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Impact of machining parameters on surface roughness in CNC hardwood milling: A multivariate approach

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ABSTRACT

Wood processing remains a manufacturing field that relies heavily on craftsmanship and the experience of skilled workers. Although Computer Numerical Control (CNC) techniques have introduced significant progress in wood manufacturing, one of the main challenges remains the natural variability of wood. Variations in grain direction, density, moisture content, and other wood properties can result in inconsistent cutting behavior, increased surface roughness, and dimensional inaccuracies. Furthermore, the growing need to conserve natural resources continuously drives innovation in wood processing. This paper investigates CNC machining of hardwoods with a particular focus on evaluating surface roughness as a key quality parameter. Aiming to achieve better surface roughness leads to eliminating or reducing sanding operations. Cutting conditions, tool path optimization, and time efficiency during hardwood processing remain crucial factors in the furniture industry. Finished wooden components are typically assembled from multiple pieces using joining techniques; however, unlike in the forestry industry, the quality of the prepared samples is not systematically monitored and is often assessed solely by human judgment. Consequently, the impact of variable parameters, such as feed speed, timber species, fiber orientation, during the cutting and workpiece preparation was evaluated by multivariate statistical analysis. The study of milling curvilinear shapes in hardwoods (ash, oak, walnut) revealed that the annual growth ring section is the most significant factor affecting the quality of the finished product. Consequently, the adapted tool path according to the materials growth ring section would be advantageous while milling curvilinear shapes of the hardwood materials.

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