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CNC Machining of Face Cam on a Cylindrical Sector

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Abstract
Machining of Face Cam for Loader's Fire safety switch in an Armoured Fighting Vehicle involves establishment of required cam profile and surface finish for the effective functioning and smooth travel of the cam follower. This paper discusses different approaches followed in the development Face cam and its machining methods, cutting tools and cutting parameters.
Key words: Face cam, point milling, flank milling, templates, parametric.

I. INTRODUCTION

The main features of a battle tank are Firepower, Mobility, and Protection. Among these, firepower (Weapon System) is is an important feature. The weapon system consists of fire control system, Gun control system, vision system and ammunition system. In the fire control system, a fool proofing arrangement is made to protect other systems and crews from the hot ammunition cartridge case. The gunner loads the ammunition and he should properly lock the breech end of the gun. Then the firing trigger has to be operated. To control theloader's activity a cam-operated lever is provided. If he doesn't lock the breech end properly the firing switch will not switch on.

The operation of cam is most important. This has a disk type Face cam geometry. This has to be machined to use in safety mechanism of a high caliber gun. The prime requirement of the machined surface is to have a smooth surface so that the follower does not experience undue jerks or sticking during operations.

II. GEOMETRY

The geometry of Face cam is shown in Fig. 1.

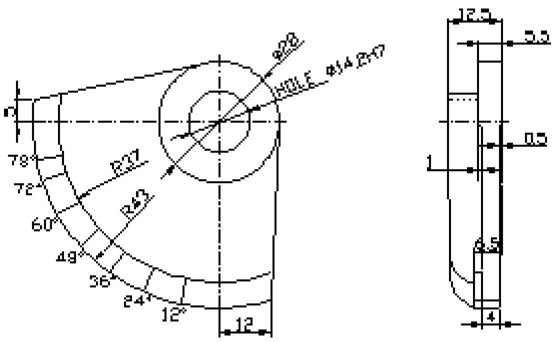


Fig. 1: Face cam

The dimensions are tabulated in Table 1. The cam lift is given against the degrees. It also shows the lift of the cam per degree.

Table. 1: Face cam dimensions

DRG. VALUES	DEGREE	0°	6°	12°	18°	20°	24°	30°	36°	42°	48°
	HEIGHT	6.50	7.70	8.90	10.10	10.50	10.64	10.85	11.05	11.26	11.47

CAL. VALUES	RISE/DEG	0	0.2	0.2	0.2	0.2	0.035	0.035	0.035	0.035	0.035

DRG. VALUES	DEGREE	54°	60°	66°	72°	78°	84°	90°
	HEIGHT	11.67	11.88	12.09	12.29	12.50	12.50	12.50

CAL. VALUES	RISE/DEG	0.035	0.035	0.035	0.035	0.035		

III. WORKDONE

Machining of cam profile or cam surfaces involves number of calculations of cam data at various sections, manufacture of templates or masters and replicating the profile or surface on the actual component. Due to developments in machine tools with Computerized Numerical Control systems, manufacture of cam profile or surfaces have become relatively easier without the need for meeting lengthy calculations or master templates.

Different approaches have been followed in arriving at the best possible solution with the available resources. (i) Manual method and (ii) Computer Aided Manufacturing (CAM) method by modeling and generating CNC part programs.

3.1 Computer Aided Manufacturing

Computer Aided Manufacturing method was adopted initially. The solid model was developed using I-deas Artisan Solid modeler and exported to SmartCAM CAM package to generate CNC part program. The model of the tool path generated in CAM package is shown in Fig. 2. The CNC part program was down loaded to a CNC vertical milling machine and the cam surface was machined. The sequence of operations followed by this method is given below.

1. Turning in a circular disc
2. Cutting sector
3. Modeling in CAD software
4. Tool path and code generation in CAM package
5. Cam machining in 3 axis CNC machine

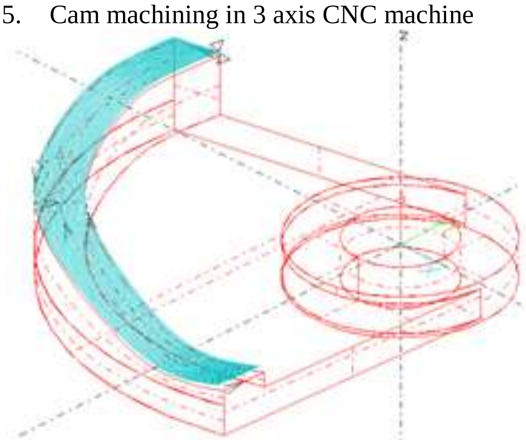


Fig. 2: Tool Path Generation

In this method, since the ruled surface of the cam comprises of number of polylines, the length of the program was quite high. In addition, in order to ensure the surface quality the number of passes has to be increased, which again lengthened the part program. This necessitates higher memory storage in CNC machine. Also the generation of part program requires knowledge of CAD/CAM operation. All these factors led to increase in time and cost of manufacture thus a simple manual method is attempted and studied the machining activity.

3.2 Manual Method

Machining trials were conducted in various ways such as point milling and flank milling on a 3-axis vertical CNC milling machine and 4-axis CNC machine (with CNC rotary table). The surface finish of the machined surface was optimized through these exercises. The operation sequence is as follows.

