Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

One of the production processes is machining, in which extra material is removed from the work piece to give it the desired shape. This extra material from the work piece is removed as a chip by using the proper insert for the cutting tool. The term machinability measured by is the quality or state of being machinable by different types of machining operations, such as drilling, turning, milling, etc. The current research investigates the machinability of drilling duplex stainless steel 2205 with environmental friendly machining techniques. The overall description of the solid carbide drill is shown in Figure 1.1.

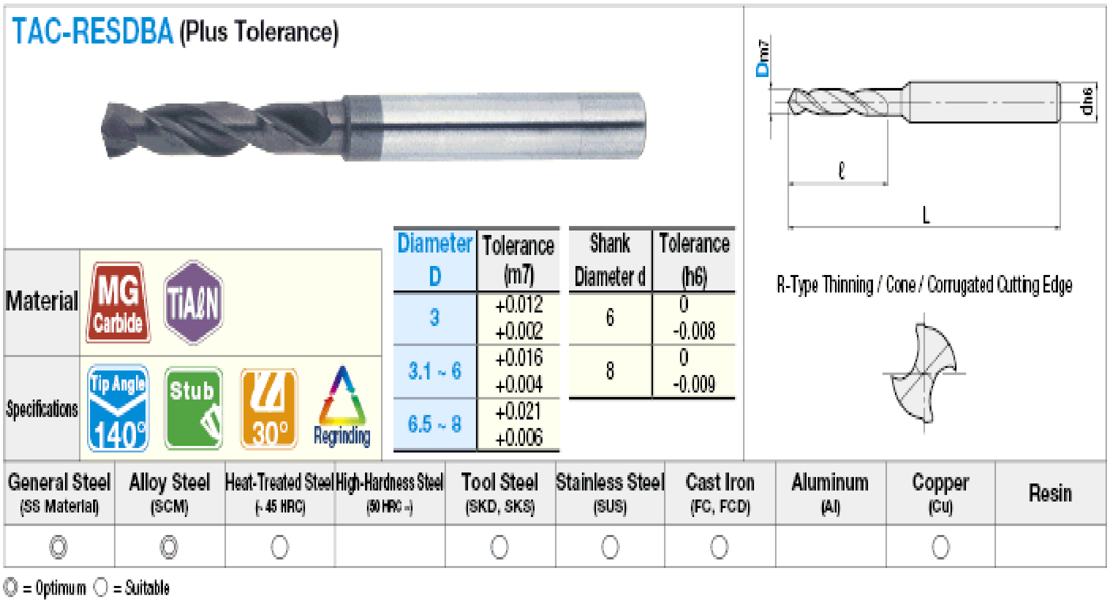

Fig. 1.1: Specification of solid carbide drill [Misumi industry]

Drilling operations are used to create round holes in both metallic and non-metallic materials. The fundamental workings of the drilling process are shown in Figure 1.2. Drilling is a basic machining operation in which the tool is fed against the workpiece material while rotating at a cutting speed.Drilling is a cutting process where a drill bit is spun to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multi-point. The bit is pressed against the work-piece and rotated at rates from hundreds to thousands of revolutions per minute.A suitable choice of input variables is required to produce a more accurate estimate of the amount of the product that will be machined as well as other encouraging outcomes, including a longer tool life. The manufacturing and ecological sectors have recently been more interested in technological advancements. More precise components with better dimensional accuracy, surface quality, and cutting tool life are in demand in the present scenario. The completed drilling process, which has been looked into particularly for steels, has received more attention. In this regard, a thorough comprehension of tool life analysis in machines would definitely handle the aforementioned important challenges for improved sustainable production. The goal of machining is to provide a high-quality product at a reduced cost while keeping a better level of dimensional accuracy. In this present investigation, the prime factor of study is surface quality, which prime attribute of machined parts. Figure 1.3 shows the fishbone diagram of drilling operation. In this diagram, the red color shows selected parameters in current research.

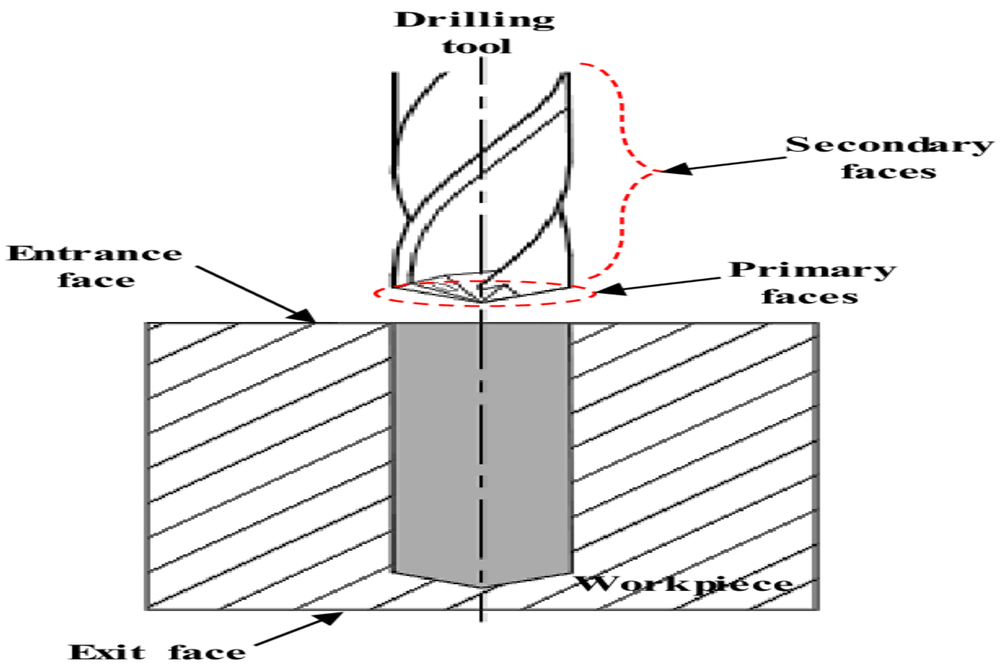

Fig.1.2: Drilling Process [Chegdani et al., 2018]

