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Optimization of Cylindrical Grinding Process Parameters on Material Removal Rate of EN21AMsteel

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Abstract: **Grinding is the machining processes which improve surface quality and dimensional accuracy of the work piece. Various process parameters, which affect the cylindrical grinding operation, are depth of cut, material hardness, work piece speed, grinding wheel grain size, number of passes, material removal rate and grinding wheel speed. Speed and feed are critical factors because increasing the both speed, and feed has an adverse impact on surface roughness but high material removal cause reduction in surface roughness.**

Cylindrical grinding is one of the important metal cutting processes used extensively in the finishing operations. Metal removal rate and surface finish are the important output responses in the production with respect to quantity and quality. In this thesis, is to arrive at the optimal grinding conditions that will minimize surface roughness and maximize metal removal rate when cylindrical grinding of EN21AMsteel is done for the optimization of grinding process parameters. During this experimental work input process parameters i.e. speed, feed, depth of cut is optimized using Taguchi method. 3D modeling done by CREO parametric software.

Key words: Grinding, CREO parametric Software, Analysis, Surface Finish, Taguchi Method.

INTRODUCTION

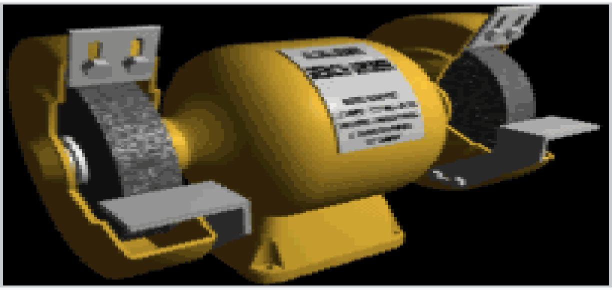
Grinding is the most widely used abrasive finishing process among all traditional processes used in production. In grinding operation the material is removed from the work piece surface by relative motion of a cylindrical wheel having abrasive particles embedded on its periphery. The abrasive particles are bonded together to form porous body which come into contact with work piece resulting in material removal. The size and distribution of grits along and wheel abrasive structure play an important role in grinding performance. The application of grinding is mainly available for simple geometries like cylindrical or plane surface where size is limited by grinding wheel movement. Also the metal removal rate can be maximized in very few grinding passes on work piece. The knowledge is mainly in the form of physical and empirical models which describe various aspects of grinding process. The present paper takes the following input process parameters namely work speed, depth of cut and number of passes.

Grinding Types

These machines include the:

Belt grinder: which is usually used as a machining method to process metals and other materials, with the aid of coated abrasives. Sanding is the machining of wood; grinding is the common name for machining metals. Belt grinding is a versatile process suitable for all kind of applications like finishing, deburring, and stock removal.

Bench grinder: which usually has two wheels of different grain sizes for roughing and finishing operations and is secured to a workbench or floor stand. Its uses include shaping tool bits or various tools that need to be made or repaired. Bench grinders are manually operated.



Cylindrical grinder: which includes both the types that use centers and the centerless types. A cylindrical grinder may have multiple grinding wheels. The workpiece is rotated and fed past the wheel(s) to form a cylinder. It is used to make precision rods, tubes, bearing races, bushings, and many other parts.

Surface grinder :which includes the wash grinder. A surface grinder has a "head" which is lowered to a workpiece which is moved back and forth under the grinding wheel on a table that typically has a controllable permanent magnet for use with magnetic stock but can have a vacuum chuck or other fixturing means. The most common surface grinders have a grinding wheel rotating on a horizontal axis cutting around the circumference of the grinding wheel. Rotary surface grinders, commonly known as "Blanchard" style grinders, have a grinding head which rotates the grinding wheel on a vertical axis cutting on the end face of the grinding wheel, while a table rotates the workpiece in the opposite direction underneath. This type of machine removes large amounts of material and grinds flat surfaces with noted spiral grind marks. It can also be used to make and sharpen metal stamping die sets, flat shear blades, fixture bases or any flat and parallel surfaces. Surface grinders can be manually operated or have CNC controls

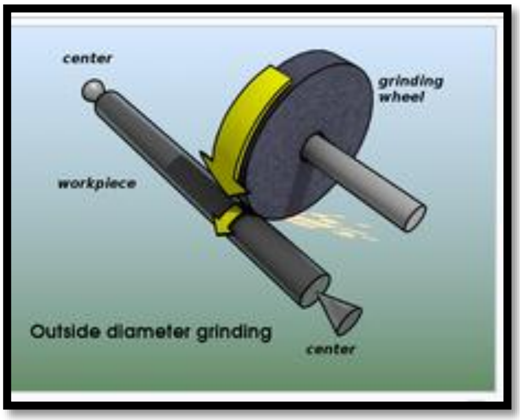
Cylindrical Grinder

The cylindrical grinder is a type of grinding machine used to shape the outside of an object. The cylindrical grinder can work on a variety of shapes, however the object must have a central axis of rotation. This includes but is not limited to such shapes as a cylinder, an ellipse, a cam, or a crankshaft.

