Optimization of Grinding Parameters of Surface Grinding Process for AISI 1018 Mild Steel by using Al_2O_3 Grinding Tool

Rajhans R. Manwatkar[1] Dr. Ramakant Shrivastava[2]
[1]PG Student [2]Head of Dept.
[1,2]Department of Mechanical Engineering
[1,2]Government College of Engineering, Aurangabad (An Autonomous Institute of Government of Maharashtra), India

Abstract— Recently, grinding is most common finishing process used for finishing different materials like Cast Iron, Steels, stainless steels, copper, crass, aluminium and its alloy, tool steel, high speed tool steel, nickel alloys etc. Generally the process used for giving finishing to the materials. Super finishing operation also carried out with the grinding process. AISI 1018 Cold rolled steel referred as low carbon steel or mild steel has good mechanical as well as physical properties. It has a good weldability, machinability, easy to forged, easy to cold rolled, good strength and provides ductility. It is used in many applications such as often employed in high volume screw machine parts, commonly employed in shafts, spindles, pins, rods, sprockets assemblies and wide variety of component parts, cars, domestic goods, constructional steel also employed in wire, plate , tin cans, mild steel flanges, tube fittings, pipe fittings, pipes, tubes, fasteners, sheets, rods, bars etc. It can be finished up to 0.46 µm with standard grinding operation generally used in industries. By optimizing grinding parameters, it is possible to achieve optimum surface roughness. Aluminium Oxide is often used in grinding of mild steels. Every parameters in grinding process should be considered for achieving minimum surface roughness value i.e. cutting speed, feed rate, depth of cut, coolant flow rate, grain size for both tool and work material(course/fine), physical properties of material, grit size for grinding tool, thermal effect etc. But still dominating parameter in grinding is cutting speed of grinding wheel second one is depth of cut.

Key words: Surface Roughness, Cutting Speed (Grinding Wheel Speed), Feed Rate, Material Removal Rate, Depth of Cut, Grain Size, Grit Size, Coolant Flow Rate

I. Introduction

Surface grinding is a finishing process used to produce smooth finish on flat surface also is the process of removing metal by the use of grinding wheels. The grinding wheel is made of abrasive grains which form the cutting edges in a wheel. The size of abrasive grain required in a Grinding wheel depends upon the hardness of the material being ground. There are two types of abrasives i.e. natural and artificial abrasives. The natural abrasives are corundum and Cmery and the artificial abrasives are silicon carbide (carborundum) and aluminum oxide (aloxite). The hardness of grinding wheel is specified by an alphabet. The alphabets A to H are soft grade, I to P are medium grades and Q to Z are hard grades. The soft grade grinding wheels are used for grinding hard materials and hard grade grinding wheels for softer materials. A soft grade grinding wheel is one in which abrasive grains can be easily dislodged and in a hard grade grinding wheel, the abrasive grains are held more securely. To obtain finishing with minimum roughness value i.e. higher finishing, mechanical as well as physical properties of material are to be considered. At higher temperature material gets weakened and loses its magnetic properties, susceptible to corrosion. Lubrication is also important as to cool and remove chips (swarf). Fluids are water soluble chemical fluid, synthetic oil, petroleum base oil. Almost 2 µm roughness is achievable with surface grinding for all ferrous and non-ferrous alloys.

Parameters to be considered are cutting speed, feed rate, MRR, depth of cut, coolant flow rate. Physical properties are grain size for both material and tool and grit size for grinding wheel and its structure of material (course and fine). It is found that course grain wheel may be used for grinding soft material and fine grained wheel for hard and brittle material. Course grinding wheel used for fast removal of material whereas fine grained wheel are used to finish of work. Higher grit size used for achieving minimum roughness value, whereas lower grit size used for achieving higher roughness value. Since Al_2O_3 is recommended for grinding carbon steels for minimum roughness because of material ductile property therefore it is taken for experimentation. Generally wrought iron, carbon steel, annealed malleable iron and high speed tool are chiefly used. AISI 1018 steel used in large volume production than any other steel, machine components, screw fasteners, bars, pipes, pipes fittings, wires, commercial purpose, automobiles, aerospace etc.

