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Effect of Process Parameters on MRR of Cylindrical Grinding

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Abstract: Cylindrical grinding is one of the important metal cutting processes used extensively in the industries for finishing operations. Material removal rate (MRR) and surface finish (Ra) are the important output responses in the production with respect to quantity and quality respectively.The main problem with grinding operations is the MRR, as it is low and thus there is a need for the increase in MRR which will reduce the cost of grinding operations and thus will reduce the overall time required for further finishing processes. The problem lies with the less MRR as the grinding wheel is unable to take the excess grinding load because, if the depth of cut is increased more than the capacity, the vibrations occurring will snap the grinding wheels and is a costly affair. The main objective of this project is to arrive at the optimal grinding conditions that will maximize MRR when grinding. The input parameters that are considered for optimization are depth of cut (DOC), work piece speed (W_{wp}) and feed (f) which are optimized with the help of response surface method (RSM) and particle swarm optimization (PSO) to obtain the required result.

Keywords*:* DOC; Vw; Vgw; Ts; Deq; (ad)DOC; Tc; Ra; Wwetc

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1. INTRODUCTION

Cylindrical grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances. As compared with other machining processes, grinding is costly operation that should be utilized under optimal conditions. Although widely used in industry, grinding remains perhaps the least understood of all machining processes.Agrinding wheelconsists of abrasive particles and bonding material. The bonding material holds the particles in place and establishes the shape and structure of the wheel. The way the abrasive grains, bonding material, and the air gaps are structured, determines the parameters of the grinding wheel, which are *Abrasive Material, Grain Size, Bonding Material, Wheel Grade, Wheel Structure.* To achieve the desired performance in a given application, each parameter must be carefully selected.

2. LITERATURE REVIEW:

The study of different aspects that have influence on the performance of grinding process has been carried out from the beginning of this type of machining. In fact it is still difficult to understand all the aspects concerning grinding due to its strong stochastic nature and multiple parameters of process. Some research lines can be found easily in this literature survey.

Heinzel and Solter [1] A versatile method to determine thermal limits in grinding' proposed a physical based method to determine limits with regard to the thermal impact of grinding processes on the machined work piece surface layer. The described method determines the dependence between the maximum contact zone temperature rise θ_m and the contact time Δt offers a versatile method to predict the resulting thermal effect of the grinding process on the work piece surface layer properties

Grzesika and Krzysztof [2] Comparison of surface textures generated in hard turning and grinding operations' investigated the problem of replacing costly and environmentally detrimental grinding operations by hard turning or milling processes by extended study on comparison of surface textures generated in both cases.3D BAC curves and appropriate functional parameters depict that ground hard surfaces have better bearing properties and based on vectorial maps of micro-valleys that ground surfaces indicate better fluid retention ability.

TaghiTawakoli,[3] 'An experimental investigation on the characteristics of cylindrical plunge dry grinding with structured cBN wheels' experimented, cylindrical plunge grinding employing both structured as well as normal wheel. The visible thermal damages in dry grinding with 25% contact layer appear in a higher specific MRR as compared with dry grinding with 100 % contact layer.

Jae-ScobKwak [4], 'An analysis of grinding power and surfaces roughness in external cylindrical grinding of hardened SCM440 steel using the RSM' studied the grinding power spent during the process and the surface roughness of the ground work piece using response surface method. The study concluded that increasing the depth of cut affected the grinding power more than increasing the traverse speed. Also increasing the depth of cut changed the maximum height of surface roughness more than average.

A. Hassui [5], 'Correlating surface roughness and vibration on plunge cylindrical grinding of steel' investigated the relationship between the process vibration signals and surface roughness. The experiment concluded as it is possible to have a good surface quality work piece with high level vibrations than that obtained using recently dressed wheel and that decrease in spark-out time increases vibration level a lot but does not damage the surface roughness.

ChangshengGuo [6], 'Energy Partition and Cooling During Grinding' studied quantitative methods to calculate grinding temperatures and energy partition to the work piece. For regular grinding with aluminium-oxide wheels, cooling at the grinding zone is not effective, and the energy partition ranges from 60% to 70%. The energy partition is reduced to 5% from 8% for grinding with vitrified CBN with water-based fluid due to effective cooling at the grinding zone.

Of all the literature surveyed for the fulfilment of the project the most effective input as well as the most affected output parameters can be seen from the following charts presented below:

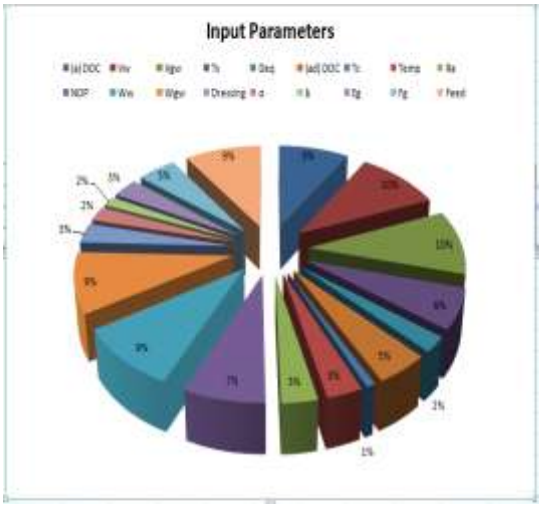

Fig.1 Pie Chart for Effective Input parameters.