Cylindrical grinding is defined as having four essential actions:

1. The work (object) must be constantly rotating
2. The grinding wheel must be constantly rotating
3. The grinding wheel is fed towards and away from the work
4. Either the work or the grinding wheel is traversed with respect to the other.

While the majority of cylindrical grinders employ all four movements, there are grinders that only employ three of the four actions.



METHODOLOGY &PROBLEM DESCRIPTION

Objective of Present Investigation

To analyze the effect of cylindrical grinding process parameters like grinding wheel speed, work piece speed, table feed, depth of cut, conditions and optimize for enhancement of surface finish and effect on material removal rate on EN21AM steel

In order to obtain applicable and practical predictive quantitative relationships, it is necessary to model the grinding responses and the grinding variables. These models would be of great use during optimization of the cylindrical grinding of EN21AM steel.

In this work, experimental results are used to calculate the analysis of variance (TAGUCHI) which explains the significance of the variables on the responses. A commercially available statistical tool MINITAB is used to provide the TAGUCHI results.

LITERATURE REVIEW

1.Review of Analysis & Optimization of Cylindrical Grinding Process Parameters on oEn15AM Steel

Grinding process is surface finishing process generally used to smoothen the surfaces by removing the limited quantity of material from the already machined surfaces. Cylindrical grinding or abrasive machining is the most popular machining process of removing metal from a work piece surface in the form of tiny chips by the action of irregularly shaped abrasive particles. In the present study, Taguchi method or Design of experiments has been used to optimize the effect of cylindrical grinding parameters such as wheel speed (rpm), work speed, feed (mm/min.), depth of cut and cutting fluid on the Material Removal Rate of EN15AM steel. Material removal rate measurements were carried out during the machining process on the work piece. EN15AM steel is generally known as free cutting steel and consists of higher machinability. It has several industrial applications in manufacturing of engine shafts, connecting rods, spindles, connecting components etc. The results indicated that grinding wheel speed, work piece speed, table feed rate and depth of cut were the significant factors for the material removal rate. The optimized parameters for material removal rate are grinding wheel speed 1800 rpm, work piece speed 155 rpm, feed rate 275 mm/min. and depth of cut 0.04 mm.

INTRODUCTION TO CAD

Computers are being used increasingly for both design and detailing of engineering components
in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. Computer-aided design systems are powerful tools and in the mechanical design and geometric modeling of products and components.
There are several good reasons for using a CAD system to support the engineering design
function:

- To increase the productivity
- To improve the quality of the design
- To uniform design standards
- To create a manufacturing data base
- To eliminate inaccuracies caused by hand-copying of drawings and inconsistency between
- Drawings

PRO/ENGINEER

Pro/ENGINEER, PTC's parametric, integrated 3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing.

Created by Dr. Samuel P. Geisberg in the mid-1980s, Pro/ENGINEER was the industry's first successful parametric, 3D CAD modeling system. The parametric modeling approach uses parameters, dimensions, features, and relationships to capture intended product behavior and create a recipe which enables design automation and the optimization of design and product development processes.

INTRODUCTION TO FEA

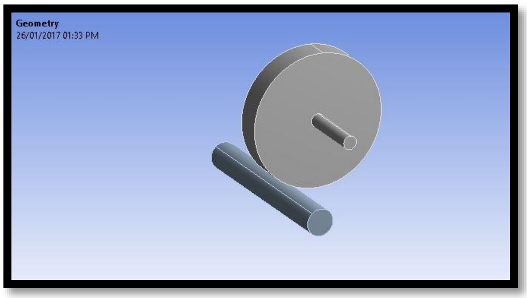
Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in.

