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The effects of machining parameters during face milling of d2 hardened steel

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Abstract:

The report is going to discuss the experimental investigation of the parameters that effects the D2 Hardened steel during the Face Milling process. The parameters that are going to be discussed here are the Speed, Feed rate and Depth of Cut. In addition, Surface Roughness and Chips Morphology is also going to be studied and discussed in this report. D2 steels are particularly used in long run applications such as the forming dies or thread rolling dies so it becomes essential to study and optimise the parameters that are included in the Face Milling process. The properties of D2 steel is also been taken into concern before the machining process. The main focus of the modern machining industries are on achievement of high quality in terms of the Surface Roughness and to reduce the irregularities on the surface of the material. The Research problem is to find the optimum combination of the drilling variables in order to get the desired shape and surface. The Graphs are plotted from the derived experimental values of surface roughness after each trials. The optimization study has been successfully completed upon its objectives, where the main parameters that affect the mechanical properties of Face Milling operation were identified among the parameters chosen.

Keywords: Face Milling, D2 Hardened Steel, Surface Roughness, Real Coded Genetic Algorithm (RCGA), Chips Morphology, Spindle Speed, Feed Rate, Depth of Cut.

I. INTRODUCTION

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the unwanted material. The cutter is a cutting tool with sharp teeth that is also secured in the milling machine and rotates at high speeds. The main focus of the modern machining industries are on achievement of high quality in terms of the Surface Roughness and to reduce the irregularities on the surface of the material. The geometry of the cutting tool, work materials and parameters like the spindle speed, feed rate and depth of cut directly affects the milling operations. So, the investigation of such parameters are being essential to optimize the milling operation. The experimental investigation of milling of D2 hardened steel will be discussed briefly in this paper. Figure 1 shows the Face milling process in which the tool is being fed into the workpiece.

II. PROBLEM STATEMENT

In Face milling operation, the parameters play a significant role over the quality of the machined surface. The quality of the surface is dependent on the machining parameters such as spindle speed, feed rate, and depth of cut and material thickness. The Research problem is to find the optimum combination of the drilling variables in order to get the desired shape and surface.

With this ultimate goal in mind, this project addresses the following questions:

- What are range of the spindle speeds and depth of cut is going to be used for this Face milling operation?
- How could the feed rate and depth of cut effect the quality of the surface of the material?

- What is the best combination of these parameters shall be used to attain the minimum surface roughness possible?

III. LITERATURE REVIEW

Milling is the machining process of using rotary cutters to remove material from a work piece by advancing or feeding in a direction at an angle with the axis of the tool. The depth of the face, typically very small, may be machined in a single pass or may be reached by machining at a smaller axial depth of cut and making multiple passes, see Figure 2 [1]. The face milling shall be carried out using both the vertical and horizontal kind of milling machines. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes. Three forces is created between the tool and the machining surface, see Figure 3. The feed force is created using the feed rate and the depth of cut whereas the back force is due to the resistance force of the material [2]. The feed force and the back force always acts perpendicular to each other.

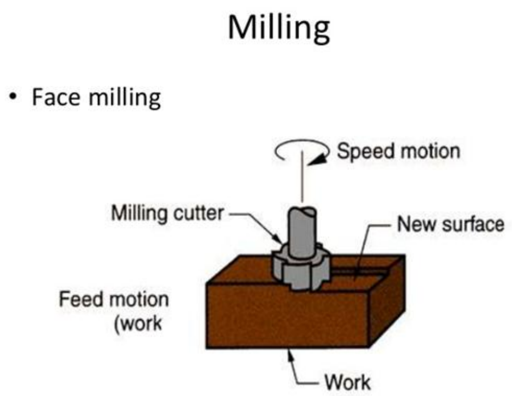

Fig.1, Process of Milling

However in all metal cutting operation, there are few important elements of machining that need to take into account. For milling operation, elements that need to consider are spindle speed, feed rate and depth of cut. The details regarding these elements are discussed below [3]:

Cutting speed is the rate at which the metal is being removed from the surface when machine's spindle rotates at a speed 'n' and it is typically measured in m/min.

