Ball Nose Milling Cutter Radius Compensation in Z Axis for CNC

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Abstract: - A new AutoCAD/VisualLISP based method to substitute the 3D tool radius compensation in Z axis for CNC milling processes is here described. Specific features of VisualLISP programming language combined with AutoCAD facilities are used to gather the data about the part to be machined and then to compute the points the tool should be driven to in order to perform an accurate cutting process. A sample that proves the rightness of the method is finally provided.

Key-Words: - CNC milling, tool radius compensation, Z axis compensation, AutoCAD VisualLISP, complex shaped parts

1 Introduction

Since only the most sophisticated CNC equipment perform 3D compensation (along Z axis), a method that computes easily the point to be programmed in CNC files in order to bring the tool in the appropriate location to cut correctly the profile of the part becomes necessary.

AutoCAD is often used as a CAD system to create 3D models of the parts. Because the VisualLISP programming language can access the geometrical data of the models by means of associated lists, it is suitable to be used in building user applications for CAM systems. Such an application is here described. It is designed to automatically engender CNC files for milling processes that require taking into account tool radius in Z axis (for ball nose milling cutters).

The input required are the 3D model of the part, the tool data and the plane (YZ or ZX) – referring to vertical CNC milling machines – processing is going to be performed. Some other technological data are also necessary to be delivered to the piece of software.

2 The Problem

Even the most common milling CNC equipments have the facility of tool radius compensation. That is that the CNC equipment assumes computing tool-path, that is the points (P_t) the center of the tool should be driven to in order to machine the programmed profile, described by means of P_p points (Fig.1). Unfortunately it applies only for profiles that lay in XY plane.

In contradiction to that, tool radius compensation in YZ or ZX planes is not delivered. The point to be programmed, P_t, depends on the slope of the profile to be machined when machining in such a plane. If the profile is not rectilinear, that is the slope is continuously varying, computing the P_t coordinates related to the points on the profile P_p, becomes a problem (Fig. 2)

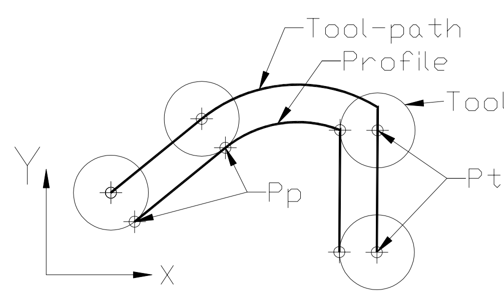


Fig. 1

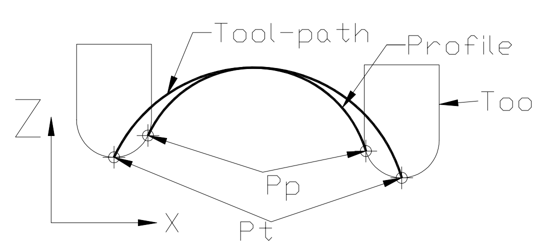


Fig. 2

The way the slope of the profile in YZ or ZX plane influences the contact point between the tool and part (P_c), on one hand, and the point to be programmed (P_S – South Pole of the ball nose) on the other hand are illustrated in Fig.3. Further more, the deformation of the tool-path related to the part profile and data used to compute co-ordinates of the point to be programmed are depicted in Fig. 4.

Although computing the co-ordinates of the points to be programmed is not very difficult, since it should be performed for any position on the profile, it becomes problem mainly for the rounded sectors: at these special shaped forms the angle between Z axis and the radius of contact point (P_c) varies continuously.

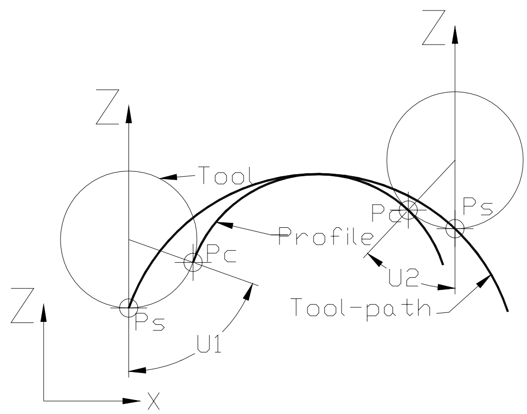


Fig. 3

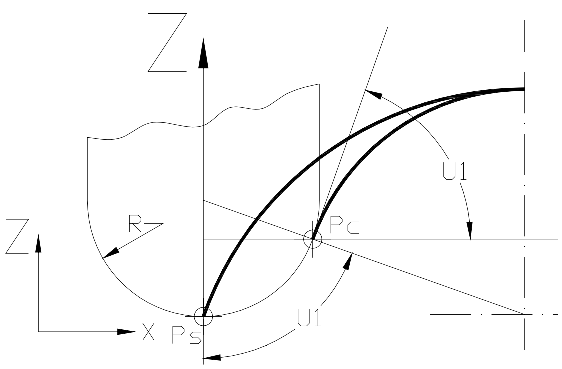


Fig. 4

3 Solving the Problem

According to Fig. 4 the coordinates of point to be programmed, Ps, can be computed related to the point on the profile, or contact point using the equations (1) and (2).

