Pergamon

International Journal of Machine Tools & Manufacture 40 (2000) 239–257

INTERNATIONAL JOURNAL OF
MACHINE TOOLS & MANUFACTURE
DESIGN, RESEARCH AND APPLICATION

Process control and dynamic process planning

R.J. Seethaler, I. Yellowley*

Department of Mechanical Engineering, University of British Columbia, Vancouver, V6T 1W5, Canada

Received 20 January 1999; accepted 17 May 1999

Abstract

Real time machine tool control and the planning activities which precede manufacture are usually interfaced through a low level language which allows little more than position, feed, and speed information to be passed between the two systems. The higher level systems used to describe geometry and tool paths also lack an adequate capability to describe manufacturing processes. The authors discuss the provision of a much richer interface between the planning and control activities which both facilitates the identification and scheduling of suitable monitoring tasks and allows the updating of process plan data from real time measurements. The result of such integration is an improvement in the efficiency of real time optimisation, and perhaps most importantly the possibility of quasi real time process planning. A system that is able to perform both initial process planning and plan refinement based upon low level feedback must also encompass the path generation activity, such a system is referred to by the authors as a dynamic process planning system. The paper describes the fundamentals of the process models, identification algorithms, control strategies, and low level process plan generation used within such an integrated system. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Process planning; Process control; Open architecture; CNC

1. Introduction

Process planning refers to the translation of design information to a suitable production plan; the activity consists of several phases which are hierarchical in nature, starting with relatively high level decisions, and proceeding to detailed planning. The typical requirements of the phases are shown in Table 1.

Generative process planning systems attempt to generate process plans from a CAD database by relying solely on models of the manufacturing process (i.e. without human interaction). This

* Corresponding author. Tel.: 001-604-822-2781; fax: 001-604-822-2403.
E-mail address: yellowle@mech.ubc.ca (I. Yellowley)

PII: S0890-6955(99)00054-1

Table 1
Process planning

High level planning phase	(A) Selection of basic processes and sequence
	(B) Selection of specific machines and order
	(C) Design of holding devices, approximate ordering of main operations at each machine
	(D) Subdivision of operations, detailed operation order selection of tool types
Low level planning phase	(E) Optimization of cutting conditions and tools
NC programming phase	(F) Detailed evaluation of tool paths
	(G) Cost estimating

approach has met with several difficulties. The major problem is the encountering of infeasibility during the planning process, as it proceeds from its highest to the lowest decision levels; such an event will require backtracking. The very large number of feasible solutions makes finding the best solution unlikely, and finding even good solutions rather difficult. Progress has been made in developing efficient algorithms for the low levels of process planning, both for single pass [1–3], for multiple pass [4–6], and for the subdivision/scheduling of volume and operations respectively [7–9]. One should realise however that most of the methods suggested for process optimisation rely on a knowledge of part geometry and process parameters which is unlikely to be available in the initial planning stage. A truly optimal process plan leaves little room for error in estimates of process parameters or indeed part geometry. Such errors will inevitably lead to the failure of tools, and damage to machines and work pieces. Computer generated process plans then usually use conservative estimates of process parameters that will lead to the safe operation of the machine tool, but generally far from optimal performance.

A partial solution to this problem is the provision of real time process control. Such a system needs significant intelligence if it is to be suitable for general use. The system should be able to identify current geometry, process parameters and tool condition, it also needs the capacity to select feeding velocity (and hopefully cutting speed although this is more difficult). The system at best will be capable of achieving close to economic cutting conditions on each feature with minimal risk of constraint violation (breakage, torque, power, surface finish, etc.). The system however cannot modify the higher level process plan (the sequencing of machining operations and the selection of tool paths). (It also should be realised that there will be some extreme transients which will defeat the best of real time control/identification algorithms without some form of warning.)

The authors believe that a real time process control system should also have the capacity to feed back identified process parameters to the process planning system. The identified parameters can then be used to optimize the higher level process plans for the remainder of the part, or subsequent parts of the same batch.

Fig. 1 shows the requirements of such an integrated system. The real time process control system running on the machine tool must be supplied with expected process parameters (this information concerns workpiece, cutter, type of operation, etc., and is normally available within the planning system but rarely at the machine tool level). The extension of the interface between the planning system and the control system should also include the capability of sending identified process parameters back to the planning system as described earlier. Most importantly the planning