INTRODUCTION



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1.1 Introduction

At present the machine tool manufacturers are facing competition internationally due to worldwide globalization of business. It is required to produce quality product at the minimized rate and to be supplied to the customer at the right time. Moreover the quality of the job produced on these machine tools depends directly on the quality and performance of machine tools. To develop good products, design engineers need to study how their designs will behave in real-world conditions. To take care of this condition, often analysis of the proposed design becomes very useful and reliable tool for the design engineer.

It is also required to produce machine tools with lightweight construction a but good rigidity. At the other end the user needs more functional capabilities in the machine tools. In such condition, the designer plays important role in machine tool design to satisfy the above requirement. The performance of a machine tool is ultimately assessed by its ability to produce work piece of the required physical features in the minimum time and at small operating cost. The extent to which the behavior of the various elements of the machine contributes to its overall performance is by no means fully understood. However, the results of research together with the experience of the user form the basis for the design procedures currently available. The aim of this work is to understand and explain the analysis of machine tool structure a prerequisite of the sound systematic design.

Surface roughness is one of the most important requirements in machining process, as it is considered an index of product quality. It measures the finer irregularities of the surface texture. Achieving the desired surface quality is critical for the functional behavior of a part. Surface roughness influences the performance of mechanical parts and their production costs because it affects factors such as, friction, ease of holding lubricant, electrical and thermal conductivity, geometric tolerances and more. The ability of a manufacturing operation to produce a desired surface roughness depends on various parameters. The factors that influence surface roughness are machining parameters, tool and work piece material properties and cutting conditions. For example, in turning operation the surface roughness depends on cutting speed, feed rate, depth of cut, tool nose radius, lubrication of the cutting tool, machine vibrations, tool wear and on the mechanical and other properties of the material being machined. Even small changes in any of the mentioned factors may have a significant effect on the produced surface [38].

Therefore, it is important for the researchers to model and quantify the relationship between roughness and the parameters affecting its value. The determination of this relationship remains an open field of research, mainly because of the advances in machining and materials technology and the available modeling techniques. In machinability studies investigations, statistical design of experiments is used quite extensively. Statistical design of experiments refers to the process of planning the experiments so that the appropriate data can be analyzed by statistical methods, resulting in valid and objective conclusions. Design and methods such as factorial designs, response surface methodology (RSM) and taguchi methods are now widely use in place of one factor at a time experimental approach which is time consuming and exorbitant in cost [12].

1.2 Turning centre

Research in the machine tool field has become divided in to five main categories.

- 1. Machine Structure
- 2. Metal removal process
- 3. Bearings
- 4. Drives and control system
- 5. Guiding and safety

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In turning center all above five categories are there. The major weight is due to the weight of the structure and also turning is the metal removal process associated with the machine. So, turning centre is selected for this research work.

1. Machine Structure

The design and construction of turning centre should be such that it meets the following main objectives:

- (i) High precision and repeatability
- (ii) Reliability
- (iii) Efficiency

To meet the requirements of high precision, repeatability and high efficiency, the numerically controlled machine tools should have a structure that is correctly designed to withstand normal weight distribution. The higher cutting speeds and feeds in turning centre result in rapid acceleration and deceleration of the slides and the machines are subjected to fluctuating and variables forces during the machining operations. The machine structure should not bend due to the heavy cutting forces. All the parts of the machine structure should remain in relative relationship regardless of the magnitude and direction of the stresses developed due to these forces. Another source of inaccuracy in the CNC machines is the thermal distortion of the machine structure. The design of machine tool structures should be such that the thermal distortion is minimum and it should have capacity to withstand all the forces acting on it. The machine tool should be protected from external heat sources and the internal heat sources e.g. head stock motor should be placed centrally so that thermal effects are equally distributed. The machine tool should be provided with an efficient and foolproof lubrication and cooling system. Also the machine structure design should be such that removal of swarf is easy and the chips etc. do not fall on the slide ways.

2. Material removal process

Turning is the process associated with turning centre. Surface roughness is one of the most important requirements in machining process, as it is considered an index of product quality. In turning operation the surface roughness depends on cutting speed,

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feed rate, depth of cut, tool nose radius, tool cutting angle, tool wear, material hardness, coolant and machine rigidity etc. Even Small changes in any of the factors may have a significant effect on the produced quality of the job. So, it is important for the researchers to model and quantify the relationship between roughness and the parameters affected on it.

3. Bearings/slide ways

In the conventional machine tools, there is a direct metal to metal contact between the slide ways and the moving slides. Since the slide movements are very slow and machine utilization is also low, this arrangement is adequate for conventional machine tools. However, the demand on slide ways is much more in turning centre because of rapid movements and higher machine utilization. The conventional type of arrangement with metal to metal contact does not meet the requirements of numerically controlled machine tools. The design of slide way in turning centre should be:

- (a) Reduce friction
- (b) Reduce Wear
- (c) Satisfy the requirements of movement of the slides
- (d) Improve smoothness of the drive

To meet these requirements in CNC machine tool slide ways, the techniques used include hydrostatic slide ways, linear bearings with balls, rollers or needles and surface coatings. The guiding surfaces of the machines are sometimes coated with low friction material such as PTFE.

