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Optimization of Drilling Parameters for Minimum Surface Roughness Using Taguchi Method

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ABSTRACT

The objective of the work is to analysis of surface properties in drilling of different die steels used in manufacturing industries. A study of the machining sector showed the drilling process is one of the most important due to both number of operations and machine time consumed. The importance of this process is even higher in aerospace industry, heat exchanger, die making and in aircraft manufacturing. As surface roughness is the main problem in drilling of various materials. This is due to various process parameters whether it is due to controllable or uncontrollable factors. The surface roughness will result in about 30% of parts reduction. The roughness will measure from surface roughness tester and average value of surface roughness will find out. The design of experiment approach has been applied for designing the experimentation work. The optimization of process parameters has been done by analysing the results.

Keywords: *Drilling, Taguchi method, Analysis of Variance, surface roughness.*

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1. INTRODUCTION

Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi-point cutting tools called drills or drill bits. Drilling is a continuous machining process. Various cutting tools are available for drilling, but the most common is the twist drill. Wide variety of drill processes are available to serve different purposes (core drilling, step drilling, counter boring, counter sinking, reaming, center drilling, gun drilling etc.).With the rapidly growing technologies quality and productivity are the major concern. Productivity is concerned with the material removal rate (MRR) during machining operation and quality refers to the product characteristics. So the quality and productivity can be improved through parameters optimization.There are number of research works related to various drilling parameters optimization for achieving the performance responses. Among them surface roughness, material removal rate (MRR) and thrust forces on drill bit are the major performance responses. Material removal rate (MRR) is the primary response variable while considering productivity. The material removal rate depends on input parameters and the machine during drilling operation. So the primary objective of optimization analysis during drilling operation is to optimize the input parameters. Also material removal rate (MRR) play a major role in surface roughness. The primary objective in all the research works relating to drilling parameter optimization is to optimize the input parameters such as spindle speed, fees rate, drill bit diameter etc. Simply the optimization means improving the material removal rate and reducing the surface roughness value. The other aspect governing the drilling parameter optimization is quality of the product. Quality relating to the product characteristics like surface roughness, wear resistance, cost etc. Design of experiment and analysis of experimental data play a significant role in parameters optimization and cost of optimization. Among all the design of experiment techniques Taguchi method is the simplest one. Analysis of variance (ANOVA) is used for analyzing the data obtained during experiment. The grey relational analysis is the most accurate and effective analysis tool for the data obtained during CNC drilling.Many of the researches in parameter optimization uses wide variety of design experiments and analysis focused on different performance parameters and different materials. So this paper concentered on drilling parameters optimization in different material using Taguchi method.

1.1. Drilling:

Drilling is a most common and complex used industrial machining processes of creating and originating a hole in mechanical components and work piece. The tool used, called a drill and the machine tool used is called a drill machine. Drilling can also be define as a rotary end-cutting tool having one or more cutting edges called lips, and having one or more helical or straight flutes for the passage of chips and passing the cutting fluid to the machining zone. The drilling operations performed on a drilling machine, which rotates and feed the drill to the work piece and creates the hole. Drilling usually performed with a rotating cylindrical tool that has two cutting

edges on its working end (called a twist drill). Rotating drill fed into the stationary work piece to form a hole whose diameter is determined by the drill diameter. Drilling makes up about 25% of all the machining processes performed.A variety of drilling processes (Figure 1) are available to serve different purposes. Drilling is used to drill a round blind or through hole in a solid material. If the hole is larger than ~30 mm, a smaller pilot hole is drilled before core drilling the final one. For holes larger than ~50 mm, three-step drilling is recommended. Core drilling is used to increase the diameter of an existing hole. Step drilling is used to drill a stepped (multi-diameter) hole in a solid material. Counter boring provides a stepped hole again but with flat and perpendicular relative to hole axis face. The hole is used to seat internal hexagonal bolt heads. Countersinking is similar to counter boring, except that the step is conical for flat head screws. Reaming operation is usually meant to slightly increase the size and to provide a better tolerance, surface finish and improved shape of an initially drilled hole. The tool is called reamer. Center drilling is used to drill a starting hole to precisely define the location for subsequent drilling operation and to provide center support in lathe or turning center. The tool is called center drill that has a thick shaft and very short flutes. Gun drilling is a specific operation to drill holes with very large length-to-diameter ratio up to 300. There are several modifications of this operation but in all cases cutting fluid is delivered directly to the cutting zone internally through the drill to cool and lubricate the cutting edges, and to remove the chips.

