Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 36 (2015) 159 – 164

www.elsevier.com/locate/procedia

CIRP 25th Design Conference Innovative Product Creation

Design and inspection of multi-fixturing pallets for mixed part types

Stefania Pellegrinelli[a,b]*, Claudio Cenati[a], Luca Cevasco[a], Franca Giannini[c], Katia Lupinetti[c], Marina Monti[c], Diego Parazzoli[a]

[a] Institute of Industrial Technologies and Automation, National Research Council, ITIA-CNR, Via Bassini 15, Milan, 20133, Italy
[b] Department of Mechanical Engineering, Politecnico di Milano, Milan, Italy
[c] Institute of Applied Mathematics and Information Technology "Enrico Magenes", IMATI-CNR, Via De Marini 6, Genoa, 16149, Italy

* Corresponding author. Tel.: +390223699954; fax: +390223699925. *E-mail address:* stefanaia.pellegrinelli@itia.cnr.it

Abstract

Over the last decades, manufacturing market has been characterized by small batch size, high variability in the part types and part type demand, continuous evolution of the products. In order to quickly answer the new and changing production requirements, the rapid redesign of the pallet in terms of number of parts and part types and the verification of physical mounted pallet became essential. Thus, this paper aims at (i) developing a dynamic process planning approach automatically providing multi-part pallet designs and (ii) identifying flexible techniques for the inspection of the physical pallet before its machining. Specifically, the approach analyzes the solution space generated by all the possible combination of part type setups in terms of number and position on the pallet. The number of produced part types per pallet is maximized, while the setup accessibility and an equal number of part types for each setup are granted. The 3D design of the pallet is compared with the scanned pallet cloud of points in order to identify possible error sources, e.g. part missing, incorrectly closed fixture, part type in wrong position. A test case will be provided in order to show the advantages deriving from the approach employment.

Peer-review under responsibility of the scientific committee of the CIRP 25th Design Conference Innovative Product Creation
Keywords: Keywords: Process planning, Multi-fixturing pallet, Pallet inspection

1. Introduction

Process planning efficiency and effectiveness is more relevant as long as the market is characterized by high product variability in terms of part types and demand fluctuations [1]. In such a dynamic environment, the majority of the parts are characterized by reduced life cycle requiring small production batches. This makes advantageous the employment of dynamic process planning and Network Part Program (NPP) techniques [2], with particular reference to the design and inspection activities for multi-fixturing pallets. On the one hand, the continuous reconfiguration of the pallet in terms of part mix and quantity can increase the capability of the system to answer an unforeseen fluctuation of the demand and a rapid evolution of the products. For instance, when the workpiece setups to be machined are known, their disposition on the pallet could be optimized by maximizing the number of finished part per pallet and granting the same number of part for each part setup. On the other hand, a high variability in pallet designs could lead to errors during the pallet mounting in terms of incorrectly closed fixtures, incorrect mounted part type, unmounted workpiece etc. Thus, a rapid and efficient pallet inspection could increase the system flexibility at the shop-floor level and the exploitation of NPP advantages.

In this paper, the Network Part Program approach is extended through the proposition of a new model for pallet design considering multi-part types and the development of a pallet inspection procedure. The paper is structured as follows: Section 2 presents the literary overview; Section 3 discusses the approach and its innovative aspects in comparison to the existent approaches; Section 4 and 5 are respectively dedicated to the description of the pallet design and inspection approach; in Section 6, results on an industrial test case are presented and discussed; finally, Section 7 presents conclusions and future work.

Peer-review under responsibility of the scientific committee of the CIRP 25th Design Conference Innovative Product Creation
doi:10.1016/j.procir.2015.01.007

2. Literary review

2.1. Process planning

Dynamic process planning [3] and Newtork Part Program [2] are traditionally structured in four main steps. The *first step* concerns the workpiece (WP) analysis aiming at the identification of the workpiece operations. When the approach is compliant to the STEP-NC standard [4], the workpiece is described in terms of machining feature, machining operation and machining workingstep (MWS), that are respectively the description of a workpiece machined region, the technological information and manufacturing strategy for the machining of a feature and the associations between a feature and an operation.