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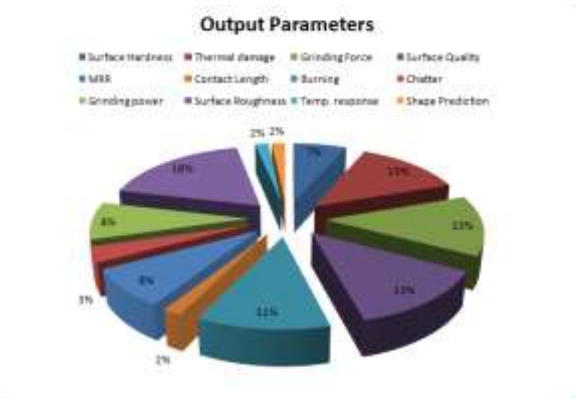

Fig. 2. Pie chart for Effective parameters

Abbreviations:

DOC - Depth of Cut; Vw – Work piece velocity; Vgw – Grinding wheel velocity; Ts – Spark-out time; Deq – Equivalent Diameter; (ad)DOC – Additional Depth of Cut; Tc – Cutting time; Ra – Surface Roughness; NOP – Number of Passes; Ww – Work piece speed (RPM); Wgw – Grinding wheel speed (RPM); α – Thermal Conductivity of work piece; Eg- Grinding Energy; Fg – Grinding force

3. METHODOLOGIES

A) Response Surface Methodology

The method was introduced by G. E. P. Box and K. B. Wilson in 1951. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. Box and Wilson suggest using a second-degreepolynomial model to do this. They acknowledge that this model is only an approximation, but use it because such a model is easy to estimate and apply, even when little is known about the process.

An easy way to estimate a first-degree polynomial model is to use a factorial experiment or a fractional factorial design. This is sufficient to determine which explanatory variables have an impact on the response variable(s) of interest. Once it is suspected that only significant explanatory variables are left, and then a more complicated design, such as a central composite design can beimplemented to estimate a second-degree polynomial model, which is still only an approximation at best. However, the second-degree model can be used to optimize (maximize, minimize, or attain a specific target for).

A) Particle Swarm Optimisation

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling, PSO shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA) [5-8].

In PSO algorithm, the potential solutions, called particles, fly through the problem space by following the current optimal particles. Each particle keeps track of its coordinates in the problem space which are associated with the best solutions (fitness) it has achieved so far. This value is called pbest. Another ‘best’ value that is tracked by the particle swarmoptimizer is the best value, obtained so far by any particle in the neighbor of the particle. This location is called lbest. When a particle takes all the population as its topographical neighbors, the best value is a global best called gbest. The PSO concept consists of, at each time step, changing the velocity of each particle towards its pbest and lbest locations. Acceleration is weighted by random term, with separate random numbers being generated for acceleration towards pbest and lbest locations. The movements of the particles are guided by their own best known position in the search space as well as the entire swarm’s best known position. When improved positions are discovered, these will then come to guide the movements of the swarm. The process is repeated and by doing so, it is hoped that a satisfactory solution will be eventually discovered. This algorithm makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solution. It can be therefore used for optimization problems which are partially irregular, noisy, change over time and particularly suited for continuous variable problems. The PSO algorithm has its own advantages, like it is insensitive to scaling of the design variables and its implementation is simple.

4: EXPERIMENTAL DATA

An experiment was set up in Eicher Motors on a External Cylindrical Grinding machine using a vitreous bond, with wheel grade A60K4V15 with the grinding wheel specifications as follows; *Wheel Diameter- 500 mm; Wheel Bore- 254 mm; Wheel Width- 65 mm; Operating Speed- 1240 RPM*

Parameters	Levels				
	-2	-1	0	1	2
DOC(Mm)	0.015	0.02	0.025	0.03	0.035
Feed (mm/rev)	4.102 * 10^-3	3.603* 10^-3	3.264* 10^-3	3.03* 10^-3	2.867* 10^-3
Work piece speed (rpm)	75	90	105	120	135
(mm/min.)	8246.6	9896.01	11545.3	13194.6	14844.02

The job under operation was a Cluster Gear which forms a part of the Gear Box used in Eicher Vehicles. Several grinding operations were used to generate a precisely ground surface for measurements. The depth of material removal in the process was limited to 0.2 mm. After grinding the face profile was measured in the radial direction using a Digital Vernier Caliper.

Orthogonal Array

Readings =17

No.	**Input**			**Output**
	DOC	**FEED**	**Wsp**	**MRR**
1	-1	-1	-1	0.7131
2	1	-1	-1	1.0696
3	-1	1	-1	0.5996
4	1	1	-1	0.8995
5	-1	-1	1	0.9508
6	1	-1	1	1.4262
7	-1	1	1	0.7996
8	1	1	1	1.1994
9	2	0	0	1.3189
10	-2	0	0	0.5652
11	0	2	0	0.8275
12	0	-2	0	1.1839
13	0	0	2	1.2112
14	0	0	-2	0.6729
15	0	0	0	0.9421
16	0	0	0	0.9421
17	0	0	0	0.9421

Table 1: Validation of experiment

No of Validation Experiment	Average MRR for optimized setting
90	1.35

* Minimum MRR observed: 0.95

* Maximum MRR observed: 1.55

VII. CONCLUSION:

Modelling and optimization aspects of Cylindrical Grinding Process parameters are considered in the present work. The problem observed in the same machine is low material removal rate. Therefore the objective considered as maximization of material removal rate. A RSM based modelling approach coupled with particle swarm optimization is proposed in this work. The results obtained showed an improvement in MRR with consistency in machining the sample. It clearly indicates that the results obtained by optimum parameter setting are consistent within very less inaccuracy. This significant improvement in results clearly indicates the potential of proposed approach to deal with real life complex problems related to parametric optimization of machining processes.

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