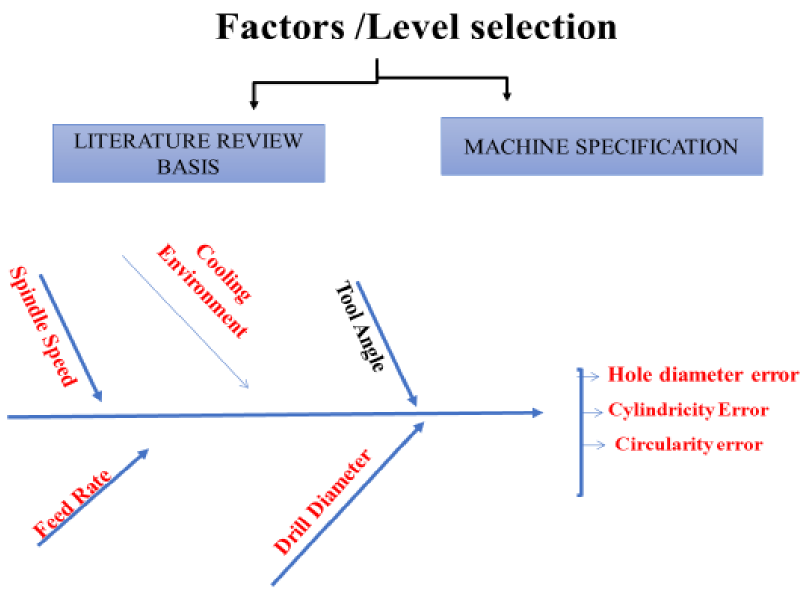

Fig. 1.3: Fishbone diagram for drilling process

1.1 Process Parameters

In metal cutting two types of process parameters e.g. input process parameters and output process parameters. For the desired shape, the engineer or operator change input process parameters as per required. These are below;

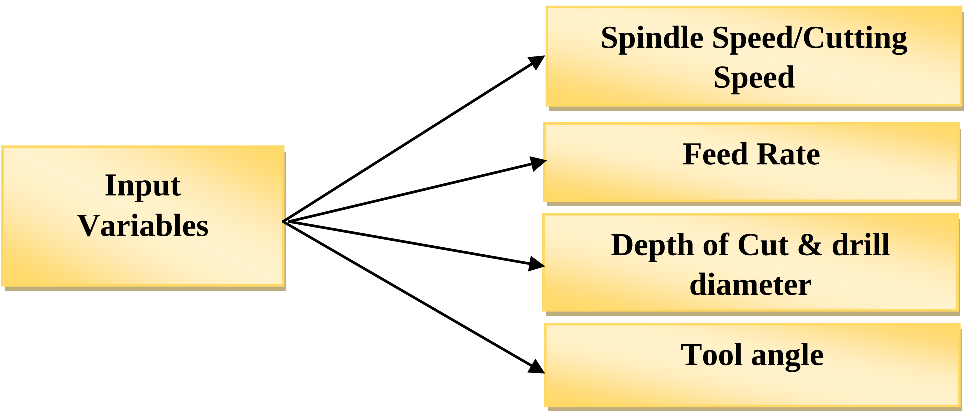

Fig. 1.4: Shows the input Variables

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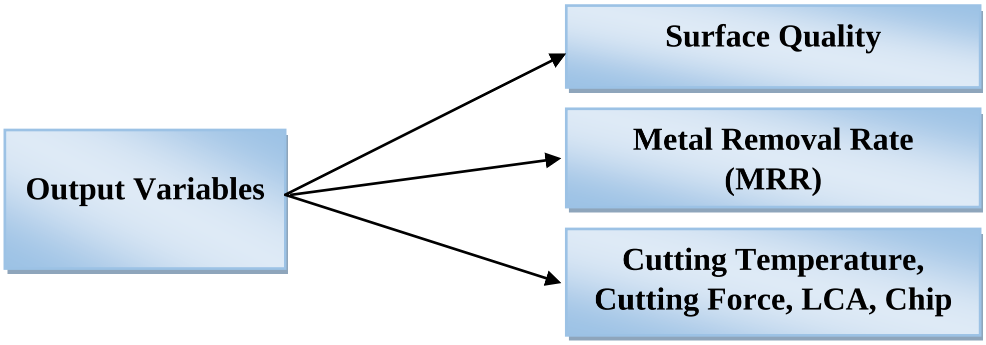

Fig. 1.5: Shows the output variables

1.2 Machinability Factors

1.2.1 Effect of Cutting Parameters on Surface Quality

One of the most crucial quality factors in the manufacturing sector is a surface finish, which affects both the cost of production and the functionality of mechanical parts. Modern enterprises have recently focused on producing high-quality goods quickly and with minimal labour input. Automated and flexible manufacturing systems with computer numerically controlled machine tools have been implemented for that reason.

One of the most important considerations when assessing a component's quality is its surface roughness, which has an impact on all of the quality characteristics described above. Since it is a crucial component of quality, it has gotten substantial attention for a long time. The usefulness of the product portion is significantly influenced by the surface's quality. Therefore, a technique for predicting surface roughness in accordance with technological factors needs to be developed. Surface roughness measurement is essential for a wide range of industries and applications, including semiconductor thin-film uniformity, micro-electro-mechanical systems inspection, medical implant efficacy, and auto component wear. Without precise surface roughness metrology, many of the significant advancements in science and industry during the previous 50 years would not have been feasible.

The present research investigates surface quality e.g. surface roughness, circularity error, hole deviation, and cylindricity error under different types of environmental friendly cooling methods e.g. dry, wet, MQL, LCO_2, and hybrid MQL-LCO_2 cooling conditions. Parametric optimization through different types of optimization techniques.

1.3 Duplex Stainless Steel

Duplex stainless steels have a combination of two phases, ferrite, and austenite in approximately equal measure. Figure 1.6 shows the actual microstructure of duplex stainless steel. This allows them to benefit from the advantages of both austenitic and ferritic stainless sheets of steel, leading to increased strength, improved weldability, higher toughness, and resistance to several types of corrosion. Because they contain less nickel than austenitic stainless steel, they are also less expensive commercially. Duplex stainless steel was invented in Sweden in 1930, but due to its extremely difficult manufacturing method, commercial production didn't start until the 1970s. After considerable improvements in steelmaking technology made it easier to make, steel has made a comeback in recent times. Due to the restrictions of their applications, they are still a relatively underutilized class of stainless steel, with a global usage of only 1% to 3%(IMOA).