II. Literature Review

K Mekala et al. [1] experimented on optimization of cylindrical grinding parameters of austenitic stainless steel rods (AISI 316) by Taguchi Method and found that depth of cut is a dominating parameter of cylindrical grinding. The optimum parameter for metal removal rate of cylindrical grinding of austenitic stainless steel rods were 560 m/min of cutting speed, 0.130 mm of Feed and 0.05 mm of depth of cut, however austenitic stainless steel (AISI 316) is good machinabilty characteristic and produce excellent surface finish. Austenitic stainless steel produce good surface finish and get minimum crack tendency.

Kamaldeep Singh et al. [2] studied on experimental investigation of machining characteristics of AISI D3 steel with abrasive assisted surface grinding and concluded depth of cut is a major factor for both surface roughness and material removal rate with a percentage contribution of 63.91 and 95.84 respectively.

Qiyong Zeng et al. [3] examined the cutting parameters affect the workpiece surface quality. Process Failure Mode and Effect Analysis (PFMEA) were conducted with cutting temperature, cutting force and mechanical vibrations are the main factors that affect the workpiece surface roughness. The cutting force, cutting temperature and vibration can be controlled by controlling cutting speed, feed rate and cutting depth. Surface roughness of the workpiece was measured by surface roughness tester. The thin film thermocouple sensor and three-dimensional piezo electric dynamometer was used to measuring the system for cutting force and cutting temperature. The piezo electric dynamometer work fast with high sensitivity is convenient for real time measuring on line. In this investigation, Polycrystalline Cubic Boron Nitride (PCBN) was used as the cutter material. Workpiece surface roughness is good under the condition of low cutting speed and low cutting depth. The thin film thermocouple is an advanced sensor used to measure the changes in temperature. It is concluded that feed rate and cutting depth affect the workpiece surface roughness than cutting speed.

M. Janardhan et al. [4] has developed model to predict and optimize the process parameters using Taguchi method, ANOVA and regression analysis. The main objective of this work is to maximize the metal removal rate (MRR) and to minimize the surface roughness (Ra). The design of experiments is conducted on CNC cylindrical grinding machine. The empirical models are developed using design of experiments and surface roughness methodology. Regression analysis used to determine the relationship of the input variables which affect the output responses. In these experiment, grinding wheel having aluminium oxide abrasive with vitrified bond with constant speed of 1650 rpm and water used as coolant. In this experiment L9 orthogonal array was used and tested with ANOVA. The input parameters of this work as work speed (rpm), feed rate (mm/min) and depth of cut (μm). The regression analysis was done by MINITAB 15 statistical software. In this work, EN 8 material is used to determine the effect of machining parameters. The concept of ANOVA and S/N ratio is used to determine the effect of process parameters. From the pareto analysis conclude that feed rate plays important role in the output response of surface roughness and metal removal rate. The optimized values for MRR and Ra for cylindrical process are 62.05 gm/min and 0.816 μm respectively.

Deepak Pal et al. [5] investigated to predict the grinding behaviour and finding optimal operating process parameters. In this paper, minimize the surface roughness (Ra) by Taguchi optimization technique. The universal tool and cutter grinding machine with aluminium oxide abrasive wheel were used for investigation. The workpiece material is used for the investigation is EN 24, EN 31 and die steel. L9 orthogonal array is used for this experimental work. The input parameters used for this work is work speed, grinding wheel grades and hardness of the material. MATLAB software is used for optimization work. It is found that the optimal value of surface roughness is 1.07 μm.

