International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 05 | May -2017 www.irjet.net p-ISSN: 2395-0072

"Optimization of Process Parameters of Face Milling on Aluminium-Bronze and Inconel 625 by Taguchi Method"

Mr. Anurag Salankar[1], Prof. M.T.Shete[2]

[1]M.Tech Scholar, Dept. of Mechanical Engineering, Government College of Engineering, Amravati
[2]Assistant Professor, Dept. of Mechanical Engineering, Government College of Engineering, Amravati

---

Abstract - Vertical milling centre is widely used in mass production manufacturing with precision without interruption in quick succession. This paper aims at monitoring Aluminium Bronze and Inconel625 made of nickel and chromium due to their high strength ,wear resistance, fatigue resistance and toughness. Their machining is performed on the vertical milling centre using Carbide tool material. Experiments have been performed to check for the surface finish, material removal rate obtained by machining on Aluminium Bronze and Inconel625 on the VMC. An experiment will be performed for the purpose of specifying the optimum process parameters for each workpiece and compare their performance results. The cutting tool adopted for experiment is Carbide tool. Statistical design of experiments (DOE) based on Taguchi orthogonal array is adopted for experimentation and signal-to-noise ratio (SN ratio) of the responses is used for finding optimally of process parameters. The influence and contribution of process parameters on the responses is been studied with the help of Analysis of Variance(ANOVA) and compare it with mathematical model for validation.

Keywords-Vertical Milling Centre, Aluminium Bronze Alloy,Inconel625, Process Parameters, Performance Parameters.

1.INTRODUCTION

Vertical milling center also known as VMC has been proven as an alternative process to conventional milling process with improved accuracy, precision, tight tolerance and interchangeability. In vertical milling rotary cutters is used to remove material from the workpiece by advancing in a direction at an angle with axis of tool. It covers a wide variety of different operations on scales of small individuals such as countering, face milling, end milling to large heavy duty gang milling operations with advent of computer numeric control with automatic tool changers, tool magazines or carousals, CNC controls, coolant system[2] . For this different types of tools are used on VMC according to the work piece materials hardness, wear and thermal resistance and power and speed capacity of tool. Any type of material can be machined using VMC irrespective of the hardness or toughness of the material. A super alloy or high-performance alloy such as inconel625 is an alloy that exhibits several following fundamental characteristic such as excellent mechanical strength, resistance to thermal creep deformation, good surface stability and resistance to corrosion or oxidation. Super alloys are the alloys which posses comparatively higher mechanical and thermal strength in comparison to individual metals. These properties of the super alloys make them eligible for the purpose where in high strength to weight ratio of a material is expected. Whereas Aluminium Bronze alloy provides good strength, corrosion resistance, good machinability and fine chip improved overall manufacturing capability in face milling process on VMC[3].

2. VMC PROCESS PARAMETERS

The process parameters which will influence the experiment of optimizing while machining of the Aluminium Bronze alloy and inconel625 are listed below[1]

- Tool Feed - It is distance advances along the workpiece when tool point passes certain position in its travel over the surface. It represents different level of tool feed in mm/rev supplied by servomotor of vertical milling centre represents kind of material being cut ,hardness and surface finish.
- Tool depth of cut – It is volume removed per unit time of tool .It will be varied in millimeters upto 0.5mm in numeric control part programming which effectively determines chip thickness, surface finish ,specific power consumption and tool characteristics.
- Tool rotational speed - It is speed at which the cutting edge passes over material. It can be varied by speed control mechanism upto 4000 rpm by changing numeric control programme logic which leads to found out surface roughness and specific power consumption and best suitable tool life.

3. PERFORMANCE PARAMETERS

The effectiveness of VMC process is evaluated in terms of its machining characteristics. The short product development cycles and growing cost pressures have forced the die and mould making industries to increase the VMC efficiency. TheVMC efficiency is measured in terms of its machining characteristics viz. material removal rate, surface roughness, tool life, machining time and specific power consumption. The most important performance parameters considered in the present work are[7]:

1. Surface Roughness (R_a): Surface finish is an essential requirement in determining the surface quality of a product. The average surface roughness is the integral absolute value of the height of the roughness profile over the evaluation length (L) and was represented by the equation given below.

$$R_a = \frac{1}{L}\int_0^L |Y(X)\,dx|$$

Where 'L' is the length taken for observation and 'Y' is the ordinate of the profile curve.

