International Journal of Control and Automation
Vol. 12, No. 4, (2019), pp. 20-28

Determining Multiple Optimal Solutions of Process Parameters for Cylindrical Plunge Grinding Operation Using NSGA II

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Abstract

Grinding is hard stage metal cutting operation carried out for generally producing better surface finish on the work piece. Cylindrical grinding is mostly used for machining accurate components of automobile industries. This paper presents multiple optimum solutions of cylindrical plunge grinding process parameters like dressing depth of cut, dressing cross feed rate and grinding feed rate. Experiments were performed on chromium bearing steel specimen by using Computer Numerical Control angular grinding head machine. Response Surface Metholodgy is used for developing mathematical models for surface roughness, grinding power and grinding ratio. Further these models are optimized by Non dominated Sorting Genetic Algorithm II using Matlab platform. Optimal pareto front obtained and it gives 18 optimum solutions.

Keywords: *Cylindrical grinding, surface roughness, grinding power, grinding ratio, NSGAII.*

1. INTRODUCTION

Industries are searching the way of reducing lead time for machining components with minimum wastages. Therefore industries prefer computer aided design and manufacturing machines. These machines are fulfilling the requirements like dimensional accuracy on parts, consistence in quality, surface quality, minimum manufacturing time, lead time, etc [1]. CNC grinding machines are mainly used for finishing the parts of automobile and machine where surface finish is key element [2, 3].

Research which is available in the field of grinding and patents are not completely transferred in grinding practice. Because grinding process is different from other manufacturing process with respect number of parameters which influence on the process. As grinding wheel is multi point cutting tool and has many cutting points and each cutting point act as individual for metal cutting. Grinding process has much number of Parameters like wheel speed, component speed, wheel velocity, component velocity, grinding depth of cut, hardness of component, component properties, wheel characteristic, wheel-component kinematics, dressing process parameters, which have an effect on grinding process [4,5,6]. Dressing process restores cutting capacity in abrasive however multipoint diamond dresser is better than single point diamond dresser with respect surface finish produce on work piece. It is found that dressing depth of cut and dressing cross feed rate are significant parameters which influence on surface finish and grinding power. Therefore multiple objective optimizations are needed for dressing process [7].

Grinding is broad name which represent all types grinding namely surface grinding, cylindrical grinding and centre less grinding. These all types of grinding process are final surface finishing processes. Success of manufacturing process is depending upon optimization and setting of parameters of process. Non dominated Sorting Genetic Algorithm II (NSGAII) is reliable and popular tool for optimizing process parameters of any type of traditional and modern manufacturing process [8,9]. NSGA II gives practical solution of set of combination of process parameters for manufacturing process [8,10,11].

After the reviewing literature it is found that very few researchers have worked on chromium bearing steel. This material used in industries for making bearings, shafts, gears etc. where surface finish is primary. This steel is wear resistance material and mainly used parts of machine where surface load is high. Quality components can be produce by combination and by setting the correct values of process parameters of manufacturing process [8,12,13]. Industries want to produce quality components with optimum use of resources. Due to increase in competitions, manufacturing engineer are facing challenges like to reduce manufacturing time, power consumption, increase tool life etc. and produce components as per customer requirement. This can be achieved by optimizing number of process parameters simultaneously [14,15,16].

So in the present work dressing depth of cut, dressing cross feed rate and grinding feed rate are selected as input parameters of cylindrical plunge grinding operation. Surface roughness, grinding power and grinding ratio are chosen as objective performance parameters of cylindrical plunge grinding operation. This paper is arranged as follows. Section 2 contains set up of experiments, section 3 gives information on mathematical modeling, Results and discussion is given in section 4, Section 5 emphasis on conclusion.

2. EXPERIMENTAL SET UP

Computer Numerical Control Angular Head grinding machine was used for experimentations. CNC machine made by(AHG 60X300 CNC) Parishudh Machines Pvt. Ltd, India.These machines are widely contributes in industries for making cylindrical shafts [4**].** Cylindrical specimens are prepared from chromium bearing steel to be used mostly for shaft based applications is considered for experimental set up and are shown in Figure 1.

Figure 1.Experiments Specimens

38A60K8VT3 is specification of grinding wheel. Metallurgical analysis of chromium bearing steel is given in Table 1.

