Virtual Design Review 3

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Current State of Design

The Safe CNC Machine project addresses the critical need for enhanced user safety while operating the Shapeoko 3 CNC router. This involves implementing safeguards that protect users from hazards such as moving parts, projectiles, and airborne particulates while allowing intuitive operation without the need for personal protective equipment (PPE).

1) Key achievements to date include:
    a) Hazard Mitigation Framework:
        i) Mechanical hazards: The design prevents physical contact with moving parts, including the point of operation and power transmission systems, through physical barriers.
        ii) Non-mechanical hazards: Dust collection systems and noise-dampening mechanisms in the design will reduce health risks and improve the operating environment.
2) Design Concepts and Prototyping:
    a) Multiple door mechanisms, such as horizontal sliding, vertical sliding, bifold, and top-hinge designs, have been considered and various style prototypes made.
    b) Hinge-style doors currently lead in concept selection due to their ease of use, minimal interference, their robust safety features, and they allow for a larger workspace.
3) Interface and Control Development:
    a) The proposed interface communicates operational hazards, helps enforce material compatibility, and restricts access when the machine is active.
    b) Early prototypes have begun incorporating intuitive controls and safety indicators to enhance user interaction.

Forecast of Work Ahead

The team has a structured roadmap to ensure the project's success:

1) Validation and Testing:
    a) Mechanical targets include preventing physical contact with moving parts while achieving noise reduction (<85 dB) and effective particle collection (<5 mg/m^3).
    b) Testing will confirm that safeguards meet the critical target of halting projectiles with an impact force of 3000 N.
    c) Non-mechanical metrics will focus on ensuring that users adhere to safe practices through intuitive design and clear communication.
2) Material Selection and Refinement:

    a) Selection of materials will focus on durability, compatibility with CNC operations, and cost-effectiveness.
    b) Prototype iterations will focus on reducing disassembly time for maintenance/reparability (<1 day) and ensuring stability under vibration (displacement within ±0.5 mm).
3) Final Assembly and Comprehensive Testing:
    a) Assemble the final prototype for end-to-end operational testing.
    b) Rigorous safety and usability tests will ensure compliance with project objectives and stakeholder expectations.

Identified Problem Areas

Despite steady progress, the project faces several challenges that require focused attention:

1) Safety vs. Accessibility Trade-offs:
    a) Achieving a balance between robust safeguards and operator convenience remains a critical issue, particularly for emergency access.
2) Material Optimization:
    a) The need for cost-effective yet high-performance materials poses design restrictions.
    b) Lightweight materials must also tolerate operational stresses and environmental factors.
3) System Integration:
    a) Including non-mechanical systems, such as particle collection and noise dampening, without compromising the machine's primary functions requires innovative design solutions.
4) Prototyping and Validation:
    a) Current prototypes need further development to meet critical performance targets, including effective projectile and vibration resistance.
5) User Interface Development:
    a) Creating an intuitive user interface that communicates hazards, enforces proper usage, and limits unauthorized access presents a considerable design and engineering challenge.
6) Aesthetic and Functional Goals:
    a) Ensuring that the final design is visually appealing while addressing stakeholder feedback on cable management, visibility, and overall usability is a complex problem.

Conclusion

The Safe CNC Machine project demonstrates significant progress in safeguarding user operations while improving machine accessibility and efficiency. The team is addressing complex challenges through reiterative design, thorough testing, and active stakeholder engagement. With a clear roadmap and focused efforts on prototype refinement, material selection, and user interface development, the project remains on track to deliver a high-impact solution that aligns with all safety, usability, and stakeholder requirements.