2. Material removal rate (MRR): Material removal rate is a desirable characteristic and it should be as high as possible to give least machine cycle time leading to increased productivity. Material removal is the difference of weight of work-piece before machining and after machining. It is calculated by the formula as given below.

MRR=Length*Width*Depth of Cut/(Cycle time)

4.RESEARCH ON VMC PROCESS OPTIMIZATION AND GAPS

VMC process conditions play an important role in improving surface roughness, dimensional accuracy, mechanical properties, material behavior and build time. Critical process parameters that affect the quality of processed part have been discussed. There has been extensive research on this topic focusing on experimental results and process optimization. Most of the researches on VMC process parameters have been directed toward optimizing process parameters to improve the surface finish, dimensional accuracy and mechanical properties for super alloys processed parts as well as ductile materials too such as Aluminium, Brass and so on[3,5] . Many researchers have suggested using appropriate statistical designs and optimization techniques to study the effects of process parameters on VMC processed parts. Super alloys such as inconel625 and extruded brass-lead alloy are machined on the VMC.inconel625 and extruded-brass lead alloy on which optimization experiment can be performed in order to found out optimized performance parameters for them while machining on the VMC. No such optimization work is done taking account of multivariable performance parameters.The objective of this article has been aimed to report the work carried out by various researchers in the field of VMC and to bridge the gap between the untouched areas[7,10]. After an elaborate scrutiny of the published work, the following number of gaps in the literature has been observed from the existing published work.

1. In most of the research ,milling operation mainly done on aluminium, mild steel, titanium alloy . our research based on the optimization of process parameters on material extruded brass and lead alloy and inconel625 which is widely used in industry due to property of retaining hot hardness, corrosion, wear, creep, fatigue resistance ,machining performance and toughness.

2. A various surface property such as wear land, surface roughness which shows poor performance on conventional materials used in milling such as mild steel ,aluminium which might shows improved performance in extruded brass and lead alloy and also in inconel625 due to its predominant properties.

3. Most of the research based on single function optimization. our aim is to optimize multiple functions simultaneously.

5. EXPERIMENTATION

5.1 Taguchi DOE based orthogonal array

Taguchi DOE is based on quality loss functions,orthogonal array (OA) and signal-to-noise ratio(SN ratio) is now widely used in many industries to efficiently manufacturing process. In present study three process parameters used i.e. tool speed ,Feed rate and Depth of cut and each have three levels and orthogonal array (L9) used for my experimentation[10]

Taguchi recommends a quality loss function to measure the performance characteristic which is deviating between the experimental values and the desired values.The statistical measure of performance like signal to noise ratio depends on optimization of the quality characteristics and is used to identify the best set of parameters for the reponses generated in operation of face milling[12].

Table.1 Experimental L9 orthogonal array for alluminum Bronze

Trial No.	A(Tool Speed)	B(Feed)	C(Depth of cut)
1	1500	150	0.3
2	1500	225	0.4
3	1500	300	0.5
4	2200	150	0.4
5	2200	225	0.5
6	2200	300	0.3
7	3000	150	0.5
8	3000	225	0.3
9	3000	300	0.4

Table 2 Experimental L9 orthogonal array for Inconel 625

Trial No.	A(Tool Speed)	B(Feed)	C(Depth of cut)
1	900	60	0.25
2	900	80	0.33
3	900	100	0.4
4	1400	60	0.33
5	1400	80	0.4
6	1400	100	0.25
7	1800	60	0.4
8	1800	80	0.25
9	1800	100	0.33

5.2 Workpiece material and face milling cutter

Aluminium bronze which have properties like Provides good strength, corrossion resistance, favourable high temperaure property, good resistance to fatigue, creep, oxidation resistance, wear resistance. And has wide application in power generations, aircraft and automotive industry, iron and steel making, shipboard marine application, deep drawing dies. And second material used in my experimentation isinconel625(nickel and chromium alloy) which has properties like provides high strength at elevated temperature, toughness as well as high resistance to creep, wear, corrosion and fracture. and has application in Aerospace structures, Turbine and engine components, automotive components. Face milling cutter is carbide inserts used due to wear resistance should be good, high hot hardness, strength and toughness should be high, thermal shock properties should be good, adequate chemical stability at elevated temperature have hardenss 350BHN.