1.2. Drill Geometric Attributes:

Drill bits are cutting tools used to create cylindrical holes. Bits held in a tool called a drill, which rotates them and provides torque and axial force to create the hole. Different point angle drills and different diameter drills and of different length of drills can be used according to the application of work. Drills with no point angle are used in situations where a blind, flat-bottomed hole is required. These drills are very sensitive to changes in lip angle, and even a slight change can result in an inappropriately fast cutting drill bit that will suffer premature wear. Diameters range of twist drill is about 0.15 to 75 mm. Body, Point, and Shank are three basic parts of twist drill twist drill has two spiral or helical grooves called flutes separated by Lands. Angle of spiral flute is call as the helix angle around 30°. Flutes helps for extraction of from the hole. Web is the thickness of the drill between the flutes and it support the drill support over its length. Point of the twist drill has the general shape of a cone having a typical value of 118°. Point can be design in various ways. However, most common design is a chisel edge. The spiral, or rate of twist in the drill, controls the rate of chip removal in a drill. A fast spiral drill is use in high feed rate applications under low spindle speeds.

2. CONVENTIONAL MACHINING:

Conventional machining in which a sharp cutting tool is used to mechanical cut the material to achieve the desired shape, size and geometry. The predominant cutting action in machining involves shear deformation of the work material to form a various kinds of chips; as the chips removed, a new surface is exposed, that is called as machined surface. Machining is a most frequently applied to shape metals.

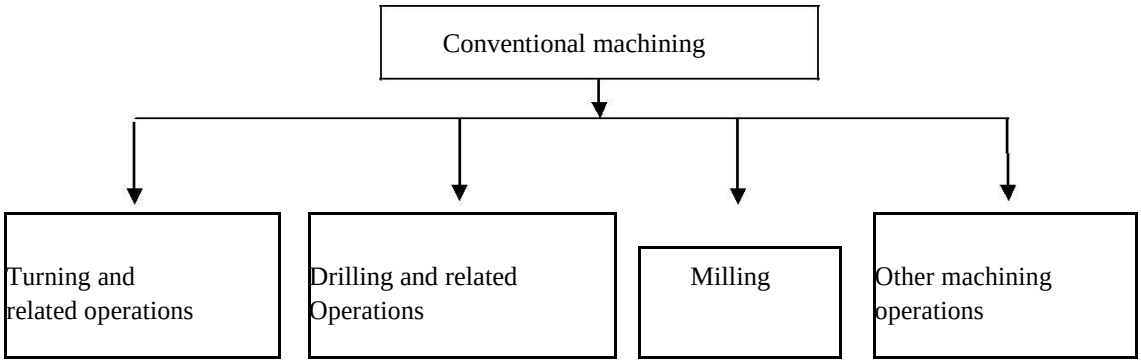

Figure: 2.1 Classification of conventional machining

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lips, and having one or more helical or straight flutes for the passage of chips and passing the cutting fluid to the machining zone. The drilling operations performed on a drilling machine, which rotates and feed the drill to the work piece and creates the hole. Drilling usually performed with a rotating cylindrical tool that has two cutting edges on its working end (called a twist drill). Rotating drill fed into the stationary work piece to form a hole whose diameter is determined by the drill diameter. Drilling makes up about 25% of all the machining processes performed. Drilling is really a Complex Process, because

Only exit for the chips is the hole that filled by the drill.

- Friction results in heat in addition to that due to chip.

Counter flow of chips makes lubrication and cooling difficult.