Thiagarajan. C. et al. [6] studied the grindability of Al/SiC metal matrix composites in cylindrical grinding process. Horizontal spindle cylindrical grinding machine with Al_2O_3 grinding wheel is used for this experimental work. The experiments are carried out to study the effect of grinding parameters such as wheel velocity, workpiece velocity, feed and depth of cut. An infra-red non-contact laser thermometer is used to measure the temperature generated between the grinding wheel and workpiece. Scanning Electron Microscope [SEM] is used for measure the surface integrity. They reported that good surface finish occurs at high grinding wheel velocity and workpiece velocity, low feed rate and depth of cut.

Janardhan M. et al. [7] investigated the optimization of surface quality and metal removal rate using the Response Surface Methodology [RSM]. In this work, wheel speed, table speed and depth of cut are control factors. The surface grinding machine with aluminium oxide abrasive wheel is used. L27 Orthogonal array is selected for this research work. MRR is calculated using the ratio of volume of metal removed from the workpiece to the machining time. Surface roughness was measured using the surface roughness tester. The material used for this investigation is EN 24. The Design Expert (MINITAB) software is used for finding the output responses.

The main objective of the work is to minimize the Surface Roughness (Ra). In order to optimize the Ra value Taguchi Method, ANOVA and regression analysis is used to predict the optimal value. This research work has study relationship between the cylindrical grinding parameters [cutting speed, feed rate, and depth of cut] and the surface roughness value.

Amandeep Singh Padda et al. [8] they found that most significant factor in surface grinding is wheel speed followed by grain size and depth of cut. Increasing wheel speed increases the tangential cutting force on material surface thus allowing more cutting and rubbing of grains. But this also increases stresses on Al_2O_3 wheel grains because of hardness and toughness of stainless steel, thus leading to high grain wear and abnormal fracture. This reduces the cutting action and causes more grain rubbing against the metal surface. As all grain size particles fail to provide better surface finish a high wheel speeds, it is clear that Al_2O_3 particles fail to grind stainless steel.

B. Dasthagiri et al. [9] studied optimization on surface grinding process parameters and predicted the result that the optimum results for the output responses namely surface roughness and metal removal rate in terms of machining parameters namely wheel speed, table speed and depth of cut on EN 8 steel on CNC surface grinding machine using DESIGN OF EXPERT V7.1.3 software were determined and presented. It can be observed that there is not much error between the experimental values and predicted values and that error is about 4 to 8 %. Thus the response optimization predicts the optimum conditions fairly well.

Pawan Kumar et al. [10] studied on optimization of process parameters in surface grinding using response surface methodology. They concluded the surface roughness and MRR in surface finishing process of EN24 steel using Al_2O_3 was modelled and analysed through RSM. Wheel speed, table speed and depth of cut have been employed to carry out the experimental study. Summarizing the main features, the following conclusions could be drawn the predicted values match the experimental values reasonably well, with R2 of 0.9164 for Surface Roughness, R2 of 1.000 for MRR.

III. METHODOLOGY

- Design of Experiment (DOE): Design of experiment principle used to determine particular parameters. They are AISI 1018 mild steel, surface grinding machine, grinding wheel, and surface roughness tester equipments used for experimentally.

A. Surface Grinding Machine

Surface grinding machine used for removal of metals on flat surfaces. M618A Surface grinding machine is used with specification given below.

Fig. 1: Photographic view of surface grinding machine

Model/item	**M618A**
1. General	
Max width to be ground	165mm
Max length to be ground	470mm
Max height to be ground	350mm
2. Table	
Table size(W x L)	155x460mm
Permanent magnetic chuck size	150x400mm
Max longitudinal trivial	500mm
Max cross travel	185mm
3. Grinding wheel	
Grinding wheel speed	3000rpm
Grinding wheel size	300mm x 50mm x 76.2mm
4. Power	
Spindle motor power	1.5 KW
Coolant pump motor	0.25 KW
5. Weight	
Maximum table loading including chuck	97kg
Machine weight	790kg

Table 1: Specifications of surface grinding machine

B. Grinding Wheel

Grinding tool of alumina with grit no. 46 medium grade taken for experimentation.

