Modeling and optimization of process parameters in face milling of Ti6Al4V alloy using Taguchi and grey relational analysis

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Summary

Using modeling and optimization techniques, an improvement of 55.81% in tool life, 6.12% in surface roughness, and 23.98% reduction in average cutting forces are obtained while face milling Ti-6Al-4V alloy. Developed models have been validated through experiments. Also, 'genetical algorithm' for process optimization is being considered to compare the results obtained using grey relational analysis. These approaches can be used in real production and industrial applications. The conducted research work has been submitted for an International Conference and Journal publication.

Introduction

- Titanium alloys have some extraordinary properties and about 40% lighter than steel but possessing nearly the same properties as steel[1].
- These are widely used in chemical, automobile, marine, aviation, biomedical industries due to having extreme corrosion and fracture resistance, high strength to density ratio, durability at elevated temperature, and much more[2,3].
- Despite having unique properties, these are considered as hard to cut materials because of high heat capacity, high chemical reactivity at elevated temperature, high rigidity, low thermal conductivity, etc.
- That's why it is always a challenge in the machining to reduce production time having better surface roughness and maximum tool life.
- Normally, axial depth of cut (a_p) is considered as an input parameter in most of the articles[4] whereas here the radial depth of cut (a_e) is considered.
- Researchers are using different optimization techniques, coated cutting tools, different cooling methods to improve the efficiency. For this analysis, flood cooling is used, and axial depth of cut is set to constant.

Objectives

- Investigating the impact of radial depth of cut (a_e) on cutting forces, surface roughness, and tool life during face milling of Ti6Al4V alloy.
- Applying ANOVA and Taguchi analysis for mono-objective optimization.
- Performing multi-objective optimization using Taguchi-based grey relational analysis.
- Developing mathematical models for predicting tool life, surface roughness, and cutting forces.
- Validating the results with confirmation experiment.

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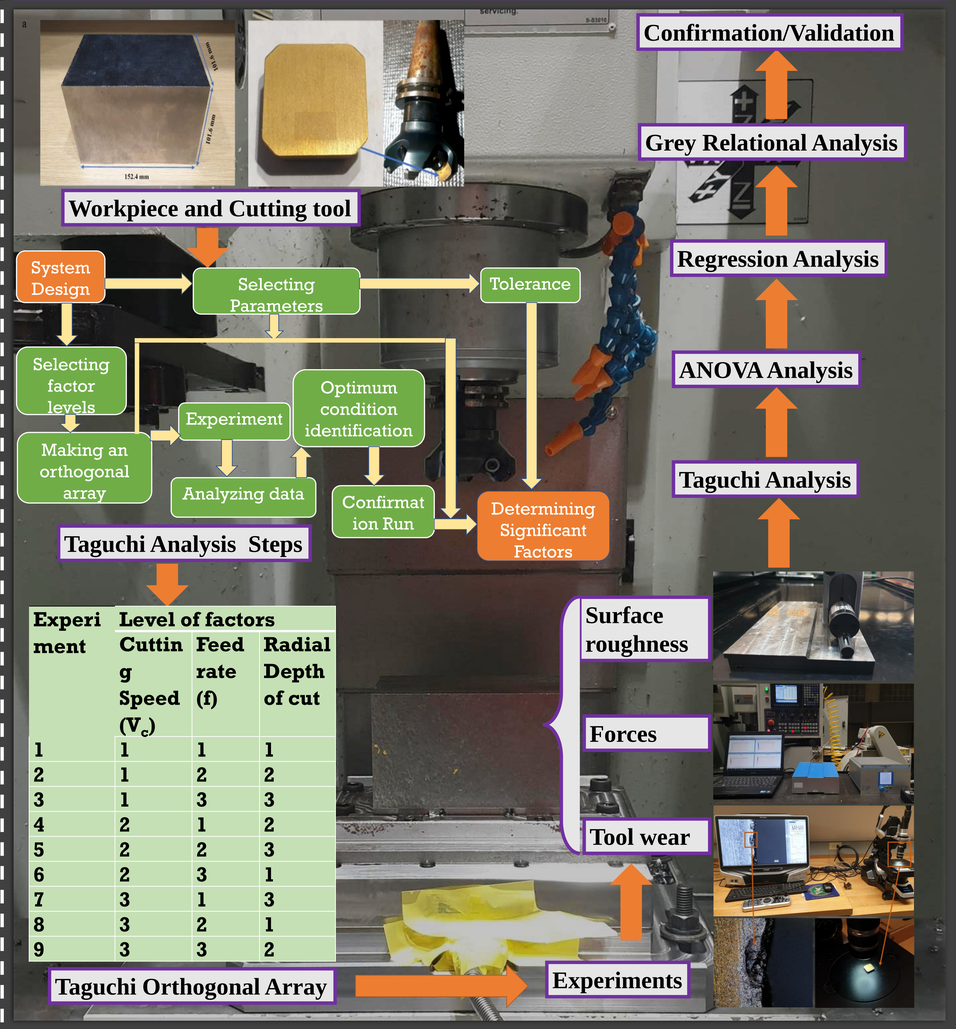
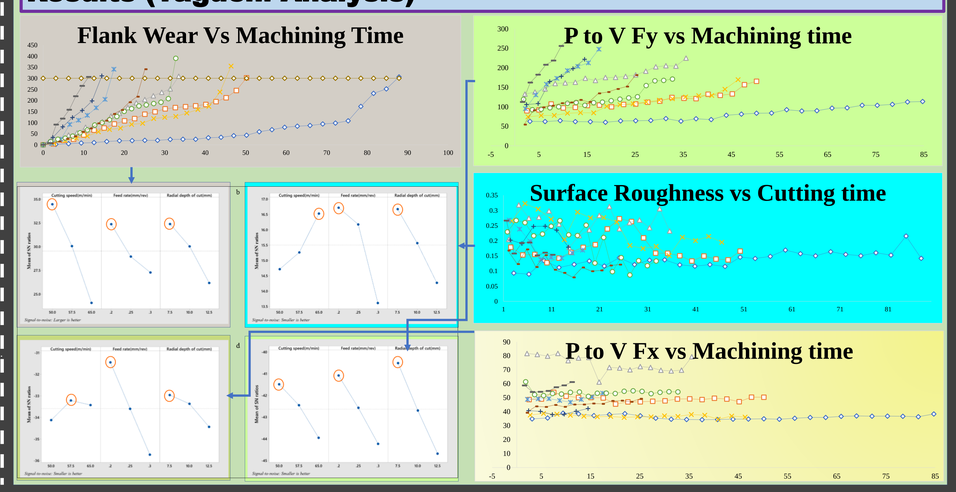
Methodology and Experimentation



