PERGAMON

Computers & Industrial Engineering 40 (2001) 15–33

computers & industrial engineering

www.elsevier.com/locate/dsw

An optimization model for concurrent selection of tolerances and suppliers

Chang-Xue (Jack) Feng[a,*], Jin Wang[b], Jin-Song Wang[c]

[a]*Department of Industrial and Manufacturing Engineering, Bradley University, Peoria, IL 61625, USA*
[b]*Department of Math and Computer Science, Valdosta State University, Valdosta, GA 31698, USA*
[c]*Institute of Manufacturing Engineering, Tsinghua University, Beijing 100084, People's Republic of China*

Accepted 15 May 2000

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.

Keywords: Quality engineering; Robust engineering design; Taguchi's method; Supplier selection; Integer programming; Concurrent engineering; Tolerance design

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

* Corresponding author.

PII: S0360-8352(00)00047-4

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
μ	The value of the centered process mean or design nominal
μ_s	The value of the skewed process mean
$M(t_i)$	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
Δ_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
σ_{ij}	Standard deviation[1] of supplier (process) j used to provide component (dimension) i
σ_i	Standard deviation of component (process) i
σ_k	Required assembly standard deviation of dimensional chain k
σ_{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)
$\Phi(Z_{\alpha/2})$	Cumulative standard normal distribution
γ	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, σ is used to denote the standard deviation of a sample and the square root of variance of the population.