Cutting action takes place inside the work piece. Feathers of drilling machines are

In drilling drill, tips are design to heat up to provide for the plastic flow of metal.

In drilling chips formed are usually long.

HISTORY OF DRILLING MACHINE

Drilling machines was first invented and developed by "Arthur James Arnot and William Blanch Brain" The twist drill bit was invented by Steven A. Morse. who received U.S. Patent 38119 for his invention 'Improvements of Drill-Bits" in 1863. The original method of manufacture was to cut two grooves in opposite sides of a round bar, then to twist the bar to produce the helical flutes. This gave the tool its name. Development and improvements of the drilling machine and components continued, which resulted in the manufacturing of heavier arbors and high speed steel and carbide drills. These components allowed the operator to remove metal faster, and with more accuracy, than previous machines. Variations of drilling machines were, also developed to perform special drilling operations. During this era, computerized machines have been developed to alleviate errors and provide better quality in the finished product. The drilling machine has revolutionized industrial work of every kind and made so such a lot of complex tasks seem easy. Drilling is the cutting process of using a drill bit in a drill to cut or enlarge holes in solid materials, such as wood or metal. Different tools and methods are using in drilling depending on the type of material, the size of the hole, the number of holes, and the time to complete the operation. Drilling is a cutting process in which a hole is originated or enlarged by means of a multi point fluted, end-cutting tool. As, the drill is rotating and advanced into the work piece, material is removed from work in the form of chips that move along the fluted shank of the drill.

TYPES OF DRILLED HOLES

- Through holes: Drill exits from the opposite side of the work piece called through hole. hole depth is equal to the work piece thickness or height.

- Blind holes: Drill does not exit from the opposite side of the work piece called blind hole, hole Depth is less than work piece thickness or height.

