The working principle of milling machines

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In previous chapter, the literature review piece and objective of present work has been discussed. This chapter introduces the speculative background of response surface methodology, introduction of milling machine, cutting principal, milling cutter taxonomy, machining parameters, chip thickness formation and milling machine parameters which influence the surface roughness

2. 1 BACKGROUND

As an central subject in the statistical design of experiments, the Response Surface Methodology (RSM) is a collection of mathematical and statistical techniques useful for the modeling and analysis of harms in which a response of interest is influenced by several variables and the objective is to optimize this response RSM also quantifies dealings among one or more measured responses and the vital input factors. The DOE++ software was used to develop the untried plan for RSM. The same software has also used to analyze the data collected.

After analyzing each response, multiple response optimization technique have performed, either by inspection of the interpretation plots, or with the graphical and arithmetic tools provided for this purpose. It has mentioned previously that RSM designs also help in quantifying the dealings between one or more measured responses and the vital input factors. In order to determine if there stay alive a relationship between the factors and the response variables investigated, the data together must be analyzed in a statistically sound manner using regression. A regression is performed in order to describe the data unruffled whereby an observed, empirical variable (response) is approximated based on a functional bond between the estimated variable, yest and one or further regress or or input variable x1, x2,…, xi. The least square technique is being new to fit a model equation containing the said regressors or input variables by minimizing the residual error measured by the sum of square deviations between the actual and the probable responses. This involves the calculation of estimates for the regression coefficients, i. e., the coefficients of the representation variables including the intercept or constant term. The calculated coefficients or the model equation need to however be tested for statistical implication.

2. 2 MILLING MACHINE

2. 2. 1 Introduction

Milling machines was first invented and developed by Eli Whitney to mass construct interchangeable musket parts. Although makeshift, these machines assisted man in maintain exactness and uniformity while duplicating parts that can not be manufactured with the use of a file. Development and improvement of the milling machine and components continuous, which resulted in the manufacturing of heavier arbors and high speed steel and carbide cutters. These components allowed the operator to remove metal more rapidly, and with more accuracy, than prior machines. Variations of milling machines were also developed to perform special milling operations. During this era, computerized machines has been developed to alleviate error and provide better.

Milling are perhaps the most versatile machining operation and most of the shapes can be generated by this action. Unlike turning, shaping and drilling tools, the milling tool possesses a large number of cutting edges. Milling is the process of machining flat, curved, or asymmetrical surfaces by feeding the work piece against a rotating cutter containing a integer of cutting edges. The milling machine consists basically of a motor driven spindle, was mounts and revolves the milling cutter, and a reciprocate regulating worktable, which mounts and feeds the work piece.

Milling machines are basically classified as vertical or horizontal. These machines is also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines has self-contained exciting drive motors, coolant systems, variable spindle speeds, and power operated table feeds.

Milling machines play an significant role in most machine shops, machining metals to various shapes and sizes by means of a revolving cutting tool or tools having a number of cutting edges called teeth. Such tools has known as milling cutters or mills. In order to machine numerous configurations in a milling machine, man have developed various types of milling cutters to fit the necessary requirements. Most milling cutters has made of high speed steel; some employ the utilize of carbide teeth and inserts.[20]

The working principle, employed in the metal removing operation on a milling machine, is that the work has rigidly clamped on the board of the machine, or held between centers, and revolving multi-teeth cutter mounted moreover on a spindle or an arbor. The cutter revolves at a fairly high speed and the work fed leisurely past the cutter as shown in figure. The work can be fed in a vertical, longitudinal or cross direction. As the work advances, the cutter-teeth do away with the metal from the work surface to produce the desired shape. [21]

Figure2. 1: Working Principle of milling operation [21]

2. 2. 2 Milling Cutter Nomenclature

Figure 2. 2 shows two views of a common milling cutter with its parts and angles acknowledged. These parts and angles are common to all types of cutters in some form. The pitch refers to the angular distance between like parts on the adjoining teeth. The pitch is unwavering by the number of teeth. The tooth face is the forward facing surface of the tooth which forms the cutting edge. The cutting edge can the angle on each tooth which performs the cutting. The land is the fine surface behind the cutting edge of each tooth. The rake angle is the viewpoint formed between the face of the tooth and the centerline of the cutter. The rake angle defines the cutting edge and provides a path for chips that have cut from the work piece. The primary clearance angle is the viewpoint of the land of each tooth, measured from a line tangent to the centerline of the cutter at the cutting edge. This angle prevents every one tooth from rubbing against the work piece after it makes its cut. The secondary go-ahead angle defines the land of each tooth and provides supplementary clearance for the passage of cutting oil and the chips.

