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CNC Machining with Better Surface Roughness under Control of Cutting Speed, Feed rate, and Depth of Cut

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ABSTRACT

The objective of this research is to study importance of CNC machining in present day manufacturing, with mechanical considerations. It's a fresh concept and main motive to develop this industry to make the more production effective and efficient. The thesis deals with a detailed importance of all major components like machine tool, roughness, body frame etc. keeping in view theoretical and practical considerations. Attention has also been to given cut down the cost of manufacturing by using simpler manufacturing techniques. Experimental determination of the effects, various process parameters such as spindle speed, depth of cut, feed and diameter on the performance measures like cyclic time, flank wear, and surface roughness in CNC turning and facing operation.

Keywords: -surface roughness, turning, cutting speed, feed rate, depth of cut etc.

1. INTRODUCTION

The machining industries are facing a great challenge to achieve high quality, good surface finish and high material removal rate with a view to economize in machining. Turning is one of the most common methods for cutting and especially for the finishing of components. The goal of the modern industries is to manufacture low cost, high quality products in short time. In turning, to achieve high cutting performance, selection of optimum parameters is very essential. Generally, this optimum parameter selection is determined by the operator's experience knowledge or the design data book.

Statistical design of experiments is one of such techniques for proper planning of the experiments to select appropriate data which after analysis can be analyzed by statistical methods resulting in valid and objective conclusions. [1].The Second World War brought rapid development of military and commercial products. The levels of automation and accuracy required to manufacture such products could not be achieved by the labour intensive machines of the time [2].

Hence, the world's first numerical controlled

(NC) machine tool was developed and demonstrated at the Massachusetts Institute of Technology (MIT) in 1952 [3].

The principle of numerical control, as demonstrated in 1952, is the electronic conversion of coded information into machine tool instructions [3]. Early NC

Machine tools read information from tapes or punched cards. This was then translated into

Movement of the machine tool table and/or head via electronically controlled lead screws. For a detailed explanation of numerical control and associated terminology, refer to Childs (1969) [3].

The mid-1970s saw "revolutionary advancement" of machine tool controllers with the advent of computer numerical control (CNC) [2], where tape and card information were replaced with computer-based information. Today CNC machine tool functionality has advanced much further.

Integrated computer systems, multi-axis geometry, cutting tool libraries and interchangeable machine beds are just some of the features utilized by CNC machining centers to process complete components in a single operation. The benefits of CNC greatly exceed those of conventional machining. The relatively high capital expenditure is therefore acceptable because payback is swift. Smith (1999) [2] discusses the important of investment in CNC as being:

But availability of valid experimental data is very limited for machining with advanced cutting tool. The mach inability of hardened steel was evaluated by measurement of tool wear, cutting forces and surface finish of the work piece. The principle of numerical control, as demonstrated in 1952, is the electronic conversion of coded information into machine tool instructions [3].

In mach inability studies, several statistical techniques were used to explore the influencing parameters and their effect on tool wear.

CNC machine tools offer increased productive throughput. By employing high traverse rates and automatic tool changing, machine idle time is significantly reduced.

Process lead times are reduced as set-up time is minimized by the automation of part loading and datum location. Thus batch sizes can be reduced, enabling an economic batch size of one and thereby reduced work in progress.

The storage and retrieval of the part program also contributes to substantial reductions in lead time, and enables the retention of invaluable knowledge.

CNC facilitates confident prediction of the accuracy and repeatability of dimensional characteristics. Hence, scrap and rework are virtually eliminated to reduce inspection, assembly and fitting costs. Smith (1999) [2] also cites the following ancillary benefits: precise processing of component modifications with minimal production disruption; improved planning and scheduling; repeat orders are easily undertaken; and tooling is reduced.

CNC machine tools are the main components in any manufacturing system. There are demands and new opportunities to empower the current CNC machines with the much needed features such as interoperability, adaptability, agility and re-configurability.

2. Objective

The objectives of this study are:

1. The selection of optimal cutting parameters for CNC turning and facing operations.
2. Machining parameters was investigated in order to minimize cyclic time, surface roughness and flank wear.
3. To improve the whole operation in cost wise and time wise.

Industrials production method

Machining system

One or more metal removal machine tools and tooling, and auxiliary equipment (e.g., material handling, control, communications), that operate in a coordinated manner to produce parts at the required volumes and quality.

Dedicated machining systems

A machining system designed for production of a specific part, and which uses transfer line technology with fixed tooling and automation.

Flexible manufacturing systems

A machining system configuration with fixed hardware and fixed, but programmable, software to handle changes in work orders, production schedules, part-programs, and tooling for several types of parts.

