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(Review Article)

Review of Boring Process Parameter for Geometric Dimension & Tolerances

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Abstract

Changing the focus to a significant channel of manufactured item components. The chosen machines come in many types of Capabilities, to satisfy the requirements. The machine part met the standards for dimensions and geometrical tolerances. In addition to meeting geometrical requirements, it is one of the most often utilized metal removal processes in the industry since it can remove material more quickly while still providing a reasonably excellent surface quality. One of the most important requirements for bored components to carry out their specified tasks is geometric conformity. In addition to the dimensional criteria, there are other geometrical requirements such as circularity, cylindricity, perpendicularity, etc. The impact of the cutting settings on them is more significant because they directly affect assembly. The present state of the research in this field is highlighted in this paper.

Keywords: Boring, Vertical Milling Machine, Cylindricity, Perpendicularity.

1. Introduction

A process called machining is used to alter the size, shape, and surface properties of a workpiece made using an originating technique like casting, forging, or rolling. A workpiece is given its final shape and size through machining by removing the extra material. The wedge-shaped single point/multipoint cutting tool of defined geometry is used to eliminate the layers of extra material from the workpiece to construct the actual drawing components. [31]

2. Boring Process

A workpiece's existing hole can be made larger or finished via the machining technique of boring. The procedure is removing material from the inner diameter of the workpiece with a single-point cutting tool to produce a round hole with a predetermined size and surface finish.

A lathe, Computerized Numerical Machine (CNC), Vertical milling machine (VMC), or a specialist boring machine can all be used for boring. The boring bar, which is placed into the workpiece and supported by a tool post or boring head, is typically used to hold the cutting tool. The cutting tool is fed into the hole while the workpiece rotates, gradually eliminating material until the hole is the right size and finish.

The allowable variance in the size, shape, orientation, and placement of the borehole is determined by geometric dimension and tolerance (GD&T) throughout the boring process. Some of the often utilized GD&T in boring include the following:

- Diameter: The diameter of the borehole is the dimension that is most frequently stated. A nominal size, like 50 mm, and a tolerance, like +/- 0.01 mm, are generally included.
- Roundness: The roundness of a borehole is a measurement of how closely it resembles a perfect circle. It is described as a tolerance zone where the hole surface must fall.
- Concentricity is a measurement of how closely the workpiece's rotational axis and the axis of the borehole line up. The axis of the hole must lie within the given tolerance zone.
- Position: The location of the drilled hole with a reference datum is measured by position. It is described as a tolerance zone that the hole center must fall within.
- Surface finish: The roughness of the surface of the borehole is measured by the surface finish. Ra 0.4 m, for example, is the maximum roughness height that is defined.

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These GD&T parameters help to ensure that the borehole is produced within the required tolerances and meets the design requirements for fit and function. They also help to ensure that the parts are interchangeable and can be assembled correctly. Precision items like engine cylinders, bearing housings, and hydraulic components are frequently made utilizing boring. Moreover, it can be used to repair worn or broken holes in current parts. With tight tolerances and superior surface finish, holes produced by boring can be extremely accurate and exact. [11, 14, 16, 31]

3. Literature Review

The change of vibration, cutting forces, and tool wear under various cutting conditions were explored to conduct an extensive investigation on the dimensional accuracy and surface roughness. The spindle speed has little to no impact on the surface roughness. On the other hand, cutting depth and spindle speed have a major impact on dimensional accuracy, however, the nose radius has little to no impact. The investigation of tool wear and vibration revealed that the impact of vibration on dimensional accuracy is much greater than the impact of tool wear. Additionally, it was found that when the feed rate was increased from a specific number, the surface roughness did not only not considerably alter but in some instances decreased. [1]

For both dry and RQL machining, it was determined by Box-Behnken design (BBD) and analysis of variance (ANOVA) that Feed rate (f) is the most important input variable on roughness mean values. The waviness that the dry machining had left behind was removed by the use of RQL. [2]