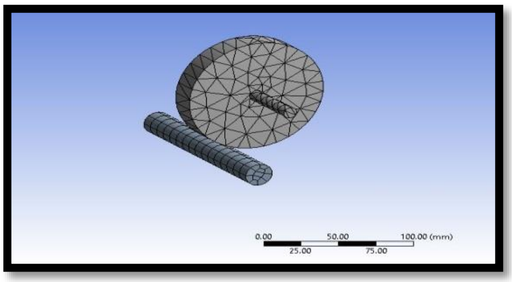
STRUCTURAL ANALYSIS

SPEED-1430RPM

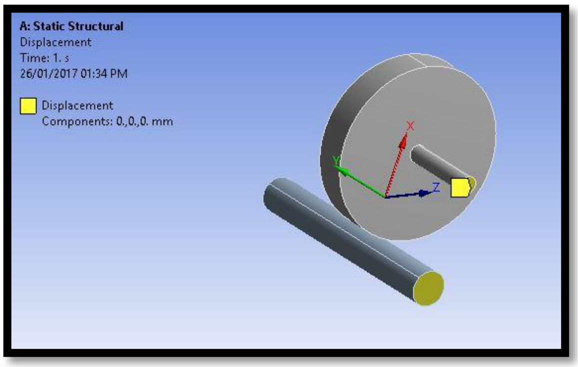
Imported model



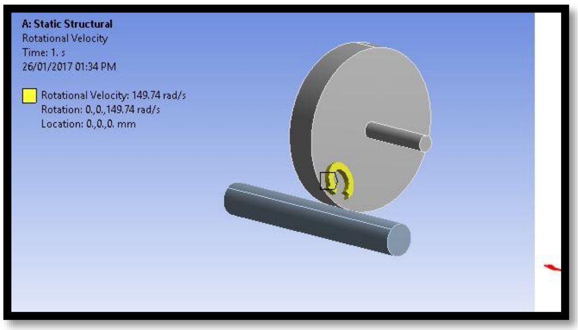
Meshed model



Boundary conditions

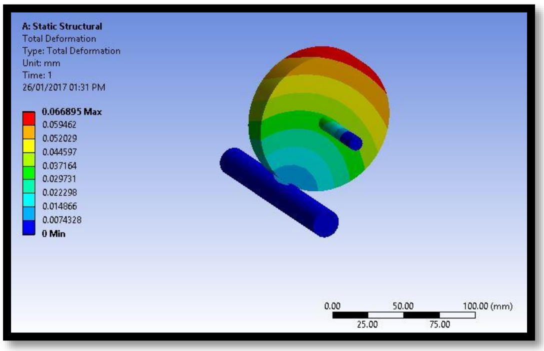

A: Static Structural
Displacement
Time: 1. s
26/01/2017 01:34 PM

Displacement
Components: 0.,0.,0. mm

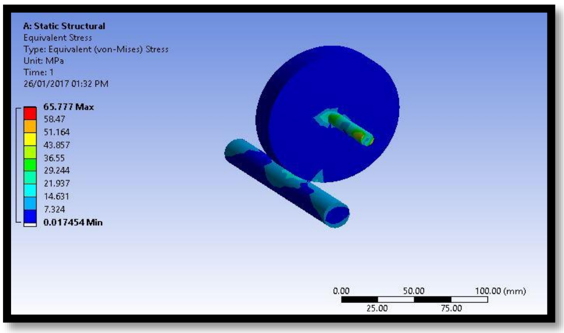

A: Static Structural
Rotational Velocity
Time: 1. s
26/01/2017 01:34 PM

Rotational Velocity: 149.74 rad/s
Rotation: 0.,0.,149.74 rad/s
Location: 0.,0.,0. mm

