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Multi-Material Mechanical Property Optimization Via Taguchi Method: Effects of Injection Parameters on PP30GF, RECYCLED PP30GF, and HYBRID GF-TALC Composites

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Abstract

This study optimizes injection molding parameters for three polypropylene (PP)-based materials: virgin vPP30GF, recycled rPP30GF, and a hybrid composite hPP12GF12T with 12% glass fiber and 12% talc. The work uses Taguchi's robust design methodology to discover and quantify the most important process variables injection temperature, injection pressure, and packing pressure on tensile strength, flexural strength, and notched impact resistance.

An L4 orthogonal array for each material allowed systematic examination of essential injection molding parameters in fewer experimental runs. Mechanical qualities were tested using ISO 527 (tensile), ISO 178 (flexural), and ISO 180 (impact) standards. The statistical contribution of each factor was further analysed using an ANOVA framework to identify the main influences on each composite system.

Results show that mechanical performance parameters change greatly between vPP30GF, rPP30GF, and hPP12GF12T. Packing pressure had the greatest effect on tensile strength and impact resistance in vPP30GF. Recycled polymers are more sensitive to temperature, as rPP30GF's tensile and impact performance was most affected by injection temperature. Injection temperature and packing pressure dominated tensile and flexural strength in the hybrid composite, while injection pressure crucially affected impact behavior.

These findings encourage industries to tailor injection molding conditions to each composite type rather of using universal settings. The study shows that Taguchi and ANOVA parameter optimization can improve virgin, recycled, and hybrid polypropylene composite performance, enabling data-driven, resource- efficient, and high-quality production.

Keywords: Thermoplastic composite, Taguchi design, optimization, Recycled, Hybrid composites, glass fiber, talc reinforcement, Injection molding