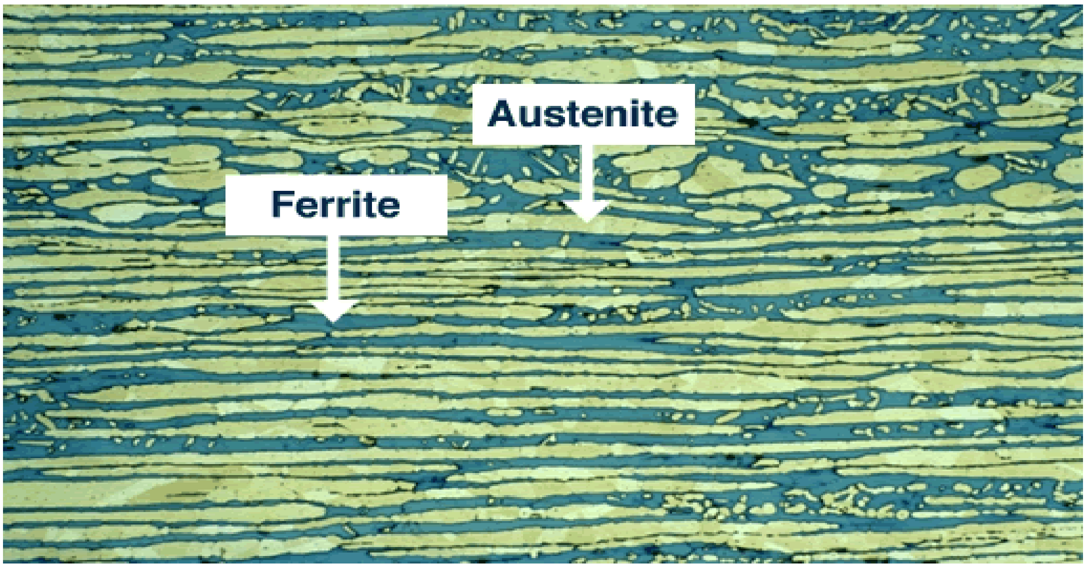

Fig. 1.6: Microstructure of duplex stainless steel [IMOA]

1.4 Machining

A technique of material removal used to produce useful components is known as machining. Typically, it produces metallic goods. It includes mechanically cutting the material to the appropriate geometry using power-driven machine equipment and a sharp cutting tool. The work piece, tool, and machine are all considered to be parts of a system in a machining operation.

1.4.1 Chip Formation During Machining

The work material undergoing a small-scale shear deformation right where the tool's cutting edge will be. When cutting, the tool and work piece move relative to one another, compressing the material close to the tool and causing a shear deformation that results in the chip.

In metal cutting operation some types of chips are formed. These are below;

- **Continuous Chip**

The term "continuous type of chip" refers to a metal chip that has not broken into any segments throughout the milling process. Continuous chips are easily depicted in Figure 1.7. When ductile metal is cut at a high cutting speed and there is little friction between the chips and the tool face, continuous chips are produced.

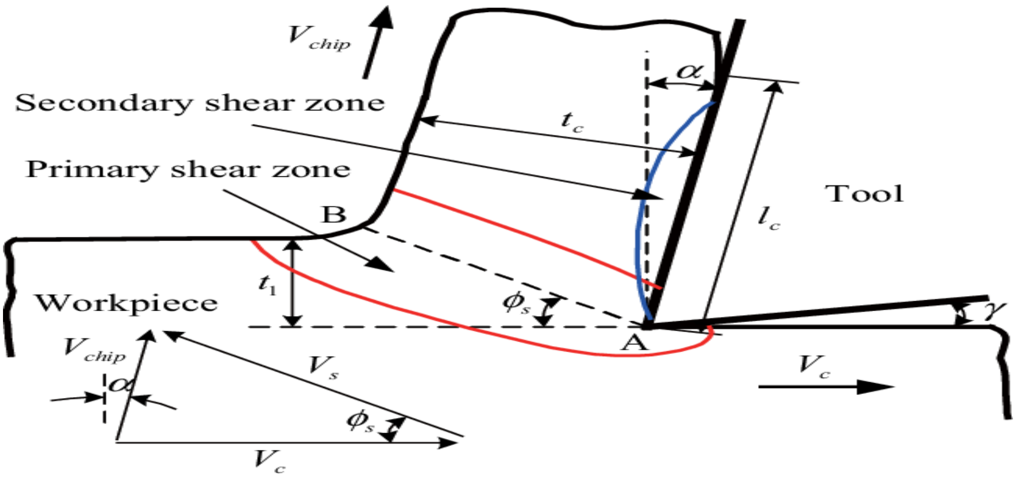

Fig. 1.7: Continuous chip [Liu et al.,2021]

- **Discontinuous Chip**

A discontinuous chip is one that was generated with fracture during the metal-cutting process and is not continuous. A discontinuous chip is depicted in Figure 1.8. When brittle materials like bronze, brass and cast iron are employed, a discontinuous chip is produced.

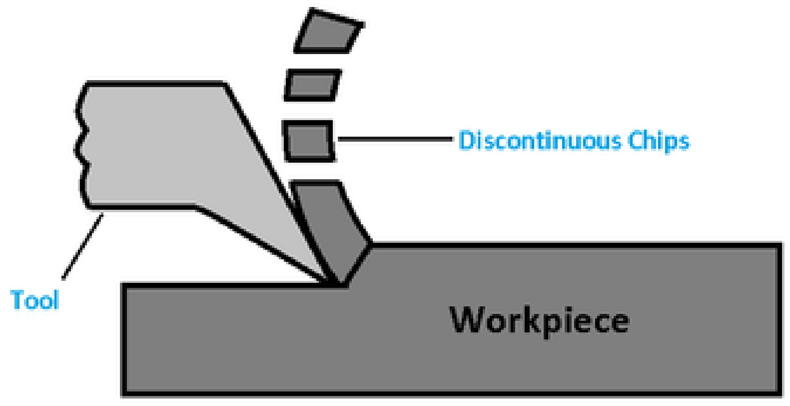

Fig. 1.8: Discontinuous chip [Field, 1949]

- **Continuous with Built up Edge**

The production of continuous chips with built-up edges involves machining ductile materials with a high-friction chip-to-tool interaction. How to become continuous with a built-up edge is seen in Figure 1.9. It is comparable to continuous-type chips, but because of the built-up Edge, it is less lubricated.

