.235	302.365	0.235	150.015	0.21

The plot of force vs cut depth is created to assess the forces under various cutting conditions. It shows that the force increases with cutting depth, but the amount depends on the type of coolant employed. It has been noted that employing solid lubricants results with two times of observations in less force being needed and better surface finish.

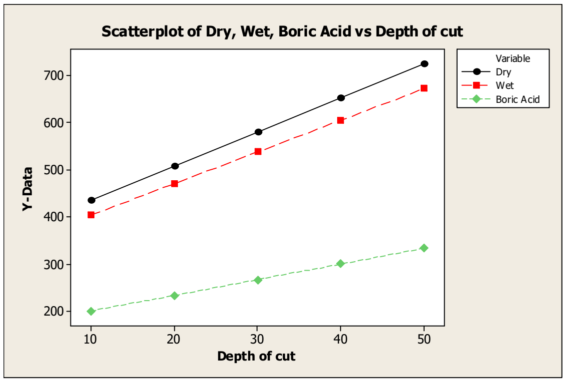

Fig. 2. Effect of coolants on force under varying depths of trim or cut

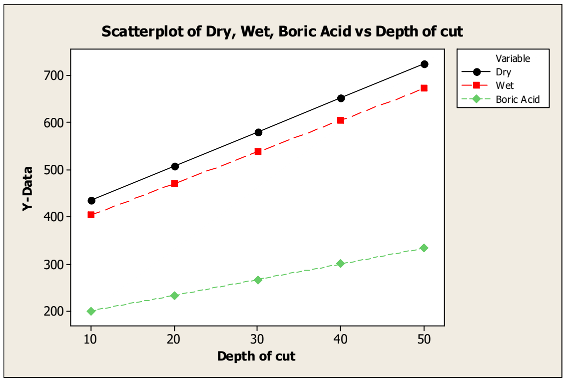

Fig. 3. Surface crudeness for AISI 4140 applying various cooling agents.

Extension of experiments using Taguchi methods

For the extension of experimental conceptions and drawings for functioning quality and cost, Taguchi methods of experimental design offer a straightforward, effective, and systematic approach. It has been proven effective in numerous manufacturing scenarios. The standard experimental design processes concentrate on the typical performance characteristics of the product or process. The Taguchi technique, however, focuses less on averages and more on the impact of variation on the quality features of the product or process. To put it another way, the Taguchi method renders the performance of the product or process insensitive (resistant) to change due to uncontrolled or noisy sources. This can be accomplished, according to Taguchi, by properly designing the parameters during the off-line quality control phase known as "parameter design." In order to evaluate two or more parameters simultaneously and independently for their capability to impact the irregularity of a precise product or process characteristic, he created a variety of standard orthogonal arrays (OAs).

The best possible combination of these parameters is then chosen. The study's fixed objectives are as follows: Research the impact of using boric acid on the amount of force needed to grind and the surface roughness that is produced, and compare the applications to different alloy steels.

The force needed (F) and the surface roughness (Ra) of the ground piece are used as the process's quality indicators. A Mitutoyo surftest is used to measure the surface finish, which is a direct process result. The two components of force were recorded by a dynamometer, which was used to measure force. The associated resultant force is measured and is taken into report as a individual reaction.

During the experiment, the working boundaries, containing speed and feed, are continued constant. Infeed rate, workpiece material, and lubricant flow rate are taken into account for variance. For each of the components, three levels with equal spacing are chosen within the working range, as shown in Chart 3.

Chart 3. Levels in Experimentation

Elements	**Stage 1**	**Stage 2**	**Stage 3**
Material	AISI 4140	AISI 4310	AISI 52100
Infeed (Depth of trim or cut), (µm)	5	15	25
Flow Rate, (mm^3/min)	10	20	30

The problem of repeating the tests is resolved by selecting the L27 orthogonal array because the array itself encourages the repetitions. This makes it easier to get more trustworthy information from the experiment's statistical analysis. The measurement systems record quality attributes such as force (F) in N and surface roughness (Ra) in m. Pieces are base giving seven groups of upward and downward spark out permits to have consistent outcomes with Ra.

