MULTI OBJECTIVE OPTIMIZATION OF CUTTING PARAMETERS IN MILLING OPERATION TO REDUCE TOOL VIBRATION AND CUTTING FORCES

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ABSTRACT

These days one of the most important machining processes in industries is milling. Milling is affected by many factors such as the cutting velocity, feed rate, depth of cut and geometry of cutting tool etc., which are input parameters in this project work. The desired product of dimensional accuracy and less surface roughness is influenced by cutting force and tool vibration which are the responses and the functions of these input parameters.

In this project work we determine the optimal setting of cutting parameters cutting speed (N) , depth of cut(d) , feed(f) and principal cutting edge angle (Φ) of the tool to get a minimum cutting force and tool vibration.

Tool vibration and surface roughness are two important parameters which affect the quality of the component and tool life which indirectly affect the component cost. In this paper, the effect of cutting parameters on tool vibration and surface roughness has been investigated during end milling of EN-31 tool steel. Response surface methodology (RSM) has been used to develop mathematical model for predicting surface finish, tool vibration and tool wear with different combinations of cutting parameters. The experimental results show that feed rate is the most dominating parameter affecting surface finish, whereas cutting speed is the major factor effecting tool vibration. The results of mathematical model are in agreement with experimental investigations done to validate the mathematical model.

INTRODUCTION

In the modern industry technology is advancing. For that engineers should be ready to achieve product of good surface finish, economic production, less wear of cutting tool with optimizing the use of resources. One of the most important manufacturing process in mechanical engineering is metal cutting which is defined as metal removal of chips from job to achieve the desired product of appropriate shape, size and surface roughness.

Due to its capability for enhancing product rate coupled with desired product quality, high-speed machining has gained popularity in manufacturing industry. However, higher values of cutting parameters used in high-speed machining adversely affect the surface roughness of work piece and tool vibration. Tool vibration further lowers the component quality and reduces tool life. Empirical models can correlate surface finish, tool vibration, and tool wear to the machining parameters for machining of EN-31 die steel machining with tungsten carbide tool in high-speed machining.

In addition to vibration cutting forces also affects the deformation of work piece, dimensional accuracy and chip formation. So it is also an important response in metal machining. Our main concern now a day is to achieve improved quality and economic productivity with reduced cost and time. It is challenging to acquire good surface finish and less tool wear while working with materials having high strength, corrosive resistance and wear resistance in milling. In order to overcome the above problem, optimized cutting parameters are to be employed [8].So optimization of multi response is very much essential in industrial application. As compared to single response optimizing technique it is better because all factors is affected at a time by all the input factors. For this drive Taguchi method is introduced which is an important statistical tool that provides cost effective and systematic way to optimize cutting parameters. It has been successfully used in designing good quality at low cost in the field of automotive, aerospace etc. The theory of grey system is an advanced procedure for performing prediction, relational analysis, and decision making in many areas which is used for finding optimal solution in this project work.

LITERATURE SURVEY

Kline et al. [1] investigated the effects of vibration, deflection, and chatter of the tool workpiece system on roughness in end milling.

Hamdan et al. [2] investigated the machining parameters like speed, feed, and axial depth of cut with dry and wet machining in high-speed machining of stainless steel using coated carbide tool for better surface finish.

Suresh et al. [3] focused on machining mild steel by TiN-coated tungsten carbide cutting tool for developing a surface roughness prediction model by using response surface methodology (RSM). A genetic algorithm (GA) was used to optimize the objective function and the results were compared with RSM results.

Kumar and Thirumurugan [4] introduced Taguchi's robust design method suitable to optimize the surface roughness in milling of die steel. The significant factors for the surface roughness in milling process were the spindle speed and the tool grade, with contribution of 30.347 and 29.933, respectively.

Zhang and Chen [5] demonstrated a tool condition monitoring approach in an end milling operation based on the vibration signal collected through a low-cost, microcontroller-based data acquisition system. The examination tests of this developed system had been carried out on a CNC milling machine. Experimental studies and data analysis were performed to validate the proposed system.

Routara et al. [6] investigated the parameters the influence of machining parameters on the quality of surface produced in CNC end milling. Experiments were conducted for three different workpiece materials to see the effect of workpiece material variation. It was found that the response surface models for different roughness parameters were specific to workpiece materials.