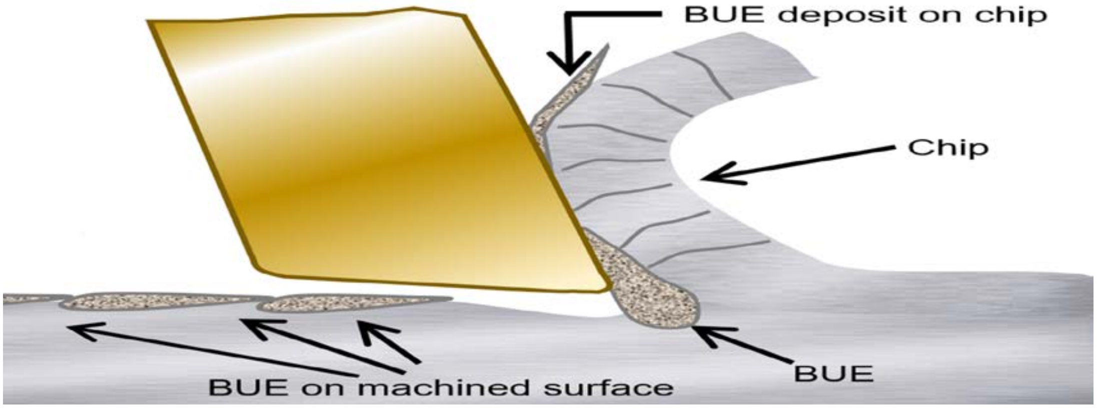

Fig. 1.9: Built-up Edge [Wang, et al,. 2016]

- **Serrated Chip**

Chips with serrations are typical of high-speed cutting. It is a crucial component of a high-speed cutting device and has a big impact on cutting force, cutting temperature, and tool wear. The creation of a chip with serrations is depicted in Figure 1.10.

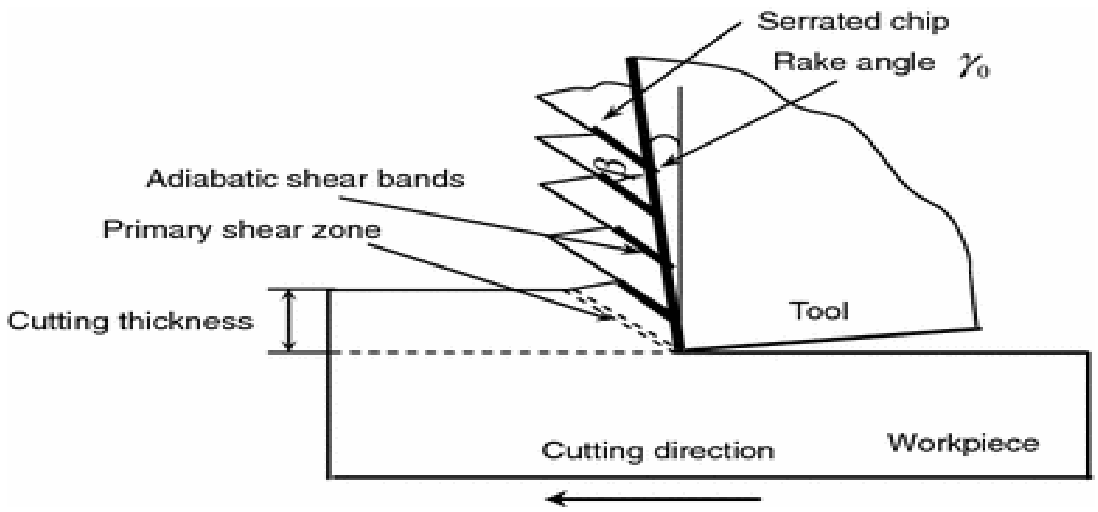

Fig. 1.10: Formation of the serrated chip [Duan et al.,2009]

1.4.2 Surface Roughness (Ra)

The average vertical deviation from the nominal surface over a surface's given length is what is referred to as surface roughness. The basic mechanisms of surface roughness are shown in Figure 1.11. It is measured by a real surface's vertical divergence from an ideal form. The workpiece's surface is rough if the divergence is significant. The surface is smooth if the deviation is minor. Using the centre line average approach, a surface roughness average value (Ra) was obtained.