Figure 2. 2: The two views of a common milling cutter with its parts and angles identified. [21]

The hole diameter determines the size of arbor that is essential to mount the milling cutter. A keyway was present on all arbor-swelling cutters for locking the cutter to the arbor. Plain milling cutters that has more than 3/4 inch in width can usually made with spiral or helical teeth. A plain spiral-tooth milling cutter produces a better and smoother draw to a close, and requires less power to operate. A plain helix-tooth milling harvester is especially desirable where an jagged surface or one with holes in it have to be milled. The teeth of milling cutters are either right-hand or left-hand, viewed from the back of the machine. Right-hand milling cutters cut when rotate clockwise; left-hand milling cutters cut when rotated counterclockwise.

Saw Teeth: Saw teeth are whichever straight or helical in the smaller size of plain milling cutters, metal slitting saw milling cutters, and closing stages milling cutters. The cutting edge is usually given about 5° primary clearance angle. Sometimes the teeth have provided with offset nicks which shatter up the chips and make coarser feeds promising.

Formed Teeth: Formed teeth can usually specially made for machining unbalanced surfaces or profiles. The possible varieties of formed-tooth milling cutters are more or less unlimited. Convex, concave, and corner-rounding milling nail clippers are of this type.

Inserted Teeth: Inserted teeth had blade of high-speed steel inserted and rigidly held in a blank of machine steel or cast iron. unlike manufacturers bring into play different methods of holding the blades in place. Inserted teeth are more cost-effective and convenient for large-size cutters because of their reasonable initial cost and because worn or broken blades has be replaced more easily and at less price tag

2. 2. 2. 1 Recommended Angles for Milling Cutter

The angle between the face and the land of the cutter tooth is called lip angle (β). Its value depends upon the values of rake and relief angles. A larger lip angle ensures a brawny tooth. As such, the endeavor should be to keep it as large as practicable. This is particularly chief while milling harder metals and when deeper cuts to be employed. Cutters having helical teeth are made to contains a helix angle between 10- (degree) and 50- (degree) the recommended values of principal angles are given in the table [19]

Table 2. 1: Recommended Angles for Milling Cutter [21]

Material

Recommend values in degree

Rake angle(degree)

Relief angles(degrees)

H. S. S Tools

Stellite Tools

Cemented carbides

Cast iron(Soft)

10-15

6-8

3-6

4-7

Cast iron(Hard)

10

3-6

0-3

4-7

Mild steel

10-15

3-6

0-(-5)

3-5

Aluminum alloys

20-30

10-15

10-20

10-15

Brasses and Bronzes

10-12

5

2-3

10-15

Mg. alloys

20-30

15-20

15-20

10-12

2. 2. 3 Machining Parameters

2. 2. 3. 1 Selection of Speed

The approximate standards given in may be used as a guide for electing the proper cutting speed. If the operator finds that the machine, the milling cutter, or the work piece cannot be handle suitably at these speeds, instantaneous readjustments shouldcan be made. If carbon steel cutters have used; the speed should be about one-partially the recommended speed in the table. If carbide-tipped cutters are used, the speed could be doubled. If a bountiful supply of cutting oil is theoretical to the milling cutter and the work piece, speeds can be increased 50 to 100 percent. For roughing cuts, a moderate speed and coarse feed often give best results; for last cuts, the best practice is to reverse these conditions, by means of a higher speed and lighter feed.

The formula for manipulative spindle speed in revolutions per minute is as follows:

Where,

– Spindle speed (in revolutions per minute).

– Cutting speed of milling cutter.

