VIRTUAL ANIMATION FOR CHECKING INTERFERENCE OF GLOBOIDAL CAM

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This article proposes some important tasks which are necessary in the modeling procedure of globoidal cams. These tasks are modeling and virtual animation of the globoidal cam mechanism for checking interference between components of the system. The acceptable cam is the one that has no interference between the cam and its rollers assuming that the clearance between cam surfaces and roller is zero or very small. Techniques of animation and checking interference of globoidal cam mechanism are performed in Pro/ENGINEER Wildfire 2.0.

Keywords
modeling, animation, interference, globoidal cam, follower

1. Introduction

Globoidal cam mechanisms are spatial cam mechanisms. Compare to other cam-follower mechanisms, the structure of globoidal cam-follower mechanisms are relatively compact. These mechanisms also have some special features such as: high loading capacity, low noise, low vibration, and high reliability. Hence globoidal cams have widely been used in various automatic equipments in industry. Typical usages of globoidal cam mechanisms are in machine tools, automatic assembly lines, paper processing machines, packing machines, and many other automated manufacturing devices.

A number of methods of modeling globoidal cams have been proposed. Some methods are based on the mathematical expressions of the globoidal cam surfaces (working surface) and some based on the movements in machining point globoidal. Checking the cam model and finding errors after modeling are important tasks. Cheng [Cheng 2002] modeled the globoidal cam mechanism with oscillating follower. He also developed a computer program for solid modeling to simulate the kinematic motion of the system. Yan and Chen [Yan 1994], [Yan 1995] wrote their own computer program that simulates kinematic motion of the roller gear cam with cylindrical rollers or hyperboloid rollers. Tsay and Lin [Tsay 2006] wrote a program in C++ language to generate the surface of the globoidal cam with conical rollers and a program to test the constant turret motion. By using CAD software, a globoidal cam can be modeled by some methods. En-hui et al. [En-hui 2001] used computer to develop a package for modeling roller gear cam (another name of globoidal cam). This package is a combination of AutoCAD R14, 3D Studio Max, and VBA. This package has simulation function for checking kinematics motion of the system. Chen and Hong [Chen 2008] used Unigraphics to get the CAD model of the roller gear cam with spherical roller. He also checked the relationship between the cam and the turret according to the analysis of the sequential chart of the motion.

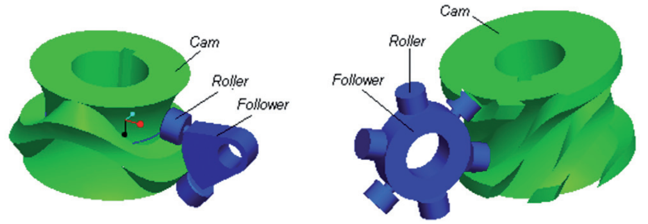
From the same input data, angular input and output displacements of the cam and the follower, we (Tuong and Pokorny) modeled two types of concave globoidal cam with several methods by using the software Pro/Engineer Wildfire [Tuong 2008a], [Tuong 2008b], [Tuong 2008c]. We found that it was necessity to check the models according possible modeling errors which might become crucial either for CNC machining or cam performance. This task can be done by making animation and checking interference of the globoidal cam system.

The purpose of this paper is to present techniques of making animation and checking interference of the concave globoidal cam mechanism. Since then we can visualize the motion of the mechanism and find out which cam model can meet the required accuracy. These cams are modeled by different methods from the same input data of several examples.

The outline of the paper is as follows. In Section 2 we describe the classification of globoidal cams and two modeling methods on concave globoidal cams. In section 3 we describe briefly the method of making animation and checking the interference on globoidal cam in Pro/Engineer. Two application examples are presented in Section 4. Finally, conclusion remarks are given in Section 5.

2. Classification of globoidal cams and modeling methods of concave globoidal cam

Globoidal cams are classified in to two kinds. The first kind has a groove with a circumferential contour cut in its surface and the roller follower oscillates when the cam rotates. The second one has one or more ribs on its surface with indexing a follower in a form of a turret (Fig. 1). The second kind is the object of this study. Although there are some differences in shape between the two cams, see Fig. 1, their geometrical parameters can be calculated using the similar calculations with the same formulas.