Vc = (Dc * 3.14 * n) / 1000 m/min
'Dc' is Diameter of the cut
'n' is the speed of the spindle

Feed rateis the relative velocity at which the cutter is advanced along the work piece. Feed rate is measured in mm/min.

Vf = fz * Z * n mm/min
'fz' is feed per tooth
'Z' is No. of. Teeth
'n' is the spindle speed

Depth of cutis the thickness of the metal that is removed in one cut. It is the perpendicular distance between the machined surface and the non-machined surface of the work piece. It is usually measured in mm.

IV. D2 HARDENED STEEL

D2 steel is an air hardening, high-carbon, high-chromium tool steel. It has high wear and abrasion resistant properties. It is heat treatable and will offer a hardness in the range 55-62 HRC, and is machinable in the annealed condition. D2 steel shows little distortion on correct hardening.D2 steel's high chromium content gives it mild corrosion resisting properties in the hardened condition. As the steel is high strength steel, it is considered to be low in toughness and machinability [4]. This steel been widely used in the industries due to its special characteristics. Some of the D2 steel common applications are blanking, drawing dies and as machine parts.

There are some previous work regarding AISI D2 steel as they investigated the surface integrity with hardness of 62 HRC under high speed condition using tools called PCBN [5]. The researches, Kishawy and Elbestawi, design the experiment by using 140-500 m/min for the cutting speed range, 0.05-0.2 mm/rev for the feeds range, depths of cut in the range between 0.2 to 0.6 mm, and using edge, sharp, honed and chamfered tools [5]. They found out that, the surface roughness increased as the wear of the tool increased when the cutting speeds exceed 350 m/min and this was due to material side flow. Moreover, some defects were observed such as micro-cracks and cavities on the surface of the workpiece that been machined. The destiny of the micro-cracks produced were found out to be affected by the cutting speed and feed. In their study also, they found out that when machined with worn tools, but not the sharp tools, some white layer will be formed onto the machined surface.

Other than that, Poulachon and his group of researchers had studied regarding the wear behaviour when turning hardened steels [6]. One of the hardened steel that they investigates is the AISI D2 steel and all the steels are tested with hardness of 54 HRC. They observed that under identical conditions, the steels showed different flank wear rates.

V. SURFACE ROUGHNESS

Surface roughness often shortened to Roughness, is a component of surface texture. Surface finish of milled components has massive influence on the quality of the finished product. Surface finish in milling had been found to be influenced in varying amounts by a number of factors such as feed rate, work hardness, built-up edge, cutting speed, depth of cut, cutting time, cutting edge. According to these parameters, a comprehensive literature survey is carried out by Srikanth and Kamala [7] developed a Real Coded Genetic Algorithm (RCGA) to locate optimum cutting parameters and explained its advantages over the existing.

The mechanism behind the formation of surface roughness is very dynamic, complicated, and process dependent. Several factors will influence the final surface roughness in a CNC end milling operation such as controllable factors (spindle speed, feed rate and depth of cut) and uncontrollable factors (tool geometry and material properties of both tool and work piece) [8]. The below graph shows the difference in the metal removal rate values and its difference between the predicted and measured values during the milling operation, See Figure 4.

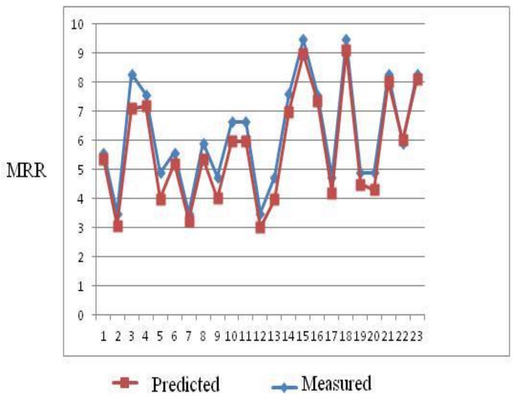

Fig.2, Metal Removal Rate

By insertion of the total operating time into the model in order to reflect the effect of the tool wear on surface roughness, it was possible to use the same tool during the experimentation. In this way, the measurement of the tool wear after each run was bypassed and the time consumed during the experimentation was shortened [9]. If these deviations are large, the surface is rough; if they are small, the surface is smooth, See Figure 5 [10]. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion. In view of past reviews did by Garg and Goyal [11], they stated that technological quality of a product can be measured by surface roughness. Mechanical properties of machined parts such as corrosion resistance and fatigue behaviour are influenced by surface roughness as it is one of the critical performance parameter. Therefore, it is vital to obtain the desired surface quality for the mechanical parts functionality. Ra is the arithmetic roughness which means the mean arithmetic deviation from the mean line of the roughness as given in the equation below:

$$Ra = \frac{\Sigma A + \Sigma B}{L}$$

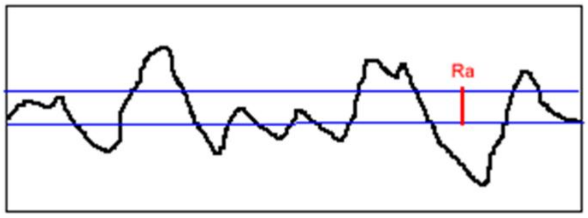

Fig. 3, Arithmetic Value of Ra

VI. METHODOLOGY

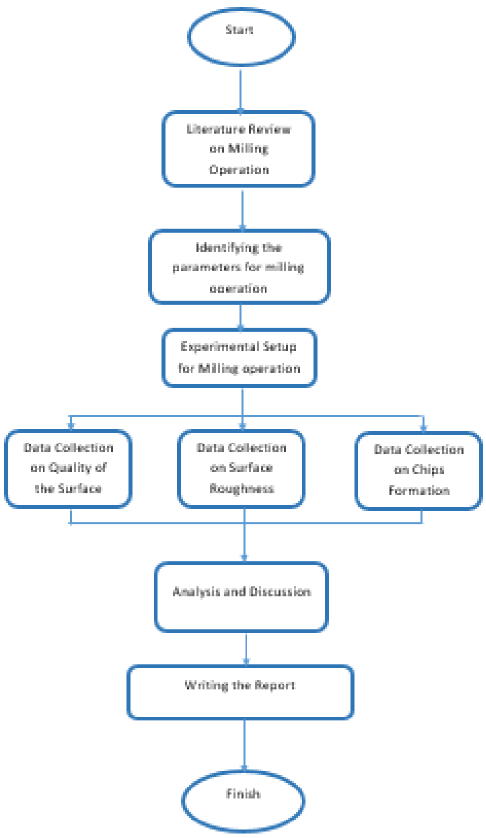

Fig. 4, Process Flow

VII. EXECUTION OF EXPERIMENT

There will be in total of 9 sets of trials will be carried out and 3 consecutive machining has to be done for each trial. The machining will be done using the TIN coated carbide tool, 3 different cutting speed (500, 800 and 1000 rpm) while the depth of cut is varied (12.5, 25, 50) and for different depth of cuts (0.3, 0.6 and 1 mm).

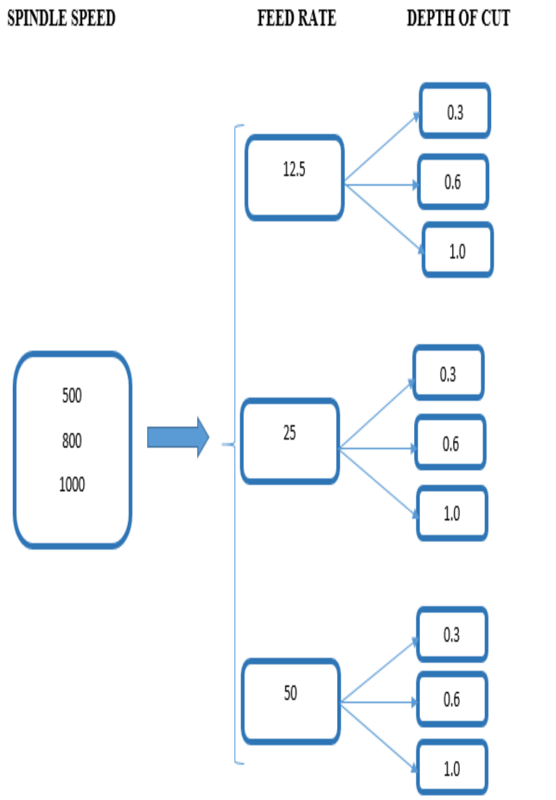

Fig. 5,Execution of Experiment

In addition, the following assumptions are made:

1. The cutting tools used are identical in property and a new tool is used for every operation.
2. The hardness of each work piece is same throughout the length of the work piece.
3. Surface roughness values measured within the measuring area are sufficient to represent the roughness of entire work piece.
4. Vibration is negligible.
5. Cutting edge of the tool is constant.

VIII. RESULTS

The results are drawn after the machining operation gets completed after each set of trials. The results are gathered using the surface roughness and the chips morphology. The surface roughness is measured for every 10 mm and plotted in a graph for every trial. The graphs are also made with respect to the individual parameters such as the spindle speed, feed rate and depth of cut.

The graphs on the surface roughness given below shows the difference in surface roughness with respective to the length and combination of the effect of all parameters.

Three random graphs of surface roughness for three different sets of trials are given below,

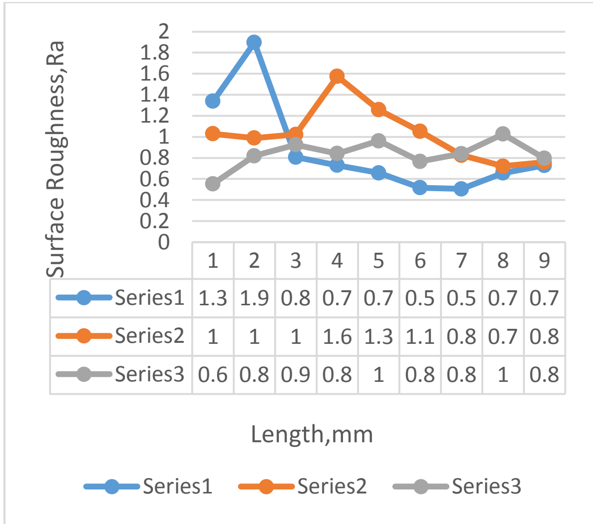

Fig.6, Graph of Series 1

Also, after every specimen, the cutting tool was cleaned to avoid chip formation or a built-up edge (BUE) which might affect the surface roughness of the specimens.

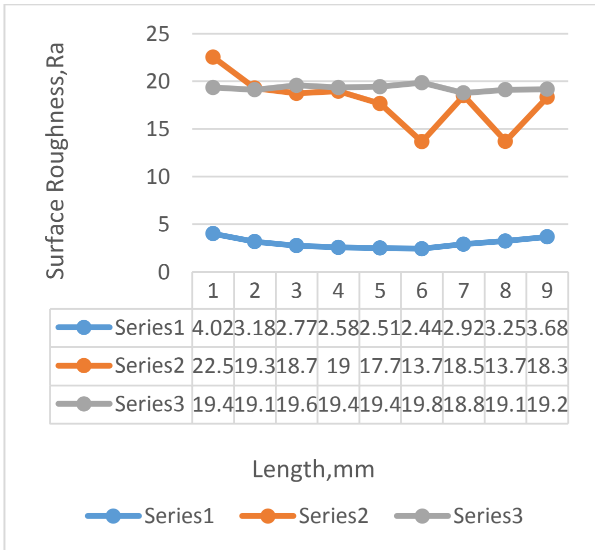

Fig. 7, Graph of Series 2

Since the feed rate gets doubled, the surface roughness gets increased and thereby the depth of cut is also increased so that the surface roughness reaches its maximum level of 20+. But the series 1 clearly shows a lesser roughness in comparison to the other two series because of the lesser depth of cut. In addition to the surface roughness, the machine also experienced certain vibrations.

It is being confirmed from the next graph that the lesser depth of cut provides us the minimum surface roughness, but on the edges of the material the surface roughness is always being high.