$$X_{Ps}=X_{Pc}-R*\sin(U1); \quad (1)$$
$$Y_{Ps}=Y_{Pc}-R*(1-\cos(U1)); \quad (2)$$

R – the radius of the tool

U1 – the contact angle, which is equal to the slope of the profile in the contact point

As has already stated above, it is not effective to compute doyens of points for an arc, so another method was set up by means of AutoCAD and VisualLISP: it consist of several steps:

1. to get the profile that has to be machined in a certain vertical plane, the 3D model of the part is first sectioned in AutoCAD by the appropriate plane;
2. the region obtained by sectioning is exploded into entities;
3. the desired entities (only those on the top surface of the part) are converted and joined into a polyline;
4. an offset to the polyline at a distance equal to the radius of the milling cuter is built above the profile (above the polyline));
5. the offset is moved downward with a distance equal to the radius of the milling cuter;

The curve obtained at stage 5 is the tool-path that has to be programmed. Is seems to be (and is) deformed from the original curve. It is no more an equidistant to the profile since, the point to be programmed is either even on the profile (P1 in Fig. 5) or at a certain distance from the profile for any other point

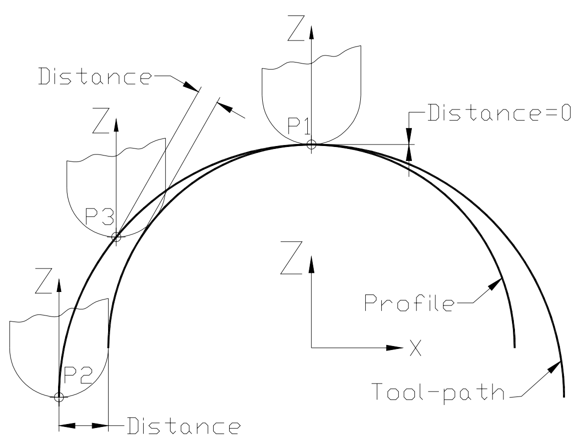


Fig. 5

In practice, some problems may occur if parts of the profile are special curves that cannot be joined to a polyline (e. g. arcs of ellipses or splines) In such cases if build offsets to each part, the output is not usable as tool-path. because of the discontinuity of the output curve (Fig. 6)

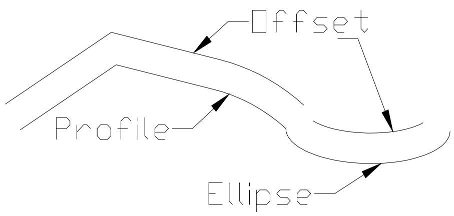
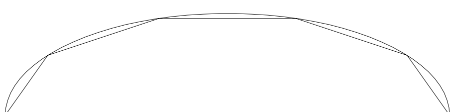


Fig. 6

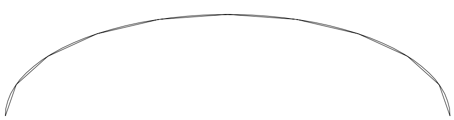
To overcome this drawback the solution is to approximate the ellipse and/or the spline by a sequence of short enough segments.

An original method to approximate ellipses by sets of segments (Fig. 7) is described in [1]. The originality consists in that the segments are not of the same length. The smaller the curvature of the elliptical arc, the larger chord that it substitutes.. The set of segments that substitutes the elliptical curve is designed to follow two rules:

1. to reduce as much as possible the number of points to be programmed
2. to keep under control the deviation from the original shape, that is not to overcome the limit allowance.

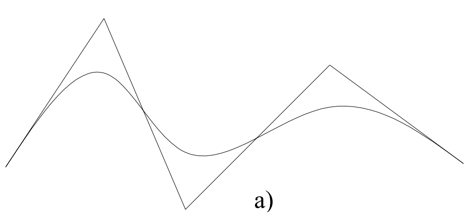


a) exaggerated allowance

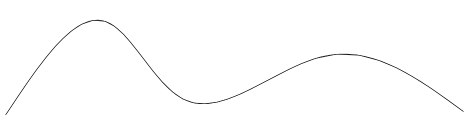


b) normal allowance

Fig. 7



a)



b)

Fig. 8

In a similar manner a spline can be substituted by a set of segments. If the spline is defined by few points the approximation cannot be good enough (Fig. 8 a). Although, in practice, the splines obtained by sectioning solids are smooth enough and are defineg by many points as they can be precisely enough approximated (Fig. 8 b)..

