An optimization model for concurrent selection of tolerances and suppliers

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Abstract

The quality loss function incorporates the quality cost for design of tolerances, however, it does not consider the manufacturing cost and design constraints. In this paper, a stochastic integer programming (SIP) approach is presented for simultaneous selection of tolerances and suppliers based on the quality loss function and process capability indices. A direct link between the minimum manufacturing cost and the required level of manufacturing yield is established through the process capability index. The optimization model is illustrated with examples for concurrent selection of mechanical and electrical tolerances and the suppliers. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Why is concurrent selection of tolerances and suppliers important? In today’s manufacturing environment, every firm purchases various portions of components or subassemblies for its final product assembly. An internationally established firm in Reading, Pennsylvania used to purchase 80\% of materials by volume and 50\% by dollars. A recent corporate decision has called for the total elimination of its machining operations. Therefore, this plant is switching to 100\% purchasing of its components. Based on the first author’s consulting experience with this firm in quality and supplier management, most quality experts now agree that a majority of the problems and related costs associated with a firm’s product quality is caused by the quality and variability of incoming materials used in the manufacturing

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Nomenclature

Parameters

\( i \)  Component tolerance index
\( I \)  Total number of components with tolerance requirements
\( I_k \)  Total number of component tolerances in dimensional chain \( k \)
\( j \)  Supplier index
\( J_i \)  Total number of suppliers available for component tolerance \( i \)
\( k \)  Dimensional chain index
\( K \)  Total number of dimensional chains
\( c_{ij} \)  Purchasing cost for component \( i \) from supplier \( j \)
\( \mu \)  The value of the centered process mean or design nominal
\( \mu_s \)  The value of the skewed process mean
\( M(i) \)  Purchasing cost of component \( i \)
\( L(x) \)  Quality loss resulted from \( x \)
\( Q_L \)  Total quality loss cost for the entire assembly
\( p(x) \)  Probability density function
\( A \)  Estimated quality loss coefficient
\( T_k \)  Single side functional tolerance stackup limit for dimensional chain \( k \)
\( \Delta_k \)  Full range functional tolerance stackup limit for dimensional chain \( k \)
\( C_p \)  Process capability index for a centered process
\( C_{pk} \)  Extension of \( C_p \) which considers the process mean shift in relation of the design nominal (mean) value
\( \sigma_{ij} \)  Standard deviation \(^1\) of supplier (process) \( j \) used to provide component (dimension) \( i \)
\( \sigma_i \)  Standard deviation of component (process) \( i \)
\( \sigma_k \)  Required assembly standard deviation of dimensional chain \( k \)
\( \sigma_{ASM} \)  Actual standard deviation in a dimensional chain
\( \partial f/\partial X_i \)  Partial derivation of the functional dimension with respect to component dimension \( i \), which reflects the dependency of the functional dimension on component dimension \( i \) (Wu, Elmaraghy & Elmaraghy, 1988)
\( \Phi(Z_{a/2}) \)  Cumulative standard normal distribution
\( \gamma \)  Manufacturing yield in percentage
\( USL_i \)  Upper specification limit of dimension \( i \)
\( LSL_i \)  Lower specification limit of dimension \( i \)

Variables

\( x \)  Dimension obtained from a manufacturing process, \( x = \mu \pm t \)
\( t \)  Single side tolerance value
\( y \)  Total of the manufacturing and quality loss cost
\( t_{ij} \)  Three sigma value of supplier (process) \( j \) for providing component (dimension) \( i \) with a centered process

\(^1\) In this paper, \( \sigma \) is used to denote the standard deviation of a sample and the square root of variance of the population.
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