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FEATURE RECOGNITION & TOOL PATH GENERATION FOR 5 AXIS STEP-NC MACHINING OF FREE FORM / IRREGULAR CONTOURED SURFACES

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Abstract: *This research paper presents a five step algorithm to generate tool paths for machining Free form / Irregular Contoured Surface(s) (FICS) by adopting STEP-NC (AP-238) format. In the first step, a parametrized CAD model with FICS is created or imported in UG-NX6.0 CAD package. The second step recognizes the features and calculates a Closeness Index (CI) by comparing them with the B-Splines / Bezier surfaces. The third step utilizes the CI and extracts the necessary data to formulate the blending functions for identified features. In the fourth step Z-level 5 axis tool paths are generated by adopting flat and ball end mill cutters. Finally, in the fifth step, tool paths are integrated with STEP-NC format and validated. All these steps are discussed and explained through a validated industrial component.*
Key words: *Machining, Tool Paths, STEP-NC format*

1. INTRODUCTION & LITERATURE REVIEW

Generation of tool paths to machine Free form / Irregular Contoured Surface(s) (FICS) is a complex process as it requires the crucial information of feature data comprising the details of geometry and topology, surface shapes (up / down bends), direction and location in the planes. Generally, in an industrial component FICS contain the details of complicated design and very subtle characteristics of surface shapes. These complicated surface shapes are formed either with the variation of Bezier or B-Spline surfaces. The feature data of these surfaces are mainly required as it is used to generate the tool path motions for different machining environments. In case of FICS machining, a 5 axis machine is required as it posses significant advantages over other machining environments (2½, 3 & 4 axis machining). Some of them are (i) higher degrees of freedom (translation along X-axis, Y-axis, Z-axis, two rotations about any mentioned axis) (ii) minimal path movement to complete a part (Fig.1a) (iii) increased tool accessibility over curved surfaces (Fig.1b) and (iv) reduction in machining time.

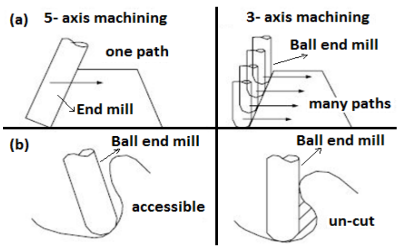


Fig.1. 5 axis versus 3 axis milling showing advantage in a free form / irregular contoured surface machining

In the present scenario, the feature data is extracted from CAD/CAM package either through Application programmable Interface (API) or from a standard neutral format. The tool paths created using this data for 5 axis machining environments face many problems such as (i) uncut region (ii) gouging (iii) scallops and (iv) interference. This is due to the inconsistency of algorithm(s) adopted to create these surfaces inside a CAD/CAM package. When viewed from high precision aerospace or oil and gas compressor components (which contain 2000 - 2500 FICS surfaces), the feature data need to be accurate enough to support tool path generation. Otherwise, there are high chances of a getting a defective product with poor limits. Further, these components are machined at one location using the G&M codes obtained from a different location. These codes are prone to errors due to the variation in the error compensation values given for cutting tool, work piece and the machine. Hence, in this research a tool path algorithm inclusive of feature recognition methodology (for checking and validation of FICS data) has been developed and integrated with a new machining technology STEP-NC (ISO 10303-28/ AP-238). STEP-NC replaces the G&M codes and reduces 75% tool data preparation time, 35% setup time and 50% machining time. It also eliminates post processor and allows the integrated tool path data to be used globally in any machine.

In recent years, many researchers focussed their attention on FICS and STEP-NC integration. It is necessary to address those research works to support the above defined problem. Triangular meshes have been adopted (Sun Yuwen et al., 2006) for generating iso-parametric tool-path for free form machining. The algorithm begins by detecting the boundary curve along the triangular meshes being machined via a discrete harmonic map. Tool-paths for free form surfaces has been generated (Yin, 2004) using progressive fitting and multi-tire solution. He used data point models captured by 3D contact or non-contact measuring apparatus. Iso-scallop tool paths have been generated for five axis machining of free form surfaces to avoid scallop and interference. (Ahmet Can & Ali Unuvar, 2010). They adopted STEP AP214 CAD format and developed and machined various possibilities of surfaces generated through B-Spline / Bezier curves. Testing and inspection of machining data has been conducted by (Brecher et al., 2006) by using STEP-NC program in a closed loop CAPP/CAM/CNC process. They following all necessary steps and validated using STEP-NC based controller in a CNC milling machine. A frame work to interpret the data in AP-238 has been done by (Liu et al., 2006). They adopted a PC based STEP-NC prototype for a STEP compliant CNC and interfaced the details required for processing the AP-238 format. By analysing an exhaustive literature, a 5 step tool path algorithm inclusive of feature recognition methodology is developed and integrated with STEP-NC format. The next section explains the steps with the help of a part with FICS surface.

2. ALGORITHM TO GENERATE TOOL PATHS

The 5 step algorithm developed in this research generates tool paths for 8 FICS surfaces. They are (i) Feature with single down side bend (FSDB) (ii) Feature with single upside bend (FSUB) (iii) Feature with single left side bend (FSLB) (iv) Feature with single right side bend (FSRB) (v) Feature with two bends (FTB) (vi) Feature with four bends (FFB) (vii) Feature with five bends (FFIB) and (viii) Feature with ten bends (FTNB). A schematic representation of three surfaces with their feature codes are shown in Fig.2. These surfaces are generated based on various types B-Splines curves (uniform periodic, open uniform, non-uniform) with polynomial degree of 3. Fig.3a shows the tool path generated for the surface with 'FTNB'.