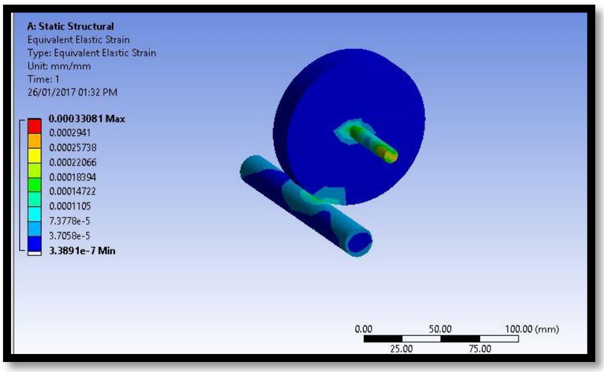
Total deformation



Stress

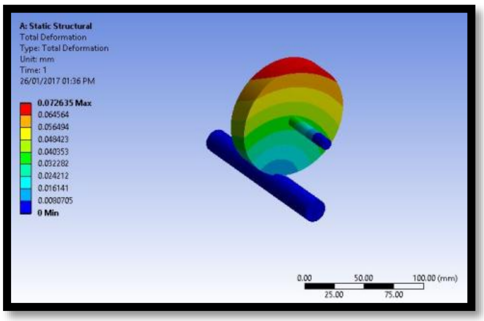


Strain

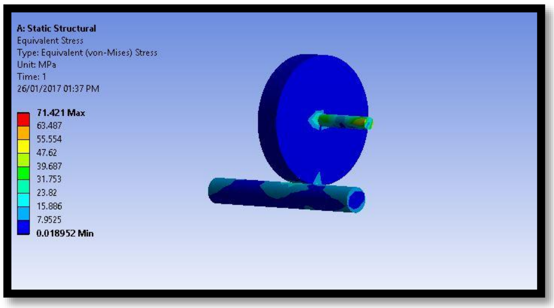


AT SPEED-1490RPM

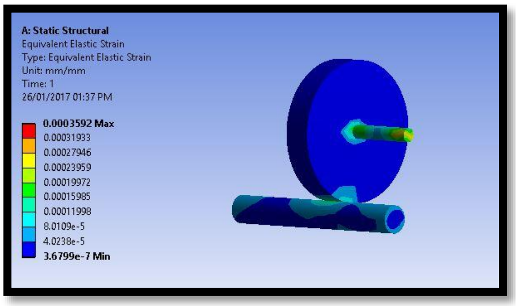
Total deformation



Stress

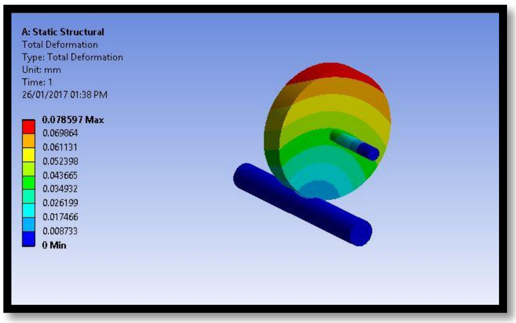


Strain

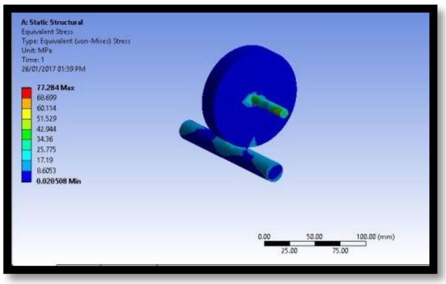


AT SPEED-1550RPM

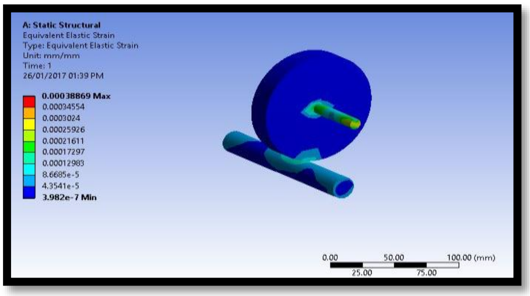
Total deformation



Stress



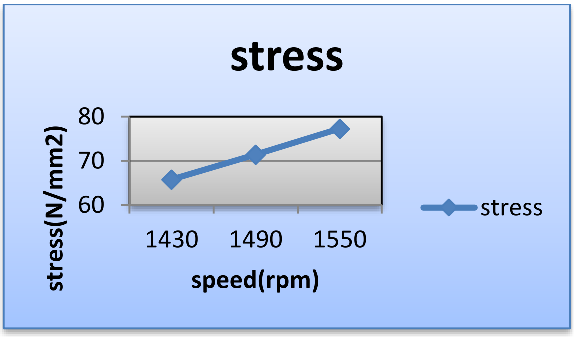
Strain



RESULT TABELS

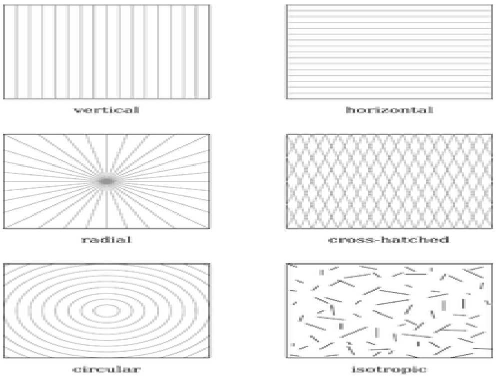
SPEED (RPM)	DEFORMATION (mm)	STRESS (N/mm^2)	Strain
1430	0.06	65.777	0.00033081
1490	0.0726	71.421	0.0003592
1550	0.0785977	77.284	0.00038869