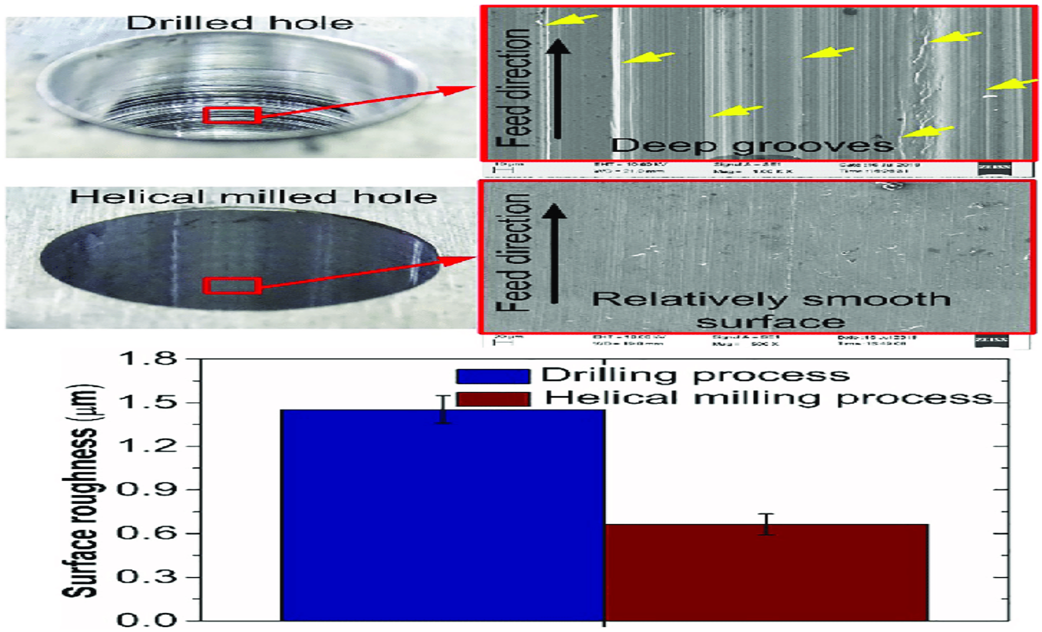

Fig. 1.11: Shows surface roughness [Gonsalves et al.,2020]

1.4.3 Tool Wear

Regardless of the cutting circumstances, tool wear develops on the cutting tool during metal machining as a result of interaction with the workpiece material. How to analyse tool wear during drilling operations is shown in Figure 1.12. To further enhance the functionality and tool life of the cutting tool insert, it is crucial to analyse and comprehend tool wear as this is the cause of tool failure. The material and geometry of the tool, the material of the workpiece, the cutting fluids, and the cutting temperature are just a few examples of the many variables that can affect tool wear.

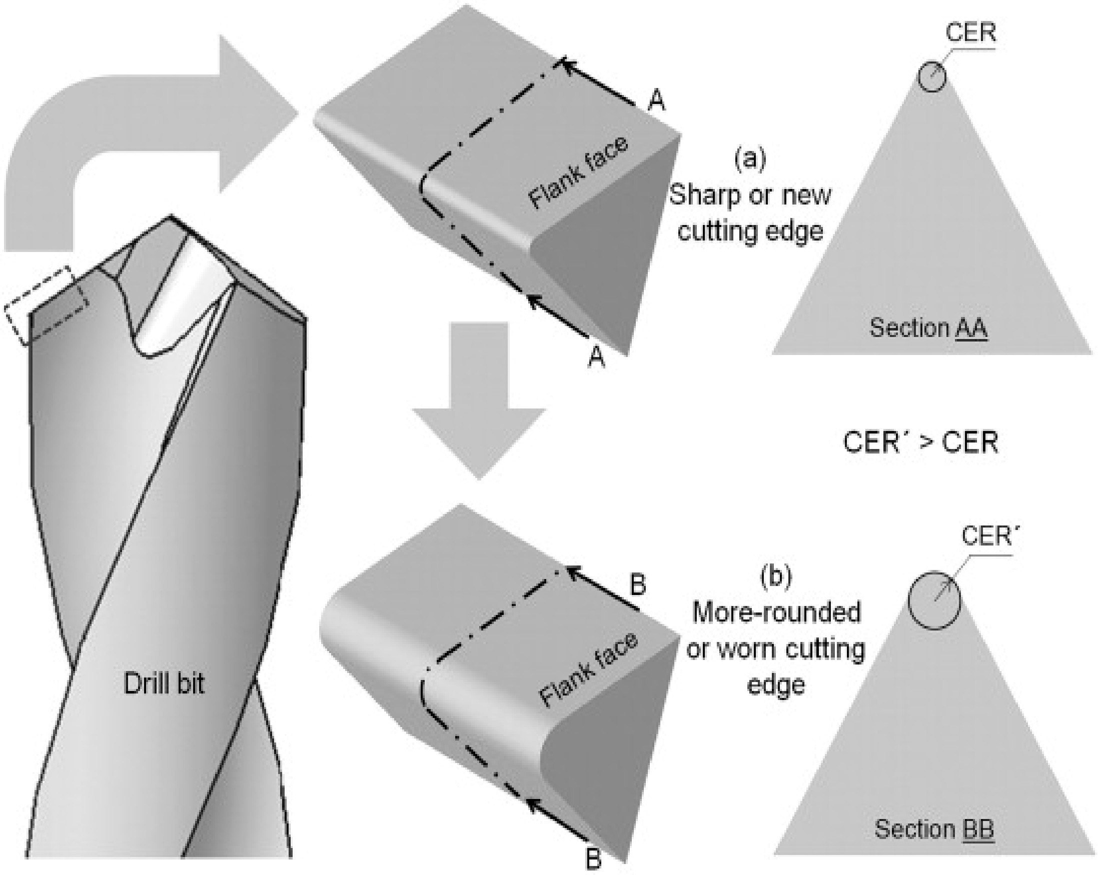

Fig. 1.12: Tool wear analysis [Faraz et al.,2009]

1.4.4 Hole Dimensional accuracy

The diameter of a production tool used to drill holes is referred to as a hole diameter. As a result, plated-through holes and non-plated-through holes have different hole diameter calculations. The calculation for a non-plated through-hole is the product of the finished hole size and +0.00mm/0mil. Figure 1.13 shows the drilling operation's hole deviation. The development of hole deviation error is another factor.

