Final Year Design Project Showcase
Batch-2022
Year 2026

Department: Industrial and Manufacturing Engineering **Programme:** Bachelor of Engineering in Industrial and Manufacturing Engineering	
1	**Project Title** Optimization of High-Speed Pocket Milling Parameters using Taguchi and Minitab Analysis
2	**Project Idea** To develop an experimentally validated parameter-selection framework for high-speed pocket milling of SS304 on a VMC 850. The project combines a Taguchi L9 design, Minitab statistical analysis, response-surface/desirability optimisation and DEFORM 3D wear visualisation to identify spindle speed, feed rate and depth of cut that improve surface finish while maintaining practical productivity.
3	**Process** 1. Selected SS304, a 12 mm TiAlN-coated carbide end mill, and three factors at three levels: spindle speed 1000/1250/1500 RPM, feed rate 300/600/900 mm/min, and depth of cut 0.2/0.4/0.6 mm. 2. Conducted nine controlled pocket-milling trials on a VMC 850 using a Taguchi L9 orthogonal array. 3. Measured Ra, Rq and Rz using a Mitutoyo SJ-301 surface-roughness tester and calculated material removal rate (MRR). 4. Analysed results in Minitab using S/N ratios, main effects, ANOVA, residuals, GLM, interactions, regression and contour/surface plots. 5. Applied quality-weighted desirability and DEFORM 3D comparative wear assessment to select the final machining setting.
4	**Outcome** Feed rate was identified as the most influential factor. Run 4, at 1250 RPM, 300 mm/min feed rate and 0.4 mm depth of cut, produced the lowest measured roughness: Ra = 1.992 µm, Rq = 2.456 µm and Rz = 11.101 µm. It achieved an MRR of 1,440 mm^3/min and the highest combined desirability of 0.901. The Taguchi model explained 92.8% of the S/N variation. This setting was recommended as the best balance of surface finish, machining stability, productivity and comparatively lower tool-wear tendency.
5	**Evidence (Theoretical Basis)** SS304 is difficult to machine because its low thermal conductivity, work-hardening behaviour and adhesion tendency can increase heat, cutting load, tool wear and surface damage. Milling theory predicts that feed rate raises chip load and feed-mark height; the experimental results confirmed feed rate as the dominant factor. Taguchi's smaller-is-better S/N method evaluated three factors at three levels in nine trials instead of a full 27-run factorial experiment. ANOVA and GLM assessed factor influence, RSM and desirability combined surface quality with MRR, and DEFORM 3D/FEM provided comparative evidence of stress, temperature and wear tendency. The recommendation is supported by measured Ra, Rq and Rz values, MRR calculations and statistical model diagnostics.
6	**Competitive Advantage or Unique Selling Proposition** *Relevant aspects retained from the university template are listed below.*
a	**Attainment of Sustainable Development Goals**

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	Supports SDG 9 through data-driven manufacturing innovation, SDG 12 by reducing rework, material waste and unnecessary trials, and SDG 13 by avoiding energy-intensive trial-and-error machining. This is useful for regional manufacturers that need reliable quality improvement with limited testing resources.	
b	**Environmental and Resource-Efficiency Aspect** The L9 design reduces the selected three-factor, three-level study from 27 full-factorial combinations to nine physical trials. Optimised parameters can reduce unnecessary machining passes, scrap, rework, tool replacement and machine running time, lowering material and energy consumption.	
c	**Cost Reduction of the Existing Machining Process** Provides a repeatable parameter window that can reduce costs caused by poor finish, rejected components, excessive tool wear and prolonged setup trials. A moderate parameter combination maintains useful productivity while reducing the risk associated with overly aggressive cutting conditions.	
d	**Process Improvement and Superior Consistency** Replaces operator-dependent parameter selection with a structured workflow based on DOE, measurement, statistics and simulation. Manufacturers can use the recommended setting as a validated starting point for SS304 pocket milling and refine it for their machine, toolpath and coolant conditions, improving consistency and decision speed.	
7	**Target Market** CNC machine shops, precision-engineering firms, die and mould manufacturers, and automotive, aerospace, medical-device, chemical/process-equipment and general manufacturing companies that machine SS304. Primary end users include CNC process engineers, manufacturing engineers, production managers, machinists, tool-room teams, and engineering students or researchers seeking a validated starting point for SS304 pocket milling.	
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10	**Supervisor Name** *(with email address)*	Ms. Rabia Siddiqui, Assistant Professor and Project Advisor *Email: rabias@cloud.neduet.edu.pk*
11	**Video (If any)**	No video link was provided in the FYDP report.