– Diameter of milling cutter (in inches)

2. 2. 3. 2 Selection of Feed

The rate of feed, or the speed at which the work piece pass the cutter, determines the time obligatory for cutting a job. In selecting the feed, there are several factors which should be well thought-out are as follows:

Forces are exerted against the work piece, the cutter, and their property devices during the cutting process. The force exerted varies directly with the amount of metal unconcerned and can be regulated by the feed and the depth of cut. Therefore, the wrong amount of feed and depth of cut have interrelated, and in turn are dependent upon the rigidity and power of the machine.

The feed and depth of cut also depend upon the type of milling cutter being used. For example, deep cuts or foul-mouthed feeds should not be attempted when using a small diameter end milling cutter, as such an attempt would spring or break the cutter. Coarse cutters with muscular cutting teeth can be fed at a faster rate because the chips may be washed out more without problems by the cutting oil.

The feed of the milling machine may be selected in inches per minute or millimeters per minute the milling feed has determined by multiplying the chip size (chip per tooth) desired, the integer of teeth on the cutter, and the revolutions per minute of the cutter. Example: the formula used to hit upon the work feed in inches per minute

Where

– Feed rate in inches per minute

– Chip pert tooth

– Number of teeth per minute of the milling cutter

Figure 2. 3 shows the path of feed during the cutting operation. It is usually regarded as standard practice to feed the work piece against the milling cutter. When the piece is fed aligned with the milling cutter, the teeth cut under any weighing machine on the work piece surface and any backlash in the feed screw is taken up by the weakness of cut. As an exception to this recommendation, it is advisable to feed with the milling cutter, when cutting off accumulation, or when milling comparatively deep or long slots. The direction of cutter rotation had related to the behavior in which the work piece is held. The cutter should rotate so that the piece springs away from the cutter; then there will be no predisposition for the force of the cut to loosen the work piece. No milling cutter should be rotated toward the rear as this will break the teeth. Never revolutionize feeds while the cutter is rotating.

Figure2. 3 Direction of Feed during machining operation [21]

2. 2. 4 Chip Formation in Milling Operation

The scheme of chip formation during plain milling using a straight cutter is explained in figure 2. 4. The cutter has a diameter and the depth of cut provided by. When milling is done straight-edge cutter, the operation is orthogonal and the kinematics of chip formation is shown in figure 2. 4. Since all the cutting edges take part in machining, a study of the process is facilitated by considering the action of only a single tooth. If is the feed velocity of the table in mm/min, the effective feed per tooth in mm will be, where is the cutter rpm and is the number of teeth in cutter. The material removal rate per unit width of the job is given by. It is clearly seen from figure that the thickness of the uncut material in front of cutting edge increases gradually, reaching a maximum near the surface and again drops to zero quickly. If the feed velocity is small as compared with the circumferential velocity of the cutter, then

Figure 2. 4: Details of chip formation [22]

Where is the angle included by the contact arc at the cutter center O in radians. Now, considering the triangle OAT, we have

Hence,

Neglecting the higher order terms in as it is normally very small. Using this value of in the expression of the maximum uncut thickness, we get

It is obvious that when cutting with a straight cutter, there is no component of the cutting force along the straight cutter axis. The average uncut thickness can be taken as half of the maximum value. Thus, From the above equation show that when the depth of cut increases, the chip thickness increases so that increases the cutting resistance and the amplitude of vibrations. As a result, cutting temperature also rises. Therefore, it is expected that surface quality will deteriorate. When the feed rate increases, the chip thickness increases so that increases in cutting force and vibration.

2. 3 SURFACE ROUGHNESS PARAMETERS

Surface roughness is an chief factor when dealing with issues such as friction, lubrication, and wear. It also have a major impact on application involving thermal or electrical confrontation, fluid dynamics, noise and vibration control, dimensional tolerance, and abrasive processes, among others. The resultant roughness fashioned by a machining process can be thought of as the amalgamation of two independent quantities

Ideal roughness: Ideal surface roughness was a function of feed and geometry of the tool. It represents the best promising finish which can be obtained for a given tool shape and feed. It can be achieved only if the built-up-edge, chatter and inaccuracies in the machine tool activities are eliminated completely. For a sharp tool without nose radius, the maximum height of disproportion is given by

