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AN ANALYSIS FOR OPTIMAL CHASING CAM DESIGN

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ABSTRACT

The design of chasing cam is necessary due to continuous development of thread cutting. The machine productivity will be determined according the speed of the cam and the number of passes.

The cam speed is often limited by the inertia forces.

Therefore, it is imperative to choose the cam profile (motion program) with minimum acceleration. This work prese_nts an analysis for various profiles. Six family of curves are deduced, namely; Constant acceleration, Harmonic, Cycloidal, Cubic, Polynomial, and Elliptical.

The develpment of numerical controlled machines as well as digital computers requires the combination curve having the optimal value which ensures minimum acceleration.

It is hoped that the proposed combination curves can be a useful aid in the field of chasing cam design.

INTRODUCTION

Thread chasing is mainly applied if threads cannot be cut, rolled or milled. Such attachment yield threads of high accur_acy. It is also applicable for higher tensile materials, behind shoulder threads and for threads of large diameter. The thread chasing attachment is suited for chasing single or multiple, right or left_hand threads, cylindrical or tapered internal or external threads.

Fig.1 shows a longitudinal feed_drive scheme for a thread_cutting lathe on which a thread is cut by the repeated pass method (chasing). Chasing cam speed is often limited by ine_rtia forces. Fig.2 shows a schematic out line of chasing cam profile.[1]

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Therefore it is important to determine cam shape for which acceleration are minimum.

PRACTICAL GEOMETRY OF MOTION

Fig.3 shows more details for the chasing attachment.The chasing slide performs two motions:
1_ axial; chasing stroke and return (chasing cam).
2_ radial; a_ advance and return (cam plate).
b_ infeed (cross slide cam).

The combined actions of chasing cam and cam plate result in the typical chaser motion as follows;
1_ The tool advances in 20 degree.
2_ Chasing stroke in 240 degree.
3_ The tool returns in 20 dgree.
4_ Return stroke in 80 degree.

Therefore plate cam has the following positions(RDRD-rise, dwell, return, and dwell);
from 0 to 20 degree rise, the tool advances.
from 20 to 260 degree dwell.
from 260 to 280 degree return, the tool returns.
from 280 to 360 degree dwell.

And the chsing cam DRDR;
from 0 to 20 degree dwell.
from 20 to 260 degree rise, the chasing stroke.
from 260 to 280 degree dwell.
from 280 to 360 degree return, return stroke.

The present work investigated the 4 th. point only,because any change in the 2 nd. point (helical line or constant vel_ ocity motion) will produce non_symmetrical thread pitches.

COMBINATION CONDITIONS ANALYSIS

Generally, the forces acting on cam_follower system include the applied load, the inertia force,the frictional resistance, the vibratory forces and spring load. The applied load depends on chip area, in our case it will be named as chasing area,and the specific cutting presure as well as on cutting condition.

Different chasing areas are illustrated in Fig.4.Friction is inevitable between contacting parts in relative motion.The pr_ imary functions of a spring force in a cam_follower system are to counteract the inertia of the follower and to maitain cont_ act between a follower and a cam throughout the motion cycle.

Inertia forces are caused by the necessity of moving masses lineally. A cam follower may have a lineal movement,and it may produce a simple motion. The inertia force is the product of a mass and the acceleration of a follower system.

The present research studies the profile of a cam. The kn_ own curves of motion may be developed to be used as curves fa_ mily. These groups of curves can be called as constant accele_ ration, harmonic, cycloidal, cubic, polynomial,and elliptical.

Generally, the known curves are inadequate for control pu_ rpose for the required specific velocities, intermediate disp_ lacements or accelerations, and motion specification for unsy_ mmetrical rise or fall.In this case,the combination of motions must be frequently used. The combination conditions are widely varied from one case to the other. In this moment the combina_ tion conditions must be investigated. This study may give the optimal design.

Fig. 3 shows chasing cam_profile. This profile is the return curve ABCD which represents a typical DRD event. From this figure it is seen that the sum of displecements during each motion equals to the total stroke H. On the other hand, the sum of angles during each motion appears to be the total chasing return angle T_r. In our attachment this angle is 80 degree.

As the transition point at sequential stages of the given curve (see Fig. 5) must be the same. This may be true for both velocity and acceleration. It is seen that the path BC will be the constant velocity motion and it can be preced to both AB and CD of the curves family. It must be noted that the acceleration at points A, B, C, and D will be equal to zero. Also, the velocity at points B and C should be the same. On the other hand the zero velocity may be appeared at points A and D. This proves that the two curves AB are CD are the important factors in our study. These curves AB and CD are suitable for only cycloidal or polynomial curves family. The accelerations of remainder four curves family of constant acceleration, harmonic , cubic and elliptical have trnsition points with different values so that their connection will be impossible

1_ CYCLOIDAL CURVES FAMILY

The cycloidal curves family are four while only two of them can be used in the above concept. These two curves may be expressed as;

$$Y_1 = H[(t/T)-(0.5/\pi)\sin(\pi t/0.5 T)]$$
$$Y_2 = H[(t_m/T)-(0.5/\pi)\sin(\pi t_m/0.5T)]$$

The second curve appears to be the better for the minimum acceleration. The difference between the two curves can not compensate the cost of machining. This means that this curve is expensive.