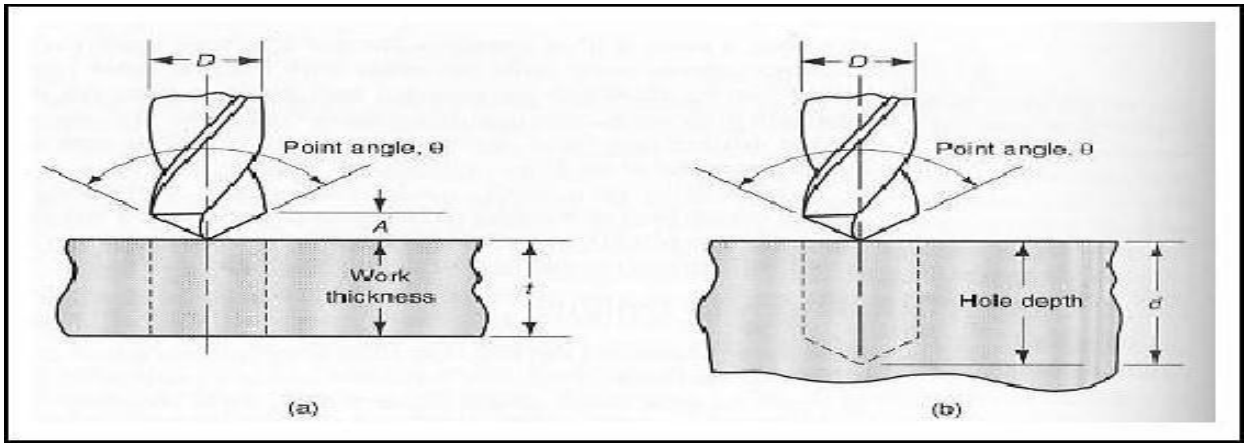

Figure: 2.2 Types of drilled holes

RADIAL DRILLING MACHINE

Radial Drilling machine is a machine fitted with a rotating cutting tool called drill bit. This radial drilling machine is use for drilling holes in various materials such as steel, cast iron, composite, plastic and concrete etc. The use of machine is in the metal working industry. A radial drilling machine is a large gear headed drill press in which the head moves along the arm that radiates from the column of the machine. The arm of the machine can swing in relation to the base of the machine. This swing operation helps the drill head to move out of the way so a large crane can place the heavy work piece on the base of the radial drilling machine. In addition, this helps in drilling holes at different locations of the work piece without actually moving the work piece. Power feed of the spindle is a common feature. In addition, coolant system is a common feature of the radial drilling machine. When it comes to mechanical machining, radial drilling machine is used for all functions such as drilling, counter boring, spot facing, lapping, screwing reaming, tapping and boring. Radial drilling machines work well with a variety of material such as cast iron, steel, plastic etc. Drilling machines hold a certain diameter of drill (called a chuck) rotates at a specified rpm (revolutions per minute) allowing the drill to start a hole. A radial drilling machine or radial arm press is a geared drill head that is mounting on an arm assembly that can be move around to the extent of its arm reach. The most important components are the arm, column, and the drill head. The drill head of the radial drilling machine can be move, adjusted in height, and rotated. Aside from its compact design, the radial drill press is capable of positioning its drill head to the work piece through this radial arm mechanism. This is probably one of the reasons, why more machinists prefer using this type of drilling machine. In fact, the radial drilling machine considered the most versatile type of drill press. The tasks that a radial drilling machine can do include boring holes, countersinking, and grinding off small particles in masonry works. Although some drill presses are floor mounted, the most common set-up of radial arm drill presses are those that are mounting on workbenches or tables. With this kind of set-up, it is easier to mount the drill and the work pieces. There is no need to reposition work pieces because the arm can extend as far as its length could allow. Moreover, it is easier to maneuver large work pieces with the radial arm-drilling machine. Large work pieces we can mount on the table by cranes as the arm can be swiveled out of the way.

KINEMATIC SYSTEM OF GENERAL PURPOSE DRILLING MACHINE AND THEIR PRINCIPLE OF WORKING:

Kinematic system in any machine tool is comprised of chain of several mechanisms to enable transform and transmit motion from the power source to the cutting tool and the

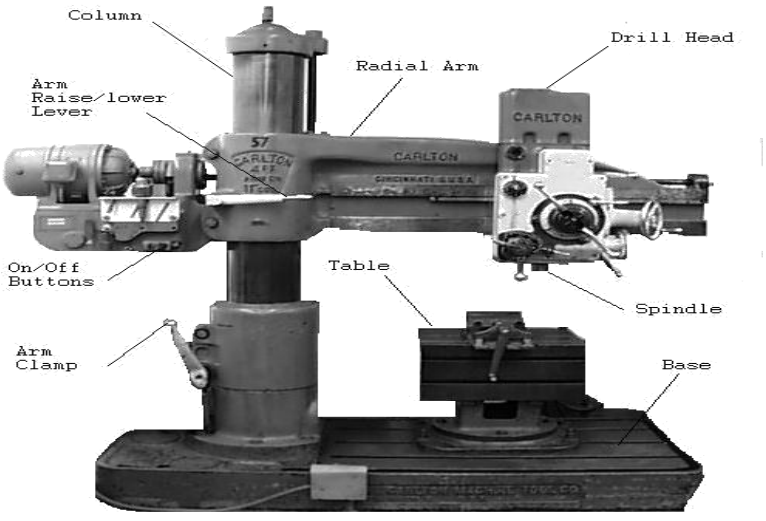

Figure: Radial drilling machine

work piece for the desired machining action. The kinematic structure varies from machine tool to machine tool requiring different type and number of tool-work motions. Even for the same type of machine tool, say column drilling machine, the designer may take different kinematic structure depending upon productivity, process capability, durability, compactness, overall cost etc targeted. Typical kinematic system of a very general-purpose drilling machine are, a column-drilling machine having 12 spindle speeds and 6 feeds. The kinematic

system enables the drilling machine the following essential works as:

Cutting Motion

The cutting motion in drilling machines is attain by rotating the drill at different speeds (rpm) Like centre lathes, milling machines etc, drilling machines also need to have a reasonably large number of spindle speeds to cover the useful ranges of work material, tool material, drill diameter, machining and machine tool conditions. It is show that the drill gets its rotary motion from the motor through the speed gearbox (SGB) and a pair of bevel gears. For the same motor speed, the drill speed can be change to any of the 12 speeds by shifting the cluster gears in the SGB. The direction of rotation of the drill can be change, if needed, by operating the clutch in the speed reversal mechanism.