Table 3. Chemical Composition of aluminium bronze

Cu	Sn	Zn	Ni	Al	Fe	Mn	Pb
79 %	0.1%	0.5%	4-5%	8.5 %	3.5 %	0.8 %	0.05%

Table 4. Chemical composition of inconel625

Fe	Ni	Cr	Nb	No	Ti	Al
2.8 %	61.10%	21.10 %	5.07%	3.60%	1.15 %	0.65 %

5.3 Experimental set up

Rectangular work piece material of 50mm*40mm*20mm size. 5 pieces of each material(18 faces) used for experimentation. HAAS CNC Vertical Milling center 5 axis ,4000RPM Tool capacity is 20 and motor of 7.5KW have SIEMEN 840D controller and Cutting Fluid used is BIOCOOL-10 (Bio stable semi synthetic cutting fluid)and is shown in Fig. 1, Taylor Hobson Surface Tester subtronic 3 unit is used for measuring Surface Roughness at offline on the three diametrical points of the machined surfaces and average is considered as Surface Roughness (Ra) value.

Fig 1 HAAS CNC Vertical Milling Machine.

Fig 2 Taylor-Hobson surface roughness tester.

5.4 Experimentation Methodology

Performing DOE for selecting orthogonal array for number of experiments to be conducted. Conducting experiments on 50mm*40mm*20mm blocks of aluminium bronze and inconel625 by carbide tool(40mm dia.) having hardness 350BHN by Changing process parameters like feed, depth of cut and tool rotational speed in face milling operation. Since there are three factors, L9 orthogonal array is chosen for different combination of three factors of each one has three levels. Set CNC program for face milling and set block to zero position by offsetting X,Y,Z axis and then perform machining. Thereafter experimental data of cutting time for each block to be machined is calculated by stop watch to find material removal rate and surface finish. Evaluate of optimum speed, depth of cut and tool rotational speed to get optimum performance parameters which improves surface finish ,surface hardness and material removal rate based on optimization tool like ANOVA technique altogether needed for improving quality function in material itself leading to improving durability ,precision and interchangeability. Finally Validation of statistical model with mathematical model.

6. RESULTS AND DISCUSSION

Effect of Process Parameter on on material removal rate(MRR) and surface roughness(SR)

Table 5 ANOVA And Signal To Noise Ratio Results For MRR and SR(Aluminium Bronze)
For MRR

Source	DOF	SS	MS	F	P	% Contribution	Rank
A	1	6.703	3.3515	1.42	0.287	0.07	3
B	1	596.40	298.20	126.2	0.00	63.90	1
C	1	306.592	153.296	64.89	0.00	32.84	2
Error	5	23.623	4.725				

For SR

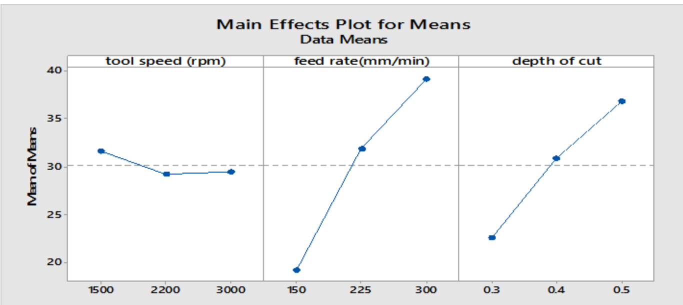
Source	DOF	SS	MS	F	P	% Contribution	Rank
A	1	0.00098	0.00115	2.58	0.169	54.87	1
B	1	0.00106	0.000492	2.80	0.115	23.80	2
C	1	0.00026	0.00133	0.7	0.441	6.3	3
Error	5	0.00038	0.00095				

Table 6 ANOVA And Signal To Noise Ratio Results For MRR and SR(Inconel625)
For MRR