Stress plot



INTRODUCTION TO SURFACE FINISH

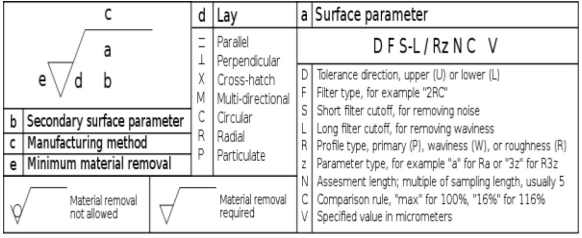
Knowing the magnitude of the cutting forces in the turning process as function of the parameters and conditions of treatment is necessary for determining of cutting tool strength, cutting edge wearing, limit of the maximum load of the cutting machine and forecasting the expected results of the processing. In particular, during machining with high cutting speed, using modern materials and modern cutting machines imposes the necessity of studying physical phenomena in the cutting process and their mathematical modeling.



Various lay patterns

Specification

In the United States, surface finish is usually specified using the ASME Y14.36M standard. The other common standard is International Organization for Standardization (ISO) 1302.



EXPERIMENTAL INVESTIGATION

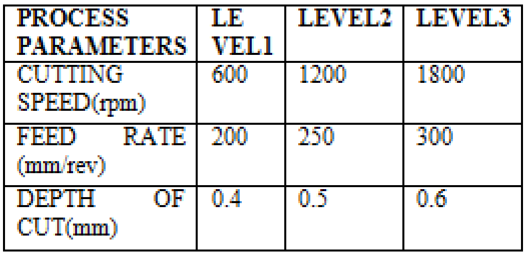
The experiments are done on the cylindrical grinding machine with the following parameters:

WORK PIECE MATERIAL – EN 21 AmTool Steel

FEED –0.075mm/min, 0.095mm/min, 0.120mm/min

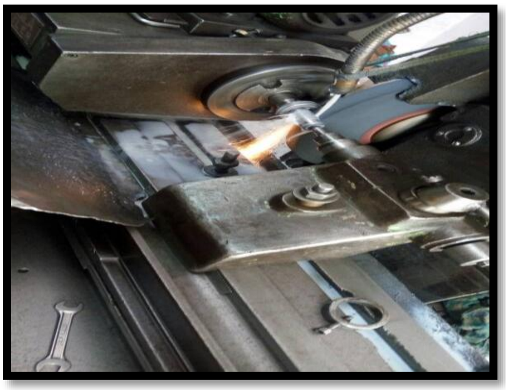
CUTTING SPEED – 1000rpm, 700rpm, 500rpm,

DEPTH OF CUT – 0.02mm, 0.03mm, 0.04mm



PROCESS PARAMETERS	LE VEL1	LEVEL2	LEVEL3
CUTTING SPEED(rpm)	600	1200	1800
FEED RATE (mm/rev)	200	250	300
DEPTH OF CUT(mm)	0.4	0.5	0.6

EXPERIMENTAL PHOTOS



Cylindrical grinding process

Speed (Rpm)	Feed (mm/min)	Depth of cut(mm)	Weight (before grinding)	Weight (after grinding)	Time (sec)
1000	0.075	0.02	108.23	108.19	38
1000	0.095	0.03	108.29	108.23	38
1000	0.120	0.04	108.42	108.435	38
700	0.075	0.02	108.51	108.491	60
700	0.095	0.03	108.24	108.19	60
700	0.120	0.04	108.39	108.36	60
500	0.075	0.02	108.40	108.36	70
500	0.095	0.03	108.432	108.41	70
500	0.120	0.04	108.631	108.33	70

Final component of cylindrical grinding

SURFACE FINISH VALUES

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)	Surface finish (R_a) µm
1	1000	0.075	0.02	0.235
2	1000	0.095	0.03	0.248
3	1000	0.120	0.04	0.354
4	700	0.075	0.02	0.312
5	700	0.095	0.03	0.325
6	700	0.120	0.04	0.297
7	500	0.075	0.02	0.212
8	500	0.095	0.03	0.225
9	500	0.120	0.04	0.230

FACTORS	PROCESS PARAMETERS	LEVEL1	LEVEL2	LEVEL3
A	CUTTING SPEED(rpm)	1000	700	500
B	FEED RATE (mm/rev)	0.075	0.095	0.120
C	DEPTH OF CUT(mm)	0.02	0.03	0.04

INTRODUCTION TO TAGUCHI TECHNIQUE

- Taguchi defines Quality Level of a product as the Total Loss incurred by society due to failure of a product to perform as desired when it deviates from the delivered target performance levels.

- This includes costs associated with poor performance, operating costs (which changes as a product ages) and any added expenses due to harmful side effects of the product in use.