The design of experiments has been utilized to investigate the impact of key turning parameters on the surface roughness of AISI 410 steel, including feed rate, tool nose radius, cutting speed, and depth of cut. Based on those factors, a mathematical surface roughness prediction model has been created. Using the Response Surface Methodology, it has been determined how these characteristics affect the surface's roughness. (RSM). Response surface contours were built to identify the ideal circumstances for a specific level of surface roughness. The established prediction equation demonstrates that the feed rate is the primary component that determines surface roughness, followed by tool nose radius. It was discovered that the surface roughness increased as the feed increased and decreased as the feed increased. [3]

The surface characteristics of average and maximum roughness as well as roundness were chosen as the quality objectives. Through GRA, the ideal parameter combination for the CNC boring process was discovered. It is possible to determine the extent to which each controllable process component has an impact on specific quality targets by looking at the grey relational grade matrix. The feed rate is found to have the most impact on the average and maximum roughness, whereas the cutting speed has the greatest impact on roundness. According to the weighted total grade of the roughness average, roughness, and the analysis of variance (ANOVA) that was used to determine the most significant factor, the feed rate is the most significant controlled factor for the CNC boring operations. [4]

In this study, regression analysis is used to optimize cutting parameters such as speed, feed, and coolant flow for mild steel SAE1541 utilizing Taguchi parameter optimization methods. The quality goals were chosen to be surface roughness. According to the results of the investigation, coolant flow rate, and cutting speed have a less substantial impact on surface roughness than feed rate and cutting speed. [5]

Important factors including speed, feed, and depth of cut, among others, have an impact on the surface finish. The optimization of tedious process variables is difficult and time-consuming. Taguchi's robust design is a crucial tool that provides a straightforward and methodical approach to improving a design's performance, quality, and cost. [6]

By using the Taguchi technique and analysis of variance to look at the workpiece's surface roughness, it was possible to analyze the impact of vibration in boring. (ANOVA). It has been demonstrated that using Vibration Cutting when boring significantly reduces surface roughness. They suggested the shading-area method as a straightforward and workable method for the analysis of burrs in crossing holes. Effectively reducing the burr formation in intersecting holes is high-frequency vibration boring. According to the testing findings, using Vibration Cutting significantly lessens the burrs in intersecting holes. [7]

To discover the ideal process parameter for CNC finishing machining, a signal-to-noise ratio was used. When examining the performance characteristics of machining parameters (spindle speed, feed, depth, and width), high surface quality and high material removal rate (MRR) are taken into account using an L9 orthogonal array and analysis of variance (ANOVA). Surface finishing and the velocity of material removal have been recognized as quality features and are thought to be directly related to rising productivity. The feed is the most efficient factor for MRR, and the results produced by the Taguchi technique and signal-to-noise ratio nearly match those obtained by (ANOVA). And the best factor for surface roughness is spindle speed. Surface roughness and material removal rate multiple regression equations are developed to estimate the projected value. [8]

For CNC drilling machining, the signal-to-noise ratio was used to determine the best process parameter. To examine the performance characteristics of machining parameters (spindle speed, feed, and depth) with consideration of good surface finish as well as high material removal rate (MRR), an L9 orthogonal array and analysis of variance (ANOVA) are utilized. One of the main demands of customers of machined products is surface finishing. The feed is the most efficient factor for MRR, and the results produced by the Taguchi technique and signal-to-noise ratio nearly match those obtained by (ANOVA). And the best factor for surface roughness is spindle speed. Surface roughness and material removal rate multiple regression equations are developed to estimate the projected value. [9]

Using digitally controlled computer lathe and ceramic cutting tools in two different geometries and three different material grades, Inconel 718 is machined under dry cutting circumstances. The process of removing metal is done at four distinct cutting speeds while maintaining a constant cutting depth of cut and feed rate. The experiments show that the ceramic cutting tool with the KYON 2100 SNGN 120712 geometry produces the lowest main cutting force while the ceramic cutting tool with the KYON 4300 RNGN 120700 geometry produces the highest main cutting force. [10]