The sampling data for surface roughness (Ra in m) and force (N) within the boric acid-assisted grinding method are displayed in Chart 4. The data gathered has a high degree of consistency, making it trustworthy for statistical analysis.

Chart 4. Observations and Analysis

Trial	**Material**	**In feed (µm)**	**Flow Rate (mm^3/min)**	**Force (N)**	**Surface roughness (µm)**	**S/N Ratio**	**Std. Dev.**	**Mean**
1	1	1	1	269.14	0.42	-48.822	6.3851	276.097
2	1	1	1	277.46	0.43	*	*	*
3	1	1	1	281.69	0.45	*	*	*
4	1	2	2	305.03	0.42	-49.865	7.2559	311.323
5	1	2	2	309.68	0.43	*	*	*
6	1	2	2	319.26	0.45	*	*	*
7	1	3	3	305.03	0.42	-49.910	7.2351	312.913
8	1	3	3	314.46	0.43	*	*	*
9	1	3	3	319.25	0.45	*	*	*
10	2	1	2	274.09	0.46	-48.936	6.5161	279.743
11	2	1	2	278.27	0.47	*	*	*
12	2	1	2	286.87	0.50	*	*	*
13	2	2	3	326.99	0.47	-50.513	7.7588	335.443
14	2	2	3	337.10	0.48	*	*	*
15	2	2	3	342.24	0.51	*	*	*
16	2	3	1	601.08	0.49	-55.757	14.292	613.477

17	2	3	1	610.24	0.50	*	*	*
18	2	3	1	629.11	0.53	*	*	*
19	3	1	3	288.10	0.47	-49.414	6.8335	295.547
20	3	1	3	297.01	0.48	*	*	*
21	3	1	3	301.53	0.51	*	*	*
22	3	2	1	564.91	0.49	-55.218	13.4306	576.560
23	3	2	1	573.52	0.50	*	*	*
24	3	2	1	591.25	0.53	*	*	*
25	3	3	2	536.67	0.49	-54.817	12.7298	550.540
26	3	3	2	553.26	0.50	*	*	*
27	3	3	2	561.69	0.53	*	*	*

Represented Plots for Force as A Prime Feature

On the groundwork of the represented findings of force essential for grinding process with the support of boric acid as solid lubricant for the materials chosen, AISI 4140, AISI 4340 and AISI 52100 are viewed in Fig.4 to Fig. 6.

