ELSEVIER

Journal of Materials Processing Technology 138 (2003) 297–300

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Integration of scheduling with computer aided process planning

Manish Kumar[a,*], Sunil Rajotia[b]

[a]Department of Production and Industrial Engineering, J.N.V. University, Jodhpur, India
[b]Department of Mechanical Engineering, J.N.V. University, Jodhpur, India

Abstract

Computer aided process planning (CAPP) and scheduling are two major activities in a modern manufacturing system. The existing CAPP systems have not taken account of shop floor conditions while developing process plans. This paper discusses the importance of integration of scheduling and CAPP and proposes a method for the same.

There can be several methods to machine a part and several machines capable of performing the process required to complete the part. Based on this concept, this paper suggests a method of scheduling and its integration with CAPP, so that on-line process plan can be generated taking into account the availability of machines and alternative routes.

A scheduling factor for an operation and machine combination has been defined taking into consideration the actual working conditions and capabilities of the machines. Finally operation–machine assignment is made on the basis of these actual scheduling factors. This helps in generating more realistic process plans and helps in improving the efficiency of the manufacturing system as a whole.

Keywords: CAPP; Scheduling

1. Introduction

Computer aided process planning (CAPP) has been recognized as playing a key role in a computer integrated manufacturing (CIM) environment. Two of the major activities in a manufacturing system are process planning and scheduling. Process planning as defined by Chang and Wysk [1,2] is the act of preparing detailed operation instructions to transform an engineering design to final product.

The detailed plan contains the route, processes, process parameters, machines and tools required for production. It generates operational details such as: sequence of operations, speeds, feeds, depths of cut, material removal rates, and job routes. Required inputs to the planning scheme include: geometric features, dimensional sizes, tolerances, materials and surface finishes. These inputs are analyzed and evaluated in order to select an appropriate sequence of processing operations based upon available machinery and workstations.

Generation of good, consistent and accurate process plans requires the establishment and maintenance of standard databases and the implementation of an effective and efficient method to process the data. The computerization and the resultant automation of process planning has evolved due to a substantial need caused by the lack of qualified personnel, inconsistency in planning, and the need for the incorporation of knowledge on continually evolving new processes [3,4].

Scheduling is defined as the allocation of resources over time to perform a collection of tasks. The objective of scheduling is to assign specific task to specific machine in order to balance load distribution among different machines so that the available machines can be effectively utilized. This enhances efficiency and effectiveness of the machine shop [5].

2. Need for the integration of process planning and scheduling

Existing CAPP systems fail to incorporate scheduling while generating a process plan. Scheduling is done separately after the process plan has been generated, and therefore, it is possible that process plans so generated may not be optimal from the scheduling point of view. If process plans are generated without consideration of job shop status information, many problems arise within the manufacturing environment. Some of the difficulties encountered are [6–8] as follows:

* Corresponding author.
E-mail address: mkumargupta@rediffmail.com (M. Kumar).

0924-0136/03/$ – see front matter © 2003 Elsevier Science B.V. All rights reserved.
doi:10.1016/S0924-0136(03)00088-8

(i) Process planners assume an ideal factory with unlimited resources on the shop floor. They plan for the most recommended alternative process. Thus, desirable machines are selected repeatedly by various process planners. As scheduling follows the process planning, actual process plans when carried out result into queues at various workstations and thus these optimal process plans become infeasible.
(ii) Often process planning and scheduling have conflicting objectives. Process planning emphasizes the technological requirements of a task, while scheduling involves the timing aspects of it.
(iii) The throughput target of orders in a workshop often suffers from disruptions caused by bottleneck machines, non-availability of tools and personnel, or breakdown of machines and equipment. A readily generated schedule becomes invalid and has to be regenerated.
(iv) In most of the cases for both process planning and scheduling, a single criterion optimization technique is used for determining the best solution. However, the real production environment is best represented by considering simultaneously more than one criterion.
(v) The time delay between planning phase and execution phase may cause trouble. Due to the dynamic nature of a production environment, it is very likely that when a design is ready to be manufactured, the constraints that were used in generating the plan have already changed greatly, thus rendering, that plan sub-optimal or totally invalid [9,10].

Investigations have shown that 20–30% of the total shop load in a given period has to be redirected to alternative machines to attain the desired output target [5]. Only a small part of the job shop orders actually comply with the production plan. This implies that 20–30% of all process plans are not valid and have to be altered when production starts. There is thus a major need for an integrated process planning and scheduling system. A process planning system should interface with a scheduling system for generating more realistic process plans and schedules. In doing so, the efficiency of the manufacturing system as a whole is expected to improve. Without the integration of process planning and scheduling, a true CIM system, which strives to integrate the various phases of manufacturing in a single comprehensive system will not effectively materialize [11,12].

Many researchers have attempted contributions to integrate process planning with scheduling. Some of the work done in this direction are by Torri et al. [11], Halevi and Weill [13], Chryssolouris and Chan [6], Sundaram and Fu [10], Tonshoff et al. [14], Khoshnevis [15], Khoshnevis and Chen [16], Liao et al. [5], Usher and Fernandes [17], Gu et al. [18] and Yang et al. [19]. However very few of these approaches reported above consider machine capacity and the current status of the shop while generating a process plan. Scheduling is done separately after the process plan is generated and, therefore, it is possible that process plans so generated are either not feasible or sub-optimal from the scheduling point of view. In some of the cases where alternative process plans are generated in conjunction with satisfaction of scheduling criteria, the solution search space increases. This increases the time required to generate an optimal plan and schedule and renders it impractical for real time applications. This work tries to investigate the above highlighted points.

3. Methodology

This paper suggests a method for integrating scheduling with CAPP by considering the shop floor conditions of the machines, i.e., availability, initial cost, cost of operation, cycle time and breakdown condition while assigning machines to various processes to develop process plan This helps in generating process plans that are feasible with respect to the current availability of the production facilities. In this method real time status of shop floor is crucial and dynamic feedback is required for scheduling. This method may be called on-line process planning [7,20].

4. On-line machine scheduling

This step involves modification of the process decision rule to ensure that the machine that is assigned to perform an operation is the best possible machine from among all the alternatives in the shop, after the scheduling criteria have been taken into account. The machines that are capable of achieving the same tolerance or surface finish requirements without violating the process planning criteria are the alternatives for a particular operation.

The scheduling criteria considered here are the mean flow time and the number of tardy jobs. The integration of CAPP and scheduling is expected to reduce both the mean flow time and the number of tardy jobs. This results in rapid response to demand and closer adherence to deadlines.

In this system a scheduling factor, μ, is developed as [5]:

$$\mu = \frac{X_1 C}{X_2 C_o X_3 T X_4 N}$$

where C is the cost of the machine, C_o the operating cost of machine per unit time, T the average cycle time for performing the operation on a machine, and N the number of alternative machines that can prepare the job.

X_1–X_4 are the important ratings given to respective variables on a scale of 1–10 (1—least important and 10—most important).

The machine with the highest value of scheduling factor is selected for a particular operation. This factor is directly