4. Drive and control units

Drive motors are required to perform the following functions:

- (i) To drive the main spindle (Spindle drive)
- (ii) To drive the saddle or carriage (Axis drive)

In addition there may be some more motors in the turning centre for services such as coolant pumps, swarf removal etc.

Spindle Drive

In turning centre, large variation in cutting speed is required. The cutting speed may vary from 10 meters per minute to 1000 meters per minute or more. The cutting speeds are provided by rotation of the main spindle with the help of an electrical motor through suitable gear mechanism. The multi change gear boxes with fixed speed ratios used in conventional machine tools are not suitable for turning centre. To obtain optimum cutting speeds and feeds, the drive mechanism should be such as to provide infinitely variable speeds between the upper and the lower limits. The infinitely variable speed systems used in turning centre employ either electrical motors (A.C. or D.C.).

Axis Drive

All the axis in a turning centre are controlled by servomotors. The movement along the different axis is required either to move the cutting tool or the work material to the desired positions. In order to accomplish accurate control of position and velocity, stepper motors are used for axis drive. The principal of working of a stepper motor is that on receiving a signal i.e. pulse, from the control unit, the motor spindle will rotate through a specified angle called step. The step size depends on the design of the motor and lies between 1.8 degree and 7.5 degree, which means that one rotation of the spindle can be divided into 200 parts. If a single pulse is received from the control system the motor spindle will rotate by one step. The control unit generates pulses corresponding to the programmed value of movement required of the tool or work. The rate of movement of tool or work is controlled by the speed at which the pulses are received by the stepper motor. The distance travelled by the carriage is calculated by the known value of lead of the axis lead screw and by counting the number of pulses. The rate at which pulses are sent to the stepper motor is accurately governed by the control system. Hence there is no need of providing positional or velocity feedback system. The use of steeper motor considerably simplifies the system as feedback devices are not used. The cost of the machine tool is also less. However stepper motors are suitable only for light duty machines due to low power output.

Control units

In turning centre the control of all machines functions is totally transferred to a computerized control system. The control unit should be situated so that it is convenient for the operator to operate the machine from central place. The facilities which a control unit should offer are:

1. Indicate the current status and position of various machine tool features and give feedback.

2. Allow manual or semi manual control of machine tool elements.

3. Enable machine tool to be programmed.

The control unit part for allowing manual control and programming of the machine may be housed on the machine structure itself or a separate control panel may be installed near the machine or it may be mounted on a swing arm to allow it to be adjusted according to the position of the operator.

The facilities for indication of present status of the machine features and to give feedback have to be provided at suitable place on the machine tool itself so that actual movement of slides, etc. can be monitored and feedback to the control system. To monitor the position of the slides, two types of transducers are used i.e., linear transducers and rotary transducers.

5. Guarding and Safety

Since the turning centre is under continuous automatic operation, there is a need to protect the machine guide ways and to ensure safety of the operator since the machines run at high speeds with automatic auxiliary operations. Protection of machine guide ways, drive screws and transducers, etc. is very important for efficient working and long life of the machine. Various types of collapsible guards and covers are used to protect those elements. All the sliding elements are fitted with wipers and the drive screws are normally protected by using telescopic covers. Jets of cutting fluid are used to wash away swarf and clear the tool work area. To ensure safe working conditions the turning centres are provided with metallic or plastic guards. Where it is not possible to provide effective guards, proximity protection is provided by light barriers.

1.3 Response Surface Methodology

Response surface methodology or RSM is a collection of mathematical and statistical techniques useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response. For example, suppose that a mechanical engineer wishes to find the levels of feed (x_1) and depth of cut (x_2) that maximize the yield (y) of a process. The process yield is a function of the levels of temperature and pressure, say

$$y = f(x_1, x_2) + \epsilon$$
 (1.1)

where \in represents the noise or error observed in the response y. If we donate the expected response by $E(y) = f(x_1, x_2) = \eta$, then the surface represented by

$$\eta = f(x_1, x_2)$$

is called a response surface.

In most RSM problems, the form of the relationship between the response and the independent variables is unknown. Thus the first step in RSM is to find a suitable approximation for the true functional relationship between y and the set of independent variables is employed. Usually a low-order polynomial in some region on the independent variables is employed. If the response is well modeled by a linear function of the independent variables, then the approximating function is the first-order model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k + \epsilon$$
 (1.2)

If there is curvature in the system, then a polynomial of higher degree must be used, such as the second-order model

$$y = \beta_0 + \sum_{i=1}^k \beta_i x_i + \sum_{i=1}^k \beta_{ii} x_i^2 + \sum_{i< j} \sum \beta_{ij} x_i x_j + \epsilon$$
(1.3)

Almost all RSM problems use one or both of these models. Of course, it is unlikely that a polynomial model will be a reasonable approximation of the true functional relationship over the entire space of the independent variables, but for a relatively small region they usually work quite well. By using response surface methodology and (3^4) full factorial design of experiment, quadratic model has been developed for different materials like AISI 1040 steel, AISI 410 steel, Mild steel and Aluminium with 95% confidence level.

In the next chapter, literature review about machine tool structure and surface roughness is discussed.