Source	DOF	SS	MS	F	P	% Contribution	Rank
A	1	0.0255	0.01275	0.09	0.773	0.05	3
B	1	22.3494	11.1747	81.11	0.00	51.72	1
C	1	19.4576	9.7288	70.62	0.00	45	2
Error	5	0.2755	0.6888				

For SR

Source	DOF	SS	MS	F	P	% Contribution	Rank
A	1	0.06541	0.00327	56.23	0.001	48.23	1
B	1	0.00601	0.003	51.72	0.001	44.37	2
C	1	0.00001	0.0008	0.14	0.727	0.01	3
Error	5	0.00011	0.00029				



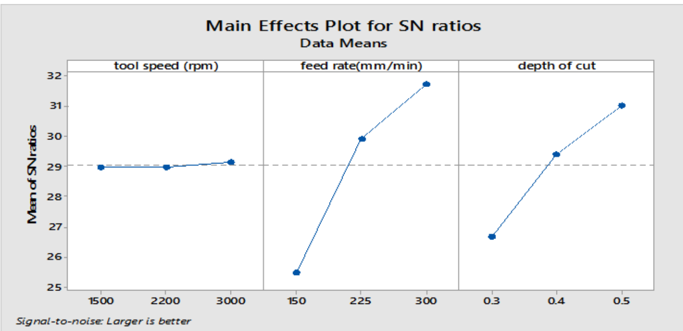


Figure 2 Main effect plot for means and signal to noise ratio for MRR(Aluminium Bronze)

Main effect plot for means shows effects of various process parameters on Material removal rate(MRR) for aluminium Bronze. This graph depicts feed rate is dominant factor on MRR followed by depth of cut and tool speed. Percentage contribution is feed rate=63.90%,depth of cut=32.84% and tool speed=0.07% from Table1, whereas main effect plot used for acquiring process optimization parameters. I select optimum parameters from it at maximum S/N ratio(larger magnitude selected) and hence optimum process parameters for maximum material removal rate is tool rotational speed at 3000rpm,feed rate at 300mm/min and depth of cut 0.5mm for a given set up of MRR for stated material Aluminium Bronze. From ANOVA Analysis, MRR value predicted as 45.32mm^3/s.

Regression Equation

MRR(mm^3/s) = -25.25 -0.00141 tool speed (rpm) + 0.1329 feed rate(mm/min) + 71.48 depth of cut (mm)

At optimum process I get MRR is 46.13 mm^3/s.

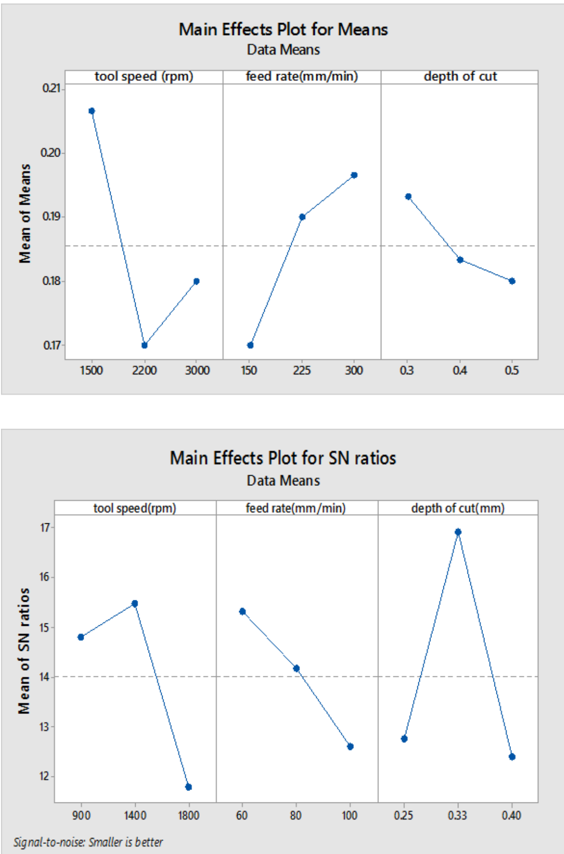


Figure 3 Main effect plot for means and signal to noise ratio for SR(Alluminium Bronze)