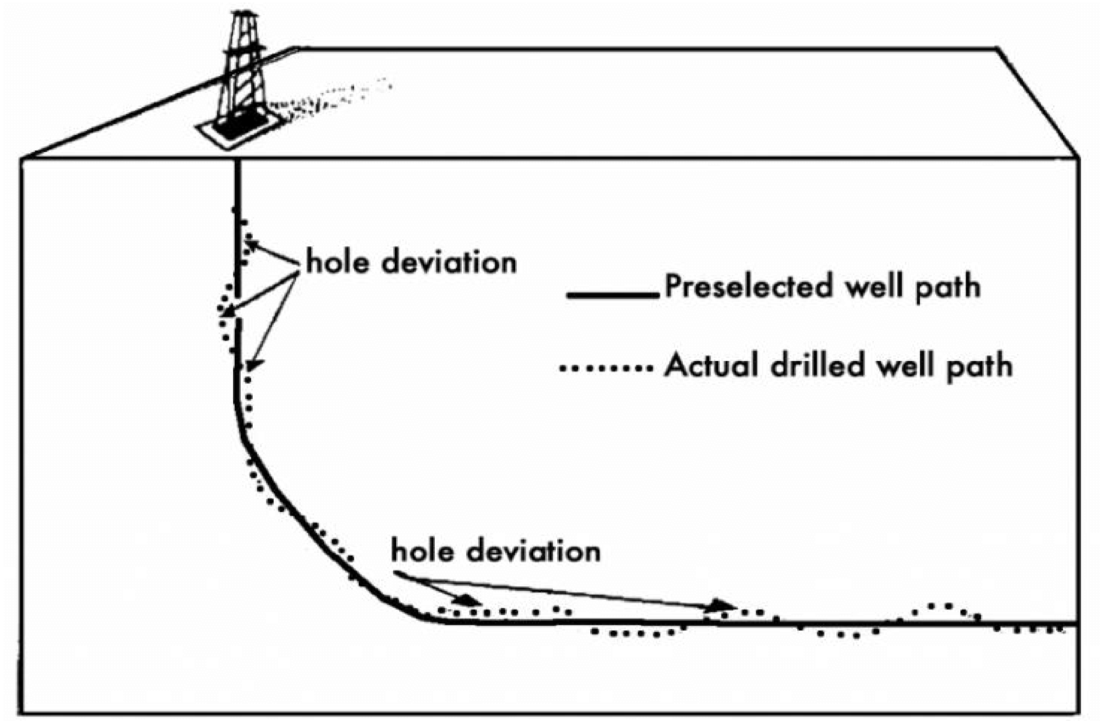

Fig. 1.13: Hole deviation error [Deshpande, 2021]

1.5 Cutting Tool Materials

The pressures of technical change and economic competitiveness have compelled the creation of novel cutting tool materials. By using fast-developing tool material technology, hard material is easily cut to the desired shape at higher material removal rate and cutting velocity with improved performance reliability thanks to fast-developing tool material technology.

1.5.1 Need of Coating on Tool

When working with work materials, a cutting tool's surface and bulk requirements differ and are incompatible. The surface should typically have a low thermal conductivity. Considering that the heat produced during machining should be dissipated by the chips and prevented from penetrating the cutting tool. In contrast, the tool's main body should be robust, shockproof, has high thermal conductivity, and be strong enough to withstand high-temperature plastic deformation while maintaining shape and geometry. A tool that has been coated can be used to achieve this combination of qualities. The specific purpose of the coating is as fellow:

- Work as a diffusion barrier.
- To improve the abrasion resistance.
- To control the cutting-edge temperature.

1.6 Problems for Machining of Duplex Stainless Steel

Authors assert independently that the following list includes some of the additional machining characteristics of duplex stainless steel:

- Duplex stainless steel is a superb option for a variety of applications due to its excellent corrosion resistance, wide range of strength levels, good formability, and aesthetically pleasant look. However, because of their low heat conductivity, high built-up edge (BUE) creation tendency, and high deformation hardening, they are harder to machine than other alloy steels.
- Due to the greater austenite and nitrogen concentrations of modern duplex stainless-steel grades, these materials are typically challenging to process. Due to its enhanced pitting corrosion resistance equivalent, stress corrosion resistance, and high strength, the utilisation of DSSs has grown.

1.7 Environmental-Friendly Machining

The demand for renewable and biodegradable cutting fluids is increasing daily as a result of environmental concerns, increasing contamination, and pollution regulations. One of the most recent cost-effective and environmental favourable methods to increase machinability is environmental-friendly machining. There are numerous environmental friendly machining methods, including dry machining, high-pressure cooling, cryogenic machining (using LN2 and LCO2), MQL machining and high-pressure machining. The demand for renewable and biodegradable cutting fluids is increasing daily as a result of environmental concerns, increasing contamination, and pollution regulations. One of the most recent cost-effective and environmentally favourable methods to increase machinability is environmental-friendly machining. There are numerous environmentally friendly machining methods, including dry machining, high-pressure cooling, cryogenic machining (using LN_2 and LCO_2), MQL machining and high-pressure machining. This study's main objectives are to assess various eco-friendly machining techniques and enhance the cooling strategy when cutting metal. As a result, it was discovered through the literature research that green machining is both economical and environmental benign. Types of environmentalfriendly machining are displayed in Figure 1.14.

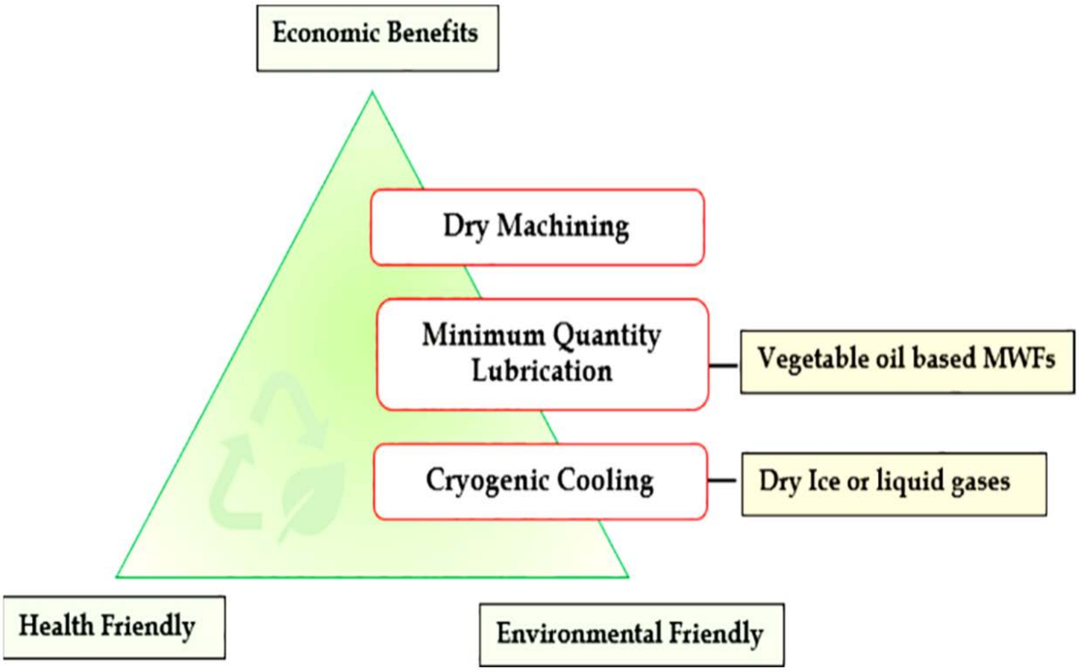

Fig. 1.14: Environmental friendly machining [Khan et al.,2022]

1.7.1 Classification of Environmental Friendly Machining

It is possible to use a variety of environmental friendly machining techniques, such as dry machining, cryogenic machining, high-pressure cooling, and minimum quantity lubrication (MQL), etc.