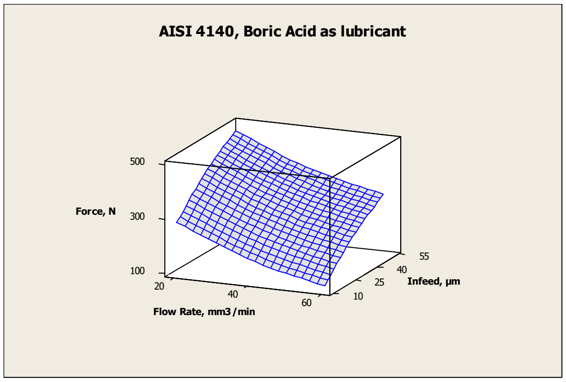

Fig. 4. Boric Acid as lubricant, AISI 4140

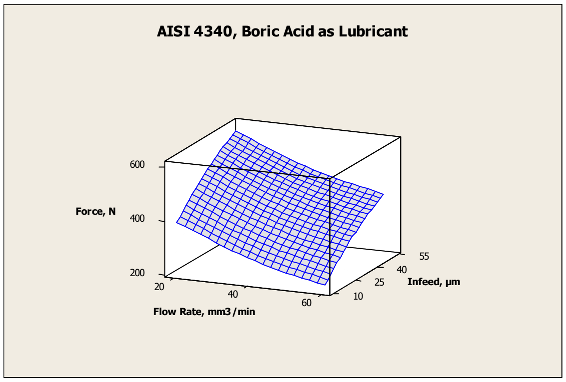

Fig. 5. Boric Acid as lubricant, AISI 4340

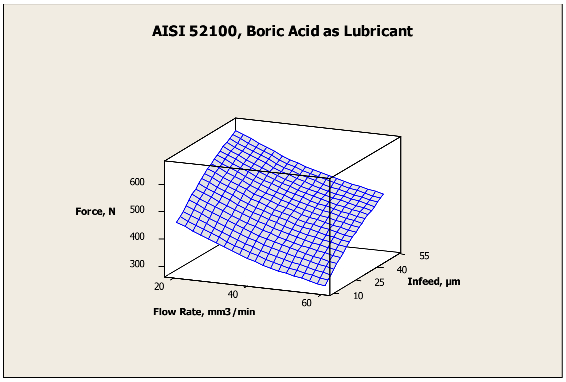

Fig. 6. Boric Acid as lubricant, AISI 52100

Study for Surface Crudeness and Roughness

In the same direction and in the same order of the force, Taguchi analysis is performed for surface roughness attained in the boric acid assisted grinding action. By the results of the represented findings of surface crudeness and roughness achieved in grinding process in consequence of boric acid as solid lubricant for the materials chosen, AISI 4140, AISI 4340 and AISI 52100 are provided in Fig.7 to Fig.9.

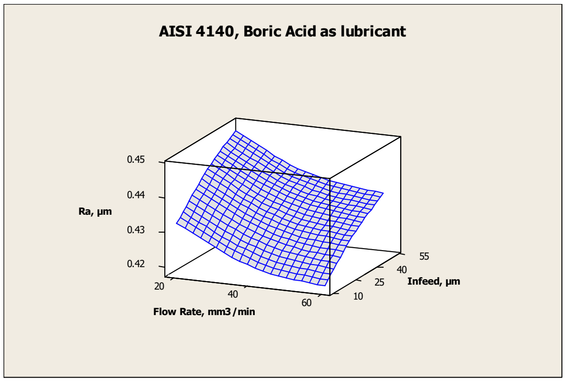

Fig. 7. Boric Acid as lubricant, AISI 4140

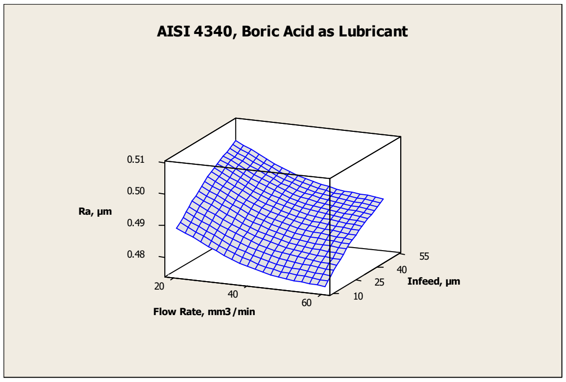

Fig. 8. Boric Acid as lubricant, AISI 4340

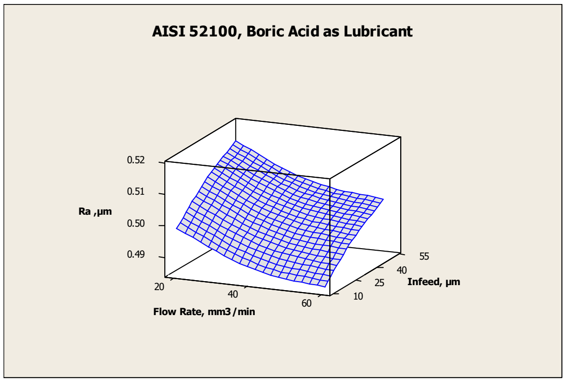

Fig.9. Boric Acid as lubricant, AISI 52100

Conclusions

The surface finish and cutting forces involved in the process have been enhanced using the experimental arrangement developed for the utilization of boric acid as a approach to decrease the heat produced in the grinding area. The research employ the Taguchi method of experimental design. Boric acid significantly reduces the force needed for grinding operations when compared to dry grinding and grinding with standard coolants, and the surface finish is also improved. Hence, the improvement in output metrics demonstrated the boric acid's beneficial role as a lubricant.

Other solid lubricants such as molybdenum disulphide, zinc phosphate, and graphite can be used in similar experiments, which may result in the most effective solid lubricant for surface grinding.

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