ANBALAGAN, A. 2010. Integration of CAD/tool path for 5 axis STEP-NC machining of free form/irrregular contoured surfaces. In Katalinic, B. (ed.) Proceedings of *21st Danube Adria Association for Automation and Manufacturing (DAAAM) international symposium 2010: intelligent manufacturing and automation, 20-23 October 2010, Zadar, Croatia*. Vienna: DAAAM International [online], article ID 617, pages 1233-1234. Available from: https://www.daaam.info/Downloads/Pdfs/proceedings/proceedings_2010/24469_Symp_1_head.pdf

Integration of CAD/tool path for 5 axis STEP-NC machining of free form/irrregular contoured surfaces.

ANBALAGAN, A.

2010

Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
DAAAM Symposium

INTEGRATION OF CAD/ TOOL PATH DATA FOR 5-AXIS STEP-NC MACHINING OF FREE FORM / IRRREGULAR CONTOURED SURFACES

ANBALAGAN, A[rivazhagan]

Abstract: *This research paper presents the work on feature recognition, tool path data generation and integration with STEP-NC (AP-238 format) for features having Free form / Irregular Contoured Surface(s) (FICS). Initially, the FICS features are modelled / imported in UG CAD package and a closeness index is generated. This is done by comparing the FICS features with basic B-Splines / Bezier curves / surfaces. Then blending functions are caculated by adopting convolution theorem. Based on the blending functions, contour offsett tool paths are generated and simulated for 5 axis milling environment. Finally, the tool path (CL) data is integrated with STEP-NC (AP-238) format. The tool path algorithm and STEP-NC data is tested with various industrial parts through an automated UFUNC plugin.*
Key words: *Tool Path Generation, STEP-NC, Automation*

1. INTRODUCTION & LITERATURE REVIEW

Machining Free form / Irregular Contoured Surface(s) (FICS) is a complex process as the data required to generate tool path movement requires crucial information on surface shapes (up / down bends), direction & orientation in the planes and CAD/CAPP data (FICS features / machinable volumes, machining plan and setup / fixture plans). Mostly, these features are machined using 5 axis milling environment and majorly seen in turbines blades, flight wings, oil & gas compressor casings, marine propellers etc.

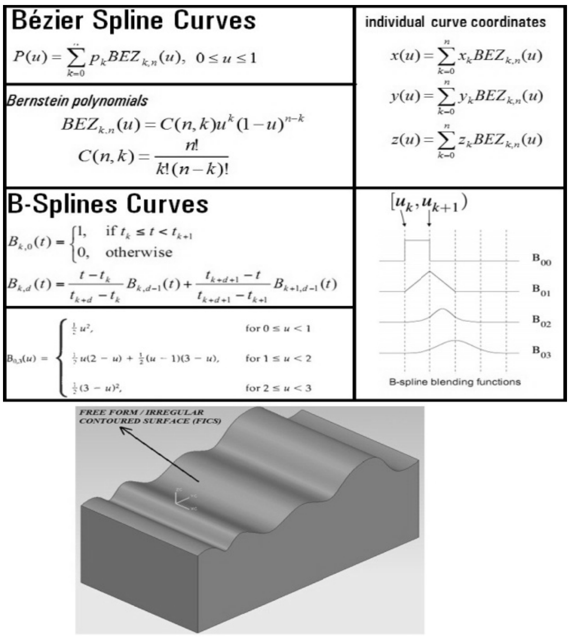


Fig.1. General formula (e), blending function(s) for Bezier / B-Spline curves and a FICS part

In these components, FICS is considered to be a main / crucial feature as it contains the details of complicated design and very subtle / delicate characteristics of surface shapes. Generally, these surfaces are formed due to the variation in the shape of Bezier or B-Spline surfaces. The general formula(e) to calculate blending function for Bezier / B-Spline curves and a part with FICS are shown in Fig. 1.

In the present scenario, all CAD/CAM packages have capability to model FICS features and able to preserve necessary geometrical and topological data. The effectiveness of these data purely relies on the algorithm(s) adopted in CAD/CAM systems to model FICS which inturn affect the generation of CL data / tool paths for 3/4/5 axis environment. In aerospace & oil and gas compressor domains, components contain more number (2000 - 2500) of FICS features which increase the time taken to generate CAD/CAPP/tool path data. In such case, 50% of total machining time is spent on selection / transfer of cutting tool, operations sequence, setup/ fixtures and 20% of time is spent on generation / transfer of tool path data. To avoid these delays, now-a-days researchers adopt STEP-NC (ISO 10303-28/ AP-238) as it reduces 75% tool data preparation time, 35% setup time and 50% machining time and eliminates post processor required for machining. In recent years, many research works have been conducted on FICS and STEP-NC and needs to be addressed for the purpose of validation of this problem.

