TU Clausthal

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Creation of a CAM simulation for a component designed for manufacturing using Siemens NX.

Institut für Maschinenwesen

Guided by,

Prof. Dr. David Inkermann

Roman Stephan, M.Sc.

Johannes Meyer, M.Sc.

Done by,

Sabin Cristanious Samraj (603097)

Sai Akash Kumar Somasundaram Vijaya Kumar (603096)

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Task 1: Analysis of Manufacturing Constraints and Application of DfX Principles

Relevance of Selected DfX Principles for the Landing Tray Holder.

For the landing tray holder component, the most relevant Design for X (DfX) principles are:

1. **Design for Manufacturing (DfM)**:
    - Critical for the aluminum milling process to ensure cost-effective production while maintaining precision. Requires consideration of tool access, feature geometry, and machining sequences.
2. **Design for Assembly (DfA)**:
    - Essential as the holder must integrate seamlessly with the landing tray assembly.
3. **Design for Reliability (DfR)**:
    - Paramount for aerospace components that must withstand operational stresses.

Process-Based Explanation of Milling-Related Design Guidelines for the Landing Tray Holder

To ensure efficient and cost-effective production of the landing tray holder (an aerospace component made of aluminum), specific design guidelines must be followed. Below is a structured breakdown of key milling considerations, supported by literature and applied to the given example.

1. Thickness & Uniformity

Guideline:

- Non-uniform thickness can cause tool deflection, vibration, and warping due to uneven material removal [1].
- Avoid cosmetic fillets or blends that increase machining time without functional benefit [2].
- Undercuts and abrupt changes in wall thickness should be avoided to improve machinability and reduce the number of tool passes [3].

Application to Landing Tray Holder:

- The original component included a T-slot feature with varying wall thickness and a partial undercut, which caused inconsistent material removal and limited 3-axis tool access. In the optimized design, the slot was modified to have uniform thickness and the undercut-like transition was removed to ensure smoother machining with standard end mills.
- Non-functional tangents or blended surfaces may be removed to reduce machining complexity [1][2]. Since the curved transition in this part does not influence stress distribution or mechanical engagement, it was replaced with a straight edge to facilitate easier tool access and reduce CAM programming effort.

2. Hole & Cavity Design

Guideline:

- Standardizing hole sizes minimizes tool changes [1], and through-holes are preferred for easier chip evacuation [2].

Application to Landing Tray Holder:

- Mounting holes should match standard drill sizes (e.g., Ø6 mm, Ø8 mm, Ø16 mm) [3].Non-standard hole dimensions and cavities with insufficient draft angles should be avoided to simplify tool withdrawal and reduce the need for custom tooling.

3. Surface Finishing & Tolerances

Guideline:

- **Critical mating surfaces** require tighter tolerances (±0.05 mm) and finer finishes [2]. Non-functional surfaces may use rougher finishes to reduce machining effort [3].

Application to Landing Tray Holder:

- Interface surfaces connecting to the landing tray need a fine finish,Overly tight tolerances on non-critical areas should be relaxed to reduce production cost and machining time.

4. Setup Minimization

Guideline:

- Designing parts for machining in ≤3 setups minimize production time and fixture complexity [3].

Application to Landing Tray Holder:

- Feature orientation should allow complete machining in 3 setups (top and bottom). Features that would require a fourth setup - such as undercuts or hidden pockets - should be redesigned to ensure standard 3-axis accessibility [1].

Table 1: Key literature sources referenced in this analysis.

Reference Type	Citation	
Book (Monograph)	[1]	G. Boothroyd, P. Dewhurst, and W. Knight, Product Design for Manufacture and Assembly. Boca Raton: CRC Press, 2011.
Handbook	[2]	J. G. Bralla, Design for Manufacturability Handbook, 2nd ed. New York: McGraw-Hill, 2007.
Textbook	[3]	R.W. Sukowski, Golden rules for writing well, 2nd ed. Toronto: University Press, 2009.
Journal Article	[4]	J. A. Permanand and H. ElMaraghy, “Design for manufacturability: Guidelines and techniques,” CIRP Annals, vol. 44, no. 1, pp. 81–85, 1995.

