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Effect of operating Parameters in Grinding

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ABSTRACT: *The grinding process depends on operating parameters like feed rate, depth of cut and speed. These parameters are co-related with each other and are equally important to optimize the grinding process in terms of minimum consumption of grinding energy and minimum rate of wheel wear there by maximizing the grinding ratio. According to theory of single grit performance, the grinding wheel is an assembly of the number of small grains and each grain acts as a single point cutting tool taking part in cutting action. In present investigation SPSS software used to check the experimental value with the theoretical one. This work outlines the influence of cutting parameters on the specific cutting energy during a grinding process analytically and practically*.

Keywords*:- Grinding, Specific cutting energy*.

I. Introduction

Grinding is one of the most important machining processes for producing discrete components with high precision, and it accounts for about 20% to 30% of the total expenditure on machining operations [4]. So, it becomes imperative that the grinding process must be understood properly to have full control over the quality, productivity, and cost aspects of the process. Many experimental investigations reveal that depth of cut, wheel speed, and feed are the major influential parameters that affect the quality of the ground part. Thus determining the optimum parameters lie in the proper selection and introduction of suitable design of experiments. In this paper an attempt is made to determine the optimum grinding conditions and to minimize the specific cutting energy, which is greatly affected by the grinding parameters. An experiment has been designed to measure the forces during cutting action in grinding process with the help of a digital dynamometer for computing the specific cutting energy.

II. Cuttting Action In Grinding

The grinding wheel consists of abrasive particles, bond and voids. The projecting abrasive particle acts like cutting tool tip and removes metal as well as performs self-sharpening action. As the process goes on, the abrasive particle or sharp edge of the tool becomes dulled and weak due to the resistance offered by work piece material, which resists the cutting action. This weak sharp edge wears out and new cutting point comes out which carries out further cutting action. This process continues till the abrasive grains brakes down. The main problem often arises out of wrong selection of grinding wheel specifications or by improper cutting conditions, which leads to wheel glazing and wheel loading. Wheel glazing refers to the condition when the grains are worn down to the level of the bond there by reducing the rate of cutting because the depth of penetration is reduced. Increasing the wheel speed or changing specifications can reduce it. Thus the selection of grinding wheel for correct, continues and efficient cutting demands the correct selection of type of abrasive size of the grains, type of bond and the size of the voids. Further more, the wok piece material, cutting speed, depth of cut and feed rate, affects the behavior of grinding wheel.

III. Mechanics of the Grinding

Since grinding is a complex process and is difficult to analyze mathematically there has not been much progress made in this direction [5]. A brief account including the direction of development in research in the field of mechanics of grinding is given here. The grinding process as shown in figure (3.1) is essentially the same as milling except that in grinding an abrasive grain in the wheel cuts out chip from the work.

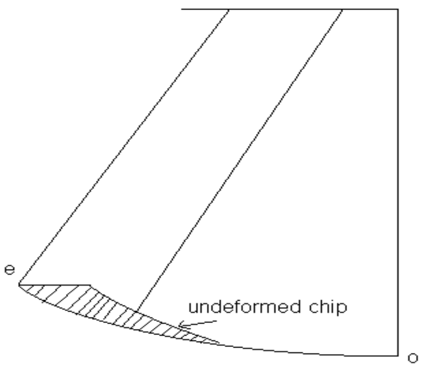

Fig.(3.1) Grinding Geometry

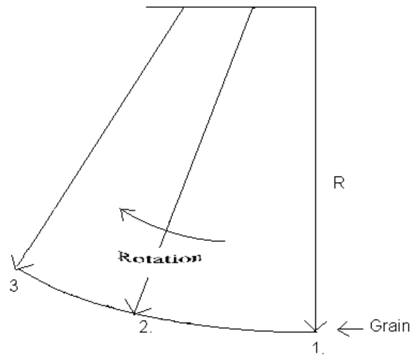

Fig.(3.2) Material removed

As shown at Fig (3.2), from the beginning of the cut at (o) to the end at (e) the material removed will be as shown sectioned, and this is termed as un-deformed chip, which, at the end of the cut will assume either a curved or segmental form. The size and the shape of the un-deformed chip are considered important in the analysis of the grinding process and of particularly important is chip thickness "t" shown at Fig (3.3).

