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Achieving Product Robustness through Variation Simulation: An Industrial Case Study

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Abstract : In power protection and control products, assembly process variations due to the individual parts manufactured from single or multi-cavity tooling is a major problem. The dimensional and geometrical variations on the individual parts, in the form of manufacturing tolerances and assembly tolerances, are sources of clearance in the kinematic joints, polarization effect in the joints, and tolerance stack-up. All these variations adversely affect the quality of product, functionality, cost, and time-to-market. Variation simulation analysis may be used in the early product design stage to predict such uncertainties. Usually, variations exist in both manufacturing processes and materials. In the tolerance analysis, the effect of the dimensional and geometrical variations of the individual parts on the functional characteristics (conditions) of the final assembled products are studied. A functional characteristic of the product may be affected by a set of interrelated dimensions (functional parameters) that usually form a geometrical closure in a 3D chain. In power protection and control products, the prerequisite is: when a fault occurs in the electrical network, the product must respond quickly to react and break the circuit to clear the fault. Usually, the response time is in milliseconds. Any failure in clearing the fault may result in severe damage to the equipment or network, and human safety is at stake. In this article, we have investigated two important functional characteristics that are associated with the robust performance of the product. It is demonstrated that the experimental data obtained at the Schneider Electric Laboratory prove the very good prediction capabilities of the variation simulation performed using CETOL (tolerance analysis software) in an industrial context. Especially, this study allows design engineers to better understand the critical parts in the product that needs to be manufactured with good, capable tolerances. On the contrary, some parts are not critical for the functional characteristics (conditions) of the product and may lead to some reduction of the manufacturing cost, ensuring robust performance. The capable tolerancing is one of the most important aspects in product and manufacturing process design. In the case of miniature circuit breaker (MCB), the product's quality and its robustness are mainly impacted by two aspects: (1) allocation of design tolerances between the components of a mechanical assembly and (2) manufacturing tolerances in the intermediate machining steps of component fabrication.

Keywords : geometrical variation, product robustness, tolerance analysis, variation simulation
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