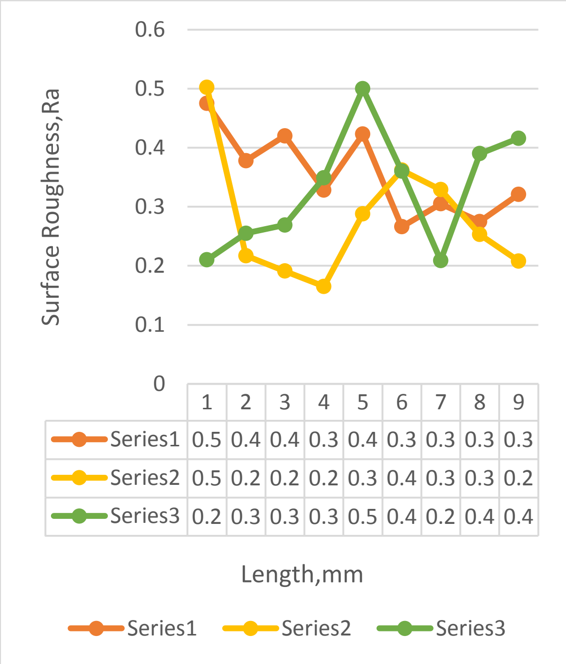

Fig 8, Graph of Series 3

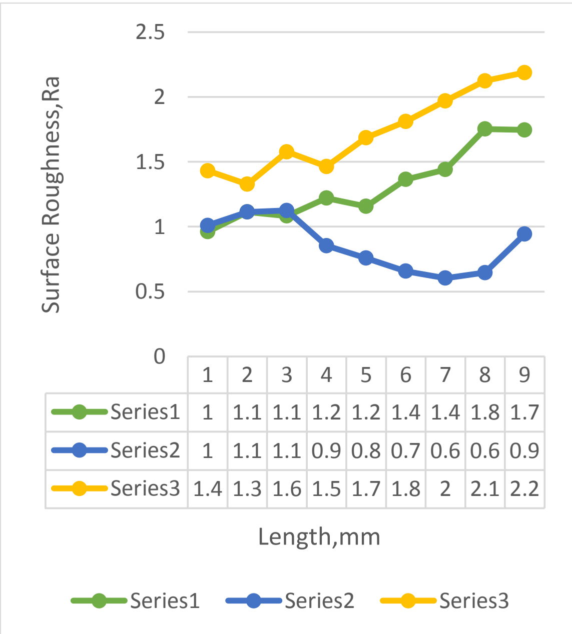

Fig.9, Graph of Series 4

Even the speed of 1000 rpm with a higher feed rate of 50 m/min shows higher roughness value that other trials so that we shall know the importance of the feed rate in the face milling process.

Three graphs are also plotted with respective to the Surface Roughness and individual parameters.When the Speed gets decreased the friction coefficient would increase because of the time of contact between the tool and a particular point of the surface.