Table 1. Metallurgical laboratory analysis of chromium bearing steel

Name of alloy	C.	Mn.	Si.	S.	p.	Cr.
% of alloy	0.97	0.36	0.22	0.012	0.012	1.49

Levels of dressing parameter are selected which are actually used in grinding practice. These levels are chosen as per the industry standards. If values of dressing parameters are high it produces poor surface on the work piece. Hence three levels of dressing depth of cut, dressing cross feed rate and grinding feed rate were selected as shown in Table 2.Experiments were done as per L-9 replica [17].

Table 2. Input parameters, their levels and coded values

Name of parameter	Symbol	Unit	Level I	Coded value for level I	Level II	Coded value for level II	Level III	Coded value for level III
Dressing depth of cut	D	Micron	10	-1	20	-0.33	40	1
Dressing cross feed rate	C	mm/min.	60	-1	80	-0.33	120	1
Grinding feed rate	Fr	mm/min.	0.60	-1	1.2	-0.33	2.4	1

Experiments performed at grinding spindle speed was 1250rpm, Work piece spindle speed was 100rpm and depth of cut of grinding was 300micron.Monocrystalline Diamond Dresser (MCD) type multi point diamond dresser was used for dressing of wheel. Grinding operation was carried out by using soluble oil as coolant and plunge condition shown in Figure 2.

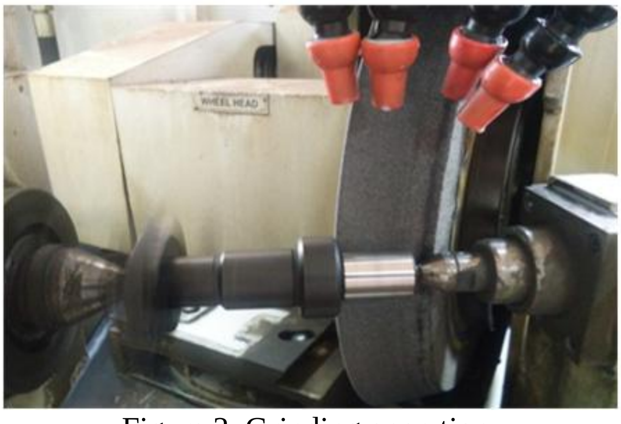

Figure 2. Grinding operation

Mitutoyo SJ410 was used for measuring surface roughness and it is shown in Figure 3. Grinding power was measured by Filed Instrument System (FIS).

Figure 3. Measurement of surface roughness

Third parameter is grinding ratio. (Gr) It is a defined as volume of work piece removal to the volume of wheel wear. High grinding ratio is desirable. Novel method is developed for finding grinding ratio [19]. Earlier grinding ratio was measured by weight of work piece and grinding wheel was taken before and after grinding process so it affects on quality and it consumes time. Novel method uses graphite coupons sheet for measuring the wheel wear and grinding ratio is calculated Flow process diagram of measuring the grinding ratio is given in Figure no 4.

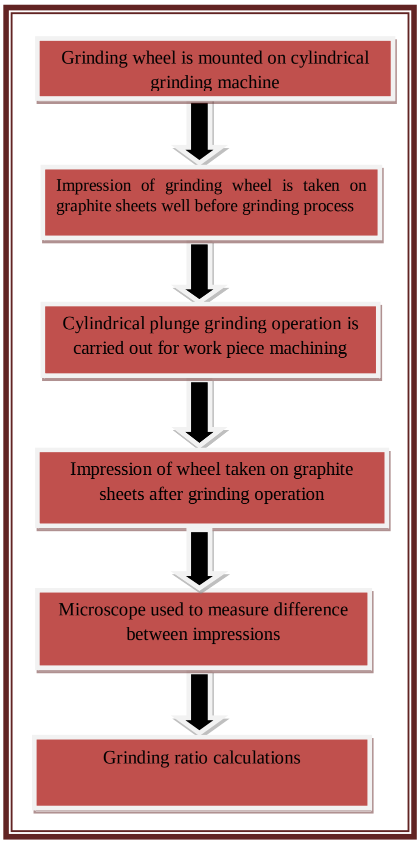

Figure. 4 Flow process diagram of measuring grinding ratio

Experiment results are shown in Table 3.