Pictures

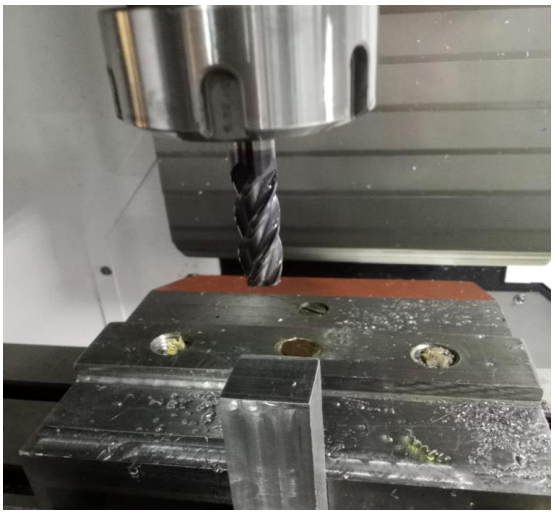

Figure 1. Actual SS304 pocket-milling setup on the VMC 850.

Figure 2. Final machined SS304 pocket specimens after the trials.

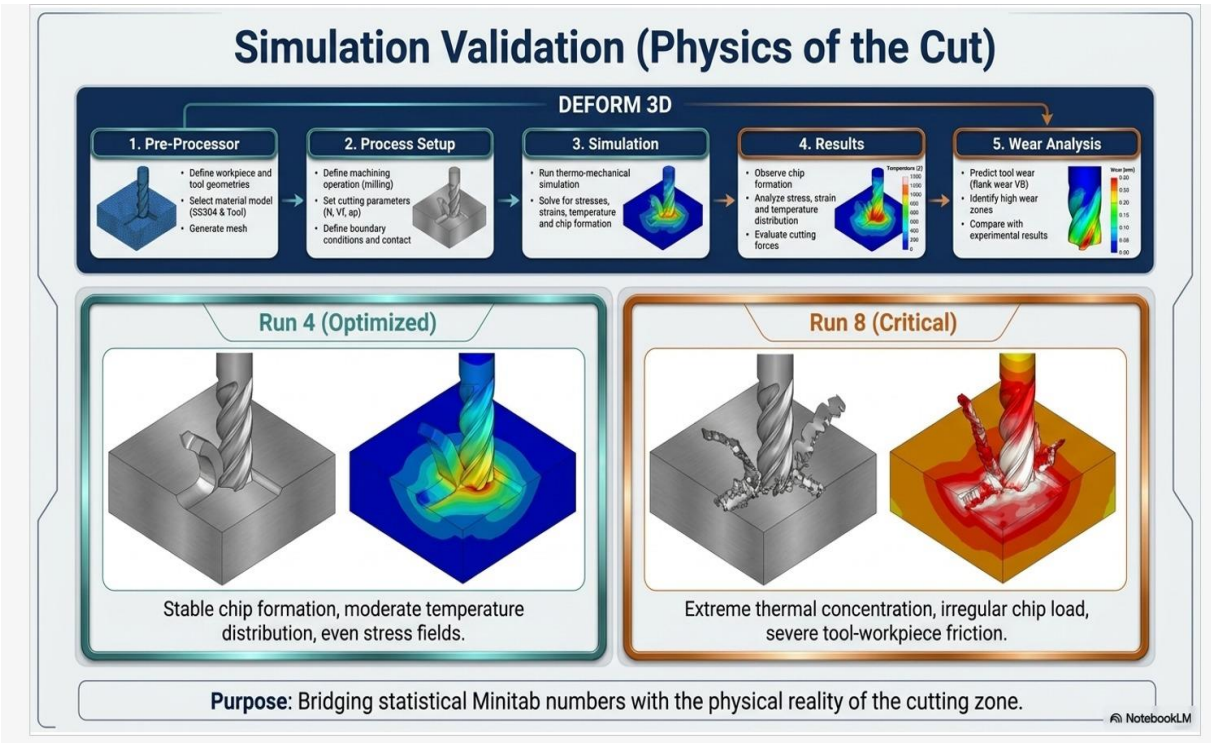

Figure 3. DEFORM 3D simulation validation: optimized Run 4 versus critical Run 8.

Project Poster

NED University of Engineering & Technology

Department of Industrial & Manufacturing Engineering

Experimental and Simulation-Based Optimization of High-Speed Pocket Milling Parameters of SS304 on VMC 850

Final Year Design Project | Department of Industrial & Manufacturing Engineering | NED University of Engineering & Technology

Group 19 | Batch 2022–2026

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1 PROBLEM STATEMENT

- High-speed milling improves productivity but increases trade-offs.
- Surface finish, tool wear, and material removal rate (MRR) are interdependent.
- Optimizing RPM, feed rate, and depth of cut is essential for aerospace analogue materials using structured DOE and statistical analysis.