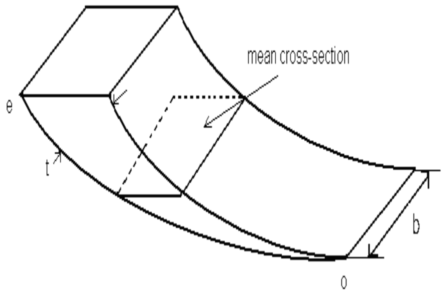

Fig.(3.3) The shape of un-deformed chip for assumed constant width b.

Since the chip thickness varies from zero at (o) to a maximum at (e), it is necessary to estimate the value of the mean thickness. The shape of the cross section of the un-deformed chip is not easy to determine since it depends on the shape of each particle of abrasive grains. Since the grains are of different shape, which changes with their attritious wear, and fracture, it becomes necessary in investigations to assume the geometry of a mean un-deformed chip. Since the first paper investigating the size of chips in the grinding operation in 1914 to understand the process grinding [6]. Since still here much considerable progress made remain in the direction of understanding the grinding process. The work of Bacher and Merchant [7] has thrown consideration light on the subject. An attempt is made to analyze the force on a mean grain as it removes a chip as shown here in fig (3.4). Indications were that the effective mean rake angle was roughly 30° (α).

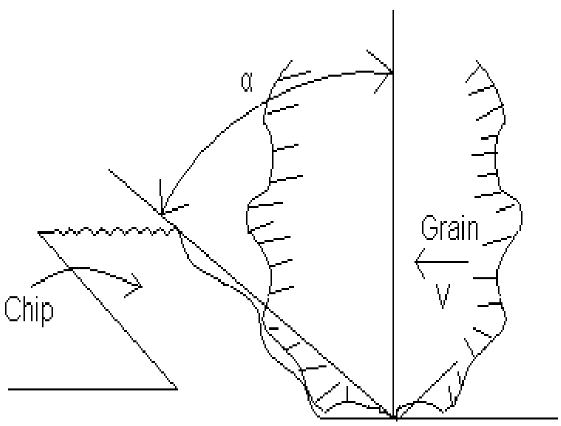

Fig (3.4) (Particle of grain in grinding)

Specific Cutting Energy can be defined as the work required for converting one cubic millimeter of material in chips.

Following factors 3 influences specific cutting energy.

1. Effective rake angle of tool. (Specific cutting energy is decrease about 1% per degree increase in rake angle.)
2. Work piece metallurgical properties and physical properties. (Specific cutting energy is approximately proportional to work piece hardness.)
3. Un-deformed chip thickness. (Specific cutting energy varies approximately as follows with un deformed chip thickness, the inverse relationship is sometimes referred to the size effect.)

The specific cutting energy is a function of the work piece material and the mean chip section and it is generally independent of the other variables. It decreases with an increase in chip thickness and decrease in the work piece toughness. For estimation of the specific cutting energy the estimation of the force is essential. In the grinding process there are two forces one is the tangential force and another is normal force [8].In the surface grinding the force acting on the grinding wheel are shown here. The horizontal force determines the power consumed in the process.

Work done in grinding = F_h x V_{wh}.

Where F_h = horizontal grinding force. V_{wh} = peripheral speed of grinding wheel.

The vertical force F_v determines the rate of stock removed in non precision grinding the ratio of F_h/F_v in grinding is known as coefficient of grinding and varies from 0.1 to 0.3 for snagging to 0.04 to 0.5 for weight precision grinding [9].

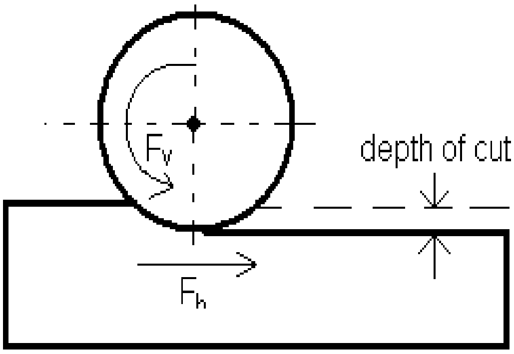

Fig.(3.5) Forces during Grinding Process

The specific grinding energy can be calculated as:

$U=F.V_{wh}/Q$ in J/m^3.

……………eq. (A)

Where--

F = force tangentially acting in kgf V_{wh} = wheel speed m / min.

Q = volume of the metal removal in m^3/s. For the surface grinding the volume of the metal removal, mm^3/min. is given by

$Q = b_c$ x t_1x f_t m^3/s

………………eq. (B)

Where--

b_c=Cross feed mm/pass t_1=Depth of grind, mm f_t= Table traverse feed rate mm/min

IV. Observations

The force is measured with the help of dynamometer and the specific cutting energy for different feed rate for same increase in depth of cut is calculated with these forces.