(a) Oscillating follower. *(b) Indexing turret follower.*

Figure 1. *Globoidal cam – rib type.*

There are many methods to model these concave globoidal cams. We introduced two methods to create them, namely Pitch surface-based modeling and Standard cutter-based modeling, and they are described in detail in Ref. [Tuong 2008a], [Tuong 2008b], [Tuong 2008c].

In the first method, the working surfaces of the cam are created by offsetting the pitch surfaces of the cam at a distance that is equal to the radius of the roller. Other surfaces will be added and merged together to become a united surface. Then, the united surface is converted to solid. Some other simple steps can be done to get the desired cam. In the second method, from machining point of view, the motion of the cutter, which has the same diameter as the roller, will be similar to the motion of the roller in the machining process. Therefore, the working surface of the cam can be created if cut by a rectangular section which has the same size and similar motion to the roller. Other surfaces of the cam can be done by using some similar cuts.

3. Method of animation and checking the interference

In order to make animation and verify the interference between components in the globoidal cam mechanism, first, an assembly of the cam and the follower is made. After that, using the Mechanism Design module to define the geometrical relationships of the system, it may move and analysis of its motion may be made. Last, using a kinematics analysis we obtain information on interference between components. The following is the procedure to make animation and check interference [www].

a) Creating the assembly model
b) Modifying Joint Axis Settings
c) Creating a slot-follower
d) Checking the assembly model
e) Creating servomotor
f) Creating and Running Analyses
g) Viewing results and taking measurements

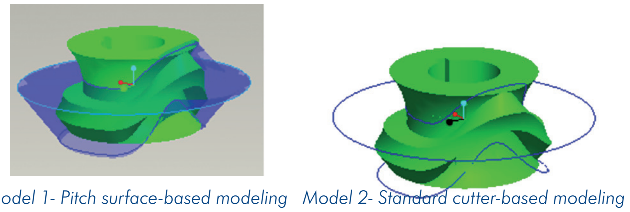
The servomotor is always applied on the cam axis so that the cam can move about its axis. When the cam moves, the roller will ride along a 3D datum curve. This curve is the locus of a point (point PNT0 in Fig. 3), which is located on the roller axis, as the follower is rotating. This curve is also utilized to create the working surfaces of the cam [Tuong 2008a], [Tuong 2008c].

4. Application examples

4.1 Example 1

A globoidal cam mechanism with oscillating follower has two rollers. The angle between two axes of the two rollers is 60^0. Some examples of angular input/output displacements and other parameters of the system are presented in Ref. [Tuong 2008a].

In Fig. 2 are two models designed by two methods that are mentioned above. In this figure, the pitch surfaces of model 1 are in transparent state to see the cam surface easy. To choose the accurate model, the interference between the cam and the rollers must be checked.



Model 1- Pitch surface-based modeling Model 2- Standard cutter-based modeling

Figure 2. *Two models of example 1.*

The cam-follower system at the initial position, (before running the Analysis), is shown in Fig. 3. When making servo motor definition, the driven entity is Joint Axis, applied for the connection axis of the cam. Because the cam rotates at constant speed thus the velocity option is chosen with constant magnitude when defining the specification of the movement of the servomotor. This constant value can be 1. It is describes the number of revolution of the cam.

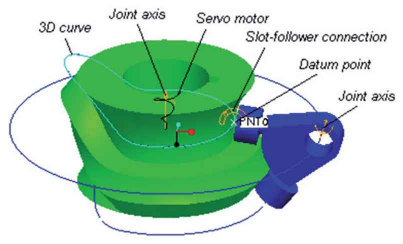


Figure 3 *Cam-follower system in Mechanism application.*

The animation will be done in 360 seconds, for example. When making definition for the kinematic analysis, the start time and end time are set zero and 360, respectively. If the time between frames (minimal interval) is 0.2, then the total frames number are:

$$\text{Framecount} = \frac{\text{Endtime} - \text{starttime}}{\text{int erval}} + 1 = \frac{360 - 0}{0.2} + 1 = 1801$$

This value is equivalent to the number of the input angles, and the interval is equal to the increment of the angular input displacements [Tuong 2008a], hence it is very convenient to compare the animated output angles with those of in the input data.

