

Design and development of a modular 5-axis CNC milling machine for small and medium enterprises (SMEs)

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Computer Numerical Control (CNC) technology has been evolving rapidly over the last few decades, facilitating various industrial applications with high precision and speed. 5-axis CNC machines are utilized to fabricate complex components by allowing the cutting tool to approach the workpiece from different orientations. Due to the higher price of 5-axis CNC machines, SMEs struggle to expand their operations by utilizing these technologies. This research study focuses on developing an affordable and modular 5-axis CNC machine that can handle soft materials such as wood, plastic and soft metals; aluminum and copper. The system features executing both milling and laser engraving functions separately. Design started with conceptualizing, and the CAD model was developed using SolidWorks (2024 service pack 4). Comprehensive simulations were done to validate the mechanical stability of the system. NEMA 23 stepper motors with TB6600 motor drivers were used for actuating X, Y and Z axes and NEMA 17 stepper motors with A4988 motor drivers were used for handling A and B axes. The Arduino-Mega-2560 controller was selected for controlling the system and GRBL Mega 5X open-source firmware was installed successfully. Natural air cooling was sufficient to meet the cooling requirement of the machine, since this system is developed for handling soft materials. The precision of the motions was ensured using CN5X++ software, achieving 1 mm movement per 1 step for linear axes (X, Y, Z) and 1° movement per 1 step for rotational axes (A, B). This machine has a working envelope of 30×30×30 cm³. Tests were carried out using nylon cubes which resulted maximum deviation of ±0.06 mm. There was a maximum ±0.03 mm deviation between same size work pieces when repeating. By developing a cost effective and modular 5-axis CNC machine, this study facilitates SMEs and hobbyists to improve their outcomes more efficiently.

Keywords: *5-axis CNC milling machine, Modular design, Small and Medium Enterprises (SMEs)*