Taguchi Methods

- Help companies to perform the Quality Fix!
- Quality problems are due to Noises in the product or process system
- Noise is any undesirable effect that increases variability
- Conduct extensive Problem Analyses
- Employ Inter-disciplinary Teams
- Perform Designed Experimental Analyses
- Evaluate Experiments using ANOVA and Signal-to noise techniques

TAGUCHI PARAMETER DESIGN FOR GRINDING PROCESS

In order to identify the process parameters affecting the selected machine quality characteristics of turning, the following process parameters are selected for the present work: cutting speed (A), feed rate (B) and depth of cut (C). the selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted.

Selection of Orthogonal Array

The process parameters and their values are given in table. It was also decided to study the two – factor interaction effects of process parameters on the selected characteristics while turning. These interactions were considered between cutting speed and feed rate (AXB), feed rate and depth of cut (BXC), cutting speed and depth of cut (AXC).

TAGUCHI ORTHOGONAL ARRAY

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)
1	1000	0.075	0.02
2	1000	0.095	0.03
3	1000	0.120	0.04
4	700	0.075	0.02
5	700	0.095	0.03
6	700	0.120	0.04
7	500	0.075	0.02
8	500	0.095	0.03
9	500	0.120	0.04

OBSERVATION

The following are the observations made by running the experiments. The cutting forces are measured using dynamometer.

SURFACE FINISH

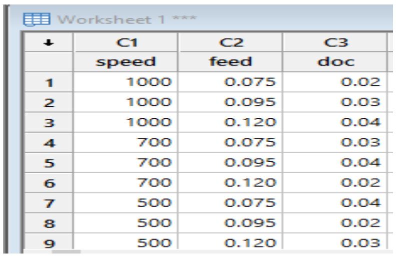
Surface finish (R_a) µm
0.235
0.248
0.354
0.312
0.325
0.297
0.212
0.225
0.230

OPTIMIZATION OF SURFACE FINISH USING MINITAB SOFTWARE

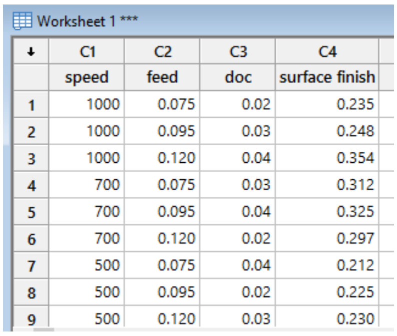
Design of Orthogonal Array

First Taguchi Orthogonal Array is designed in Minitab15 to calculate S/N ratio and Means which steps is given below:

OPTIMIZATION OF PARAMETERS

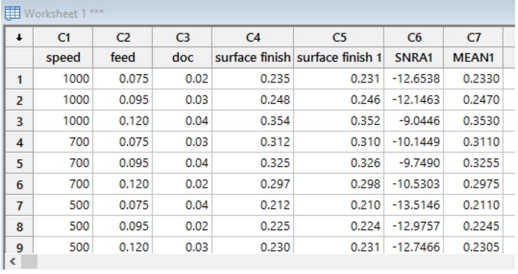

Worksheet 1 ***

↓	C1	C2	C3
	speed	feed	doc
1	1000	0.075	0.02
2	1000	0.095	0.03
3	1000	0.120	0.04
4	700	0.075	0.03
5	700	0.095	0.04
6	700	0.120	0.02
7	500	0.075	0.04
8	500	0.095	0.02
9	500	0.120	0.03

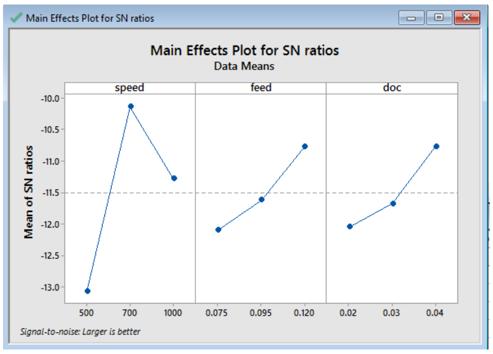

Worksheet 1 ***

↓	C1	C2	C3	C4
	speed	feed	doc	surface finish
1	1000	0.075	0.02	0.235
2	1000	0.095	0.03	0.248
3	1000	0.120	0.04	0.354
4	700	0.075	0.03	0.312
5	700	0.095	0.04	0.325
6	700	0.120	0.02	0.297
7	500	0.075	0.04	0.212
8	500	0.095	0.02	0.225
9	500	0.120	0.03	0.230