During the animation, the motions of the cam and the follower are simulated, and if there is any interference between the two components, Pro/Engineer will highlight the interfered positions. In this study, after making animation, no interference between model 1 and its roller were found, while model 2 has many positions where interferences occur in the forward and return periods (Fig. 4). Hence, it can be said that model 1 appears better than model 2 and hence model 1 can be accepted. Fig. 5 shows the animation playback of model 1.

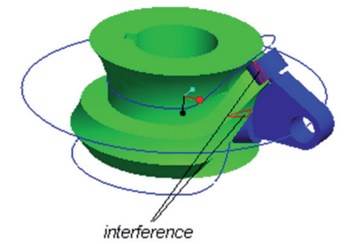
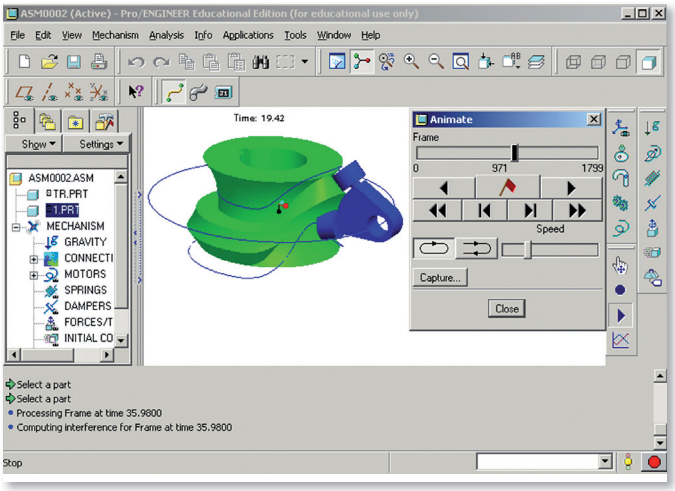


Figure 4. *Interferences (in red color) occur between components*



Select a part
Select a part
Processing Frame at time 35.9800
Computing interference for Frame at time 35.9800

Figure 5. *Animation playback of model 1.*

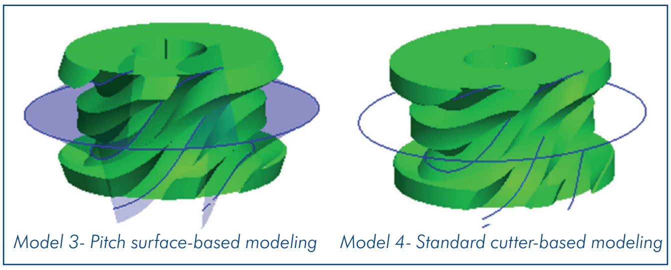
Although there is no interference between the components in the system there might be clearances between the cam surfaces and their rollers. If these clearances are large, the errors of output angular displacements will be large, too. These clearances can be measured in assembly standard mode or in mechanism mode. In general, these clearances are always less than 0.2 mm. Some selected clearances are given in Table I in the appendix. These gaps cause errors in the output angular displacements but these errors are very small so they can be ignored. Now, it is safe to say that model 1 is acceptable model.

4.2 Example 2

A globoidal cam indexing mechanism has 6 rollers, which are equally spaced on a pitch circle. Some examples of angular input/output displacements and other parameters of the system are presented in Ref. [Tuong 2008b].

In Fig. 6 are two models of the cam designed from preceding data. In this figure, the pitch surfaces are in transparent state to see the cam surfaces easily. The two cams look similar in shape. But the better cam is that one that has no interference between components in the system and no clearance between the cam surfaces and the roller (or the clearance must be small enough).