Investigations on the effects of various cutting conditions, such as spindle speed, feed rate, inserts, and coatings, are being done to decrease the boring cycle time and enhance the quality of the cylinder holes. During the procedure, cutting forces are measured with a dynamometer in real time. Under various cutting settings, the surface roughness of the engine cylinders, flank, and crater tool wear are measured and compared. The cost of the automotive engine boring process can be greatly decreased by choosing appropriate cutting conditions that allow cutting pressures to be controlled below a threshold value, cycle time to be shortened, tool life to be extended, and part quality to be increased. [11]

On AISI 316 stainless steel, studies were conducted to determine the surface roughness and RMS of workpiece vibration. RSM, ANN, and SVM statistical models were created to predict surface roughness and the RMS of workpiece vibration. The influence of nose radius, cutting speed, and feed rate on the reactions were investigated using an ANOVA. Impacts of edge geometry and workpiece hardness two-factor interactions, the cutting speed and feed rate, as well as the edge geometry and feed rate, also seemed to be significant. Better surface roughness was achieved by using specifically honed edge geometry and workpieces with decreased surface hardness. It is discovered that cutting-edge geometry, workpiece hardness, and cutting speed have an impact on force components. The refined edge shape and decreased workpiece surface hardness. Impacts of a two-factor Interactions between the edge geometry, the feed rate, the cutting speed, and the workpiece hardness Feed rates also seemed to be significant. Better surface roughness was produced, especially by sharpened edge geometry and lower workpiece surface hardness. It is discovered that cutting-edge geometry, workpiece hardness, and cutting speed have an impact on force components. Decreased tangential and radial forces were produced as a result of the workpiece's decreased surface hardness and tiny edge radius. [12]

On AISI 316 stainless steel, studies were conducted to determine the surface roughness and RMS of workpiece vibration. RSM, ANN, and SVM statistical models were created to predict surface roughness and the RMS of workpiece vibration. The influence of nose radius, cutting speed, and feed rate on the reactions were investigated using an ANOVA. With the use of RSM, ANN, and SVM algorithms, surface roughness and RMS of workpiece vibration velocity were predicted. In terms of predicting cutting parameters, ANN and SVR were discovered to be superior to the RSM model. [13]

The studies were carried out using cemented carbide tool inserts to bore AISI 316 steel. Eight experiments using two levels of cutting parameters were carried out according to the prepared experimental design. Through evaluation of the workpiece's vibration amplitude and surface roughness, the effects of cutting parameters were examined. Roughness and the amount of removed metal. To determine the significant cutting factors influencing the workpiece vibrations, surface roughness, and volume of metal removed, Taguchi, analysis of variance, and regression analysis techniques were utilized. Cutting speed is identified as a major parameter for the vibration's amplitude. Nose radius effect on tool nose radius. It was discovered that feed rate and cutting speed significantly contribute to the amount of metal removed. [14]

Using Taguchi DOEs and analysis techniques, it was experimentally determined how the turning process parameters cutting speed, feed rate, depth of cut, material hardness, cutting insert form, relief angle, and nose radius affected flank wear and surface roughness. ANOVA was used to determine the significance of the effects of the control parameters, their levels, and the percentage contribution of these effects to the variation in the response variables. The ideal flank wear and surface roughness values for the best configuration of the control parameters are found.1 [15]

This study uses artificial neural networks to construct a tool displacement (amplitude of vibration), cutting temperature, and tool wear prediction model for the boring process. (ANNs). On all-geared head lathes with the experimental setup, a full factorial design was used for the experimentation. The neural network model, which was created using the feed-forward back propagation technique using training data and tested using test data, is used to verify the effectiveness of the constructed model. The percentage deviation and average absolute % deviation have been used to assess the model's ability to forecast tool displacement (vibration amplitude), cutting temperature, and tool wear data. The projected values by the ANN model closely match the outcomes of the experiments. [16]