In order to determine the optimal combination curve for the cycloidal_ constant velocity_ cycloidal, the above conditions should be satisfactory. From the above analysis the following expressions may be valied:

$$V_B = V_C \quad (1)$$
$$V_A = V_D = 0 \quad (2)$$
$$A_A = A_B = A_C = A_D = 0 \quad (3)$$
$$h_1 + h_2 + h_3 = H \quad (4)$$
$$T_1 + T_2 + T_3 = T_r \quad (5)$$

Applying the above equations the acceleration A as well V velocity can be computed at diferent points on the combination curve. The results of calculations are listed in Table 1 .

Table (1); A & V for (cyc._c.v._cyc.) combination curve.

Point	Path	Velocity	Acceleration
A	cyc.	Zero	Zero
B	cyc.	$2\ h_3/\ T_3$	Zero
B	c.v.	$h_2/\ T_2$	Zero
C	c.v.	$h_2/\ T_2$	Zero
C	cyc.	$2\ h_1/\ T_1$	Zero
D	cyc.	Zero	Zero

. . .

From the equations (1_5) and the results of Table 1, We can determine that

$(2h_3/T_3) = (h_2/T_2) = (2h_1/T_1)$ (6)

$HT_1 = h_1(T_r + T_2)$ (7)

In order to minimize the inertia forces by the minimum acc_eleration, the optimal point should be found. The acceleration may be expressed as;

$A = [\pi\, h_1/(T_1)^2]$ (8)

or $A = -[\pi\, h_3/(T_3)^2]$ (9)

As the variation in the value h_1 is possible, the min. acceleration can be appeared at the minimum h_1. In the other hand, the value of h_1 can not less than the depth of cutter or follower approach. This is illustrated in Fig. 6. Also, the return stroke may be computed. The results of calculations in the studied case are given in Table 2.

Table 2; Optimal combination conditions by cycloidal.

Path	Curve	Stroke height	Stroke angle
AB	cyc.	$h_3 = 0.05$ H	$T_3 = 0.09\ T_r$
BC	c.v.	$h_2 = 0.9$ H	$T_2 = 0.82\ T_r$
CD	cyc.	$h_1 = 0.05$ H	$T_1 = 0.09\ T_r$

2_ POLYNOMIAL CURVES FAMILY.

The equation of polynomial curves family as follows;

$Y = C_p K^p + C_q K^q + C_r K^r + C_w K^w + \ldots\ldots$

When $K = t/T_r$

$p < q < r < w$

$2p + 1 < w$

$C_p = q.r.w..../(q\_p)(r\_p)(w\_p)$

$C_q = p.r.w..../(p\_q)(r\_q)(w\_q)$

$C_r = p.q.w..../(p\_r)(q\_r)(w\_r)$

$C_w = p.q.r..../(p\_w)(q\_w)(r\_w)$

Accelerate degree are 1,2,3,or 4,....... as well as the begining will be 2,3,or 4,.,. The first accel_erate degree 1 may be suitable for the above combination con_ditions while the other degrees will not give the symmetrical acceleration. Also, the minimum begining leads to the minimum acceleration. In the present case, the first degree (1) with first begining (2) may produce unsymmetrical acceleration. So that the first degree (1) with begining (3) should be conside_red as formulated by simple polynomial 3_4_5 as follows;

$Y = H\ (\ 10K^3\ \_\ 15K^4 + 6K^5\ )$

In order to determine the optimal combination curve for the polynomial_constant velocity_ polynomial,the above conditions should be satisfactory. Appliying the above equations (1_5)the acceleration A as well as velocity V can be computed at diffe_rent points on the curves. The results of calculations are li_sted in Table 3.

From results of Table 3, we can determine that

$(30\ h_1/8) = (h_2/T_2) = (30h_3/8)$ (10)

In order to minimize the inertia forces by the minimum accel_eration.On the other hand the values of h_1&T_1 can not less than the approach of cutter or follower (see Fig.6).Also, the results of calculations in studied case are given in Table 4.

Table 3; The acceleration and velocity by pol._c.v._pol.