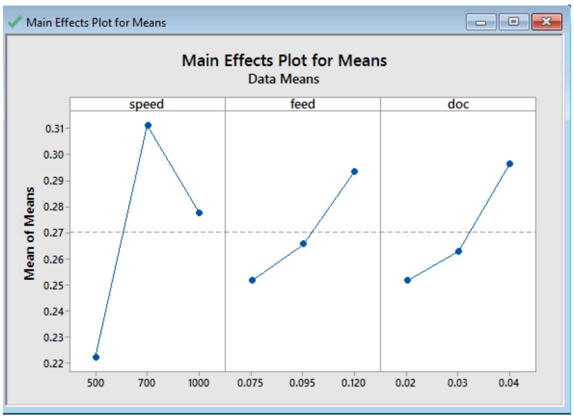
Analyze Taguchi Design – Select Responses


Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7
	speed	feed	doc	surface finish	surface finish 1	SNRA1	MEAN1
1	1000	0.075	0.02	0.235	0.231	-12.6538	0.2330
2	1000	0.095	0.03	0.248	0.246	-12.1463	0.2470
3	1000	0.120	0.04	0.354	0.352	-9.0446	0.3530
4	700	0.075	0.03	0.312	0.310	-10.1449	0.3110
5	700	0.095	0.04	0.325	0.326	-9.7490	0.3255
6	700	0.120	0.02	0.297	0.298	-10.5303	0.2975
7	500	0.075	0.04	0.212	0.210	-13.5146	0.2110
8	500	0.095	0.02	0.225	0.224	-12.9757	0.2245
9	500	0.120	0.03	0.230	0.231	-12.7466	0.2305



Effect of turning parameters on force for S/N ratio



Effect of turning parameters on force for Means

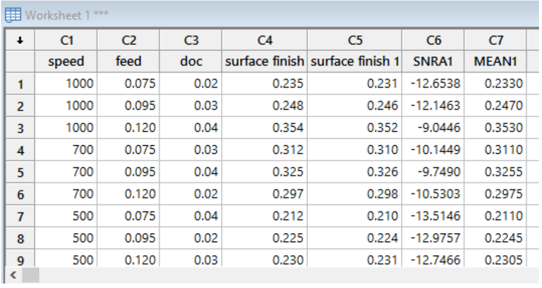
RESULTS

Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The cutting force is considered as the quality characteristic with the concept of "the smaller-the-better". The S/N ratio for the smaller-the-better is:

$$S/N = -10 * \log(\Sigma(Y^2)/n))$$

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration above Eqn. with the help of software Minitab 17.

The force values measured from the experiments and their corresponding S/N ratio values are listed in Table


Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7
	speed	feed	doc	surface finish	surface finish 1	SNRA1	MEAN1
1	1000	0.075	0.02	0.235	0.231	-12.6538	0.2330
2	1000	0.095	0.03	0.248	0.246	-12.1463	0.2470
3	1000	0.120	0.04	0.354	0.352	-9.0446	0.3530
4	700	0.075	0.03	0.312	0.310	-10.1449	0.3110
5	700	0.095	0.04	0.325	0.326	-9.7490	0.3255
6	700	0.120	0.02	0.297	0.298	-10.5303	0.2975
7	500	0.075	0.04	0.212	0.210	-13.5146	0.2110
8	500	0.095	0.02	0.225	0.224	-12.9757	0.2245
9	500	0.120	0.03	0.230	0.231	-12.7466	0.2305

Material Removal Rate: MRR can be defined as the ratio of volume of material removed to the machining time.

MRR= (Wb-Wa)/Tm

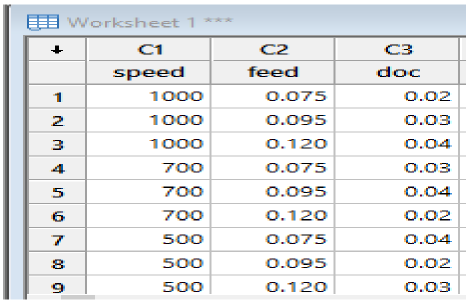
Wb =weight of work piece material before grinding

Wa = weight of work piece material after grinding

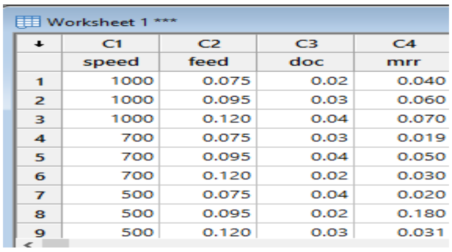
Tm = machining times (min/sec).