Cui and Zhao [7] investigated the cutting performance of coated carbide tools in high-speed face milling of AISI H13 hardened steel. Chip morphology, tool life, tool wear mechanisms, and surface roughness were analyzed and compared for different cutting conditions. It was found that as the cutting speed increased, the chip morphology evolved in different ways under different milling conditions.

Raju et al. [8] reported an integrated study of surface roughness and cutting parameters in end milling of 6061 aluminum alloy with HSS and carbide tools under dry and wet conditions. Genetic algorithm (GA) supported with the regression equation was utilized to determine the best combinations of cutting parameters providing roughness to the lower surface through optimization process. The value obtained from GA was compared with that of experimental value and was found to be reliable.

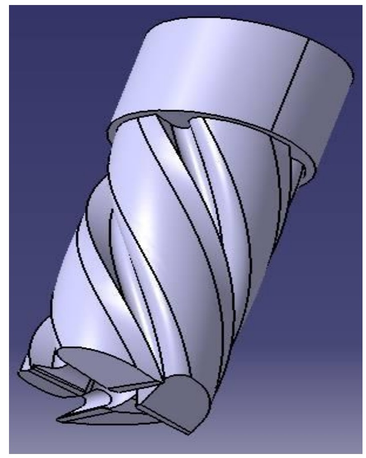
Prajina [9] focused on RSM for the multiple response optimizations in CNC end milling operation to get maximum material removal rate, minimum surface roughness, and less force. In this work, quadratic equations were developed for cutting forces, surface roughness, and machining time considering the spindle speed, feed rate, depth of cut, and immersion angle as the cutting parameters using central composite design.

Objective of present work

Many studies are carried out on single response optimization. From engineering point of view multi objective optimization is better as compared to single response optimization. So the present work shows the application of grey relation combined with Taguchi's optimization design to find optimal setting of the input parameters (feed, speed, depth of cut and principal cutting edge angle) to minimize cutting forces and tool vibration (in terms of peak to peak displacement).

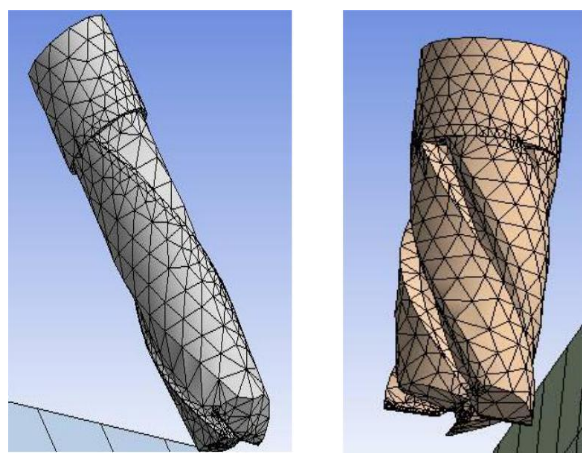
Development of Three Dimensional CAD model of micro flat end mill

The three dimensional CAD models of both the flat end mills was produced by performing solid modeling in CATIA V6 environment.



CATIA model of four flute micro end mill

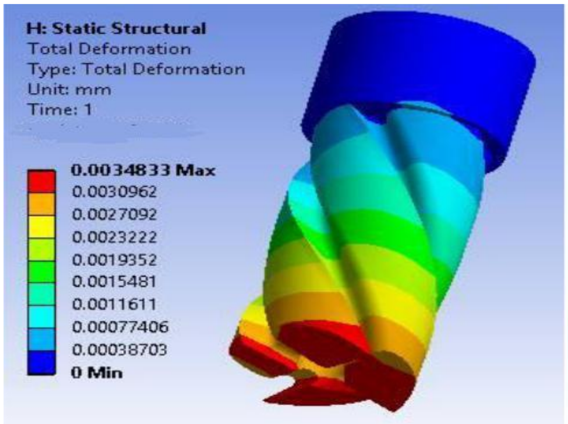
Meshing:



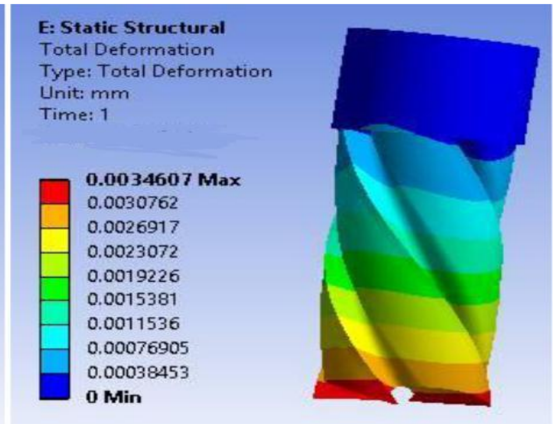
Static finite element analysis

Results

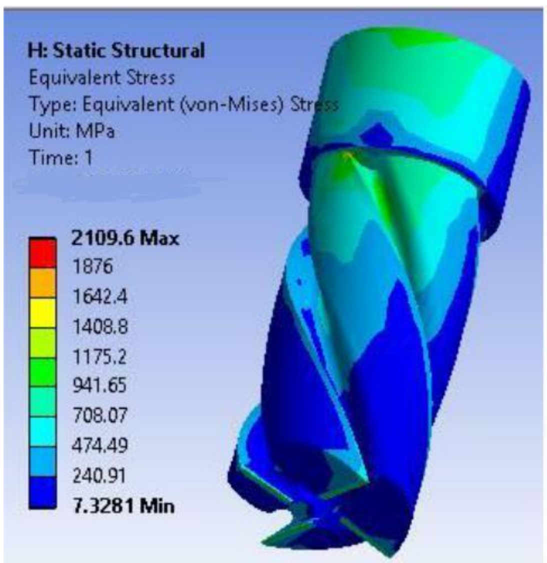
show the result for static analysis with deformed mesh and Von Mises stress respectively for the applied load for four flute flat end mill of diameter 0.3 mm.



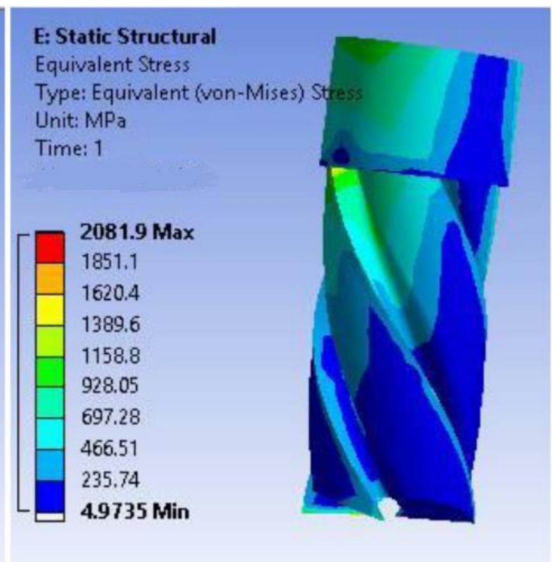
(d) Rake angle = 5º, Relief angle = 5º



(e) Rake angle = 5º, Relief angle = 6º

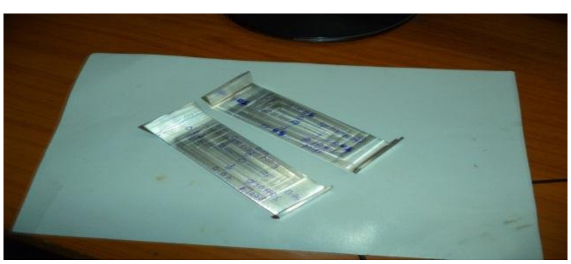


(d) Rake angle = 5º, Relief angle = 5º



(e) Rake angle = 5º, Relief angle = 6º

Experimental procedures and practical results

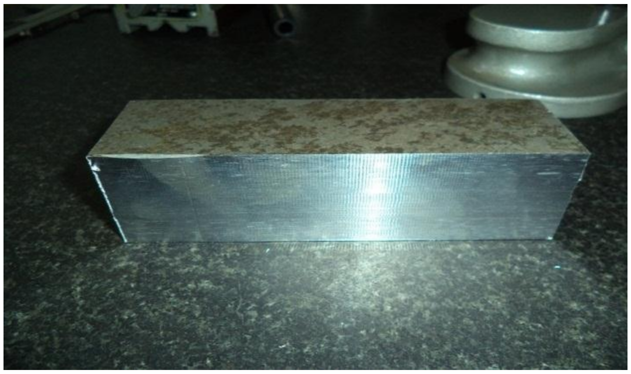


Raw material;

1.Total components: 4 components-final sizes-120x40x25

So raw material will be taken in to multiple with 10mm each side for making right angle.

