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Optimization of Steel Box Column for a Pillar-type Drilling Machine using Particle Swarm Optimization

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Abstract

The design of any machine tool is required to possess rigidity, impact resistance and absorption or damping of vibrations. The structural member needs to be lightweight satisfying the strength requirement. This paper deals with the optimum design of thin plated steel box column of a pillar-type drilling machine. Under dynamic conditions, the maximum permissible inclination of the drill resulting from the deformation tells upon the accuracy of the hole. The existing formulation of behavioral and geometric constraint equations is solved by means of (i) Particle Swarm Optimization (PSO). The results obtained with PSO are compared with (i) exhaustive search results (ii) results obtained by using Davidon-Fletcher-Powell (DFP) method and (iii) results obtained using genetic algorithm (GA) available in the literature. The results are presented in the form of optimum values of cross-sectional dimensions for minimum weight of column. The agreement and the enhancement in results indicate the fruitful application of PSO to the present case.

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*Keywords:*steel box column; minimum weight; exhaustive search; Particle Swam Optimization

1. Introduction

The welded built up steel box columns of relatively large size are commonly used in tower cranes, building frames and machine tools. The advantage of using built-up sections is that they can be easily fabricated to any

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practical size to get advantage of weight and cost saving as per Liew et al [1]. Heisel et al [2] used artificial neural network for optimal configuration decisions at design stage. Kushmir et al.[3] considered various materials for use of optimum structure by satisfying the strength requirements. Nakaminami et al. [4] analyzed the requirements of compound multi-axis machine tools based on functions to be carried out. A single compound multi-axis machine tool functions as 2-axis CNC lathe and as a 5-axis machining center. It executes inclined surface machining and gear cutting as well. The authors discussed the systematic analysis and methodology to determine the compound multi-axis machine tool specifications from the quality and cost viewpoint. The relation of machine features, productivity and investment effectiveness with mechanical structures was presented. With increasing trend of using various optimization techniques [5,6,7,8,9,10,11] due to rapid developments in computer technologies, it is now possible to use the evolutionary methods to get the optimum design parameters for minimum weight, cost etc. along with the necessary and sufficient requirement of strength and rigidity in present case. The objective of minimum weight helps in saving material and cost. Also, the recent growth in manufacturing technology facilitates the production of required optimum dimensions [12,13,14]. This paper specifically deals with the optimization of the cross sectional dimensions of a pillar type drilling machine column for minimum weight. The objective function and corresponding constraints are discussed below [15,16].

Nomenclature

W	weight (kg)
	mass density of the material (kg/m^3)
H	total height of the column (m)
t	thickness of the column (mm)
t_{min}	minimum thickness of the box section (mm)
a	length of the box section (mm)
b	width of the box section (mm)
	direct stress (N/m^2)
P	thrust force at the tip of the drill (kgf)
I_{xx}	moment of inertia about x-axis
D	drill diameter (mm)
K	material combination constant
S	feed (mm/s)
	yield stress (MN/m^2)
E	modulus of elasticity (N/m^2)
l	horizontal distance between centre of the column and centre of the drill (m)
h	maximum distance between the bracket supporting the drill head and table (m)

1.1. Objective function

$$\text{Weight } W = 2\rho H t(a+b) \text{ or } W = 31200\,t(a+b) \quad (1)$$

where $\rho = 7800\,kg/m^3$ and $H = 2\,m$ (considered) (Refer Fig.1)