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A simple and robust setup planning scheme for prismatic workpieces

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ABSTRACT

Computer Aided Process Planning (CAPP) is a link between Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). Setup planning is the main function to integrate the designing and manufacturing processes. Despite significant progresses in the modern manufacturing, setup planning is still being considered an experience based activity. Its reason can be fixturing constraints, tolerance requirements (specially stack-up in tolerancing), geometric relationships among machining features, and Tool Approach Direction (TAD). All aforementioned limitations introduce setup planning as a complicated nonlinear task. Setup planning not only determines features must be machined in each setup but also defines locating datum for each setup. This study focuses on the development of a simple and easy-understanding series of steps to generate feasible setups. Tolerance stack-up has been eliminated using datum face as a reference plane in the fixture design. Three concepts namely "control face", "control factor", and "machining priority" have been employed for this aim. The capability of proposed scheme has been proved by applying it on two practical case studies. The suggested algorithm has successfully reduced the number of setups from 7 to 6, which is the least number of achievable setups and shows its sufficiency.

Introduction

Setup planning is a routine which deals with the tolerance relation between features, feature priority correlations, and TAD. Setup planning usually includes: (a) grouping either features or operations and datums into setups; (b) sequencing the setups, and (c) sequencing the operations within each setup [1]. Fixture planning specifies an accurate locating and rigid clamping for workpieces based on part design and process requirements. In addition, the optimum locating and clamping layout is recognized in this step [2].

All aforementioned procedures are in a close relation, and the constraints of fixturing should be noticed in every setup. However, as it will be remarked in the following, most studies have focused either on fixture design or on setup planning. It can be considered as a main reason for their lack of functionality in both domains. Among setup planning techniques, graph theory, intelligence algorithm-based, fuzzy set, mathematical and heuristic reasoning methods can be mentioned.

Graph theory methods

To solve the problem of setup planning according to tolerance analysis, Huang et al. [3] proposed a graph theoretical approach to identify the optimal setup plan for rotational parts. Zhang and Lin [4] suggested a hybrid graph approach and matrix theory in which a tolerance analysis was the main factor for setup planning decision-making. Yao et al. [5] developed a systematic approach for automated setup planning employing flexible manufacturing resources. In their approach, both Datum Machining Graph (DMG) and Feature Tolerance Graph (FTG) were performed to define the part and setup information respectively. Setup planning was described as transmuting FTG to DMG based on tolerance and manufacturing resource capability analysis. To describe precedence constraints explicitly for setup planning, Sun et al. [1] proposed a new directed graph approach. They, also, used a Setup Priority Graph (SPG) to describe priority constraints among setups. While generating the SPG, the minimal number of tolerance violations was guaranteed preferentially using vertex cluster algorithm for serial vertices. Then, applying variants of the breadth-first search the minimal number of setups

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was achieved. The principal barrier of the graph-based approaches is that the priority constraints are not considered properly during setup formation.

Intelligent algorithm methods

In order to plan the machining setup, some researchers persented an intelligent algorithm. The common algorithms such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Ant Colony (AC), Simulated Annealing (SA), and etc. have been employed in the literatures. Kafashi [6] proposed a GA-based optimization algorithm in order to integrate setup planning and operation sequencing problem. The outputs of this study were optimized setup plan and sequence of operation as well as an optimized selection of the machine, cutting tool, and TAD for each operation. To optimize the sequence of operations, Krishna and Rao [7] developed an ant colony (AC) algorithm. They applied a traveling salesman problem (TSP) for modeling the operation planning problem. In an intelligent algorithm, the penalty strategy, which is little effective in performance, is the method to handle precedence constraints [1]. In addition, it does not reflect the influence of precedence constraints on setup plan's explicitly.

Other papers propose artificial intelligence techniques for resolution of the setup planning problem. Peng et al. [8], Liu and Peng [9] used fuzzy logic to define the direction for each feature, while sequencing problem was approached using neural networks by the interpretation of the sequencing problem as a Traveling Salesman Problem (TSP). Ding et al. [10] proposed an optimization procedure for process sequencing based on multi-objective GA (shortest manufacturing time, minimum manufacturing cost, and best satisfaction of manufacturing sequence rules). This hybrid technique was suggested to integrate a GA, Artificial Neural Network (ANN) and Analytical Hierarchical Process (AHP) for process sequencing.

Automated processing planning based on GA and/or SA also have been reported by Li et al. [11], Ma et al. [12], and Alam et al. [13]. PSO was also used by Cagnina et al. [14], and Guo et al. [15]. In Refs. [16,17], different neural networks were adopted to choose the working direction and tools for each operation, while the setup planning problem was tackled using a rule engine.