Point	Path	Velocity	Acceleration
A	pol.	Zero	Zero
B	pol.	$30h_3/8$	Zero
B	c.v.	h_2/T_2	Zero
C	c.v.	h_2/T_2	Zero
C	pol.	$30h_1/8$	Zero
D	pol.	Zero	Zero

Table 4 ; Optimal combination conditions by polynomial.

Path	Curve	Stroke height	Stroke angle
AB	pol.	$h_3 = 0.05\ H$	$T_3 = 0.05\ T_r$
BC	c.v.	$h_2 = 0.9\ H$	$T_2 = 0.9\ T_r$
CD	pol.	$h_1 = 0.05\ H$	$T_1 = 0.05\ T_r$

CONCLUSION

The development of numerical controlled machines as well as digital computers requires the compination curve having the optimal value which ensures minimum acceleration. The optimal combination conditions are recommnded as follows;

1_ 0.9 of return stroke height is helical line (constant_velocity). It is preceded by (0.05 H) a half_cycloid (or half_polynomial) and followed by another half (0.05 H).

2_ Return stroke angle is 0.09 for half cycloid and 0.82 c.v.

3_ Return stroke angle is 0.05 for half polynomial & 0.9 c.a.

It is hoped that the proposed combination curves can be a useful aid in the field of chasing cam design.

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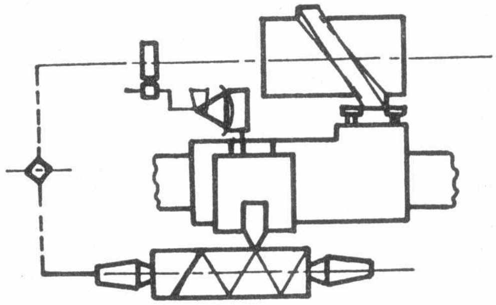