Depth of Cut in mm	Feed Rate 0.50 mm/pass	Feed Rate 0.25 mm/pass	Feed Rate 0.15 mm/pass
	Specific cutting energy in J/m^3		
0.004	2.45	4.35	9.08
0.005	2.07	3.61	7.11
0.006	1.81	3.12	5.50
0.007	1.71	2.8	4.30
0.008	1.63	2.58	3.63
0.009	1.51	2.42	3.14
0.010	1.41	2.50	2.36
0.011	1.38	2.57	2.04
0.012	1.27	2.63	1.84
0.013	1.17	2.51	1.73
0.014	1.08	2.41	1.63
0.015	1.01	2.33	1.54
0.016	0.95	2.23	1.58
0.017	0.89	2.16	1.60
0.018	0.84	2.08	1.61
0.019	0.83	2.08	1.62
0.020	0.81	2.12	1.63
0.021	0.81	2.19	1.64
0.022	0.82	2.23	1.65
0.023	0.82	2.29	2.36
0.024	0.82	2.33	2.39
0.025	0.82	2.37	2.50

Table (5.1)

The graphs are plotted between depths of cut and force at different feed rate, which are shown in figures. The value of the specific cutting energy for different feed rate with deferent depth of cut is tabulate here in

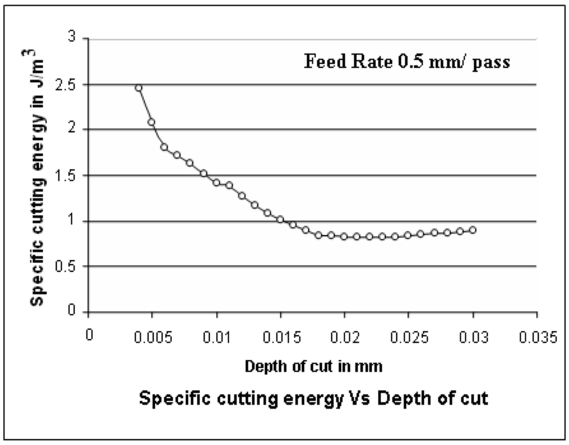

Fig.(5.1)

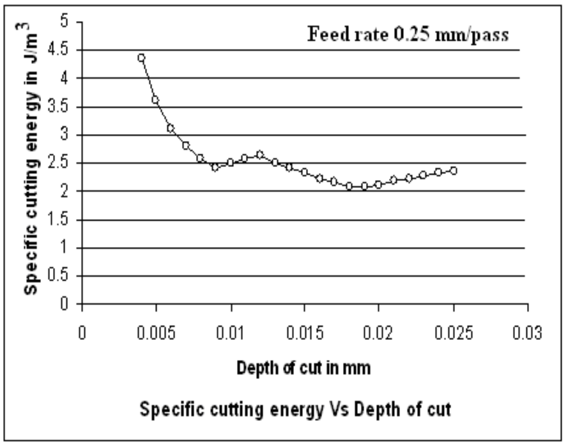

Fig. (5.2)

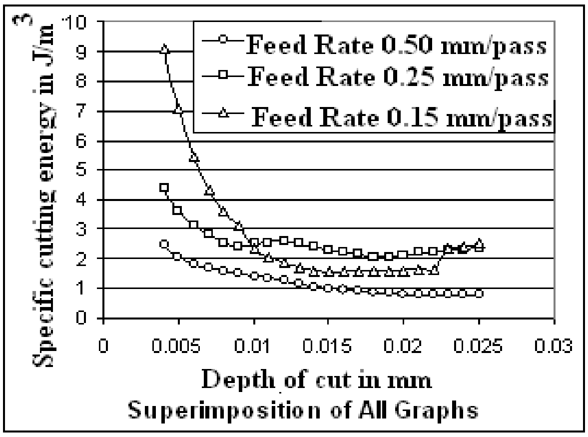

Fig. (5.3)

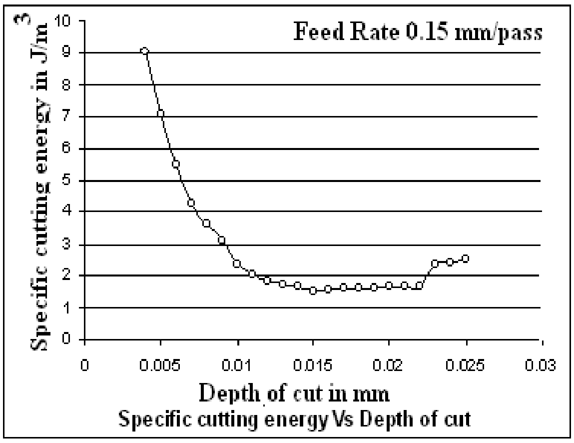

Fig. (5.4)

The specific cutting energy and depth of cut is represented here in the graphical form to understand the influence of the depth of cut on specific cutting energy on different feed rate in fig. From (Fig 5.1 to 5.4).