1.7.1.1 Machining of dry

In dry machining no coolant is used, so it is cleanest production process. But dry machining has one disadvantage such in this machining heat is more generated due to no coolant being used [10]. The fundamentals of dry machining are shown in Figure 1.15.

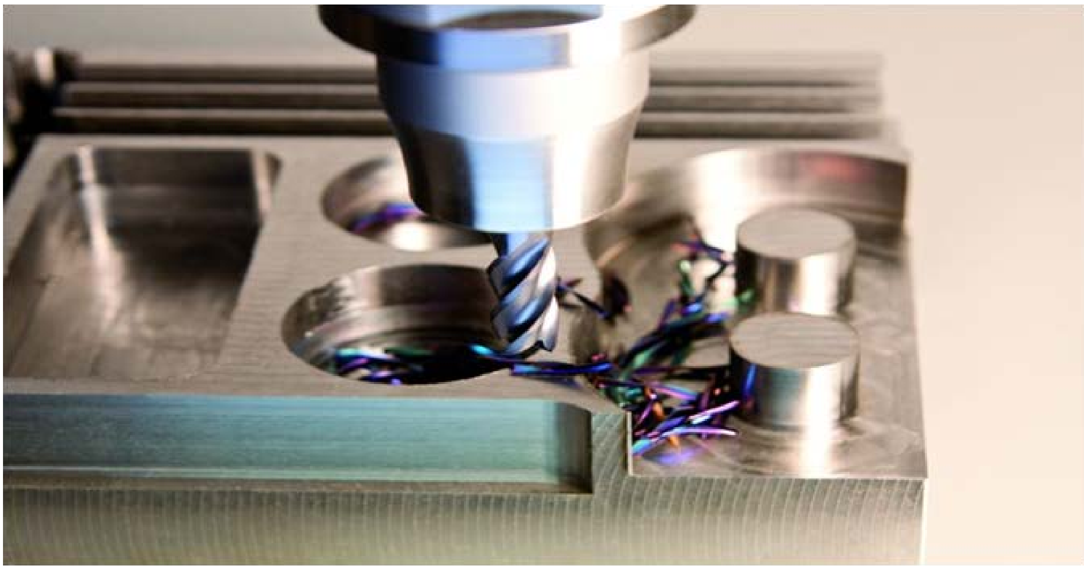

Fig. 1.15: Dry machining [Wohlfeil F.,2015]

1.7.1.2 Minimum Quantity of Lubrication (MQL)

MQL, a method of micro lubrication, enables nearly dry machining. Large amounts of cutting fluids made of water and mineral oil are replaced with a little amount of lubricant that is friendly to the environment and is blended with air. The lubricant used is typically vegetable oil. The MQL setup's schematic method is shown in Figure 1.16.

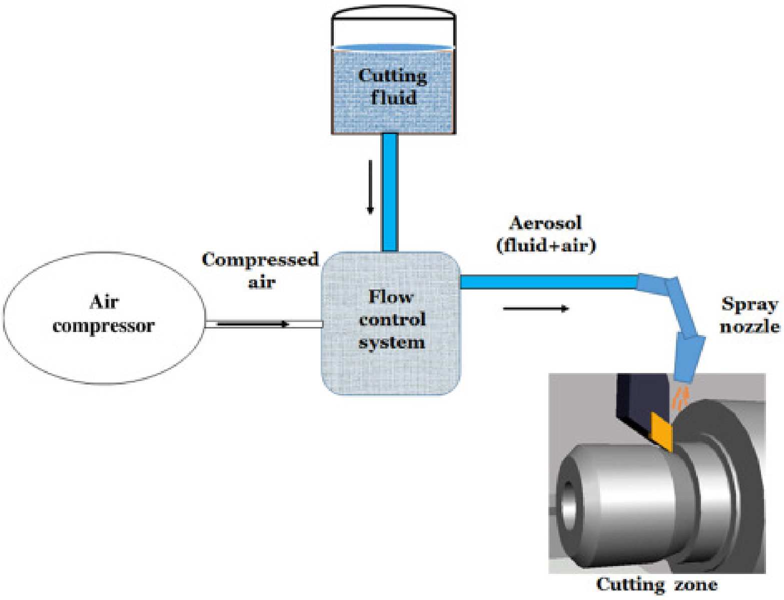

Fig. 1.16:MQL machining [Debnath,2021]

1.7.1.3 MQL-Nano Particles

The use of specifically designed nanoparticles in lubricants to enhance heat capacity is known as nanofluids MQL. There are many different kinds of nanoparticles, including polymeric nanoparticles, carbon-based nanoparticles, semiconductor nanoparticles metal nanoparticles, and ceramic nanoparticles, the fundamental steps of MQL-Nano fluid machining are shown in Figure 1.17.