Experiment	Level of factors: Cutting Speed (V_c)	Feed rate (f)	Radial Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

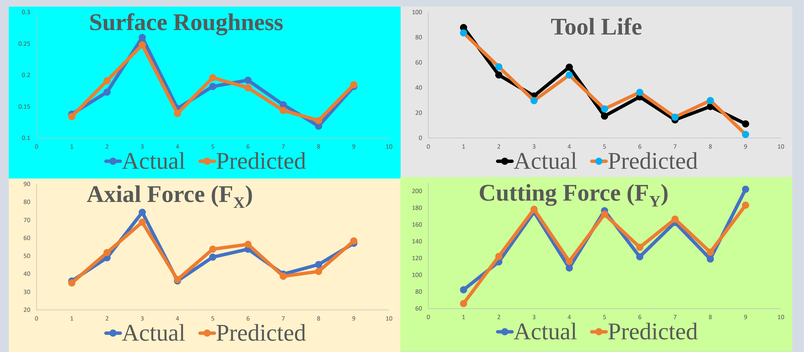
Results (Taguchi Analysis)



Results (ANOVA Analysis)

Output Characteristics	Significance hierarchy of input parameters obtained from ANOVA Analysis		
	(first)	(Second)	(third)
Tool Life	V_c	f	a_e
Surface Roughness	F	a_e	V_c
Axial Force (F_X)	f	a_e	V_c
Cutting Force (F_Y)	a_e	f	V_c

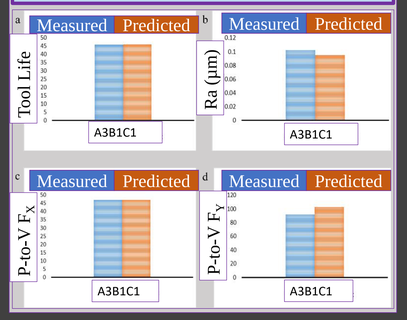
Results (Regression Analysis)



Results (Grey Relational Analysis)

	Initial Condition	Optimal Factors		
		Prediction	Experiment	Percent Improved
Level	A2B1C3	A1B1C1	A1B1C1	
Tool Life (min)	56.39		87.86	55.81%
Ra (µm)	0.147		0.138	6.12%
P-to-V F_Y (N)	108.46		82.45	23.98%
Grey Relational Grade	0.654	0.831	0.929	
Improvement of Grey Relational Grade	0.275			

Confirmation



Conclusion

- Using ANOVA analysis the most significant parameters for output characteristics are obtained and Taguchi analysis showed single objective optimized parameters.
- Mathematical models were developed through regression analysis.
- From grey relational analysis optimized parameters are obtained and
- Radial depth of cut was found the most significant factor and validation experiment confirmed the results.

References

1. Nath, C., S.G. Kapoor, and A.K. Srivastava, Journal of Manufacturing, https://doi.org/10.1016/j.jmapro.2017.04.013
2. Saini, A., et al., Journal of Engineering Manufacture, https://doi.org/10.1177/0954405416673682
3. Polini, W. et al. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, https://doi.org/10.1177/0954405414558732
4. Vijay, S. and V. Krishnaraj, Procedia Engineering, https://doi.org/10.1016/j.proeng.2013.09.186