Reconfigurable manufacturing system

A machining system which can be created by incorporating basic process modules both hardware and software that can be rearranged or replace quickly and reliably. Reconfiguration will allow adding, removing or modifying specific process capabilities, control, software, or machine structure to adjust production capacity in response to changing market demands or technology. This type of system will provide customized exibility for a particular part family, and will be open-ended, so that it can be improved, upgraded, and reconfigured, rather than replaced.

Computer Numerical Control

1. Identify and label axis of travel on CNC machinery.
2. Describe the information translation into movement process in CNC machine tools.
3. Explain the use of the Cartesian coordinate system on CNC machine tools.
4. Define and describe the EDM process.
5. Discuss the use of Tool Probes in CNC machining.
6. List the types of cutting tool materials, the advantages of each and the types of materials they were developed for.
7. Discuss the uses of coated carbide on CNC machine tools.

Setup and Operation

1. Explain the importance of part zero location for setup and programming part shapes on CNC machine tools.
2. Demonstrate procedures for setting part zero on CNC machine tools.
3. Demonstrate the ability to set tool length offsets on CNC machine tools.
4. Demonstrate the ability to load and delete programs in CNC machine tools.
5. Demonstrate the ability to dry run a program in a CNC machine tool.
6. Demonstrate the ability to run a program in a CNC machine tool.
7. Demonstrate the ability to edit program feeds and speeds for optimum part run of a CNC program.
8. Demonstrate the ability to check a part per blueprint specifications.

Introduction to Programming

1. Explain and identify G and M programming codes for CNC machine tools.
2. Demonstrate the ability to calculate cutter positions for cutting tool programming on CNC machine tools.
3. Demonstrate the ability to calculate proper feeds and speeds for given cutters used on CNC machine tools.
4. Explain the difference between Incremental and Absolute programming on CNC machine tools.
5. Identify the programming codes used on CNC machine tools for part zero and TLO register pickup.
6. Describe the use of "canned cycles" in a CNC program.

7. Demonstrate the ability to program simple part shapes for CNC machine tool part.

CNC machine tool and tool characteristic

CNC machining is an automation process in which products are produces by the programs .CNC machine have following characteristic.

1. Machine tool spindle motor power=15kW
2. Maximum diameter of the turned shaft=310mm
3. Maximum length of the turned shaft=600mm
4. Speed range=36-3600rpm
5. Maximum diameter of stock bar=80mm
6. Nose radius=0.4mm
7. Approach angle=93^0

The cutting parameters

The cutting parameter which can be consider for this research are given bellow:

The depth Of cut (mm)	The cutting Speed(m/min)	The feed rate(mm/rev)
0.5	100	0.10
1.0	150	0.15
1.5	200	0.20
2.0	250	0.30

The range of the cutting parameters

The cutting parameters which effect the product quality, product shape and size, surface roughness etc. are given below

Values	Cutting Speed	The depth of cut	The feed rate
Maximum value	250	2	0.3
Minimum value	100	0.5	0.1
Sensitivity	1	0.1	0.002

Force calculation in CNC machining

The nature of the elastic deformation errors therefore necessitates knowledge of the cutting force that is a function of the geometry of the tool, material properties and cutting conditions. The cutting force can be Expressed as:

- $\mathbf{F_{total} = F_{static} + F_{dynamic}}$

Where S_{tatic} and D_{ynamic} are the quasi-static (frequency content within the machine's servo bandwidth) and dynamic force respectively.

Because dynamic forces result in high frequency dynamic deformations of a relatively lower magnitude, and also necessitate more complex compensation Methods than current CNC controllers can support, they will not be considered in this paper. For dynamic error compensation the reader is referred to reference (Ehmann [4]). The quasi-static cutting force can be typically measured by a low bandwidth force transducer at the main bearing of the spindle. Once. The deflection due to the quasi-static cutting forces can be determined as:

Control of surface roughness

The optimum selection of process conditions is an extremely important issue as these determine surface quality and dimensional precision of the manufactured parts. It is desirable that the contact surfaces of machine elements working together must be finished to a specified roughness especially in machine design. Sometimes, precision surfaces are required while rough surfaces are sometimes suitable for the machine to function properly. Therefore, it is important that the surface roughness is determined at the design stage and that it is controlled in the manufacturing stage. Then, the surfaces can be operated at the required roughness value. The control algorithm can select the cutting parameters corresponding to the desired surface roughness with minimum machining time and maximum productivity as an important characteristic of the study. The control of the cutting parameters has been limited in an applicable range so the controller can only change the cutting parameters within given limits