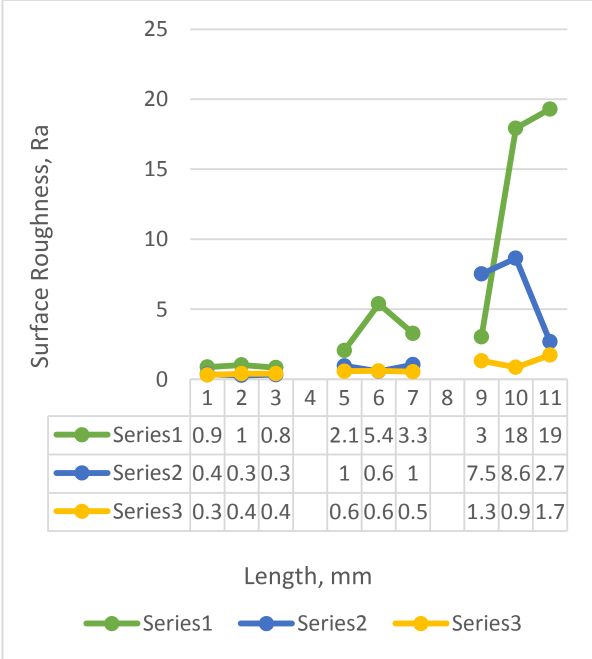

Fig. 10, Graph Surface Roughness VS Speed

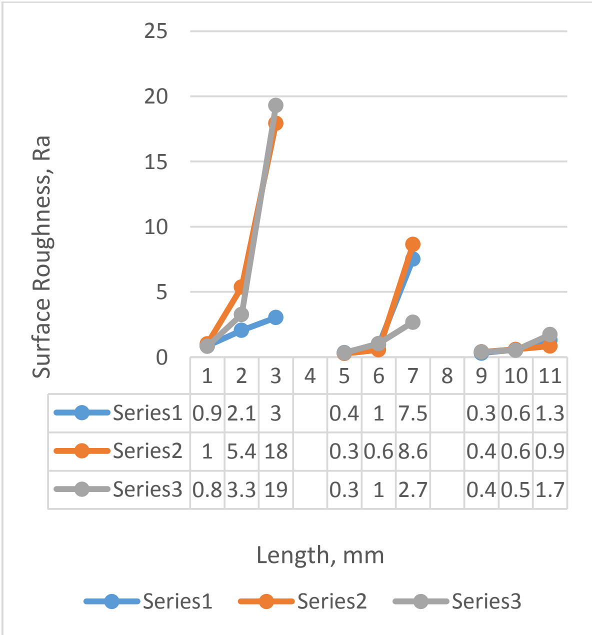

Fig.11, Graph Surface Roughness VS Feed Rate

For the first two speeds of 500, 800 rpm the surface roughness gets very high because of the incompetence of the speed to the feed rate. Whereas in a higher speed of 1000 rpm the surface roughness has got decreased significantly since the speed compensates the effects of the feed rate.

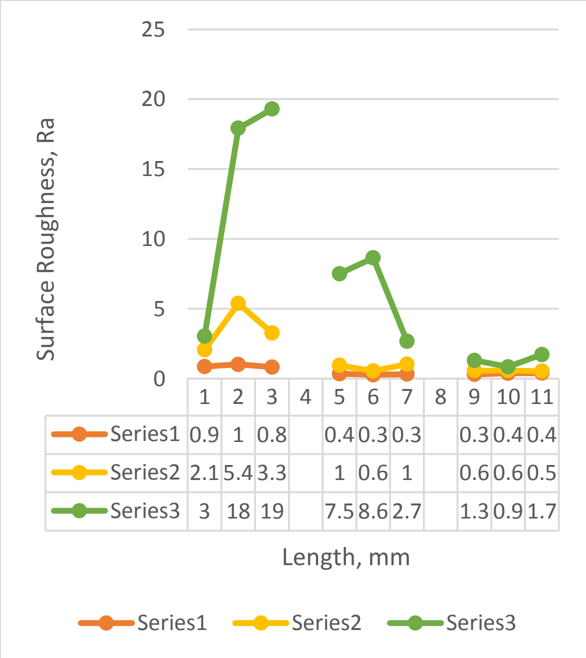

Fig. 12, Graph Surface Roughness VS Depth of Cut

The above graph clearly tells us that the speed of 500 rpm delivers a high surface roughness and when the spindle speed starts increasing the surface roughness is also starts decreasing. Whereas in a higher speed of 1000 rpm the surface roughness has got decreased significantly since the speed compensates the effects of the depth of cut.

IX. CONCLUSION

As a conclusion, the optimization study has been successfully completed upon its objectives, where the main parameters that affect the mechanical properties of Face Milling operation were identified among the parameters chosen. Besides, the effects of individual parameters on the material and operation has also been analysed to improve the machining in order to achieve the desired surface roughness during the machining up of the D2 hardened steel.

It also gives us a clear picture to achieve a good and less surface roughness using the higher spindle speed and lesser feed rate and depth of cut as well.

When the Spindle speed is low and the depth of cut is being higher the surface roughness gets severely affected and leads high surface roughness.

The feed rate shall be dependent on the spindle speed and the depth of cut.

The feed rate shall be higher when the spindle speed is higher and for a lesser depth of cut whereas the vice versa does not becomes possible due to the effect of the spindle speed towards the surface roughness of a machined metal surface.

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