Specification of grinding wheel	
Size	300mm x 50mm x 76.2mm
Wheel signature	38A46K5VBE
Grit size	46
Grains	Medium
Abrasives	Alumina(Al_2O_3)

Table 2: Specifications of grinding wheel tool

C. AISI 1018 Mild Steel or Low Carbon Steel

Mild steel is taken for experimentation as work material and its composition as follows:

Chemical composition of mild steel				
C	Mn	S	P	Fe
0.15-0.20%	0.60-0.90	0.05 Max	0.04 Max	Balance

Table 3: Chemical composition of AISI 1018 mild steel

Fig. 2: Photographic view of sample plate's mild steel or low carbon steel

D. Surface Roughness Tester

Model	Mitutoyo surface roughness tester
Power supply	100-240V,AC, 50-60HZ
Drive speed	0.25mm/sec, 0.5mm/sec,0.8mm/sec
Evaluation length	12.5mm(maximum length it can be measure depending on the cut of length)
Digital filter	2CR-75 (without phase compensation) PC-75%,PC-50% (Gaussian)
Roughness parameters	Ra,Ry,Rz,Rq,S,Sm,Pc,R_3z,mr,Rt,Rp,Rk, Rpk,Rvk, Mr1,Mr2,A1,A2,Vo (can be customized)
Stylus tip radius	200 µinch (5µm)
Measuring force	4Mn

Table 4: Specification of surface roughness tester

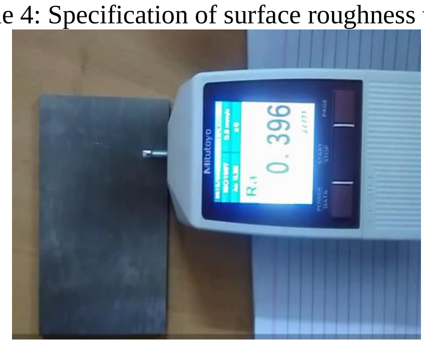

Fig. 3: Mitutoyo Sirf Test SJ201-P surface roughness tester

IV. EXPERIMENTATION

Experimentation procedure performed on surface grinding machine in three steps:

- Surface roughness value calculated at constant grinding wheel speed 3000 rpm with constant coolant flow rate 3 lit/min for different depth of cut value 10 mm, 20 mm, and 30 mm.
- Surface roughness value calculated at constant grinding wheel speed 3000 rpm with constant coolant flow rate 4 lit/min for different depth of cut value 10 mm, 20 mm, and 30 mm.

– Surface roughness value calculated at constant grinding wheel speed 3000 rpm with constant coolant flow rate 5 lit/min for different depth of cut value 10 mm, 20 mm, and 30 mm.

V. Results and Discussion

Following results has been found when working on AISI 1018 mild steel with 3000 rpm cutting speed of grinding wheel for the optimization of surface roughness for Mild steel as:

Sr. no.	Depth of cut (µm)	Coolant flow rate (lit/min)	Surface Roughness (µm)
1	10	3	0.359
2	20	3	0.408
3	30	3	0.519
4	10	4	0.321
5	20	4	0.385
6	30	4	0.402
7	10	5	0.290
8	20	5	0.342
9	30	5	0.389

Table 5: Experimentation observation of surface roughness at different depth of cut and coolant flow rate

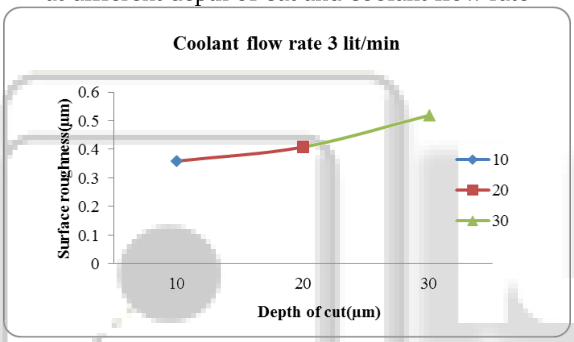

Fig. 4: Variation of surface roughness versus depth of cut for mild steel at constant coolant flow rate 3 lit/min