Main effect plot for means shows effects of various process parameters on Surface roughness(SR) for aluminium Bronze. This graph depicts Tool speed is dominant factor on MRR followed by feed rate and depth of cut. Percentage contribution is tool speed= 54.87%,feed rate=23.80% and depth of cut=6.3% from table1,whereas main effect plot used for acquiring process optimization parameters. I select smaller-is better S/N ratio, so I select optimum parameters from it at maximum S/N ratio(larger magnitude selected) and hence optimum process parameters for maximum surface roughness is tool rotational speed at 2200rpm,feed rate at 150mm/min and depth of cut 0.5mm for a given set up of SR for stated material Aluminium Bronze. From ANOVA analysis ,SR value is predicted as 0.1488um. Regression Equation

SR = 0.2103 -0.000017 tool speed (rpm) + 0.000178 feed rate (mm/min) -0.0667 depth of cut(mm)

At optimum process parameters ,I get SR is 0.16um

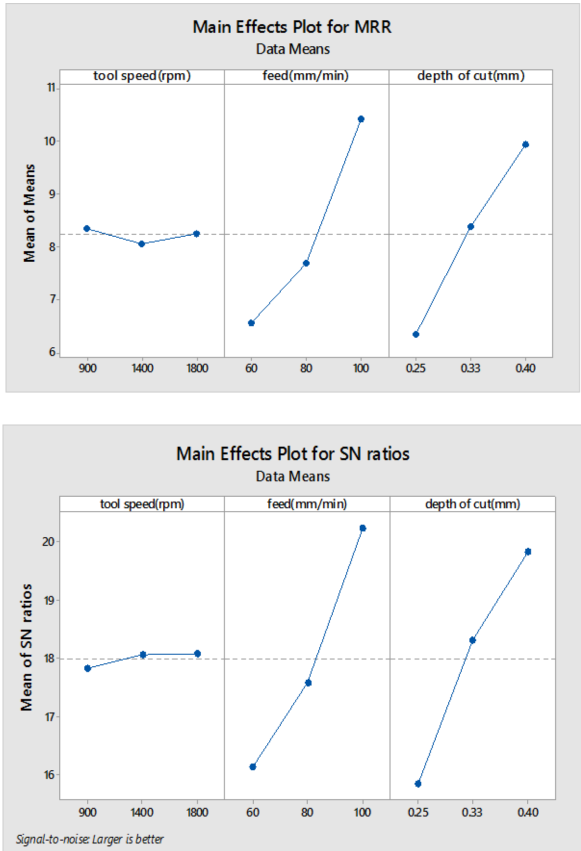


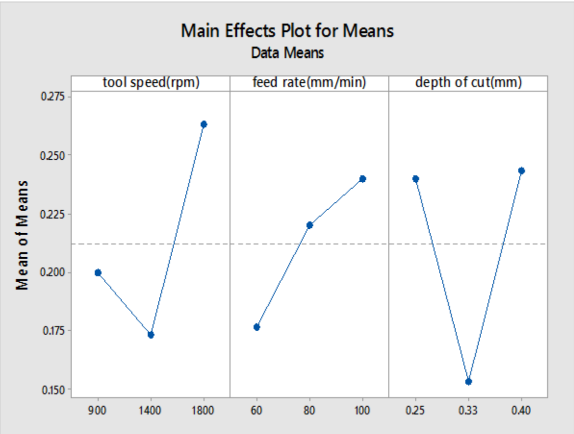
Figure 4 Main effect plot for means and signal to noise ratio for MRR(Inconel625)

Main effect plot for means shows effects of various process parameters on Material removal rate(MRR) for Inconel625.This graph depicts feed rate is dominant factor on MRR followed by depth of cut and tool speed. Percentage contribution is feed rate=51.72%,depth of cut=45% and tool speed=0.05% from Table2, whereas main effect plot used for acquiring process optimization parameters. I select larger-is better S/N ratio, so I select optimum parameters from it at maximum S/N ratio(larger magnitude selected) and hence optimum process parameters for maximum material removal rate is tool rotational speed at 1800rpm,feed rate at 100mm/min and depth of cut 0.4mm for a given set up of MRR for stated material Inconel625.From ANOVA analysis, MRR value is predicted as 12.1589mm^3/s.