Feed Motion

In drilling machines, generally both the cutting motion and feed motion are imparted to the drill. Like cutting velocity or speed, the feed (rate) also needs varying (within a range) depending upon the tool-work materials and other conditions and requirements. The drill receives its feed motion from the output shaft of the SGB through the feed gearbox (FGA), and the clutch. The feed rate can be change to any of the six rates by shifting the gears. In addition, the automatic feed direction can be reverse, when required, by operating the speed reversal mechanism. The slow rotation of the pinion causes the axial motion of the drill by moving the rack provided on the quill. The upper position of the spindle is reduced in diameter and splined to allow its passing through the gear without hampering transmission of its rotation.

Tool Work Mounting

The taper shank drills are fitted into the taper hole of the spindle either directly or through taper socket. Small straight shank drills are fitted through a drill chuck having taper shank. The work piece is kept rigidly fixed on the bed (of the Table). Small jobs are generally held in vice and large or odd shaped jobs directly mounted on the bed by clamping tools using the T-slots made in the top and side surfaces of the bed.

TAGUCHI METHODOLOGY:

The Taguchi methodology is one of the optimizing techniques that based on the design of experiments (DOE) approach. The experiments analysis will propose to conduct using the design of experiments technique. Although full factorial designs can be use where in all the possible combinations can be test, we would use fractional factorial analysis methods for the experiment.

The Taguchi Design is a design of experiment (DOE) approach developed by Dr. Genichi Taguchi in order to improve the quality of manufactured goods in Japan. Although similar to factorial design of experiment, the Taguchi design only conducts balanced (orthogonal) experimental combinations, which makes the Taguchi design even more efficient than a fractional factorial design. The Taguchi methodology has been proposed to overcome the limitations of full factorial analysis by simplifying and standardizing the fractional factorial design . Taguchi methodology involves identification of controllable and uncontrollable factors and the establishment of series of experiments to find out optimal combinations of the factors that has the greatest influence on the performance and least variation from the target of the design. The main advantage of Taguchi Design is its efficiency in that multiple factors can be consider at once and the optimal parameters can be identified with fewer experimental resources than the traditional (DOE) approach. In addition, Taguchi design allows looking into the variation caused by control factors and noise factors, while the variation caused by noise factors is usually ignore in the traditional DOE approach.

Taguchi methods as an engineered system that comprises four main components as illustrated in Fig. 3.6. It is designed to employ energy transformation in converting input signal into specific, intended function requested by customers by applying the laws of physics. Taguchi methods advocate that when all the applied energy is transformed into creating its intended function without any noise effects, a system reach its ideal function. As shown in Fig. 3.7 at the most common way of expressing the system's ideal function is

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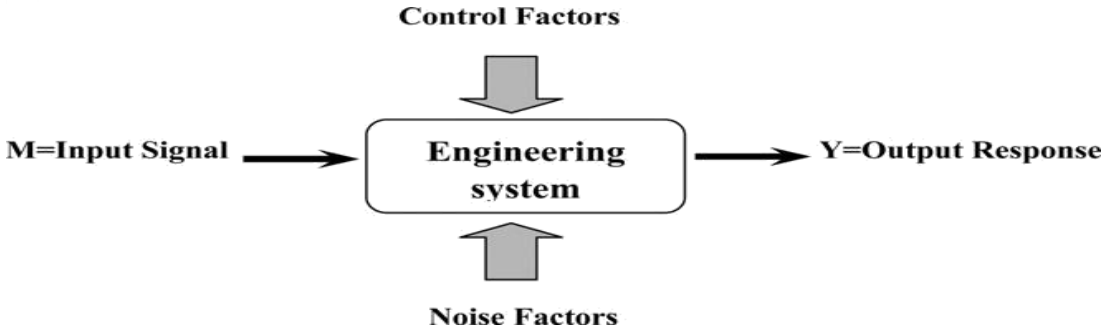