Unlike example 1, the 3D curve in this example is not closed and the total angular input displacement of the cam is 372.5 degrees [Tuong 2008c] as it describes the movement of the follower reference point. Thus, if this 3D curve is used to make a slot-follower con-


Model 3- Pitch surface-based modeling

Model 4- Standard cutter-based modeling

Figure 6. *Two models of example 2.*

nection for the turret then the animation will not be smooth because each cycle of the animation will stop after the cam rotating an angle of 372.5 degrees and the next cycle will start at the initial position of the cam. Meanwhile, the angle of the cam at the initial position is 0 degree or 360 degrees. To get a better animation, instead of using a slot-follower connection for the turret, here a servo motor is applied on the turret axis (Fig. 7). The specification of the movement of servo motor 2 can be defined in a table that consists of the angular input/output displacements which are only from 0 to 360 degrees for the cam and the equivalent values for the turret. These data are stored in a file with the "tab" extension. By using servomotor on the turret axis, the initial position of the turret is also adjusted easily. The specification of the movement of servomotor 1 is still the same as that of in the previous example.

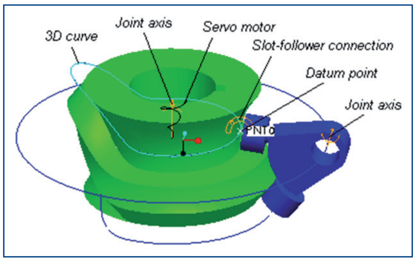


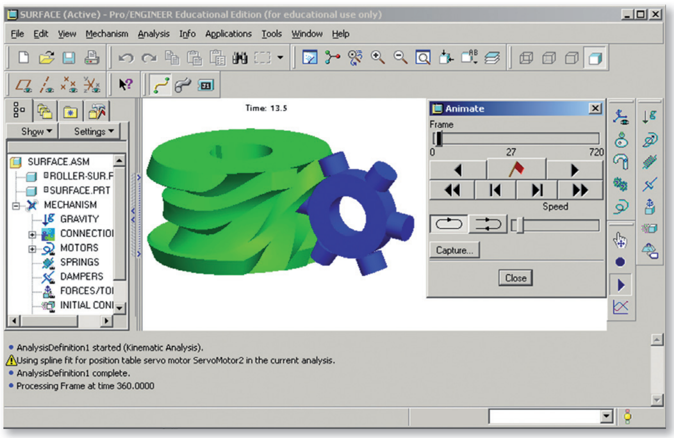
Figure 7. *Cam-follower system in Mechanism application.*

Because the increment of the angular input displacements in this example is 0.5 degree [Tuong 2008b], therefore the minimal interval here can be 0.5. In the analysis definition window, if the start and end time are set zero and 360, respectively, then the total frame No. is:

$$\text{Framecount} = \frac{\text{Endtime} - \text{starttime}}{\text{int erval}} + 1 = \frac{360 - 0}{0.5} + 1 = 721$$

This value is equivalent to the number of the input angles from 0 to 360^0 (one revolution of the cam).

Between the two models, model 3 has no interference between the cam and the roller when the cam rotates. Model 4 has 280 positions of interference in the index period. There are totally 721 positions checked for a full revolution of the cam. Fig. 8 shows the animation playback of model 3. Fig. 9 shows example of interferences occurs between model 4 and its rollers.



- AnalysisDefinition1 started (Kinematic Analysis).
- ⚠Using spline fit for position table servo motor ServoMotor2 in the current analysis.
- AnalysisDefinition1 complete.
- Processing Frame at time 360.0000

Figure 8. *Animation playback of model 3.*

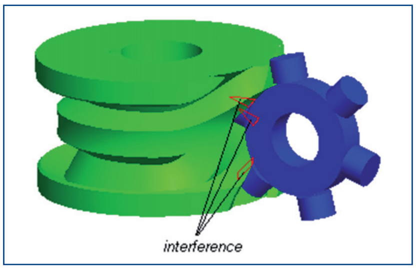


Figure 9. *Interferences (in red colour) between model 4 and its rollers.*

The clearances in assembly between the cam surfaces and the rollers of model 3 must be checked. This task can be done manually in assembly standard mode or in mechanism mode. Some examples of clearances are presented in Table II in the appendix. In general,