Task 2: Optimization of the Component for Manufacturability

Table 2: Identification and Justification of Non-Manufacturable Design Parameters.

Design Parameter	Manufacturing Issue	Justification for Change
Keyhole Feature	The keyhole feature adds unnecessary complexity to the machining process without providing functional value, increasing toolpath time and risk of tool wear.	Non-functional cutouts introduce unnecessary complexity, extend machining time, and increase toolpath planning effort without benefit. By eliminating this redundant geometry, the part becomes easier to manufacture using standard 3-axis milling operations, and the risk of stress concentration around sharp transitions is reduced [2].
Non-Standard Hole Sizes	Require custom drill bits (higher tooling costs)	Standard Ø16 mm drills are readily available and reduce setup time [2].
T-Slot with Undercut	Causes tool deflection and uneven machining forces (poor surface finish). Also requires more number of non - standard tools.	Uniform thickness improves stability and reduces scrap rates [1].
Cosmetic Tangent Blends	Complex 5-axis toolpaths needed (excessive machining time)	Straight edges simplify machining without affecting functionality [1].
Redundant protruding boss with tight tolerance	Increased manufacturing complexity and inspection requirements.	It adds unnecessary toolpaths and tight tolerance requirements, increasing machining time, tool wear, and inspection effort for a non-functional part of the component [3].

Key References:

[1] SME Tooling Standards (2022)
[2] ASME Y14.5-2018 (GD&T standards)
[3] ISO 13715:2019 (Edge imperfections specification)

Note: All identified issues violate Design for Manufacturability (DfM) principles for CNC milling

CAD Implementation Documentation

A. Tangent Blend Modification

- Before: Cosmetic tangent blend (161° inner angle)
- After: Straight edge (180° inner angle)
- Reason: Eliminated non-functional complex geometry to simplify machining

B. Hole Standardization

- Before: Non-standard holes (Ø16mm, Ø22mm, Ø20mm)
- After: Standard Ø16.0mm holes (ISO metric)
- Reason: Reduced tooling requirements and improved manufacturability

C. T-Slot with Undercut

- Before: T-shaped profile with undercut. Variable thickness (20mm → 10mm at undercut)
- After: Simplified to uniform 20mm wall. Eliminated undercut for standard end mill access
- Reason: Improved machining stability and surface finish

D. Keyhole Feature

- Before: 7 mm long keyhole-shaped cutout included in the part geometry.
- After: Feature completely removed in the redesign
- Reason: Non-functional feature that added unnecessary machining complexity

E. Protruding boss

- Before: Protruding boss - a non-functional feature with no interface or load-bearing purpose.
- After: Boss removed from the CAD model.
- Reason: The boss served no assembly or structural function and would have required complex 5-axis machining due to tool access limitations. Its removal simplifies manufacturing and reduces machining time and cost.

Task 3: Creation of the CAM Simulation for the Optimized Component

Manufacturing Workflow:

Material: Aluminum
Machine: 3-Axis CNC Mill
Software: Siemens NX 1988 Series

Key Process Stages -

1. Setup & Workpiece Preparation
2. Roughing Operations
3. Finishing
4. Hole making & Detailing

Table 3: Tools Required

Tool	Tool Type	Tool Specification
T01	End Mill carbide	Ø63mm 8-flute carbide
T02	End Mill carbide	Ø10mm 3-flute carbide
T03	End Mill carbide	Ø15mm 2-flute carbide
T04	End Mill carbide	Ø45mm 6-flute carbide
T05	Standard Drill bit	Ø15mm , 118 PA,2-flute PVD (TI,AL)N

Table 4: Manufacturing operations used in Siemens NX set up 1 – **Run time 4mins 13 seconds**

Step	Manufacturing Operation	NX CAM Command	Purpose
1	Floor facing without walls	FACE_MILLING	Create a flat reference surface
2	Solid profile 3D	ADAPTIVE_MILLING	Rough out 90% of the material volume
3	Hole milling	HOLE_MILLING	Pre-finish the hole features
4	Floor facing 1 without walls	FACE_MILLING	Created pathway for cable duct