The findings of a study employing a 3-level factorial design of an experiment-based response surface methodology to examine the impact of machining conditions on a few performance measures during dry and hard boring of ASTM

A304 low alloy steel round bars with tungsten-carbide inserts are presented in this work. Modeling, predicting, and optimizing the performance parameters with restrictions on variance in the machining settings were included. To simulate, forecast, and determine the ideal machining conditions and the relevant performance characteristics, use Design Expert software. The study showed that the control variables had a range of effects on the response variables, with cutting speed being the most important factor for tool wear, cutting temperature, and material removal rate. As a result, it is advised that the determined values of these parameters be used for the best machining possible of the aforementioned material. [17]

In this paper author studies cutting parameters that affect surface roughness, tool wear, cutting force, tangential force, and workpiece vibration while boring AISI 4340 steel, statistical mathematical models have been constructed. 27 experiments are carried out using AISI 4340 as the workpiece material and multi-layered coated carbide inserts coated with TiCN, Al2O3, and TiN. The GRA is utilized to optimize a single objective of grey relational grade from a multi-response optimization issue. The author identifies that cutting parameters affect surface roughness, flank wear, cutting force, tangential force, and vibration of the workpiece. [18]

Taguchi-based grey relational analysis is used to examine and optimize the effects of the machining parameters cutting speed, feed rate, and depth of cut, as well as the geometrical parameters cutting insert shape, relief angle, and nose radius. To investigate the effects of change in carbide insert geometry, 18 ISO-specified uncoated cemented carbide inserts with various shapes were turned on practically used automotive axles. Based on tests created using Taguchi's Design of tests, performance metrics such as flank wear, surface roughness, and material removal rate (MRR) were optimized using grey relational grading. (DoE). To reduce flank wear and surface roughness and to increase MRR, a weighted grey relational grade is generated. Cutting insert shape is the most important characteristic that influences output reactions, followed by feed rate and depth of cut, according to an analysis of variance results. A higher MRR is associated with lower flank wear and surface roughness in an experiment carried out under the identified optimum condition. The calculated confidence interval, which is contained within the interval's width, is used to confirm the outcomes of the confirmation process. [19]

The boring bar vibrations are the primary focus of this article. Accelerometers have been used to measure the vibrations caused by boring bars in alloyed steel, stainless steel, and cast iron in both the cutting speed direction and the cutting depth direction. A boring bar's dynamic response appears to be a time-varying process that displays nonlinear actions. Non-stationary parameters that are not in the operator's or experimenter's control have an impact on the process. [20]

The focus of this work is on the optimal parameter selection for a passive dynamic vibration absorber (DVA) attached to a boring bar. The stability of the system was examined in terms of the bar and absorber properties after the boring bar was modeled as an Euler-Bernoulli cantilever beam. A traditional method for unconstrained optimization issues has been utilized to get the absorber's ideal settings. [21]

In this work, an experimental examination of the effects of cutting parameters, boring tool material, and boring tool overhang ratio (tool clamping length) on the deviation from the circularity of a bored hole. The examination of the signal-to-noise (S/N) ratio in the Taguchi technique can be used to estimate the ideal cutting condition. Using the Analysis of Variance, the individual contributions of each factor to the divergence from circularity were computed. (ANOVA). Therefore, it might be seen whether a factor is important or not at the determined condition. Additionally, it was found that at lower values for the depth of cut, the values of departure from circularity greatly increased with an increase in the effective tool length. Additionally, by increasing the depth of cut values for the same tool clamping lengths, the circularity might be enhanced. [22]