OPTIMIZATION OF MRR USING MINITAB SOFTWARE

OPTIMIZATION OF PARAMETERS

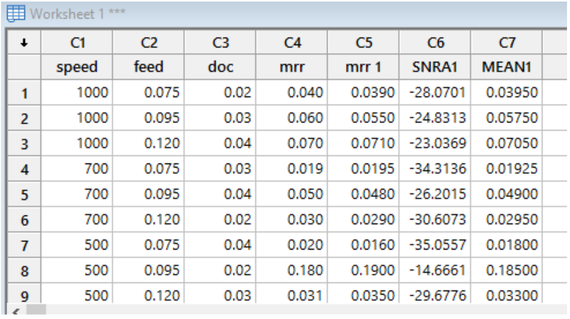


↓	C1	C2	C3
	speed	feed	doc
1	1000	0.075	0.02
2	1000	0.095	0.03
3	1000	0.120	0.04
4	700	0.075	0.03
5	700	0.095	0.04
6	700	0.120	0.02
7	500	0.075	0.04
8	500	0.095	0.02
9	500	0.120	0.03

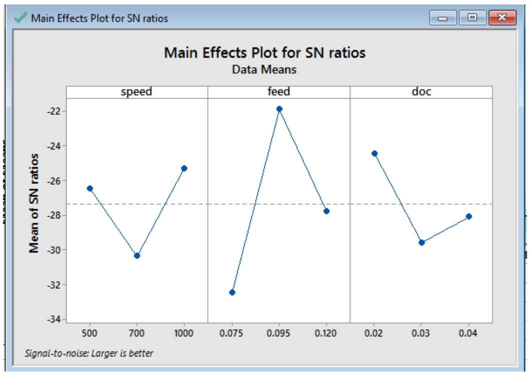


↓	C1	C2	C3	C4
	speed	feed	doc	mrr
1	1000	0.075	0.02	0.040
2	1000	0.095	0.03	0.060
3	1000	0.120	0.04	0.070
4	700	0.075	0.03	0.019
5	700	0.095	0.04	0.050
6	700	0.120	0.02	0.030
7	500	0.075	0.04	0.020
8	500	0.095	0.02	0.180
9	500	0.120	0.03	0.031

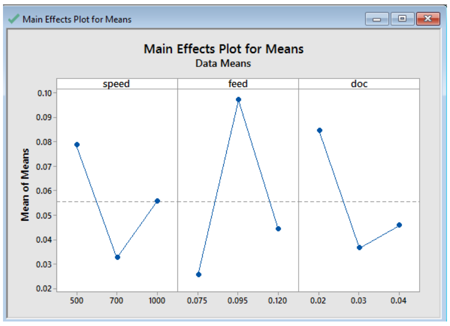
Analyze Taguchi Design – Select Response



↓	C1	C2	C3	C4	C5	C6	C7
	speed	feed	doc	mrr	mrr 1	SNRA1	MEAN1
1	1000	0.075	0.02	0.040	0.0390	-28.0701	0.03950
2	1000	0.095	0.03	0.060	0.0550	-24.8313	0.05750
3	1000	0.120	0.04	0.070	0.0710	-23.0369	0.07050
4	700	0.075	0.03	0.019	0.0195	-34.3136	0.01925
5	700	0.095	0.04	0.050	0.0480	-26.2015	0.04900
6	700	0.120	0.02	0.030	0.0290	-30.6073	0.02950
7	500	0.075	0.04	0.020	0.0160	-35.0557	0.01800
8	500	0.095	0.02	0.180	0.1900	-14.6661	0.18500
9	500	0.120	0.03	0.031	0.0350	-29.6776	0.03300



Effect of turning parameters on force for S/N ratio



Effect of turning parameters on force for Means

CONCLUSION

In this thesis an attempt to make use of Taguchi optimization technique to optimize cutting parameters during cylindrical grinding of EN 21 steel using.

The cutting parameters are cutting speed, feed rate and depth of cut for turning of work piece EN 21 tool steel. In this work, the optimal parameters of cutting speed are 1000rpm, 700rpm and 500rpm, feed rate are 0.075mm/min, 0.095mm/min and 0.120mm/min and depth of cut are 0.02mm, 0.03mm and 0.0.04mm. Experimental work is conducted by considering the above parameters. material remove rate and surface finish are validated experimentally.

By observing the experimental results and by taguchi, the following conclusions can be made:

To get better surface finish, the optimal parameters are speed – 1000rpm, feed rate – 0.12mm/min and depth of cut – 0.04mm.

To maximize material removal rate, the optimal parameters speed – 1000rpm, feed rate – 0.12mm/min and depth of cut – 0.04mm.

By observing the analysis results, the stress values are less than the yield stress values.

REFERENCES

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