INTEROPERABLE PROCESS PLANNING FOR TURN/MILL COMPONENTS

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Abstract

This paper presents the application of new standards for CNC machining to enable quality assured customised part manufacture by implementing the new standard, ISO 14649 otherwise known as STEP-NC. The STEP-NC standard presents the opportunity to develop a new structure for feature-based process planning for manufacturing through the direct use of CAD data which form the direct input format into the NC and to address the process planning and machining of turn/mill discrete components. This paper proposes a STEP Compliant NC structure for generation of ISO 14646 code which can be used for turn/mill component manufacture and proposes manufacturing and process models based on a combination of the ISO 14649 standards to represent turning, milling and their respective tooling standards. Finally, the use of the individual parts of the evolving standard ISO 14649, namely Part 10, 12, and 121 has been investigated to provide the means to represent STEP-compliant turn/mill component program.

Introduction

Today manufacturing is more competitive and challenging than ever before. Companies from east and west and all over the world have truly become a world market. To satisfy customers’ demands for geometrical variety and the industrial need for high precision, numerically controlled machining with multiple axes are required. The key to successful manufacturing of complicated geometry in numerically controlled machines lies in the control and quality of operations planning. Process planning, as it is considered plays an important role in the innovation process. It is the interface between product development and manufacturing system development. Hence, in this paper, process planning is considered to be an active part in the concurrent development of products and their manufacturing systems, not only as an activity where manufacturing resources are selected. The authors focus on the use of the new standard; ISO 14649, to address the process planning and machining of turn/mill discrete components. Today complex turn/mill components can be produced on a wide range of turning centre configurations with multi axes, twin spindles and dual turrets. Due to the complexity of programming there is a need to model their process capability to improve the interoperable manufacturing capability of machines such as turning centres. This paper identifies a view of how ISO 14649 can be used to combine turning and milling operations to achieve the complete machining of rotational asymmetric components at a single turning centre. The use of the individual parts of the evolving standard ISO 14649, namely Parts 10, 11, 12, 111 and 121 [1-5] has been investigated to provide the means to represent STEP-compliant turn/mill component programs.
Major Issues in Turn/Mill Operation

1. No Standard for Turn/mill
   ISO 6983 describes only simple movements and switching instructions and does not support complex geometry [6]. The new programming and process-planning environment will support a two-way flow of data and information between shop floor and planning but currently, there is no publication of an ISO 14649 standard for turn/mill machining. So far International Standards are published separately; DIS/ISO 14649 Part 11 is for milling machining and DIS/ISO 14649 Part 12 is for turning machining [2, 3]. Also, Part 111 Tools for Milling and Part 121 Tools for Turning [3, 4].

2. Characteristic of milling-type features and usage
   Features recognized from the finished shape can be used as a machining feature by which tool paths can be generated. Thus, in many milling cases features are negative features. Milling features recognition is based on the finished shape and is used as the machining feature for the working steps, where one operation is assigned to one machining feature (e.g., grooving, cut-in).

3. Characteristic of Turning-type features
   Turning-type features are defined by the shape left from machining and are therefore positive features. Removal volumes in turning operations need to be computed by the Boolean operation between raw material and the feature. Turning feature recognition is based on the removal volume to be used. The shape of removal volume can be represented by turning features (e.g., Rough turn side). Feature recognition for both rough-cut and finish cut is a necessity.

4. Range of Advanced Turning Centre
   There is a wide range of turning centres produced by CNC manufacturers around the world from standard turning machines to more complex machine with multi spindles and multi tool turrets, which has a significant effect on the process planning and set-up for turn/mill components. The machine configuration of a single or dual spindle requires different set-ups and process planning (i.e., tooling orientation and geometry), and is a major difference compared to other CNC processes (e.g., CNC milling machine).

CNC Turning Centre Technology

After the Second World War, an increased need for precise parts for the aircraft industry emerged. This led to the development of numerically controlled (NC) equipment such as NC-milling machines and NC-turning machines. NC-machines are now used in many manufacturing industries such as automobile, consumer electronics, aerospace, ship-building, die-making, sporting equipment and toys [7]. CNC Turning Centre technology is a term that is widely used in many different domains. In contemporary industry it refers to the capability of the machine for components with a single set-up for complex design, and machining as shortest time, and increasing productivity. In this topic the authors discuss CNC turning centre manufacturer focus for a number of model/series around the world. Searching results from Techspex Inc. [8] 218 turning centre manufacturers and 1951 models from have been found manufacturers to large of model or series lead by Mazak, Japan (53), Arca, Taiwan (49), Mori Seiki, Japan (45) and Okuma and Howa, Japan (36).
centres can be classified by manufacturer, model ID, operation type, and number of axes, number of spindle, direction, and style and turn-mill operation. Figure 1 shows various examples of turning centre machine and their spindle and turret configuration.