V. Development of Mathematical Expression

In present paper a mathematical expression is derived with the help of SPSS software, which defined the nature of the curve mathematically. This expression explains influence of cutting parameters on the specific cutting energy during a grinding process. In general the parameters, which influence the specific cutting energy, are depth of cut, feed rate, and work piece velocity. In present expression the specific cutting energy is the function of depth of cut, which is the prime influencing factor.

The expression is $U= 0.248-10.279x+147.178x^2$

Where U= Specific cutting energy in kgf-m/mm^3

x= Depth of cut in mm.

This expression holds good for the feed rate 0.5 mm/pass.

Source	Sum of Squares
Regression	0.418
Residual	0.007
Uncorrected Total	0.425
Correct Total	0.046

Table (6.1)

Furthermore an ANOVA[a] test is performed on the experiment, which expresses the fitness of experimental value of the specific cutting energy with the theoretical value for different operating parameters. With the help of SPSS software R Squared is determined and which is equal to the 0.851.Thus the value of R Squared justifies that the experimental work is very close to the actual theoretical value. Further more the actual difference between the Theoretical and observed value of specific cutting energy Can be found by plotting graph as shown in Fig. (6.1).

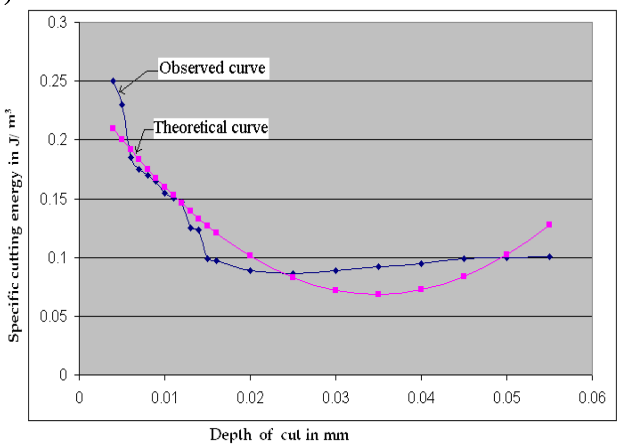

Fig.6.1

VI. Results & Discussion

The graph show that the specific cutting energy in grinding process starts to decrease with increase of material removal rate, however after attaining a certain material removal rate, the specific cutting energy may start increasing. In present case graph (Fig.5.4) between specific cutting energy and depth of cut show that curve for feed rate 0.25 and feed rate 0.5 intersect with each other at a particular depth of cut, and give the optimal result for both value of feed rates at this point for minimum specific cutting energy. After this point as depth of cut increases the specific cutting energy again starts to increase. This required the explanation for the above variation in the process. Discussion on this matter concludes at, that the specific cutting energy decrease first because of the rake angle of the cutting grit becomes more favorable (less negative) during grinding process [1]. But after attaining a certain material removal rate, the specific cutting energy again starts to increase. This happen because of the chip accommodation problem with large volume of chip, which promotes large chip-bond and chip work piece sliding leading to increase in grinding force. The study in this area suggest that grinding force increases with decrease in cutting velocity while the same increases with increase in table speed and depth of cut. Whereas Specific cutting energy is approximately the same for hard and soft steel is a paradoxical result that requires explanation [2].

VII. Conclusion

The experiment demonstrates that cutting parameters i.e. speed; feed and depth of cut play an important role in controlling specific cutting energy, which subsequently affects the productivity and economy of the process. It is evident from the results that although specific cutting energy decreases first rapidly with increase of depth of cut and then starts to increases after a particular depth of cut for different feed rate. Result shows that increments in specific cutting energy with increase of depth of cut occur due to the chip accommodation problem. In this experiment a trade off can be achieved for operating parameter, assuring the minimum specific cutting energy for the process. Therefore it has been conclusively established that by using optimum cutting parameters i.e. feed rate and depth of cut the power consumption, economy, process capability, and quality of ground part can be achieved up to desired level.

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