Based on these operations, the setups for the complete machining of the part are defined (*second step*). The setup planning problem determines the number of orientations of the workpiece in the 3D space to be completely machined. The orientation of the workpiece influences the accessibility to its operations, i.e. the visibility of the operation tool access direction (TAD). Each change in the orientation of the workpiece requires an un-mounting and re-mounting of the workpieces on the fixture, and consequently a certain time utilization and the risk of compromising the machining precision and manufacturing quality.

In case of a manufacturing system exploiting the adoption of pallets, the *third step* concerns the pallet design that is the identification of the number and position of workpieces on the pallet so that the operation and setup accessibility are granted [2]. The pallet design problem aims at determining the number, disposition (pattern) and mix of pieces to be clamped on the fixturing device of the pallet as well as part positions. Once the number of the machine tool axes is selected, the accessibility to the workpiece MWSs depends on both setups and pattern.

The *forth and last step* deals with the generation of the program of the pallet according to the standard ISO 6938 (1982) [5]. During G&M-code generation, several factors have to be considered: (i) the machine tools the pallet is going to visit, (ii) the execution sequence of the pallet operations [6], (iii) possible difference between the designed pallet and the real pallet in terms of mounted parts, tolerances due to the fixturing systems, etc. Literary review in relation to pallet design and inspection is given in the followings.

2.2. Pallet design

In [7], a setup planning and a pallet design approach minimizing the number of workpiece setup for the machining on three-, four- and five-axis machine tools is proposed. This approach is extended in [8], while granting the compliance to the STEP-NC standard [4]. A further extension towards sustainable manufacturing can be found in [2] where a mathematical model is proposed for the identification of setup planning and pallet configurations that minimize the energy consumption. However, all these approaches are limited in the number of part types that can be mounted and the number of workpiece setups that a pallet physical face can mount: the approaches consider a single part type under the hypothesis that each physical face can host several workpieces all in the same setup.

On the contrary, [9] proposes a four-step methodology for the machining of different part-types on the same pallet. Even if it copes with workpiece grouping and allocation of workpieces on the pallet, problem related to the saturation and balancing of the pallet are not considered.

2.3. Pallet inspection

The problem of pallet inspection refers to the more general of comparing real objects with ideal geometry, which has been largely studied in literature mainly for precision and quality control of produced parts and, more recently, to improve tool path planning [10]. This process is based on the measuring and the checking of the pallet: first, the measurement of the physical pallet has to be obtained; second, this measurement has to be compared with a reference pallet data for validation. On the one hand, little scientific work dealing with methods for the automatic inspection of the pallet can be found. On the other hand, industrial practice traditionally adopts low-technological methodologies.

The *measurement* of the real parts, e.g. the pallet, can be done by using contact or contactless systems, such as coordinate measuring machines (MCC) or laser/optical scanners. Contact devices are the most common in the industrial practice, even though they present several intuitive limitations, such as low reconfigurability level and customization accordingly to the object to be measured, high costs and time. With particular reference to vision systems, these limitations make contactless technologies more adequate in terms of both profitability and efficacy to the employment in dynamic environments such as Flexible Manufacturing Systems (FMS).

The *comparison* between the acquired data and the related ideal representation requires two main steps: (i) registration of the two models in a reference system; (ii) effective comparison.

Different inspection commercial systems exist, but they are not usable for the fully automatic detection of deviation as requested in Flexible Machining System monitoring, since most of them require manual intervention for the registration process. [11] and [12] present a comprehensive literature review of the main issues, methods and processes related to part inspection. Methods may differ for the common used representation: various works transform CAD data into polygonal meshes [13], while others convert acquired points to B-splines of NURBs [14]. The registration is generally provided in two consecutive steps: rough and fine localisation. Among the various methods for fine alignment, the Iterative Closest Point is the most used [15,16]. To improve efficiency, rough localisation may use only a limited number of measurement points for coordinate system alignment, possibly based on some feature detection [14,17].

For the effective difference calculation between the acquired and ideal surface, two methods have been mainly applied: computing the plane point distance or directly