I.E 150x50x35-4 Blocks



2.The raw material should be maintained to right angle to each face.

The machining process showed while machining the component with normal coolant with carbide end mill of 20 dia to make size of 120x40x25.

3.After the machining of final sizes the component is going to semi finishing because the wall thickness is very less.

4.Before going to the final machining the specimen component checked for warp age and considered that the distortion before final machining is zero and after semi-finishing the value is zero on wall itself.

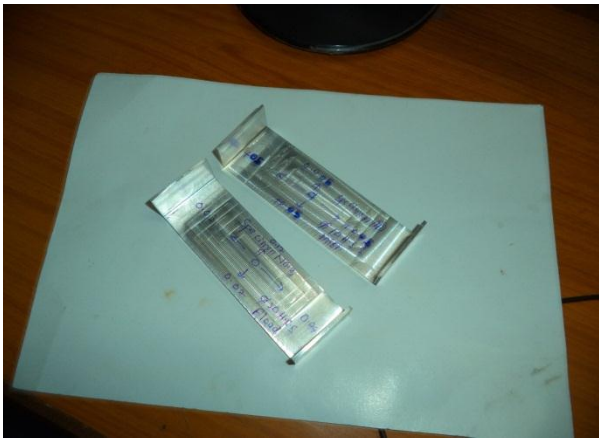
5.The component has been measured when the specimen wall has been finished as well as before taking out of fixture the distortion has been verified the distortion values will be given in a table format.

The tools speed& feeds, tool selection for each table given in the table(practical used)

S.NO	Tool used	Spindle speed	Feed rate	Depth of cut	Coolant type
Specimen-1	Ø20 carbide	1200rpm	800mm/min	0.4mm	Coolant oil
Specimen-2	Ø10 carbide	2000rpm	500mm/min	0.3mm	Normal pressure
Specimen-3	Ø20 H.S.S	600rpm	500mm/min	0.35mm	Flood
Specimen-4	Ø10 H.S.S	800rpm	300mm/min	0.3mm	High Volume

6.The final components will be released with a final pass of contour final to avoid maximum distortion at walls and floor.

RESULTS



Quality check before releasing from fixture

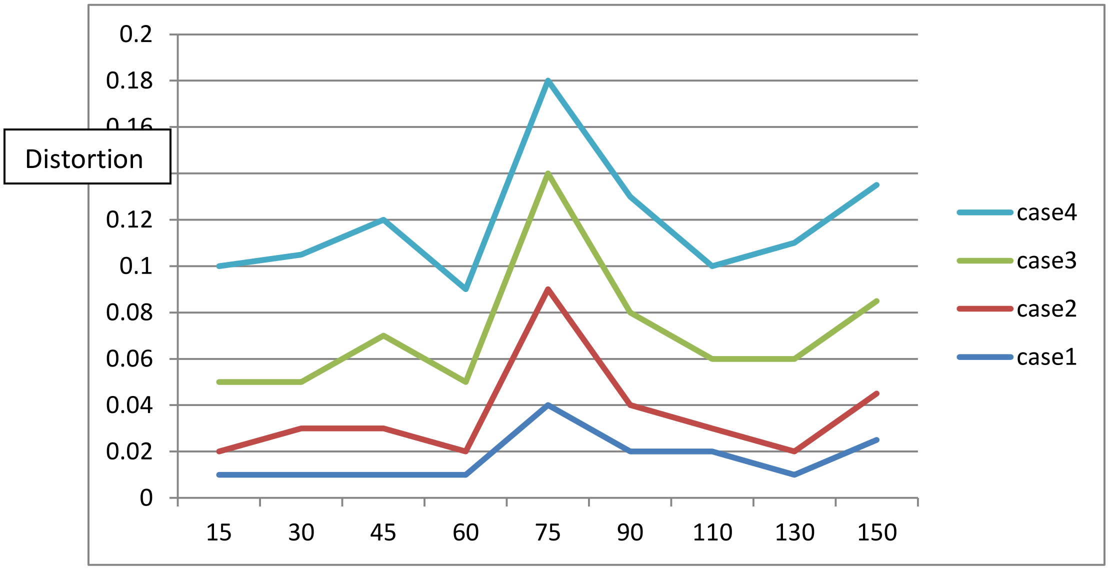
The value taken at the centre is 0.000 and the distortion checked at 4 ends as left middle, right middle, top end, top-y, bottom y. left wall top, right wall top, overall maximum distortion.

