Comparison of geometrical accuracy and surface finish of cam profile generated by wire-EDM and CNC milling machine

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Abstract. CAM is a machining element that has a curved groove or curved outline used for converting rotary motion into the form of linear motion or vice versa. The radial cam is a type of cam which having rotating plate or disc with an outer circumference shaped for producing a linear movement to a follower which is held against it. The quality of the final machined component surface depends on the accuracy and surface finish, position, orientation and run-out. The main aim of this paper is to machine a CAM profiles with CNC milling and wire cut EDM process and comparing the surface finish and accuracy of the machined surface with surface roughness tester and coordinate measuring machine (CMM).

Keywords: Cam profiles, CNC Milling, Wire-EDM, Surface roughness, Geometrical accuracy

1. Introduction

The invention of numerical control (NC) and computerized numerical control (CNC) machine tools are enhanced great value to automation and flexibility in product manufacturing and machining of complex contours. In general cam profiles are designed by geometric curvatures by the points traced follower motion as well as through a set of locus of points. Here, the cam profile is designed using CREO software and manufactured using CNC milling centre and wire EDM process. Wire electrical discharge machining also called as wire-EDM is one of the non-conventional machining process that is used widely for die manufacturing. A CMM is a device used for computing the physical geometrical characteristics of a machined component. Here the accuracy of machined cam profiles is checked using co-ordinate measuring machine. A good quality surface will increases the corrosion and wear resistance, fatigue strength of the workpiece.

Numerous studies about the CAM profiles for continuity Bezier curves based on various parameters and construction of CAM profiles plates on CNC machine tools with NC code generation are performed. The effects of input parameters on response such as surface roughness using wire EDM is investigated and the deviation error is checked with coordinate measuring machine (CMM) hence these are the manufacturing techniques developed during recent years. Inspite of these studies, new research efforts are essential to clarify the effect of various factors involved in the process.
Hetal et al. [1] concluded that end continuity conditions were applied for checking the tool path variations produced during machining. There is no tool path difference observed in parametric programmed machining or CAM system but the marks of machining commonly referred to as “manufacturing signature” that happens due to selection of manufacturing process. The final generated cam profile is checked using CMM. Kanlayasiri et al. [2] studied the effects of input variables on the surface roughness of DC53 die steel using wire-EDM process. In this work, the input process parameters such as pulse-on time, pulse-peak current, pulse-off time, and wire tension are selected. Analysis of variance method was used for finding the input process variables that affecting response such as surface roughness. The final component is manufactured using wire-EDM process and the surface roughness value is measured using surface roughness tester. Kang et al. [3] proposed a new system that was applied to marine engine cams. Only minimum time (5 mins) is required for the measurement but the old coordinate measuring machine would take over 1 hour for the measurement even with a skilled operator.

Andrzej werner [4] described a method for improving the accuracy of machined components manufactured using CNC machine and wire electrical discharge machines. After completing the machining process, coordinate measurements were performed. Ahmari et al. [5] used the Design of Experiment methods for optimizing the process parameters of surface reconstruction for freeform surfaces using reverse engineering technology. The input process parameters are number of points in percentage, noise reduction, triangle counts in percentage, and Sampling whereas the response parameters are the computational time, surface accuracy and the required computer memory space. The authors concluded that reverse engineered surfaces final accuracy depends on number of input points of point cloud data, number of triangles in polygon model, and reduction of noise.

2. Methodology and Material used
A work material such as aluminum AA6063 bar of dimension 200 mm x 150mm x 25mm was selected for the wire EDM machining and CNC machining. The design of radial disc cam profile is developed in CAM software and NC code is generated for the machining purpose in CNC milling and wire-EDM machine. The dimension of the CAM product is shown in Figure 1.

![Figure 1. Dimension of the CAM product](image)

The Figure 2 shows the Wire cut Electric Discharge Machining (WEDM) machine. This process can be used for cutting the plates having thickness upto 300mm. Electrode made of brass wire are generally used. The wire EDM parameters used for machined cam profile is shown in Table 1.
Table 1. Wire EDM Parameters

| Parameters            | Range |
|-----------------------|-------|
| Voltage (v)           | 16    |
| Pulse on time (μs)    | 1     |
| Pulse off time (μs)   | 10    |
| Wire speed (m/min)    | 5     |
| Servo voltage(v)      | 45    |

Figure 2. Wire cut - Electrical Discharge Machine

The Figure 3 shows the machined cam profile on CNC machine. The material is surface finished before machining. LV 45 CNC milling machine is used for experimentation. The end milling cutter of diameter 15mm is used for machining process and for drilling operation the drill bit of diameter 12mm is used. The CNC milling parameters used for machined cam profile is shown in Table 2.
Figure 3. Machined cam profile in CNC Machine.