By optimizing parameters (cutting speed, feed rate, depth of cut, and cutting tool nose radius), the current research efforts attempted to obtain the lowest possible coaxiality error on cylindrical machined items. The central composite design matrix and statistical analysis will be used in experiments to see how machine settings affect the coaxiality error of the high-strength alloy Al 7075. Significant effects on coaxiality error were seen for the factors of feed rate and depth of cut. The coaxiality error was not linearly influenced by any machining parameter, defining the significant interaction factor effects. The Big-Bang, Big Crunch, and Rao (Rao-1, Rao-2, and Rao-3) algorithms were utilized to determine a set of machining settings that would minimize coaxiality error using the empirical equations that were derived. Big Bang and Big Crunch algorithms are outperformed by Rao algorithms in terms of computation effort and solution accuracy. [23]

In this work, grey relational analysis is used to explore and optimize the effects of machining factors such as cutting speed, feed rate, and depth of cut (canned cycle). (GRA). The basis for reliable experiments is a 33-full factorial that is replicated twice. To forecast cylindricity and perpendicularity, second-order regression models are created. Calculating the correlation coefficient has been used to assess the models' suitability. It demonstrates how well-fitted the generated models are for predicting outcomes within the specific range of input variables. [24]

The drilling performance was examined and optimized in this study concerning various unique drill geometries, cutting speeds, and feed rates. To do it, the ANOVA-related Taguchi S/N technique was used. Dimensional precision, cylindricity, and perpendicularity—objectives that are not mutually exclusive and that are optimized under the same machining conditions—were the performance measurement criteria. The authors created, made, and used the investigated drill bits in their tests. Cylindricity, perpendicularity, and concentricity depend on drill geometry, Cutting speed, and feed rate. [25]

Aside from dimensional criteria, the geometrical requirements include circularity, cylindricity, perpendicularity, and others. The impact of the cutting settings on them is more significant because they directly affect how the components work. [26]

Using twist drills, the machinability of GLARE® fiber metal laminates was examined. The hole size, circularity, cylindricity, and perpendicularity were all examined. The goal was to investigate how drilling and three different drill coatings (TiAlN, TiN, and AlTiN/TiAlN) affected the specified hole quality metrics. There has never been researched done utilizing the same drill geometry to examine the impact of drill coatings on different GLARE® grades to determine hole quality. Drill coatings have a significant impact on drilling aeronautical multi-materials comprised of composites and metals because they can increase surface polish and extend drill life. [27]

To acquire the empirical model and to optimize the process parameters, drilling operations utilizing HSS have been performed in the Mg AZ31. The author observed that Circularity, Perpendicularity, and Cylindricity depend on Spindle speed, Feed rate, and Drill diameter [28]

This article describes an experimental study and analysis of electrical discharge machining (EDM) of the super alloys Inconel 718 and 625. Turbine blades, marine parts, and nuclear reactor components are made with the help of these super alloys. For the exact super alloy components with cylinder, square, and hexagonal machined features, regular estimations of cylindricity, circularity, perpendicularity, and parallelism are necessary. This work involved the EDM of the aforementioned super alloys and the analysis of form tolerances. We looked at the impact of the input parameter's peak current, pulse-on time (Ton), and pulse-off time (Toff) on the form tolerances. [29]

The grey relational grade (GRG), which is obtained from the grey relation analysis (GRA) for different response characteristics, such as the material removal rate (MRR), tool wear rate (TWR), circularity (CIR), cylindricity (CYL), and perpendicularity, determines the ideal machining inputs (PER). An analysis of variance is used to identify the significant parameters. (ANOVA). Finally, a confirmation test is used to validate the optimized process parameters that result in a greater MRR, lower TWR, lower form tolerance, and decreased orientation tolerance, proving that the sparking process responses may be successfully enhanced. [30]

4. Parameter Selection in the Boring Process

4.1 Speed: Speed is the rate at which a cutting tool or workpiece rotates; it is typically expressed as the number of rotations per minute (RPM). According to the type of material being machined and the particular cutting tool being used, the speed of the cutting tool should be chosen to determine how quickly it removes material from the workpiece. [26]