Regression Equation

MRR(mm^3/s) = -7.13 -0.000145 tool speed (rpm) + 0.0965 feed rate (mm/min) +23.99 depth of cut(mm)

At Optimum Process parameter, I get MRR is 11.86mm^3/s.



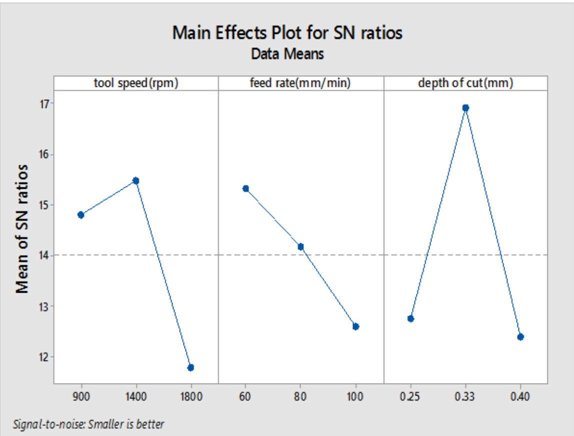


Figure 4 Main effect plot for means and signal to noise ratio for SR(Inconel625)

Main effect plot for means shows effects of various process parameters on Surface roughness(SR) for Inconel625.This graph depicts Tool speed is dominant factor on MRR followed by feed rate and depth of cut. Percentage contribution is tool speed= 48.23%,feed rate=44.37% and depth of cut=0.01% from table2, whereas main effect plot used for acquiring process optimization parameters. I select smaller-is better S/N ratio, so I select optimum parameters from it at maximum S/N ratio(larger magnitude selected) and hence optimum process parameters for maximum surface roughness is tool rotational speed at 1400rpm,feed rate at 60mm/min and depth of cut 0.33mm for a given set up of SR for stated material Inconel625.From ANOVA analysis ,SR values is predicted as 0.1711um.

Regression Equation

SR = -0.0260 + 0.000073 tool speed (rpm) +0.001583 feed rate(mm/min) +0.0217 depth of cut(mm)

At optimum process parameter, I get SR is 0.1783um.

6.1 Validation of Statistical Results with Mathematical Results

Table 7 Confirmation table for Aluminium bronze for MRR

Tool speed(RPM)	Feed rate(mm/min)	Depth of cut(mm)	Statistical Result(mm^3/s)	Mathematical Result(mm^3/s)	Error(mm^3/s)
3000	300	0.5	45.32	46.13	0.81

Table 8 Confirmation table for Aluminium bronze for SR

Tool speed(RPM)	Feed rate(mm/min)	Depth of cut(mm)	Statistical Result(um)	Mathematical Result(um)	Error(um)
2200	150	0.5	0.1488	0.16	0.0112

Table 9 Confirmation table for Inconel625 for MRR

Tool speed(RPM)	Feed rate(mm/min)	Depth of cut(mm)	Statistical Result(mm^3/s)	Mathematical Result(mm^3/s)	Error(mm^3/s)
1800	100	0.4	12.1589	11.86	0.2989

Table 10 Confirmation table forInconel625 for SR

Tool speed(RPM)	Feed rate(mm/min)	Depth of cut(mm)	Statistical Result (um)	Mathematical Result(um)	Error(um)
1400	60	0.33	0.1711	0.1783	0.0072

7. CONCLUSIONS AND FUTURE SCOPE

1. All the process parameters spindle speed, Feed rate and depth of cut content have significant effect on the process, material removal rate and surface finish as the evidenced by the percentage contribution.
2. The optimized levels of selected process parameters obtained by Taguchi methods are Tool speed:3000RPM, feed rate:300mm/min, depth of cut:0.5mm for MRR optimization of aluminiumbronze and Tool speed:2200RPM,feed rate:150mm/min, depth of cut:0.5mm for SR optimization of aluminium bronze whereas, Tool speed:1800RPM, feed rate:100mm/min, depth of cut:0.4mm for MRR optimization of Inconel625 and Tool speed:1400RPM, feed rate:60mm/min, depth of cut:0.33mm for SR optimization of Inconel625
3.The optimum level of control factors at which the effect of noise factors on the response parameter is less.
4.Taguchi method has proved its success in prediction the optimum milling process parameters to reach the best properties.
5. carbide insert face milling tool depicts better performance on Aluminium bronze than inconel 625 at its best possible operating condition.
6.The Taguchi method achieves this by making the product or performance "insensitive" to variation in factors such materials, manufacturing equipment, workmanship and operating condition.
7.A Taguchi method is new engineering design optimization methodology that improves the quality of existing products and processes and simultaneously reduces their cost very rapidly ,with minimum engineering resources and development man hours.
8.The Taguchi method is the best used when there is intermediate number of a variable (3 to 50),few interactions between variables, and when only a few variables contribute significantly.