Specimen-1	0.010	0.010	0.010	0.010	0.040	0.020	0.020	0.010	0.025
Specimen-2	0.010	0.020	0.020	0.010	0.050	0.020	0.010	0.010	0.020
Specimen-3	0.030	0.020	0.040	0.030	0.050	0.040	0.030	0.040	0.040
Specimen-4	0.050	0.055	0.050	0.040	0.040	0.050	0.040	0.050	0.050

Quality check after releasing from fixture

Specimen-1	0.020	0.020	0.050	0.050	0.075	0.070	0.055	0.050	0.060
Specimen-2	0.030	0.030	0.030	0.040	0.060	0.060	0.050	0.050	0.050
Specimen-3	0.080	0.060	0.010	0.080	0.075	0.075	0.060	0.060	0.080
Specimen-4	0.050	0.055	0.100	0.100	0.075	0.050	0.060	0.060	0.085

Distortion graphs



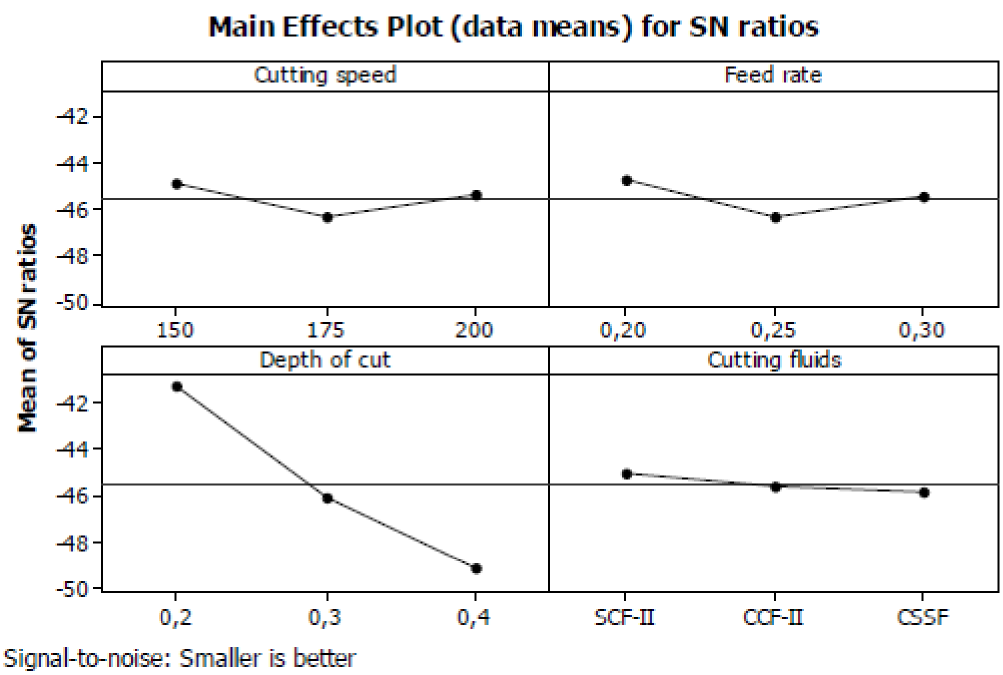
L18 Orthogonal array

Exp. No.	End Milling Machining parameters			
	A	B	C	D
01	1	1	1	1
02	1	2	2	2
03	1	3	3	3
04	2	1	1	2
05	2	2	2	3
06	2	3	3	1
07	3	1	2	1
08	3	2	3	2
09	3	3	1	3
10	1	1	3	3
11	1	2	1	1
12	1	3	2	2
13	2	1	2	3
14	2	2	1	1
15	2	3	3	2
16	3	1	3	2
17	3	2	1	3
18	3	3	2	1