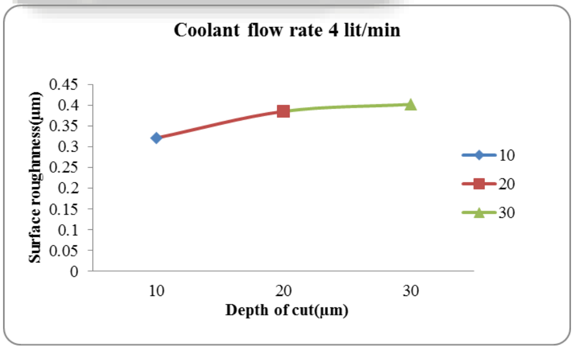

Fig. 5: variation of surface roughness versus depth of cut for mild steel at constant coolant flow rate 4 lit/min

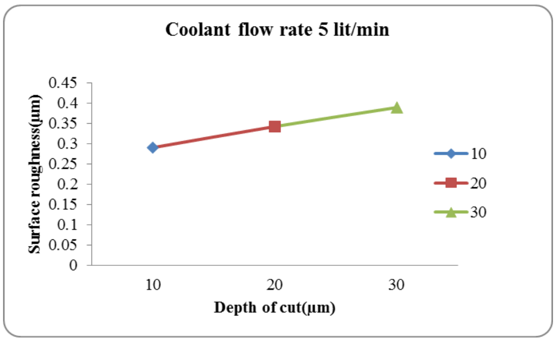

Fig. 6: variation of surface roughness versus depth of cut for mild steel at constant coolant flow rate 5 lit/min

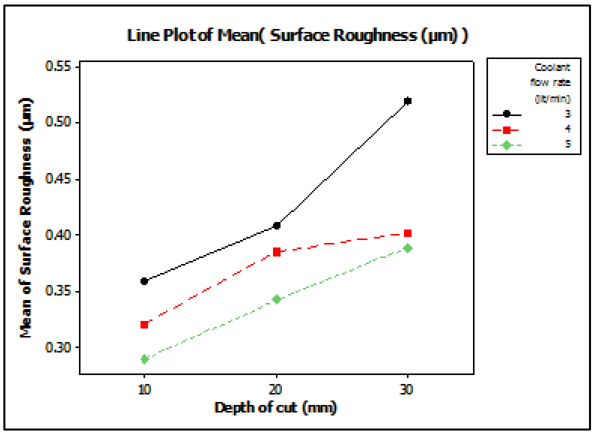

Fig. 7: Mean effect of surface roughness

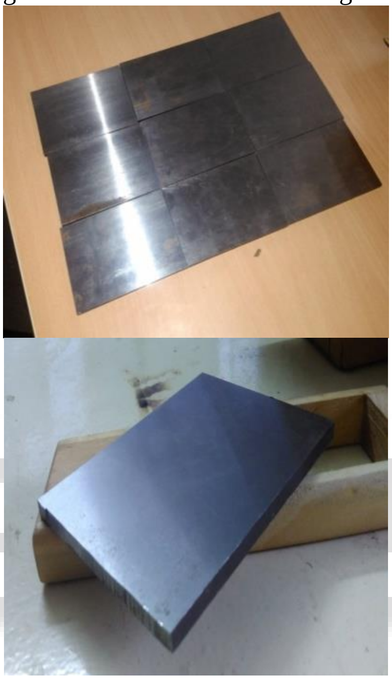

Fig. 8: Finished plates of AISI 1018 mild steel or low carbon steel

VI. Results

Minimum surface roughness 0.290 µm obtained by surface grinding process on AISI 1018 mild steel with Al_2O_3 grinding wheel (grit size 46 medium) keeping coolant flow rate 5 lit/min at 3000 rpm of grinding wheel speed by providing 10 µm depth of cut.