(a) Mazak (Quick Turn 6T), 2 axis  
(b) Okuma & Homa HL35M, 3 axis  
(c) Romi (E280B), 4 axis  
(d) Gital Gildemeister (Sprint 20 linear) 5 axis  
(e) Takisawa (TMM 200), 6 axis  
(f) Mazak (Multiplex 6200Y), 8 axis

Fig. 1: Some Examples of CNC Turning Center Manufacturer

CNC turning centres can be divided into two main groups and then into further smaller sub sections which is illustrated in figure 2. The figure shows the two main groups, these are horizontal and vertical. This refers to the orientation of the axis of rotation. With a horizontal machine, the job or work piece rotates in a horizontal plane whereas in a vertical machine it rotates about the vertical plan. There are different approaches to the classification of turning centres, but in this paper the authors have simply classified these machines as either vertical or horizontal turning centres. Both figures 2 and 3 show the detailed classification of the type of construction, horizontal or vertical spindle and the number of work holding devices for the turning centres, single, twin spindles and multi spindles.
The aim of this work is to address the process planning and machining of turn/mill discrete components and to propose a STEP Compliant NC structure for generation of ISO 14649 code which can be used for turn/mill component manufacture. The authors define “interoperability” as the ability to integrate STEP-NC compliant information in the product cycle package including CAD, CAPP, CAM and CNC, combined with the feasibility of information structures to represent various configurations of turn/mill machining centres. The overall framework is described in figure 4 using Java programming language and most of the classes are based on the EXPRESS entities defined by the ISO 14649 standard.
This system needs integrated manufacturing information about product model and manufacturing resources, and is based on an object oriented platform. Another aspect of information is describing the manufacturing process, and the product geometry can be created and manipulated. The structured model approach, shown in figure 4, shows the STEP-NC manufacturing chain which starts with the definition of the feature based design geometry in a CAD/CAM system. An ISO 10303 Part 21 physical file is then generated from a STEP-NC Compliant CAPP/CAM system based on a suite of JAVA information classes from the STEP-NC ARM model definition, developed by Loughborough University. The operator is able to define STEP-NC features and is prompted for associated manufacturing inputs such as workingsteps, operations, tools, feeds, speeds consistent with the STEP-NC ISO 14649 Part 12 & 121 standards as shows in figure 5 [9]. The ISO 10303 Part 21 physical file is automatically generated. This file is processed by the STEP-NC translator (developed by ISW, Stuttgart [10-12] and Siemens) and is converted into the Siemens proprietary format .MPF file. The generated file can then be directly machined on any CNC workstation equipped with a Siemens controller and ShopTurn CAM software.

![Fig. 4 : The overall research framework](image)

![Fig. 5 : STEP-NC Part 21 file output](image)
Turning Operation
The ISO 14649 process data for turning is Part 12, which specifies the technology specific data elements needed as process data for turning [3]. Part 10 is the general process data [1], which describes the interface between a computerized numerical controller and the programming system such as a CAM system or shop floor programming system for turning. It can be used for turning operations on all types of machines including turning machines or lathes, or turning centres. Included in part 12, are features and operation data models for conventional turning, involving x and z movements. This again only represents standard rotational turning with no representation for features and operations for composite machining such as C-axis milling operations [13]. Figure 6 shows the example turning classes based on ISO 14649.

![Fig. 6: Turning classes](image)

The turning operation has two basic categories of machining operations; either roughing or finishing. In the other way around each category has one of the following operations, namely facing, grooving, cutting_in, contouring, threading and knurling [3, 14]. All the turning operations under the machining_operation sub class are based on the operation class. Figure 7 shows the facing operation under EXPRESS Schema and the class diagram of facing objects on the entity definitions within ISO 14649.

![Fig. 7: Facing class diagram](image)

Four different types of case study components have been selected namely case study component 1; standard turning with one chuck (only one with turning features), component 2; standard turning with two chuck, component 3; turn/mill c-axis machined component with two chuck and component 4; turn/mill C & Y axis machined component with c-axis machined, two chuck. All these case study components as show in figure 4 will be tested for this system to verify and to measure the level of interoperability with different types of CNC Turning Centres. The proposed manufacturing model in figure 8 includes the resources capabilities and the process capabilities of a given workstation [10, 15]. With these, it is possible for the
process planner to decide on which machine a given workpiece shall be machined and which tools and work holding devices are to be used. This model forms the basis for further work on a STEP-NC compliant information structure to support both turning and milling operations on NC turning centres. It is expected to provide the basis to additionally define the milling capability of the NC turning centre, which can be mapped onto the mill/turn representations in parts 11 & 12 of ISO14649.

**Fig. 8 : UML diagram of a Turning Centre Model**

**Conclusion**
Modelling manufacturing information, either product model or manufacturing model in this paper is in their earliest stage of development for turn/mill discrete components. On the other hand, as the different information interacts, it is important that design information, and design rationale, can be captured as well. The information modelling in this area intends to address the problem of representing and capturing manufacturing information related to resources and processes. The interaction between the different types of models could provide a description of the products, how they should be manufactured, and what manufacturing resources that should be used. This would provide an information platform upon which several different computers based tools to support the innovation process can be built. This will allow the provision of reliable manufacturing information to assist in the performance of product development life cycle activities and related decisions.

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