VALUES OF S/N RATIOS FOR TOOL WEAR, FX AND FY

Factors				Tool wear (mm)	S/N ratio	Fx (N)	S/N ratio	Fy (N)	S/N ratio
Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)	Cutting fluids						
150	0.20	0.2	SCF-II	0.010	40.0000	116	-41.2892	116	-39.4626
150	0.25	0.3	CCF-II	0.886	1.0513	211	-46.4856	211	-46.3613
150	0.30	0.4	CSSF	0.980	0.1755	312	-49.8831	312	-48.7233
175	0.20	0.3	CSSF	0.629	4.0270	234	-47.3843	234	-46.4444
175	0.25	0.4	SCF-II	1.006	-0.0520	357	-51.0534	357	-50.2644
175	0.30	0.2	CCF-II	0.010	40.0000	141	-42.9844	141	-42.1442
200	0.20	0.4	CCF-II	0.695	3.1603	270	-48.6273	270	-48.2660
200	0.25	0.2	CSSF	0.010	40.0000	156	-43.8625	156	-42.2789
200	0.30	0.3	SCF-II	0.244	12.2522	230	-47.2346	230	-45.4368

specimen 1s/n graph with speed and feed



Analysis of Variance (ANOVA)

ANOVA was used to determine the significant parameters influencing the tool wear and force components in the milling of AISI 304. Tables showed the summary of S/N values and ANOVA results for tool wear, Fx and Fy, respectively.

SUMMARY OF S/N VALUES AND ANOVA RESULTS FOR FX

Factor	Degree of Freedom (DF)	Average S/N Values			Sum of squares	Mean square	Percentage of contribution (%)
		Level 1	Level 2	Level3			
Cutting speed	2	-45.89	-47.14	-46.57	1634.9	870.3	3.20
Feed rate	2	-45.79	-47.13	-46.70	1829.6	922.3	3.59
Depth of cut	2	-42.71	-47.03	-49.85	46112.8	23056.4	90.39
Cutting fluids	2	-46.53	-46.03	-47.04	1440.2	720.1	2.82
Error	0				0		
Total	8				51017.5		100

SUMMARY OF S/N VALUES AND ANOVA RESULTS FOR Fy

Factor	Degree of Freedom (DF)	Average S/N Values			Sum of squares	Mean square	Percentage of contribution (%)
		Level 1	Level 2	Level3			
Cutting speed	2	-44.85	-46.28	-45.28	1740.7	870.3	3.76
Feed rate	2	-44.76	-46.30	-45.28	1844.7	922.3	3.98
Depth of cut	2	-41.20	-46.05	-49.05	42672.7	21336.3	92.14
Cutting fluids	2	-45.73	-45.81	-45.82	56.0	28.0	0.12
Error	0				0		
Total	8				46314.0		100

SUMMARY OF S/N VALUES AND ANOVA RESULTS FOR TOOL WEAR

Factor	Degree of Freedom (DF)	Average S/N Values			Sum of squares	Mean square	Percentage of contribution (%)
		Level 1	Level 2	Level3			
Cutting speed	2	13.742	14.658	18.471	0.15523	0.07762	10.52
Feed rate	2	15.729	13.666	17.476	0.08654	0.04327	5.86
Depth of cut	2	40.000	5.777	1.095	1.20758	0.60374	81.82
Cutting fluids	2	17.4	14.737	14.734	0.02658	0.01329	1.80
Error	0				0		
Total	8				46314.0		100

In this study, analysis was a level of significance as 5% and level of confidence as 95%.

CONCLUSIONS

In the present study, the machining parameters in CNC milling of EN-31 die steel machining with tungsten carbide tool bit have been optimized using response surface methodology. Full factorial (3K) orthogonal array has been used and twenty-seven experiments are carried out.The primary object is to develop mathematical models based on experimental results, for obtaining low surface roughness and cutting tool vibration. The predicted surface roughness from the model is compared to the values measured experimentally. The optimum cutting parameters for minimum surface roughness and tool vibration based on the analysis of experiment results are cutting speed = 143.6 m/min, feed = 0.1 mm/tooth, and depth of cut = 1.25 mm which resulted in surface roughness of 0.189 and tool vibration of 17.772. The validity of the model

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