α [deg]	e_1[μm]	e_2 [μm]
0	0.0000020	0.0000013
15	0.0000049	0.0000053
30	0.0000049	0.0000053
45	0.0000049	0.0000053
60	0.0000048	0.0000051
75	0.0000048	0.0000051
90	0.0000048	0.0000051
105	0.0992641	0.0000000
120	0.1681920	0.0000000
135	0.0000000	0.0000000
150	0.0000000	0.0000000
165	0.0000000	0.1421750
180	0.0003888	0.0003815
195	0.0000000	0.1421750
210	0.0000000	0.0000000
225	0.0000000	0.0000000
240	0.1681920	0.0000000
255	0.0992641	0.0000000
270	0.0000048	0.0000051
285	0.0000048	0.0000051
300	0.0000048	0.0000051
315	0.0000049	0.0000053
330	0.0000049	0.0000053
345	0.0000049	0.0000053
360	0.0000020	0.0000013
Note:	*e_1: clearance between cam surface and upper roller (model 1)* *e_2: clearance between cam surface and lower roller (model 1)* *α : angular input displacement (the rotation angle of the cam)*	

Table 1. *Example of some selected clearances between cam surfaces and rollers (example 1). Although the calculated precision is non real the range is shown for understanding purpose*

α [deg]	e_1[μm]	e_2 [μm]	e_3[μm]	e_4 [μm]
0	–	0.0585316	0	0
15	0.0528666	–	0.0351234	0.0473915
30	0.063994	0.0502574	0.0056034	0.0362505
45	0.0243202	0.0170940	0.0581564	0.0820387
60	0	0.0703851	0.0011278	0.0010219
75	0	0.0605575	0.0003903	0.0011722
90	0	0.0706481	0.0032800	0.0017334
105	0.0055780	0.0142335	0	0.0957572
120	0.0063138	0.0132114	0	0.0950316
135	0	0.0706482	0.0024268	0.0017334
150	0.0060959	0.0060959	0	0.0952285
165	0.0061338	0.0134631	0	0.0952182
180	0	0.0706481	0.0024268	0.0017334
195	0.0064939	0.0130263	0	0.0953030
210	0.0033976	0.0167813	0	0.0945793
225	0	0.0706372	0.0024266	0.0017335
240	0	0.0845015	0.0090981	0.125517
255	0	0.0587580	0.0120980	0.0184087
270	0	0.0857001	0.0019144	0.0147282
285	0.0161315	0.0409393	0.0386007	0
300	0.0000570	0.0421791	0.0071429	0
315	0	0	0.124019	0
330	0	0.0887387	0	–
345	0.0065067	0.202810	0.0229045	0
360	–	0.0585316	0	0
Note:	*e1, e2: clearance between surfaces 1,2 and roller in groove 1 (model 3)* *e3, e4: clearance between surfaces 2, 4 and roller in groove 2 (model 3)* *a: angular input displacement (the rotation angle of the cam)*			

Table 2. *Example of some selected clearances between cam surfaces and rollers (example 2)*

these clearances are less than 0.2mm. These clearances may cause errors in the output angular displacements but these errors are very small and they can be ignored. The result is that model 3 is the most suitable one for this example.

5. Conclusion

Some techniques of making animation and checking interference of the concave globoidal cam mechanism have been proposed in two examples. Thanks to the animation, the motion of all components in the mechanism can be simulated, and from the results of checking interference and clearance, the better accuracy cam can be chosen for each example. In both examples, the models, which are modeled from the Pitch surface-based modeling method, meet the required accuracy and they are acceptable.

From the results of this study, it can be seen that making animation and checking interference are very essential tasks when modeling globoidal cams. The presented techniques are very useful in terms of modeling globoidal cams and they may be applied for other types of spatial cam.

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