8. REFERENCES

[1] Dong Yang , Zhanqiang Liu, "Surface topography analysis and cutting parameters optimization for peripheral milling titanium alloy Ti-6Al-4V"Int. journal of refractory metals and Hard materials Elsevier-science direct(2015)
[2] Anselmo Eduardo Diniz ,Jorge Antonio Giles Ferrer, "A comparison between silicon nitride based ceramic and coated carbide tools in the face milling of irregular surfaces" journal of materials processing technology Elsevier-science direct(2008)
[3] Yuan Ma ,PingfaFeng , Jianfu Zhang ,Zhijun Wu ,Dingwen Yu, "Prediction of surface residual stress after end milling based on cutting force and temperature" journal of material processing technology journal of material processing technology Elsevier-science direct(2016)
[4] MohdSayuti ,Ooi Ming Erh, Ahmed A.D. Sarhan , MohdHamdi, "Investigation on the morphology of the machined surface in end milling of aerospace AL6061-T6 for novel uses of SiO2 nano lubrication system" journal of cleaner production Elsevier-science direct(2013)
[5] BalkrishnaRao ,Chinmaya R. Dandekar, Yung C.Shin, "An experimental and numerical study on the face milling of Ti-6Al-4V alloy" journal of material processing technology Elsevier-science direct(2011)
[6] JieGu , Gary Barber ,Simon Tung, Ren-JyhGu, " Tool life and wear mechanism of uncoated and coated milling inserts" Elsevier-science direct (1999)
[7] Mehmet Emre Kara ,ErhanBudak, "Optimization of turn-milling processes" 9th CIRP conference on intelligent computation in manufacturing engineering-CIRP ICME 14 Elsevier-science direct(2015)
[8] A. Jawaid ,S. Sharif , S. Koksal , "Evaluation of wear mechanisms of coated carbide tools when face milling titanium alloy" journal of material processing technology Elsevier-science direct(2000)
[9] R. Arokiadass, K. Palaniradja , N. Alagumoorthi, "Prediction and optimization of end milling process parameters of cast aluminium based MMC" Elsevier -science direct(2012)
[10] NikMasmiati ,Ahmed A.D. Sarhan ,Mohsen Abdel Naeim Hassan , MohdHamdi, "Optimization of cutting conditions for minimum residual stress, cutting force and surface roughness in end milling of S50C medium carbon steel" Accepted manuscript Elsevier- science direct(2016)
[11] R.Arokiadass, K. Palaniradja, N. Alagumoorthi, "Prediction and optimization of end milling process parameters cast based alluminium based MMC"Elsevier-science direct(2012)
[12] Ahmad razlanyusuf, "Identifying Bifurcation Behavior during Machining Process for an Irregular Milling Tool Geometry" Accepted manuscript Elsevier-science direct(2016)
[13] Congbo Li, Xingzheng Chen, Ying Tang, Li Li, "Selection of optimim parameters in multi-pass face milling for mximum energy efficiency and minimum production cost."Elsevier- science direct(2012)
[14] Jui-Pin Hung a,n, Yuan-Lung Lai b, Ching-Yuan Lin c, Tzu-Liang Lo, "Modelling and machining stability of vertical milling machine under the influence of preloaded linear guide"Elsevier- science direct(2011)
[15] Xiobincui,DongWang,JingxiaGuo, "performance optimization of cemented carbide tool in high speed milling of hardened steel with initial microstructure considered." Accepted manuscript Elsevier- science direct(2016)