Figure: Experimental designs

PROCEDURES OF TAGUCHI METHOD

The brief procedure of Taguchi method is as under

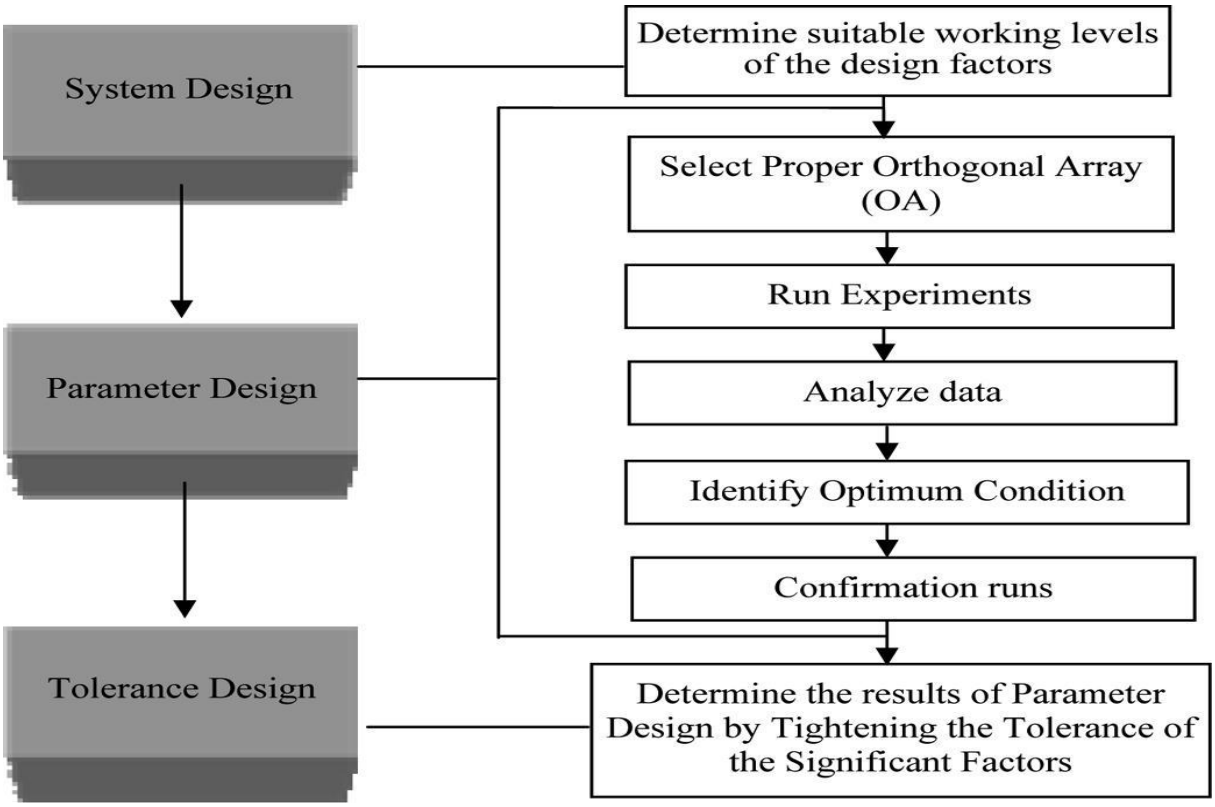

Figure: Taguchi design procedure

3. CONCLUSION:

The present study was carried out to study the effect of input parameters on the MRR, surface roughness, hole diameter error, burr height. The following conclusions have been drawn from the study:

- MRR is mainly affected by cutting speed and drill diameter.
- Surface roughness is mainly affected by work piece material, drill diameter and cutting speed
- Hole diameter is mainly affected by work piece, feed, drill material and cutting speed
- Burr height is mainly affected by feed drill material and cutting speed.

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