4.2 Feed: In machining, the term "feed" refers to the speed at which the cutting tool travels across the workpiece. This speed is typically expressed in inches per minute (IPM) or millimeters per minute (MM/min). The material being machined, the type of cutting tool, and the desired surface smoothness should all be taken into consideration when choosing the feed rate, which influences how much material is removed with each pass of the cutting tool. [26]

4.3 Depth of cut: The depth of cut, which is often expressed in inches or millimeters, relates to the space between the cutting tool and the workpiece during each tool pass. The material being machined, the kind of cutting tool being used, and the required surface finish should all be taken into consideration when choosing the depth of cut, which influences how much material is removed with each pass of the tool. [31]

4.4 Effect of cutting parameter: To achieve the desired qualities and geometrical features during the machining process, the choice of tool geometry and tool material is also crucial.

To fulfill the functional requirements, the machine tool and cutting tool are chosen along with the machining parameters like cutting speed, feed, depth of cut, etc.

Due to the vibrations or deflections of the boring bar, the surface roughness, tool wear, and cutting forces are all impacted by the boring operation. [31]

5. Geometrical Dimensions

Geometric Tolerance is categorized as

- Form Tolerance (Flatness, Straightness, Circularity, and Cylindricity).
- Profile Tolerance (line and a profile of a surface.}
- Orientation Tolerance (Perpendicularity, Parallelism, and Angularity).
- Run out Tolerance (Circular Runout and Total Runout).
- Location Tolerance (Position, Symmetry, and Concentricity). [24]

5.1 Cylindricity: A cylindrical object's degree of deviation from being exactly cylindrical is referred to as its cylindricity in metrology, the science of measuring. To put it another way, it is a measurement of how closely a cylinder's shape resembles the ideal cylinder shape.

A measuring tool like a coordinate measuring machine (CMM) or a roundness tester is commonly used to determine cylinder size. The equipment measures the cylinder at several points along its length, and the degree of cylindricity is calculated using the data.

Cylindricity is important in many industries where cylindrical components are used, such as in the manufacturing of engine blocks, pistons, and hydraulic cylinders. In these applications, even small deviations from perfect cylindricity can affect the performance and reliability of the component. Therefore, manufacturers often specify strict tolerances for cylindricity to ensure the quality and performance of their products. [24, 26]

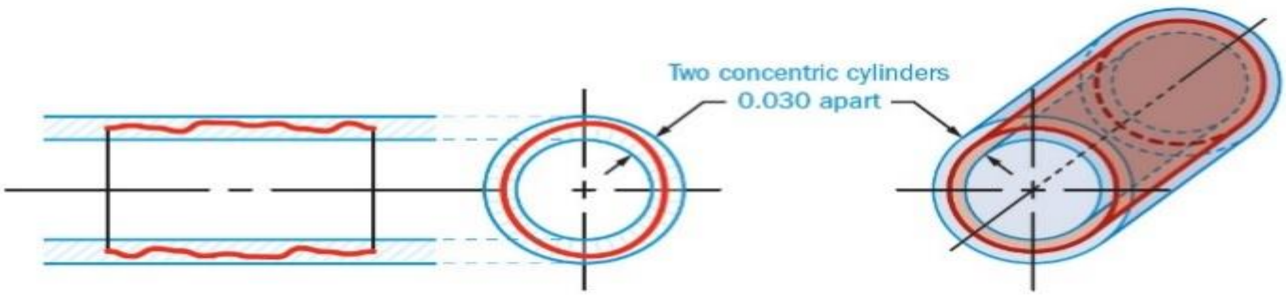

Figure 1. Cylindricity

5.2 Perpendicularity: In geometry and metrology, the term "perpendicularity" is used to indicate how closely a surface or line is perpendicular, or at a right angle, to a reference plane or line. It is a measurement of how nearly a surface or line is lined up with a perfectly vertical or horizontal plane or line, to put it another way.