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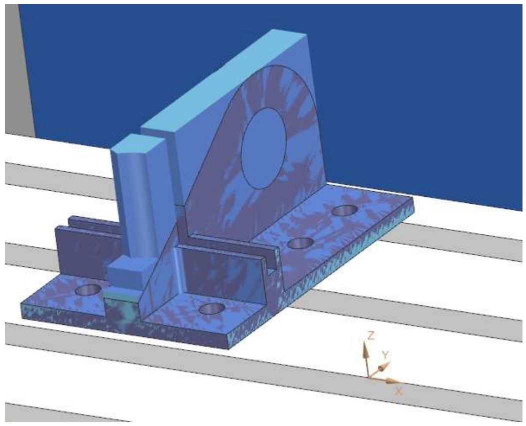

Figure 1: NX CAM simulation results for Setup 1

Table 5: Manufacturing operations used in Siemens NX set up 2 – **Run time 37 seconds**

Step	Manufacturing Operation	NX CAM Command	Purpose
1	Solid profile 3d	ADAPTIVE_MILLING	Rough machining of residual material
2	Hole milling	HOLE_MILLING	Finalize hole dimensions and surface finish

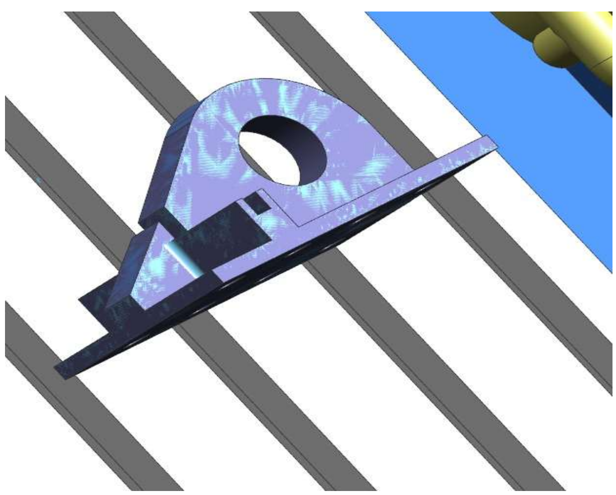

Figure 2: NX CAM simulation results for Setup 2

Table 6: Manufacturing operations used in Siemens NX set up 3 – **Run time 3 seconds**

Step	Manufacturing Operation	NX CAM Command	Purpose
1	Drilling	DRILLING	Drill standard holes to specified depth

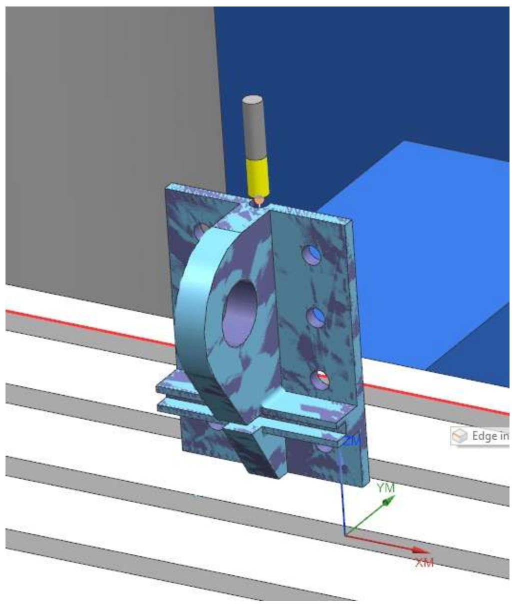

Figure 3: NX CAM simulation results for Setup 3

Setup Strategy Note:

The complex geometry and multi-directional features of the part made it infeasible to machine all critical surfaces in a single 3-axis setup. Therefore, the manufacturing process was divided into three setups to ensure proper tool access, machining accuracy, and efficient material removal.

Conclusion:

Simulations were performed on both the original and optimized parts to enable comparison. The optimized landing tray holder achieves significant efficiency gains, consolidating manufacturing into three streamlined setups totalling **4 minutes 53 seconds** (Setup 1: 4m13s, Setup 2: 37s, Setup 3: 3s) versus the original 7m34s across five orientations. By standardizing tooling (5 tools vs. 8+), and consolidating adaptive toolpaths, the redesign maintains all functional requirements.