2 OBJECTIVES

- Study the effect of spindle speed, feed rate, and depth of cut on surface roughness.
- Use Taguchi L9 DOE for reliable trials.
- Analyze S/N ratio to find optimal settings.
- Evaluate via ANOVA, regression, contour, and surface plots.
- Recommend best parameter combination for quality & productivity.
- Validate concept using DEFORM-3D simulation of tool wear.

3 MATERIALS & MACHINE SETUP

- Machine: VMC 850 Vertical Machining Centre
- Tool: 12 mm TiAlN-coated carbide end mill
- Material planned: AISI 4140 and SS304
- Final analyzed material: SS304 due to time constraints after machining.
- Workpiece size: 22 mm × 22 mm
- Pocket size: 20 mm × 20 mm
- Pocket depth: 8 mm
- Measured responses: Ra, Rq, Rz using surface profilometer.
- Calculated response: MRR

4 DOE PARAMETERS AND LEVELS

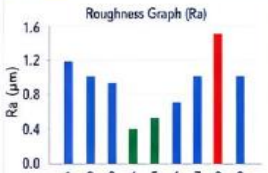
Parameter	Level 1	Level 2	Level 3
RPM	1000	1250	1500
Feed Rate (mm/min)	300	600	900
Depth of Cut (mm)	0.2	0.4	0.6

5 EXPERIMENTAL METHODOLOGY

6 TAGUCHI L9 DOE TABLE

Run	RPM	Feed Rate (mm/min)	DOC (mm)
1	1000	300	0.2
2	1000	600	0.4
3	1000	900	0.6
4	1250	300	0.4
5	1250	600	0.6
6	1250	900	0.2
7	1500	300	0.6
8	1500	600	0.2
9	1500	900	0.4

7 SURFACE ROUGHNESS RESULTS



Best surface finish:
Run 4 → 1250 RPM, 300 mm/min, DOC 0.4 mm
Ra = 1.992 µm
Rq = 2.456 µm
Rz = 11.101 µm

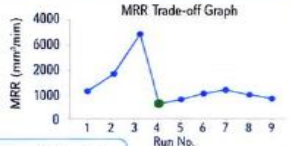
Worst surface roughness:
Run 8 → 1500 RPM, 600 mm/min, DOC 0.2 mm
Ra = 7.053 µm

Interpretation:
Lower roughness indicates better surface quality. Run 4 gives the best finish due to balanced cutting conditions.

Surface Profilometer

8 MATERIAL REMOVAL RATE

MRR (mm³/min) = radial width of cut × axial depth of cut × feed rate
(12 mm × 0.2 mm × feed rate)



- Highest MRR: Run 3 = 6480 mm³/min
- Best finish MRR: Run 4 = 1440 mm³/min

Interpretation:
Higher MRR improves productivity but the best surface finish was achieved at a moderate MRR. The final recommendation prioritizes surface quality over maximum material removal.

9 TAGUCHI / MINITAB ANALYSIS

S/N Ratio Criterion: Smaller-is-better for Ra

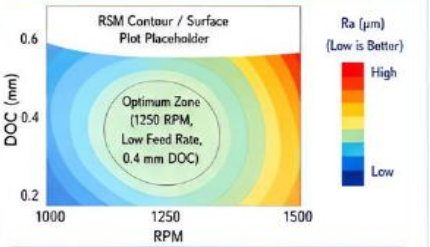
Factor ranking:
1. Feed Rate
2. Depth of Cut
3. RPM

Optimum factor levels:
- RPM = 1250
- Feed Rate = 300 mm/min
- DOC = 0.4 mm

ANOVA interpretation: Feed rate had the strongest practical effect on surface roughness. DOC had moderate influence, while RPM had the least influence among the selected parameters.

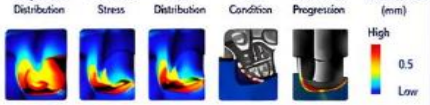
10 RSM / OPTIMIZATION

$$Ra = 0.64 + 0.00197(RPM) + 0.00133(Feed\ Rate) - 0.39(DOC)$$



Interpretation: Feed rate and RPM show positive roughness contribution in the linear model, while moderate DOC supports better cutting stability. RSM surface and contour plots indicate the best machining zone near 1250 RPM, low feed rate, and 0.4 mm DOC.

11 DEFORM-3D TOOL WEAR DISCUSSION



The DEFORM-3D visualization conceptually represents the tool-work-contact zone during SS304 pocket milling. The optimized conditions show consistent heat and stress concentrations, supporting the wear observation. Reduced abrasive wear within this regime helps explain tool behavior and extended tool life.

12 FINAL RECOMMENDED CONDITION

Best Machining Condition for SS304:
- RPM: 1250
- Feed Rate: 300 mm/min
- Depth of Cut: 0.4 mm

- Ra: 1.992 µm
- Rq: 2.456 µm
- Rz: 11.101 µm
- MRR: 1440 mm³/min
- Estimated VB: ≈ 0.11 mm