1. Turning in a circular disc
2. Sector milling
3. Cam machining

By manual method the cam was machined in both 3 axis and 4 axis CNC machines. In 3-axis machine point milling method was adopted. The cutting speed and feed is shown in Table.2. In 4 axis CNC machine, flank milling method was followed. The cutting speed and feed is shown in Table.3. The material used to machine the Face cam was carbon steel C40. The cutting tool used to machine this cam was HSS end mill and HSS ball end mill ∅8mm.

Table 2: Point milling

Cutting conditions		
Operation	Speed (rpm)	Feed mm/min
Roughing	800 rpm	120
Finishing	1500 rpm	20

3.2.1 Point Milling

In this method, the tool will be making only a point contact on the cam surface. The number of passes will become enormous to cover the entire surface area [1]. The surface finish will be poorer due to retention of left over material to the cusp height. This problem is inherent in this process. Also to achieve a better surface finish the tool has to be run at higher cutting speed and lower feed rate which ultimately resulting into increased cutting time. The schematic of the point is milling is shown in Fig-3.

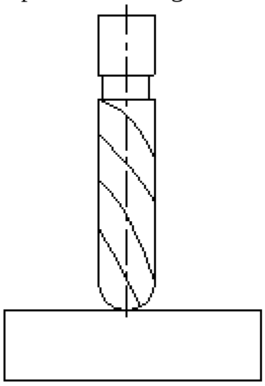


Fig. 3: Point milling

3.2.2 CNC Programming

Parametric method of CNC part programming was followed to generate the cam surface of Face cam on 3-axis CNC milling machine. The detail of the part program is given below: [2]

```
O0139 (CAM LFSS PROFILE)
G55 Z100;
G0 X0 Y0;
M13 S1000 T1 D1;
#100 = 0 ;
#102 = 50;
#130 = 0.02;
#103 = 30;
N10     #110 = #102 * COS(#100);
#111 = #102 * SIN(#100);
#112 = #103 * COS( #100);
#113 = #103 * SIN(#100);
G0 X- #111 Y- #110;
N20 #130 = #130 - 0.02;
IF [#130 LT – 4] GO TO 50;
GO Z - #130;
G1 X -  #113 Y- # 112 F150;
G0 Z10;
X - # 111 Y - #110;
IF (# 100 GE 20) GO TO 50;
#100 = # 100 + 0.1;
GO TO 10;
N50 G0 Z 100 M5;
M30;
```

3.2.3 Flank Milling

In this method, the tool will be placed parallel to the cam surface as shown in Fig-3 During flank milling the peripheral tooth of he end mill is in contact with the work piece thus problem like cusp height is totally avoided and thereby ensuring better surface finish [1]. But the finish can be affected by the dwelling of cutter over the machining surface, however, by the judicial selection of cutting parameters, this was minimized considerably.

Since the complete envelope of the cam surface is generated in a single pass, the machining time was also considerably reduced. Geometrical form created by this method be influenced by the tool deflection and inherent taper of cutter itself [3]. But the lesser width of the cam surface enabled to reduce this effect considerably, by the selection of shorter length end mills. The cutting parameters used in this method of milling are given in Table-3.

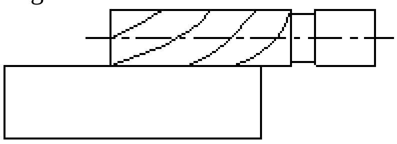


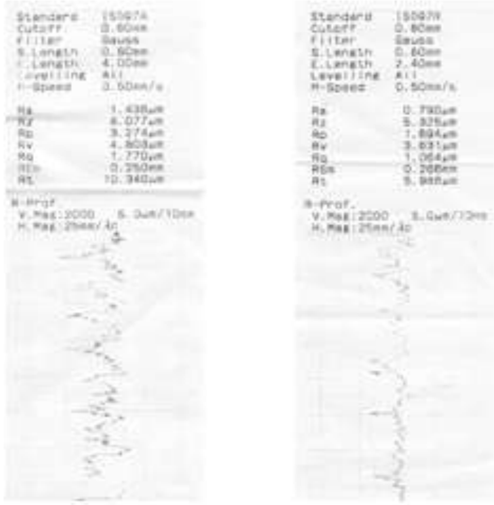
Fig. 3: Flank milling

Table 3: Flank milling

Cutting conditions		
Operation	Speed (rpm)	Feed mm/min
Roughing	800 rpm	120
Finishing	1000 rpm	50

IV. SURFACE FINISH

The surface finish achieved through both point and flank milling is shown in Fig.5 and the compared results are given in the Table. 4. Flank milling produced better surface quality, which ensured the smooth travel of the cam follower over the machined surface.



Point milling Flank milling
Fig 5: Surface finish comparison

Table 4: Surface finish comparison

Parameter	Point milling	Flank milling
R_a	1.436	0.790
R_t	10.340	5.986

V. CONCLUSION

The machined Face cam was subjected to functional test and found satisfactory. This exercise would set a basis to understand the problem in point and flank milling and also would serve a valid source for future machining requirements of similar nature.

REFERENCES

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