Table 3. Experimental results

Run	Ra(Micron)	Pw(kWatt)	Gr.
1	0.265	2.06	11.13
2	0.294	2.22	9.99
3	0.44	4.56	9.27
4	0.347	2.61	10.93
5	0.401	3.68	10.12
6	0.271	1.16	9.06
7	0.388	4.34	10.07
8	0.294	1.21	9.54
9	0.328	1.82	8.16

3. MATHEMATICAL MODELING

Performance of grinding process is evaluated by surface roughness produced on the work piece, power consumption for process and duration of wheel (which is closely associated with cost). Therefore in this study surface roughness, grinding power and grinding ratio are considered objective performance of process [15]. Response Surface Methodology (RSM) is best tool for multi objective machining problems [12,18].It has been used for developing mathematical modeling of surface roughness (Ra),grinding power (Pw) and grinding ratio(Gr).Models has been developed in terms of dressing depth of cut (D), dressing cross feed rate (C) and grinding feed rate (Fr) in coded form. Models are developed based on experimental result as Equations (1-3).

$$R_a=0.34451+0.00558x1+0.00293x2+0.06445x3-0.00458x1x2-0.01222x1x3+0.01387x2x3 \quad (1)$$

$$P_w = 2.7844+0.07752x1+0.05924x2+1.36512x3-0.2973x1x2+0.49587x1x3+0.6043x2x3 \quad (2)$$

$$G_r = 9.65103-0.4473x1-0.92214x2-0.0600586x3-0.09053x1x2+0.0045x1x3+0.04486x2x3 \quad (3)$$

Non dominated Sorting Genetic Algorithm II (NSGAII) is used for optimization of above equations. Equations (1-3) are optimized for objective functions to minimize surface roughness R_a and grinding power P_w & for maximizing grinding ratio G_r. These equations are subjected $-1< x_i <1$ where i = 1,2 and 3.

4. RESULTS AND DISCUSSIONS

Non dominated Sorting Genetic Algorithm II (NSGA II) using Matlab platform is used for multiple optimization. There were 18 point on pareto front, number of generation 194, Population size was 50, cross over probability and mutation probability were 0.8 and 0.01 respectively. Pareto front was drawn in three dimensional for surface roughness, grinding power and grinding ratio and it is shown in Figure 5.

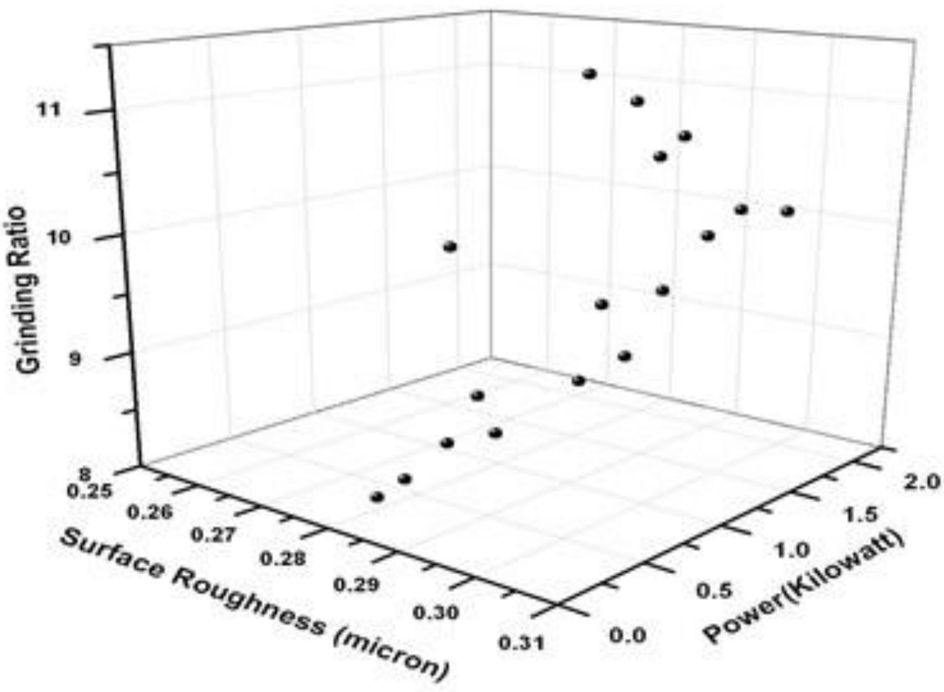

Figure 5. Optimal pareto front in three dimensional

Optimum values of design variable of grinding namely dressing depth of cut, dressing cross feed rate and grinding feed rate are shown in Table 4 in coded form.