$R_{max} = f/(\cot \varphi + \cot \beta)$

Here f is feed rate, φ is major cutting edge angle and β is the inconsequential cutting edge angle. The surface roughness assessment is given by

$R_a = R_{max}/4$

Idealized model of surface roughness have been without a doubt shown in Figure 2. 5. Practical cutting tools was usually provided with a rounded corner, and figure shows the surface produced by such a tool under ideal conditions. It can be shown that the roughness assessment is personally related to the feed and corner radius by the following expression:

Ra= 0. 0321 f 2/r

Where, r is the corner radius.

Figure 2. 5: Idealized Model of Surface Roughness [20]

Natural roughness: In practice, it is not usually possible to achieve environment such as those described above, and normally the natural surface roughness forms a outsized proportion of the actual roughness. One of the main factors causative to natural roughness is the occurrence of a built-up edge and vibration of the machine tool. Thus, superior the built up edge, the rougher would be the surface produced, and factors tending to reduce chip-tool friction and to eradicate or reduce the built-up edge would give improved surface finish.

The Principal fundamentals of surfaces are as follows:

Surface: The surface of an object is the boundary which separate that object from another substance. Its shape and extent has usually defined by a drawing or descriptive specifications.

Profile: It is the form of any specified section through a surface.

Roughness: It was defined as closely spaced, irregular deviations on a scale smaller than that of waviness. Roughness may be superimposed on waviness. Roughness is uttered in terms of its height, its width, and its distance on the surface along which it is precise

Waviness: It is a recurrent deviation from a flat surface, much like impression on the surface of water. It is measured and described in terms of the freedom between adjacent crests of the waves (waviness width) and height between the crests and valleys of the impression (waviness height). Waviness can be caused by

Deflections are tools, dies, or the work piece,

Forces or temperature sufficient to cause warp,

Un flush lubrication,

Vibration

Any intermittent mechanical or thermal variations in the system during

Manufacturing operations.

Flaws: Flaws, or defects, are random irregularities, such as scratches, crack, holes, depressions, seams, moan, or inclusions as shown in Figure 2. 5

Lay: Lay or directionality is the direction of the predominant surface pattern and was usually noticeable to the naked eye. Lay direction have been shown in Figure 2. 5

Figure 2. 6 Surface Characteristics [20]

2. 3. 1 Factors Affecting the Surface Finish

Whenever two machined surfaces come in make contact with with one another the quality of the mating parts the stage an important role in the performance and wear of the mating parts. The height, shape, arrangement and track of these surface irregularity on the work piece depend upon a number of factors such as:

The machining variables which affect the surface roughness has spiteful speed, feed and depth of cut.

The factors of tool geometry which affect to achieve surface draw to a close are nose radius, rake angle, side cutting edge position, cutting edge

Work piece and tool material combination and their mechanical property

Quality and type of the machine tool new

Auxiliary tooling, and lubricant second-hand

Vibrations connecting the work piece, machine tool and cutting tool.

2. 3. 2 Factors Influencing Surface Roughness in Milling Machine

The various factors which influence surface roughness of work piece in the milling machine are:

Depth of cut: escalating the depth of cut increases the cutting resistance and the amplitude of vibrations. As a result, cutting temperature also rises. Therefore, it has expected that surface eminence will deteriorate.

Feed: Experiments show that as feed rate increase surface roughness also increases due to the increase have cutting force and vibration.

Cutting speed: It is found that an increase of cutting speed generally improves surface eminence.

Engagement of the cutting tool: This factor acts in the same way as the distance downward of cut.

Cutting tool wears: The irregularities of the cutting edge due to wear are reproduce on the machined surface. Apart from that, as tool wear increases, other dynamic phenomena such as unwarranted vibrations will occur, thus further deteriorating surface quality.

2. 4 CONCLUDING REMARKS

In this chapter, the working principal of milling machine is presented. The categorization of milling cutter with its parts and angles are presented. Machining parameters which affect the surface roughness, chip thickness formation and factors influence surface roughness in milling machine are also presented in this chapter.