Fig.1 *TSLAF'S chasing attachment.*

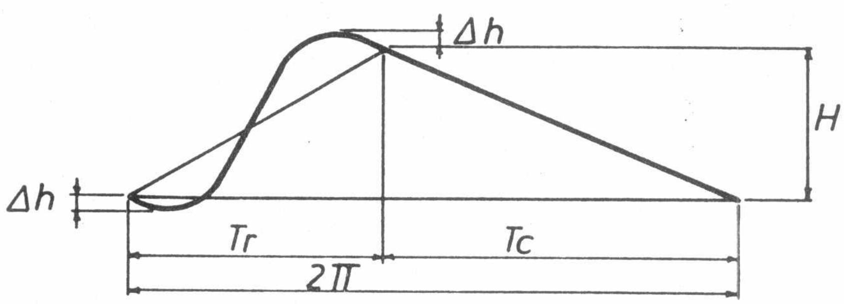

Fig.2 *TSLAF'S chasing cam profile.*

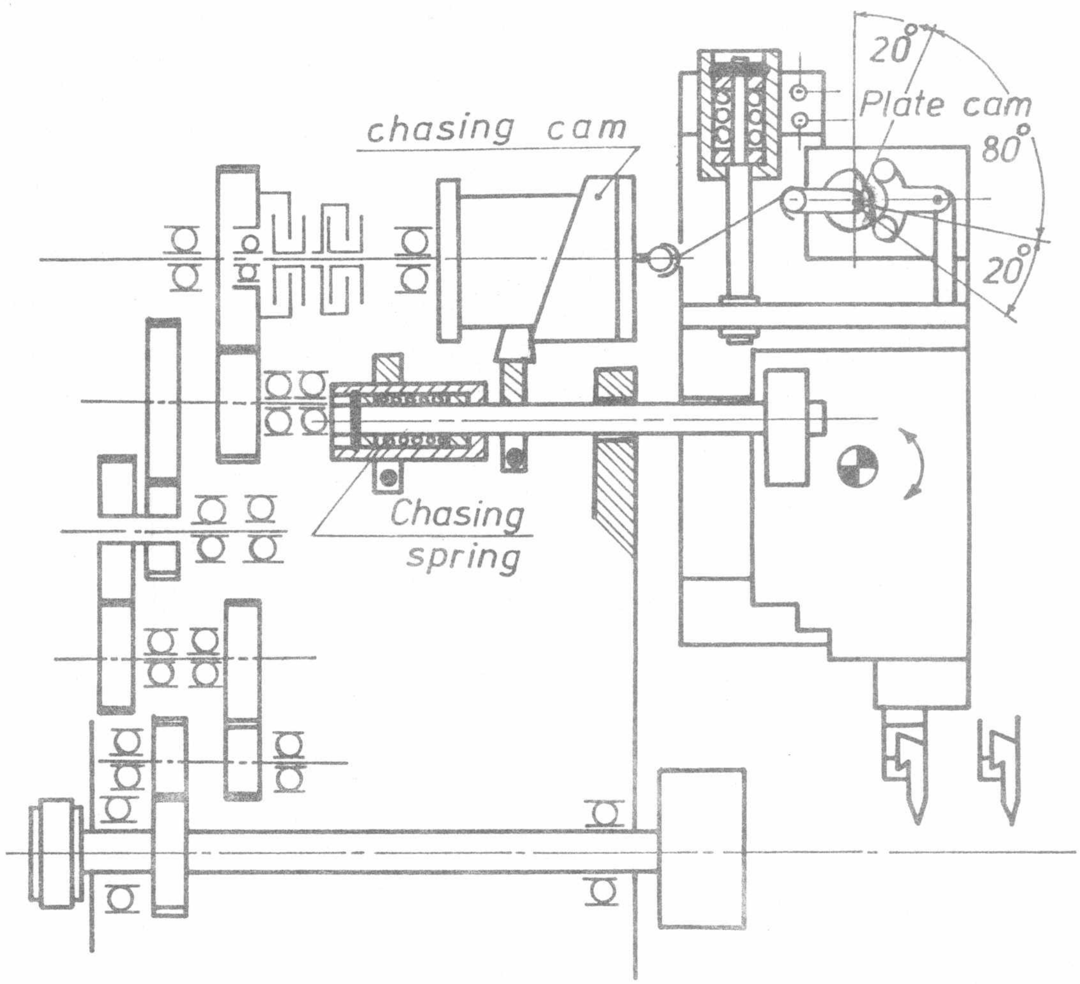

Fig.3 Chasing attachment details.

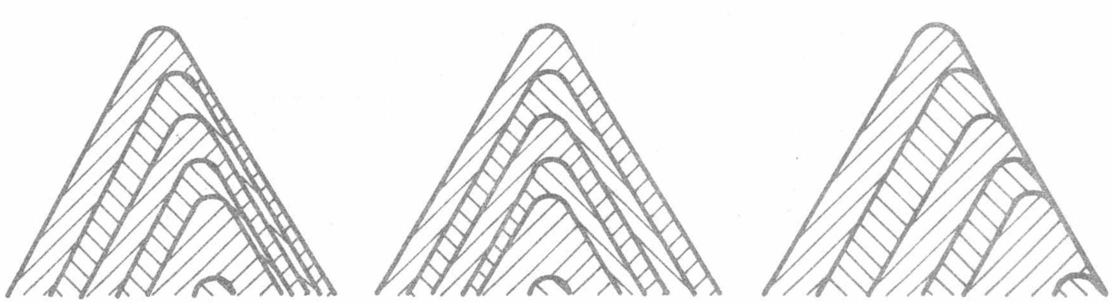

Fig.4 Different chasing area.

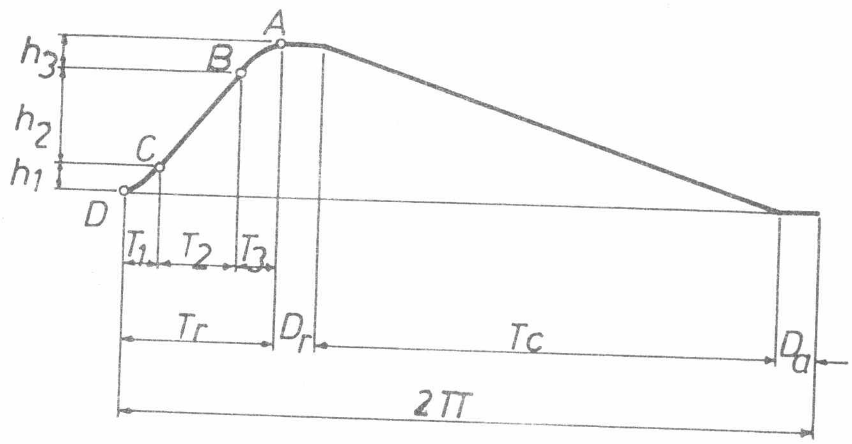

Fig.5 *Practical cam profile.*

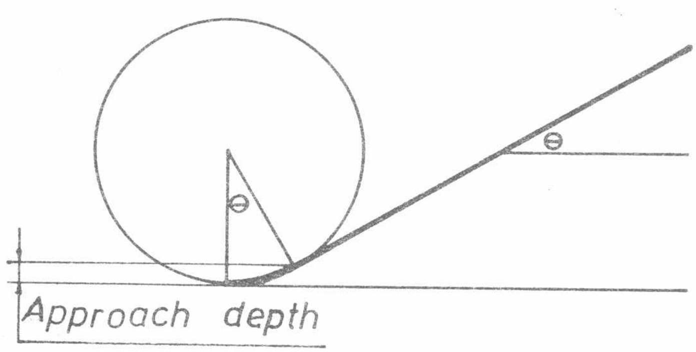

Fig.6 *Cutter or follower approach.*