Table 4. Optimum vales of dressing depth of cut, dressing cross feed rate and grinding feed rate in coded from

Sr. No.	D	C	Fr
1	-0.9972	-0.9978	-0.9854
2	-0.9729	0.7951	-0.9971
3	-0.6707	-0.9230	-0.9614
4	0.9965	0.9998	-0.9952
5	0.4833	-0.6698	-0.9768
6	0.8875	0.7328	-0.9949
7	0.9498	0.6148	-0.9715
8	0.6758	-0.1837	-0.9769
9	-0.9972	-0.9978	-0.9854
10	0.9711	0.9072	-0.9917
11	0.4991	-0.4757	-0.9713
12	0.9292	0.1030	-0.9643
13	-0.2772	-0.6523	-0.9510
14	0.5134	0.7245	-0.9621
15	-0.1943	-0.8711	-0.9786

16	0.5373	0.0216	-0.9864
17	0.6606	-0.7578	-0.9704
18	0.9380	0.2672	-0.9731

Table 5 shows objective functions of grinding surface roughness, grinding power and grinding ratio. Result table 5 shows that power consumption is less for the 4th serial number and it is 0.1730 KWatt and corresponding operating parameters are given in Table4 and serial number is 4. These are 0.9965,0.9998 and (-0.9952) dressing depth of cut, dressing cross feed rate and grinding feed rate respectively in coded form. Serial number 1 or serial number 9 from Table 5 shows that the maximum grinding ratio 11.0348 and related input parameters are given in Table 4 as serial number 1 or serial number 9.Fairly surface roughness of 0.2578 micron can produce on work piece.

Table 5. Objective functions of cylindrical grinding surface roughness, grinding power and grinding ratio

Sr. No.	Ra(Micron)	Pw (KWatt)	Gr
1	0.2696	2.0884	11.0348
2	0.2578	1.6269	9.4518
3	0.2777	2.0372	10.8465
4	0.2826	0.1730	8.2038
5	0.2986	1.7063	10.1677
6	0.2852	0.4666	8.5425
7	0.2893	0.5761	8.6338
8	0.2959	1.3103	9.5932
9	0.2696	2.0884	11.0348
10	0.2839	0.2765	8.3153
11	0.2967	1.5784	9.9648
12	0.2970	1.0134	9.1812
13	0.2843	1.8779	10.4464
14	0.2822	0.7771	8.7440
15	0.2865	1.9409	10.6238
16	0.2901	1.2017	9.4456
17	0.3038	1.7414	10.1880
18	0.2942	0.8603	9.0050

5. CONCLUSION

Three process parameters of cylindrical plunge grinding operation namely dressing depth of cut, dressing cross feed rate and grinding feed rate have been selected as input parameters. Three levels of each parameter have taken. Experiments performed on chromium bearing steel specimen using CNC angular grinding machine as per L-9 with replica. Mathematical model have been developed for surface roughness, grinding power and grinding ratio.

NSGA II has been used for optimizations of input parameters. Optimal pareto front has been drawn for objective functions of cylindrical grinding. It has been observed that when dressing depth of cut, dressing cross feed rate and feed arte of grinding are low then quality of surface finish is relatively fair, life span of grinding wheel is also good but power consumption is very high while when process parameters values are high that produces comparatively poor surface finish, life span of wheel is less but power consumption is very low.

Pareto front shows that 0.2578micron surface finish can be produced on component by setting 10 micron dressing depth of cut,120mm/min. cross feed rate and 0.60 mm/min. grinding feed rate. Power consumption will be less of 0.1730KWatt at 40micron, 120mm/min. and 0.60mm/min. dressing depth of cut ,dressing cross feed rate and grinding feed tare respectively. Life span of grinding wheel will increase when 10micron, 60mm/min., and 0.60mm/min. dressing depth of cut, dressing cross feed rate and grinding feed tare respectively. Presented results are useful to select optimum parameters of cylindrical grinding operation.

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Acknowledgement

This research was supported by Grind well Norton (Saint Gobain Limited) Limited. We are thankful to Mr. Prakash Patil, Senior Manager (Application Engineering). India (West division) Grindwell Norton Ltd.