International Journal of Precision Engineering and Manufacturing
https://doi.org/10.1007/s12541-022-00698-z

Online ISSN 2005-4602
Print ISSN 2234-7593

REGULAR PAPER

Check for updates

Development of Hybrid Artificial Neural Network–Particle Swarm Optimization Model and Comparison of Genetic and Particle Swarm Algorithms for Optimization of Machining Fixture Layout

M. Ramesh[1] · K. A. Sundararaman[1] · M. Sabareeswaran[1] · R. Srinivasan[2]

Received: 29 April 2022 / Revised: 10 July 2022 / Accepted: 3 August 2022

Abstract
In this research paper, a methodology is proposed by combining taguchi's parametric design, hybrid artificial neural network–particle swarm optimization (ANN–PSO) and evolutionary techniques to optimize the fixture layout by minimizing the maximum workpiece deformation on a 2D fixture workpiece system in end milling operation. Taguchi's parametric design with five levels is utilized iteratively to estimate the potential range to place the fixture elements around the workpiece using the data obtained from finite element method. The hybrid ANN–PSO model is developed to predict the maximum workpiece deformation within the potential range in which PSO is utilized to optimize the weights and biases of the network. The diversity of data used for training the model is ensured by combining the experimental conditions of central composite design and Box Behnken design of response surface methodology. The developed model is tested using root mean square error, which exhibited better prediction accuracy. The hybrid ANN–PSO model is then optimized by genetic algorithm (GA) and PSO. The results clearly indicate that the PSO is capable of producing better fixture layouts with 0.1936% of superiority in solution quality than GA. Hence, the proposed approach is more viable to design the improved fixture layout with huge reduction in time and computational complexity.

Keywords Fixture layout optimization · Artificial neural network · Finite element method · Evolutionary techniques · Genetic algorithm · Particle swarm optimization

1 Introduction

Modern manufacturing industries are aiming to accomplish improved accuracy and productivity with uniform product quality by reducing cost and time incurred in new product development. Effective and efficient fixture layout design can assure uniformity among the machined parts, thereby improving the accuracy in subsequent phases. While machining, externally applied clamping and machining forces induces deformation in workpiece, causing certain imperfections. This inturn impose restrictions for achieving the desired tolerance specifications and dimensional quality. During machining operation, the workpiece deformation is highly influenced by the layout of fixture elements, machining forces and clamping forces. The machining forces, particularly applied for material removal, will induce load or moment on the workpiece, which can be resisted by the application of adequate clamping forces. Hence, these two forces cannot be decreased beyond certain magnitude. Further, 20 to 60% of machining error is mainly caused by improper fixture design [1]. Therefore, the promising way of minimizing the workpiece deformation is to optimize the design of fixture layout, by which the required accuracy could be achieved, leading to increase in quality, productivity and decrease in rejection rate.

Traditionally, fixture layout was designed by the experience and expertise of the designer that resulted in huge time and cost. Rigid body models were developed for optimizing the fixturing configuration and/or clamping force problems [2–7], and were unable to predict the workpiece deformation. The finite element method (FEM) was applied

✉ K. A. Sundararaman
arunsunder@rediffmail.com

1 Department of Mechanical Engineering, SSM Institute of Engineering and Technology, Kuttathupatti Village, Sindalagundu Post, Dindigul, Tamil Nadu 624 002, India

2 Department of Mechanical Engineering, RVS College of Engineering, RVS Nagar, Paraipatti Post, Dindigul, Tamil Nadu 624 005, India

Published online: 18 October 2022