Triangluar 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. In their work, they modeled the component, generated the tool path data, process planning details, transferred to STEP-NC 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. With these works and from an exhaustive literature collected for this research, the following gaps have been identified which formed the basis to take up a research on STEP-NC based 5 axis FICS machining: (i) absence of automatic feature recognition (ii) higher machining time with tool path algorithms (ii) absence of process planning information in their CAM exchange formats (G&M codes) and (iv) difficulty in integrating FICS data in STEP-NC format owing to its structural and machining complexity.

2. ALGORITHM TO RECOGNIZE FICS FEATURES AND TO GENERATE TOOL PATHS

In this research, 8 FICS features are considered to generate tool path data and to integrate it with STEP-NC format. The list of these features with their feature codes are shown in Fig.2. These features are generated based on various types B-Splines curves (uniform periodic, open uniform, non-uniform) with polynomial degree of 3.

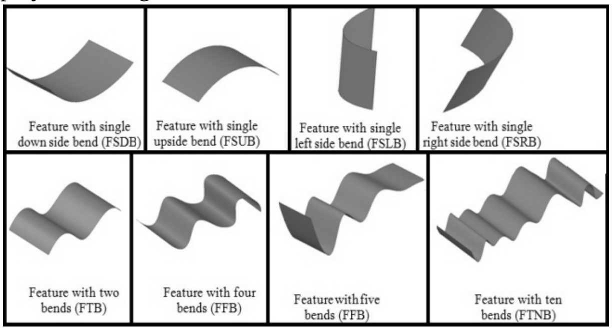
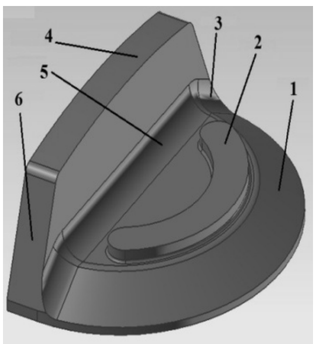


Fig.2. List of 8 FICS features considered in this research

The 5 step algorithm adopted in this research is explained through an FICS part shown in Fig. 3.



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"

Fig. 3. Part with FICS feature with STEP-NC data

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

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

Step2: Using UG/UFUNC functions extract the geometrical and topological data of the model

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 UG part model will have a single tag in the form of a number. 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". Using these tags the geometry and topological data of the sub features / objects are extracted which is used to find the closeness index with Bezier /B-Spline curves. 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.

Step3: Match the data with the basic B-Splines / Bezier curves / surfaces and calculate the closenesss index

Explanation to Step3: In this step, the extracted data is matched and a closeness index (CI) "0(0-not matching)-10(10-exact match)" is generated. It is done by calculating the control points, degree of FICS features, and various parameters (as shown in Fig.1) required for Bezier and uniform/ cubic/open/non-uniform B-Spline curves. Tab.1 shows the partial list of data extracted (applicable from steps 1-3) for the considered part (Fig.3).

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. A partial list of FICS data for Fig.2

Step4: Calculate the blending functions using convolution thereom and identify the machinable area of the FICS features.

Explanation to Step4: After finding the closeness index blending functions are calculated using convolution theorem. Using the blending function data, the rough and finish cut machinable volumes are calculated by adopting the methodology used by (Arivazhagan et al., 2009).

Step5: Adopt the contour offset procedure for the generating tool paths and integrate with STEP-NC format

Explanation to Step5: Here, offset tool paths are generated based on cutter diameter and finally, the tool path / CL data is added in STEP-NC format. A partial view of generated STEP-NC format is shown in Fig.3

3. CONCLUSION

In this paper, an approach has been presented to recognize FICS features and to generate tool path data. The algorithm is automated using UG/UFUNC and more than 30 industrial parts with various combinations of 6 FICS features have been tested and validated. The developed algorithm took minimal time to complete the process and to generate STEP-NC data. Work is being continued by adding more complicated FICS features and their integration with STEP NC format.

4. REFERENCES

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.

Yin, Z. (2004). Rough and finish tool-path generation for NC machining of freeform surfaces based on a multire-solution method. *Computer Aided Design*. 1231-1239.

Brecher C, Vitr M, Wolf J. (2006) Closed loop CAPP/CAM/CNC process chain based on STEP and STEP-NC inspection tasks *International Journal of of Computer Integrated Manufacturing*. 570-580.

Liu R, Zhang C, New man S.T. (2006). A frame work and data processing for interfacing CNC with AP-238 *International Journal of of Computer Integrated Manufacturing*. 516-522.

Ahmet Can, Ali Unuvar. (2010). A novel iso-scallop tool-path generation for efficient five-axis machining of free form surfaces. *International Journal of Advanced Manufacturing Technology.*. (Accepted / Avaliable Online). DOI-10.1007/s00170-010-2698-z.

Arivazhagan., A. Mehta., NK. & Jain., PK. (2009). A STEP AP203/214 based machinable volume identifier for identifying the finish-cut machinable volumes from rough-machined parts. *International Journal of Advanced Manufacturing Technology.* 850–872.