Table 2. CNC Milling Parameters

| Drilling operation parameter | Outer profile parameter |
|-----------------------------|-------------------------|
| Roughing operation          | Roughing operation      |
| Feed = 1200 mm/min          | Feed = 1850 mm/min      |
| Speed = 2200 rpm            | Speed = 1850 rpm        |
| Depth of cut = 20 mm        | Depth of cut = 20mm     |
| Finishing operation         | Finishing operation     |
| Feed = 1200 mm/min          | Feed = 650 mm/min       |
| Speed = 3200 rpm            | Speed = 3000 rpm        |
| Depth of cut = 20mm         | Depth of cut = 20mm     |

The machined cam profiles are checked for surface roughness and accuracy in surface roughness tester and coordinate measuring machine respectively. The surface roughness tester is used to measure the surface roughness of the machined CAM surface. A Coordinate Measuring Machine (CMM) is used for measuring the physical geometrical characteristics of a CAM profile. This machine may be controlled manually by an operator or it may be controlled by computer. The measuring range of the CMM used is 500 mm × 400 mm × 400 mm in x, y, z axis respectively. The CMM used for measuring wall angle has a following specification: resolution: 0.0001 mm (0.1µm), drive speed: 8 – 300 mm/s (CNC mode), workpiece max height: 545 mm, workpiece max mass: 180 kg, air supply pressure: 0.4 MPa, probe material used: Ruby.

3. Results and description

3.1 Calculation of Material removal rate in wire EDM process

\[ MRR = K \times H \times F_R \times \rho \]
Where, \( K \) is the cutting width in mm
\( L \) is the thickness of the material in mm.
\( F_k \) is the cutting speed mm/min.
Density of the workpiece g/mm

\[
MRR = 25 \times 25 \times 0.5 \times (2.7 \times 10^{-3})
\]
\[
= 0.625 \text{ g/min}
\]

3.2 Surface roughness comparison of cam profiles

The surface roughness is measured for machined CAM profile at different location such as top surface, bottom surface, outer profile and inner circle. The solid view with indication of different surface is shown in Figure 4. The surface roughness value for the machined CAM profile in Wire EDM and CNC Milling machine at different location is shown in Table 3.

![Figure 4. Solid view of cam profile](image)

![Figure 5. Surface measurement of outer profile and inner hole](image)

The surface roughness measurement gives 0.21\( \mu \)m and 0.33\( \mu \)m variation in inner circle and outer surface of CAM profiles which shows that CAM 1(CNC milling) has higher surface finish than CAM 2 (wire EDM).
Thus from the Table 3, it is concluded that surface finish is better in CAM 1 (CNC milling) than CAM 2 (wire EDM). From the Figure 6, it is understood that CAM profile 1 (CNC milling) have lower surface roughness value compared to CAM profile 2 (wire EDM).

Table 3. Surface Roughness Measurement

| S.No | Surface         | Cam 1 (CNC milling) | Cam 2 (wire-EDM) |
|------|-----------------|---------------------|------------------|
| 1    | TOP             | 0.74 μm             | 0.80 μm          |
| 2    | BOTTOM          | 0.76 μm             | 0.85 μm          |
| 3    | INNER CIRCLE    | 1.02 μm             | 1.23 μm          |
| 4    | OUTER PROFILE   | 1.09 μm             | 1.42 μm          |

Figure 6. Surface roughness measurement

3.3 Geometric Accuracy Measurement

CAM profiles machined from CNC milling and wire EDM process are compared for geometrical accuracy. Figure 8 shows the depth and circularity measurement for the drilled hole in cam profile using CMM. Figure 9 shows the comparison of geometrical accuracy of the cam profiles machined from CNC milling and wire EDM process. Cam profile machined from wire-EDM is more accurate than cam profile machined from CNC milling (Only slight accuracy varies).
Figure 7. Coordinate Measuring Machine (CMM)

Figure 8. CMM – Depth and Circularity measurement.

4. Conclusion

Cam profile made of aluminum alloy AA6063 is machined with CNC milling and wire cut EDM process. The cam profile machined using CNC milling and wire EDM machine, which is compared to ensure the effective processing in the view of surface finish by surface roughness tester and also the surface accuracy using coordinate measuring machine (CMM).

a) The CAM profiles are machined from CNC milling with varying speed, feed and depth of cut as well as from wire EDM.
b) The surface roughness measurement gives 0.21μm and 0.33μm variation in inner circle and outer surface of CAM profiles which shows that CAM 1 (CNC milling) has higher surface finish than CAM 2 (wire EDM).
c) The geometrical accuracy measurement was performed using CMM where Cam profile machined from wire-EDM has more accurate than cam profile machined from CNC milling.
Figure 9. Geometrical comparison of two cam profiles

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