As can be seen in Fig. 7b and in Fig. 8b if some conditions are followed the substitution is as good as the substitute almost can not be distinguished from the original profile. It means that th replacement does not affect the precision of the machined part Besides, frequently the special curves (polynomial, trigonometric, logarithmic), for which is not available interpolation in terms of CNC equipment are approximated by segments. Keep in mind that all the substitutions here described are made automatically by means of VisualLISP user defined functions.

A substituted ellipse (Fig. 7) can be joined to a polyline. In that case the offset to the profile does no more present discontinuities, so it can act as a tool-path. (Fig. 9)

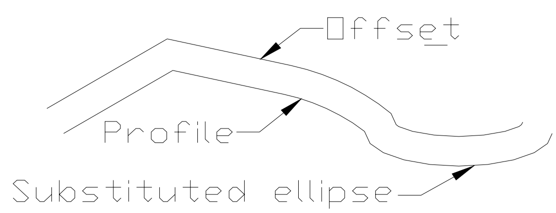


Fig. 9

All those stated above in this section are only the theoretical support for a user defined function designed to engender automatically the CNC files for milling processing in vertical planes (YZ or ZX)..A second purpose of the function is to simulate the cutting process that is to remove by subtracting from the rough material (billet) the surplus of material and leave the part as it will be after the real process.

The function performs several actions, as follows:

1. opens the file where the CNC program will be placed;
2. gathers the bounding box of the model;
3. builds the billet
4. sections successively the model by YZ or ZX planes, as user chooses. The distance between to consecutive planes is established by the user;

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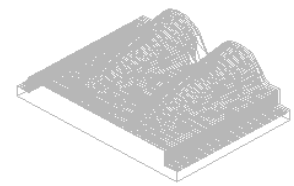
For each plane the object is transformed as described bellow:

5. the UCS is aligned to the the region obtained by sectioning is exploded;
6. the UCS is aligned to the region, in order to bring the XY plane in the regions' plane. That will allow later performing some specific 2D operations that can be applied only in XY plane;
7. by means of the associated list each entity obtained before is checked. If it is a spline or an arc of ellipse it is converted to a set of segments;
8. the splines and ellipses are erased;
9. all the segments and arcs (if they exist) are assembled into a polyline
10. an offset to the polyline (the profile) is built at a distance equal to the radius of ball nose;
11. the offset is moved downward with a distance equal to the radius of ball nose; this is the tool-path to be programmed;
12. by means of associated list are gathered the characteristic points on the polyline
13. co-ordinate transformation are applied to the points (in AutoCAD the current vertical plane is XY, while in the CNC machine tool it must be YZ or ZX);
14. the appropriate G code and co-ordinates are written in the CNC file. For arcs some additional computations are made to find either the co-ordinates of the center or radius that must be placed in the CNC file;
15. an axial section through the cutter is seeped along the tool-path to build a special solid. This new body materializes the tool as it sweeps the tool-path;
16. the solid is subtracted from the billet
17. the XY plane (now vertical) is advanced with the appropriate increment;
18. the steps 5 to 17 are repeated until all the model is sectioned
19. the CNC file is closed.

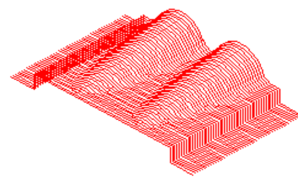
Of course, here have been mentioned only the most important stages. Some auxiliary actions are performed to make possible al the necessary transformations: managing layers, moving some entities from a layer to another in order to make their selection possible, operating with OSNAP modes, saving at the beginning of the programs the system variable that might be modified by running the function, computing lots of calculus, and so many others.

4 Application

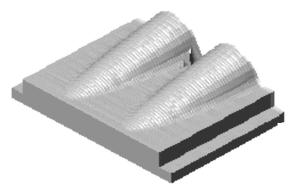
The piece of software was run several times to check its validity. No bugs were found. A sample is presented in Fig. 10.



a) the model



b) the tool-paths



c) the output of simulation

Fig. 10

5 Concluding remarks

The piece of software here presented may act as a CAD/CAM system since brings together designing and manufacturing in the same application development environment that is AutoCAD and VisualLISP. The application described is useful for pars of medium complexity that can be machined on 3 axes CNC machines endowed wis CNC equipment that does not provide the facility of 3D compensation

References:

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