Heuristic reasoning methods

Experiential based knowledge, in the form of heuristic reasoning, has also been used to facilitate setup planning. For instance, Peng et al. [18] applied a simple rule-based system in order to determine both setup and fixture layout. Using fuzzy comprehensive judgment method, they identified locating planes. This information was considered as an input of Case Based Reasoning (CBR) module leading the fixture designer to reach a practical fixture configuration design based on previous experiences. Gologlu [19] provided an automatic set-up planning module

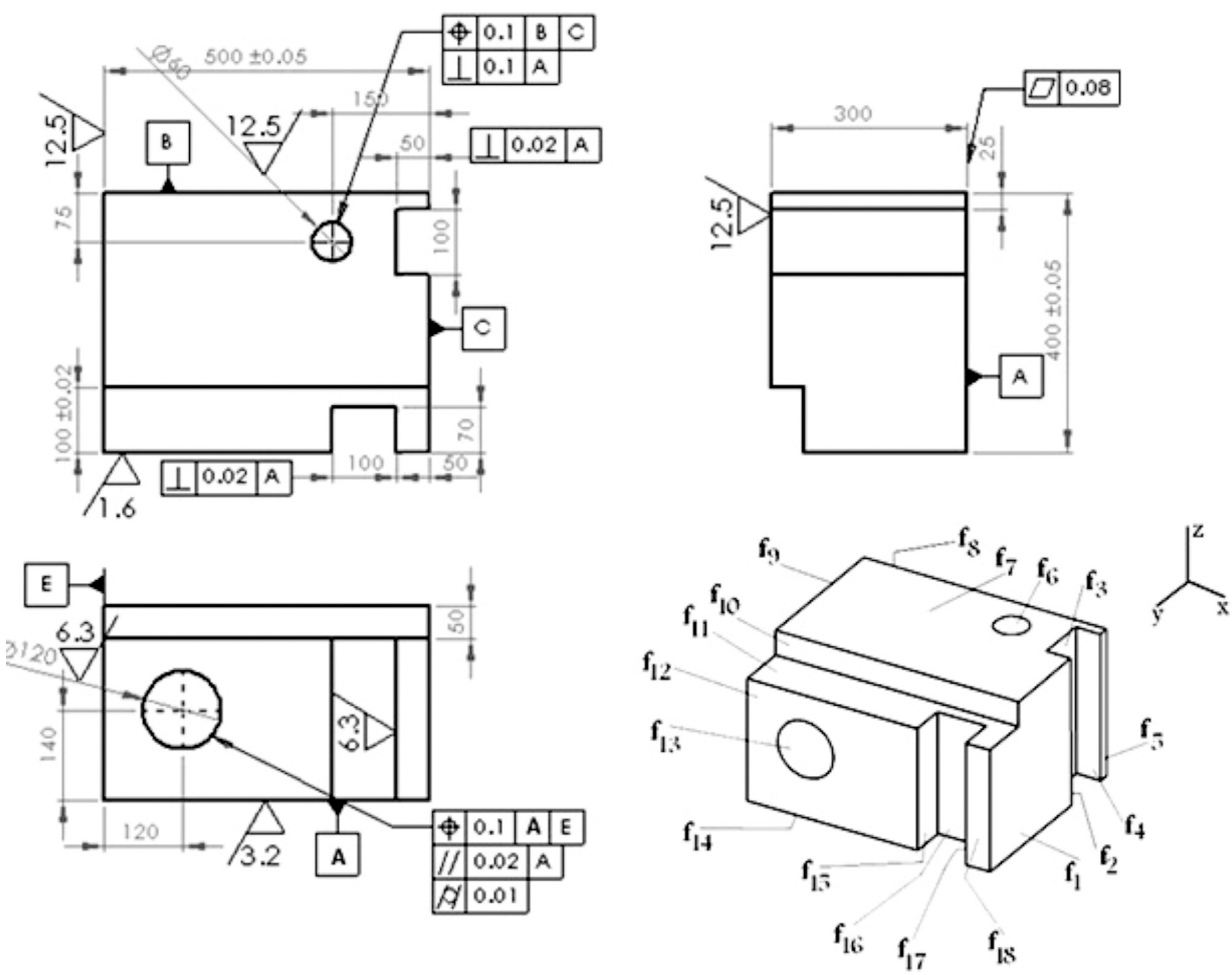

Fig. 1. Drawings of a prismatic part as a case study 1 [11].