A measuring tool, such as a coordinate measuring machine (CMM) or a laser alignment tool, is commonly used to determine perpendicularity. To calculate the degree of perpendicularity, the instrument measures the angle between the surfaces or line being measured and the reference plane or line.

Perpendicularity is important in many industries where precise alignment is critical, such as in the manufacturing of machine tools, automotive components, and aerospace structures. Even small deviations from perfect perpendicularity can affect the performance and reliability of the component, so manufacturers often specify strict tolerances for perpendicularity to ensure the quality and performance of their products. [24, 26]

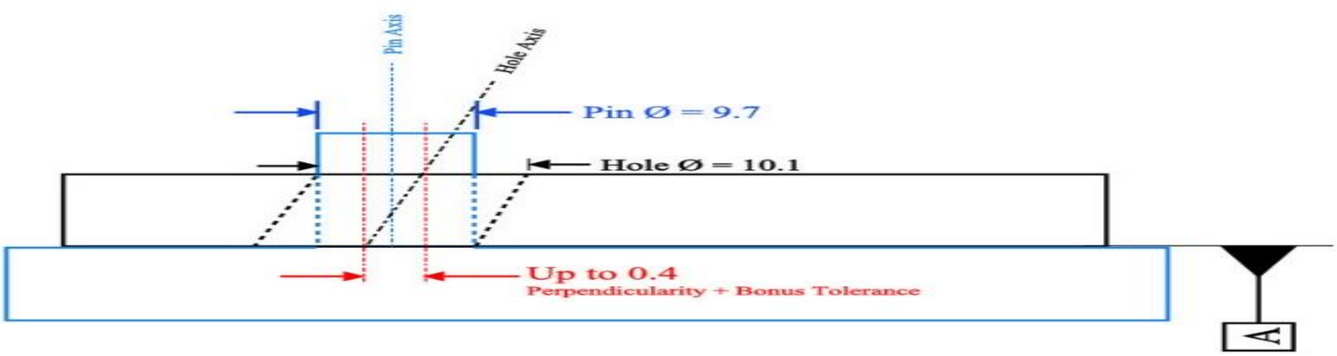

Figure 2. Perpendicularity

6. Material Specification

In this experimental work C70S6 material which is used to manufacture connecting rod the chemical composition of this material is given in table-1.

Table 1. Composition of C70S6 material. [32]

Designation%	Min.	Max.	Actual
C	0.67	0.73	0.70
Mn	0.48	0.70	0.59
Si	0.15	0.25	0.18
S	0.60	0.75	0.72
P	-	0.045	0.02
Cr	0.10	0.20	0.16
Mo	-	0.06	0.04
Ni	-	0.20	0.075
Cu	-	0.010	0.13
Fe	Remaining		

Table 2. Physical properties. [32]

Tensile strength	900-1050 N/mm^2
Yield strength	550 N/mm^2
%Elog.	8% Min
%Red. Are	10% Min

7. Conclusions

In this work review is conducted on Boring Process Parameter for Geometric Tolerances. The conclusion for this study can be summarized as below.

- By referring most of the research paper speed, feed, depth of cut, tool geometry, coating and nose radius is most significant parameter which is responsible for Geometry error, roughness, vibration, tool wear and Quality of component.
- Different method of optimization use like RSM, GRA, ANN, TAGUCHI.
- Geometrical dimension and tolerances majority depend on speed feed, and depth of cut.

The study of geometrical tolerances has a lot of potentials, according to a review of the literature, as it is crucial for assembly and results in higher component conformity.

The majority of study is conducted on the different kinds of errors involved in reaching these limits. The strategies for error compensation are also established. Nonetheless, some attention must be paid to the task involving cutting parameters, including its analysis, contribution, and selection to minimize geometrical mistakes.

According to the literature, however, cylindricity and perpendicularity are crucial geometric properties for the boring process as well since they influence workpiece assembly and cost.

During the literature review found that very little work has been reported on the boring process considering cylindricity and perpendicularity. However, it is a critical geometry parameter

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