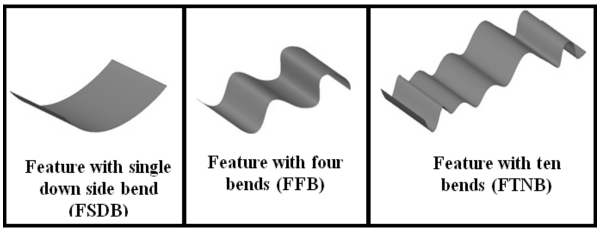
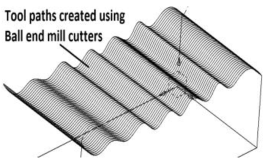
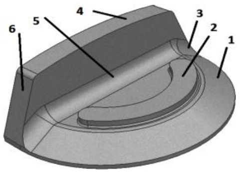


Fig.2. List of 8 FICS features considered in this research





a b

Fig. 3.(a) Tool paths generated for 'FTNB' surface (b) FICS part

The steps followed are explained through a FICS part shown in Fig. 3b.

Step1: Model / import the part with FICS features in UG CAD package

Explanation to Step1: In this step, the part is modeled in the UG NX 6.0 CAD package and parametrized. If imported, the model is checked for its continuity by utilizing the geometrical and topological data.

Step2: Using UG/UFUNC functions extract the geometrical & topological data and calculate the closeness index (CI)

Sub step2.1: Ask the tag (number) of part (specific to UG)

Sub step2.2: Using the tag, cycle all the objects in the part and count the number of features/ objects.

Sub step2.3: Get the ID's of all features/objects

Sub step2.4: Extract the data and store it in a text file.

Explanation to Step2/Sub steps 2.1-2.4: Generally, a UGpart model contain a number termed as 'tag'. This is extracted and the tags of various sub features / objects are found by cycling the part model through a UG/UFUNC function "UF_OBJ_cycle_objs_in_part". Then by using these tags the geometry and topological data of the sub features / objects are extracted which are used to find the closeness index with Bezier /B-Spline surfaces. Some of the other used functions are: (i) UF_CURVE_ask_spline_data (ii) UF_ CURVE _edit_spline_feature (iii) UF_b_curve_bezier_ subtype.

Sub step2.4: Extract the data and store it in a text file.

S.No.	Feature Name	CI	Feature Code	Extracted ID	Information on BSpline/ Bezier data
1	FICS 1	8	FSUB	ID 19101	Uniform B-Spline
2	FICS 2	9	FSUB	ID 19063	Uniform B-Spline
3	FICS 3	7	FSBD	ID 19246	Non-Uniform B-Spline
4	FICS 4	6	FSUB	ID 18958	Non-Uniform B-Spline
5	FICS 5	6	FTB	ID 19154	Uniform B-Spline
6	FICS 6	8	FFB	ID 19246	Non-Uniform B-Spline

Tab.1. Partial list of FICS data extracted for FICS surfaces.

Explanation to Step2.4: In this step, the extracted data is matched and a closeness index (CI) is generated "0(0-not matching)-10(10-exact match)". It is done by calculating the control points, degree of FICS surfaces, and various parameters (as shown in Fig.1) required for Bezier & uniform/ cubic/open/non-uniform B-Spline surfaces. Tab.1 shows the partial list of data extracted data (applicable to steps 1-3).

Step3: Calculate the blending functions using convolution theorem

Explanation to Step3: After finding the closeness index blending functions are calculated based on the standard method adopted in convolution theorem.

Step4: Adopt the Z-level 5 axis procedure for the generating tool paths.

Explanation to Step4: In this step, the required number of passes is calcauted to remove the machinable volumes. Then the Z-level tool paths are generated by adopting flat and ball end mill cutters.

Step5: Integrate the tool path with STEP-NC format

Explanation to Step5: Here, Z-level 5 axis tool paths are added in STEP-NC format. Tab.2 shows a partial list of STEP-NC format with integrated tool paths.

STEP-NC Data
<B_spline_curve_with_knots id="id31653"... Name="" Degree ="3"... Control_points_list="id31654.id31655..id31656...id31657 id31658.. id31674" Curve_form="unspecified" Closed_curve="false" Self_intersect="unknown" Knot_multiplicities="6 3 3 3 3 3 6" Knots="0 3.87292075081 22.2140874915"

Tab.2. Partial list of STEP-NC data

3. CONCLUSION

In this paper, a tool path algorithm has been presented with feature recognition capability and integrated with STEP-NC format. The alogorithm recognizes all the 8 FICS surfaces considered in this research. It is automated by coding the steps in UG/UFUNC programming language and validated for 30 industrial parts. The tool path generated for these parts are integrated with STEP-NC format using the ST-Machine software. Work is being continued to add more FICS surfaces and to integrate with STEP-NC format.

4. ACKNOWLEDGEMENTS

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Sun Yuwen, Guo Dongming, Jia Zhenyuan,Wang Haixia. (2006). Iso-parametric tool path generation from triangular meshes for free-from surface machining. *International Journal of Advanced Manufacturing Technology*. 721-726

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