Coolant flow rate also affects in small variations as coolant flow rate more at higher speed minimum surface roughness obtained. Likewise if coolant flow rate is not sufficient at higher grinding wheel speed then wear of abrasive grains (glazing) occurs and it decreases grinding rate.

VII. Conclusions

– It has been found that revolution per minute (RPM) is most influential parameter in grinding. Higher grinding speed with the combination of minimum depth of cut gives minimum surface roughness as higher rpm removes material with higher speed and friction will be more with the work material than low rpm.

- Second most influencing parameter is depth of cut. Minimum depth of cut 10 um is possibly used in industries. But it is possible to give below 10 um depth of cut with small size grinding wheels on precise metals.
- It has been found that minimum depth of cut provides good finishing on material.

REFERENCES

[1] K Mekala, J Chandradas, K Chandrasekaran, T T M Kannan, E Ramesh and R Narasing, "Optimization of cylindrical grinding parameters of austenitic stainless steel rods (AISI 316) by Taguchi Method". International Journal of Mechanical Engineering and Robotics Research. April 2014, Vol. 3, Issue 2, PP. 209-215.

[2] Kamaldeep Singh, Dr. Beant Singh and Mandeep Kumar, "Experimental Investigation of Machining Characteristics of AISI D3 Steel with Abrasive Assisted Surface Grinding". International Research Journal of Engineering and Technology (IRJET). July-2015, Volume 02, Issue 04**,** PP. 269.

[3] Qiyong Zheng, Kai Wu, Xiaofeng Zheng and Ming Zhu (2012), "Influencing factor analysis of workpiece surface roughness and measuring system design for the main factors in high speed machining". Journal of Modern Manufacturing Technology. Vol. 4, Issue 1, PP. 69-78.

[4] M. Janardhan and Dr. A. Gopala Krishna (2011), "Determination and optimization of cylindrical grinding process parameters using Taguchi method and regression analysis". International Journal of Engineering Science and Technology. Vol. 3, Issue 7, PP. 5659-5665.

[5] Deepak Pal, Ajay Bangar, Rajan Sharma and Ashish Yadav (2012), "Optimization of grinding parameters for minimum surface roughness by Taguchi parameter optimization technique". International Journal of Mechanical and Industrial Engineering. Vol. 1, PP. 74-78.

[6] C. Thiagarajan, R. Sivaramakrishnan and S. Somasundaram (2011), "Cylindrical grinding of SiC particles reinforced aluminium metal matrix composites". Journal of Engineering and Applied Sciences. Vol. 6, Issue. 1, PP. 14-20.

[7] M. Janardhan and A. Gopala Krishna (2012), "Multi-objective optimization of cutting parameters for surface roughness and metal removal rate in surface grinding using response surface methodology". International Journal of Advances in Engineering and Technology. Vol. 3, Issue 1, PP. 270-283.

[8] Amandeep Singh Padda, Satish Kumar and Aishna Mahajan, "Effect of Varying Surface Grinding Parameters on the Surface Roughnes of Stainless Steel". International Journal of Engineering Research and General Science. Volume 3, Issue 6, November-December 2015, ISSN 2091-2730, PP 314-319.

[9] B. Dasthagiri, and Dr. E. Venugopal Goud, "Optimization Studies on Surface Grinding Process Parameters". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 4, Issue 7, July 2015, PP. 6148-6156.

[10] Pawan Kumar, Anish Kumar and Balinder Singh, "Optimization of Process Parameters in Surface Grinding Using Response Surface Methodology". IJRMET Vol. 3, Issue 2, May - Oct 2013. PP. 245-252.