Surface roughness performed by CNC

Surface roughness cannot be controlled as accurately as geometrical form and dimensional quality as it fluctuates according to many factors such as machine tool structural parameters, cutting tool geometry, work piece and cutting tool materials, environment, etc. In other words, surface qualities affected by the machining process, e.g. by changes in the conditions of either the work piece, tool or machine tool. Surface roughness changes over a wide range in response to these parameters. In the past, empirical models and the

Relationship between surface roughness and cutting parameters for the turning operation were developed. A theoretical arithmetic expression was proposed (Whitehouse, 1994)[5] for average surface roughness as follows:

$$R_a=0.032f^2/R$$

Where f=federate

R=tool nose radius

An exponential empirical model for surface roughness as a function of cutting speed (v), feed (f) and depth of cut (d) was suggested as: [6]

$$R_a=C_0V^{c1}f^{c2}d^{c3}$$

Where R_a is the surface roughness, C_0 is a constant, and c1, c2, and c3 are indexes which describe the empirical model.

The following empirical expression for surface roughness in turning is: [7]

$$R=13636V_c^{-0.102}f^{0.5123}D_c^{-0.0382}$$

R=surface roughness

V_C=cutting speed

F=feed rate

Dc=depth of cut

Experimental conditions and results of surface roughness

In this paper different parameters of machining are put on the above formula and calculating the surface roughness for checking the performance level.

S. No.	Depth of cut(mm)	Cutting speed (mm/min)	Feed rate (mm/rev)	Surface roughness Ra (µm)
1	0.5	100	0.15	2.08
2	0.5	100	0.2	3.75
3	0.5	100	0.3	2.60
4	0.5	150	0.1	2.80
5	0.5	150	0.15	1.48
6	0.5	150	0.2	1.23
7	0.5	200	0.3	2.78
8	0.5	200	0.1	0.60
9	0.5	200	0.15	0.93
10	0.5	200	0.2	1.45
11	0.5	250	0.3	2.48
12	0.5	250	0.1	3.75
13	0.5	250	0.15	1.00
14	0.5	250	0.2	1.40
15	0.5	250	0.3	2.65
16	1	100	0.1	2.23
17	1	100	0.15	3.28
18	1	100	0.3	2.30
19	1	150	0.15	1.53
20	1	150	0.2	1.35
21	1	150	0.3	2.38
22	1	200	0.1	0.55
23	1	200	0.15	0.83
24	1	200	0.2	1.25
25	1	200	0.3	2.50
26	1	250	0.1	0.50
27	1	250	0.15	0.85
28	1	250	0.2	1.28
29	1	250	0.3	2.50
30	1.5	100	0.1	3.10
31	1.5	100	0.2	1.55
32	1.5	100	0.3	2.05
33	1.5	150	0.1	0.95

Improve the whole operation in cost wise and time wise.

Changing manufacturing environment characterized by aggressive competition on a global scale and rapid changes in process technology requires creating production systems that are themselves easily upgrade- able and into which new technologies and new functions can be readily integrated. These conditions require a responsive new manufacturing approach that enables (Next Generation Manufacturing Project, 1997):

1. The launch of new product models to be under- taken very quickly and rapid adjustment of the manufacturing system capacity to market demand.
2. Rapid integration of new functions and process technologies into existing systems.
3. Easy adaptation to variable quantities of products for niche marketing.

The manufacturing systems used for this new approach must be rapidly designed, able to convert quickly to the production of new models, able to adjust capacity quickly, and able to integrate technology and to produce an increased variety of products in unpredictable quantities. Reduction of lead time (including ramp-up time) for launching new manufacturing systems and reconfiguring existing systems. The rapid upgrading and quick integration of new process technology and new functionality into existing systems.

Definition of a reconfigurable manufacturing system

Definition of a reconfigurable manufacturing system is designed for rapid adjustment of production capacity and functionality, in response to new circumstances, by rearrangement or change of its components. Components may be machines and conveyors for entire production systems, mechanisms for individual machines, new sensors, and new controller algorithms. New circumstances may be changing product demand, producing a new product on an existing system, or integrating new process technology into existing manufacturing systems.

Conclusion

If the study is generalized and more parameters (tool geometry, material, life, work-peace material, etc.) are included in the system, the software of CNC machine tools can be rewritten and developed.
The conclusions that have been drawn from this study can be summarized as follows:
The feed rate is a dominant parameter and the surface roughness increases rapidly with the increase in feed rate.
The cutting speed has a critical value for which the best surface quality can be achieved. Below this critical value, the surface roughness decreases with increasing cutting speed and after this value, the surface roughness increases with increasing cutting speed.
The effect of depth of cut on surface roughness is not regular and has a variable character.

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