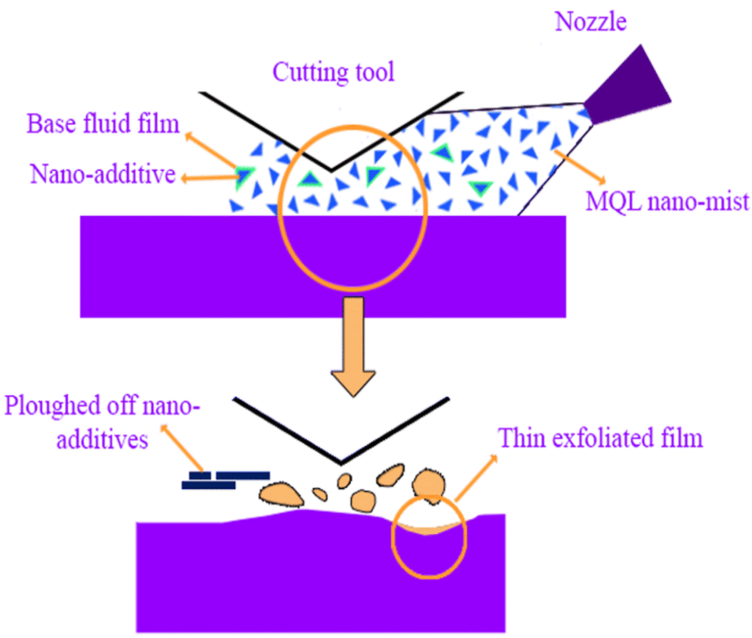

Fig. 1.17: MQL-Nano Fluid machining [Abbas et al.,2019]

1.7.1.4 Cryogenic Machining

In cryogenic machining, heat is directly rejected from the cutting zone to lower tool wear rates and enhance surface integrity. Before beginning the machining process, the tools can be cryogenically treated to increase their resistance to wear. Liquid nitrogen (LN_2) and carbon dioxide are the two gases used in cryogenic machining (LCO_2). The general workings of the cryogenic machining process are shown in Figure 1.18.

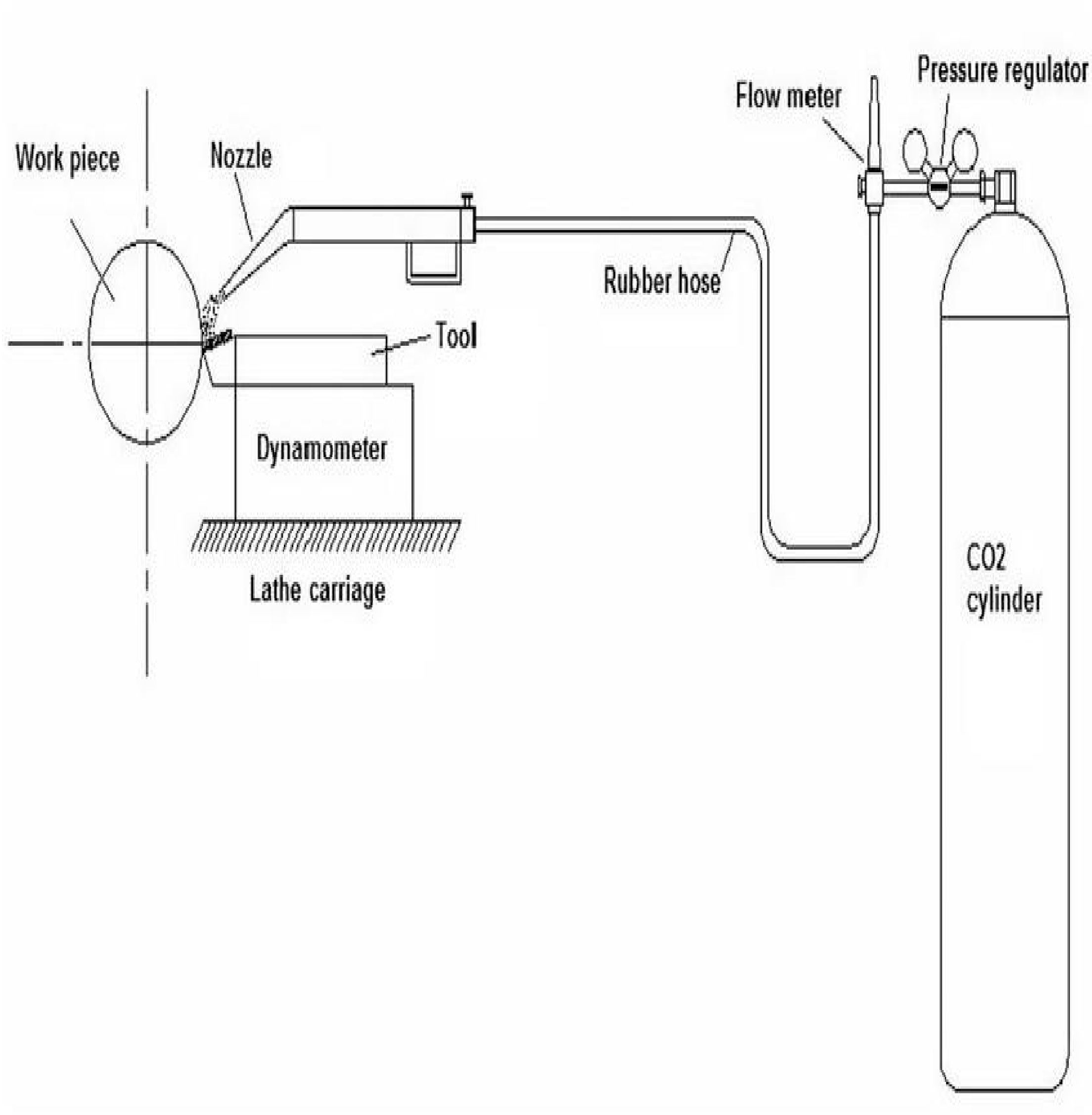

Fig. 1.18:Cryogenic machining [Jeroldet al.,2011]

1.7.1.5 High-Pressure Cooling Machining

Pumping machine tool coolant above 300 PSI is known as high-pressure cooling. This often refers to 1000 PSI in normal machining. Ultra-high-pressure coolant, or 3000 PSI, is utilized in several applications. The vapor barrier is swiftly breached by high-pressure coolant, which also quickly cools the hot zone and quenches the metal chips, making them brittle and easy to separate from the part. The chips are then promptly flushed out of the cutting area to prevent further machining. This results in superior components that enable machine operators to raise feeds and speeds and significantly increase cutting tool life—often by a factor of five or more. The fundamentals of high-pressure cooling machining are shown in Figure 1.19.

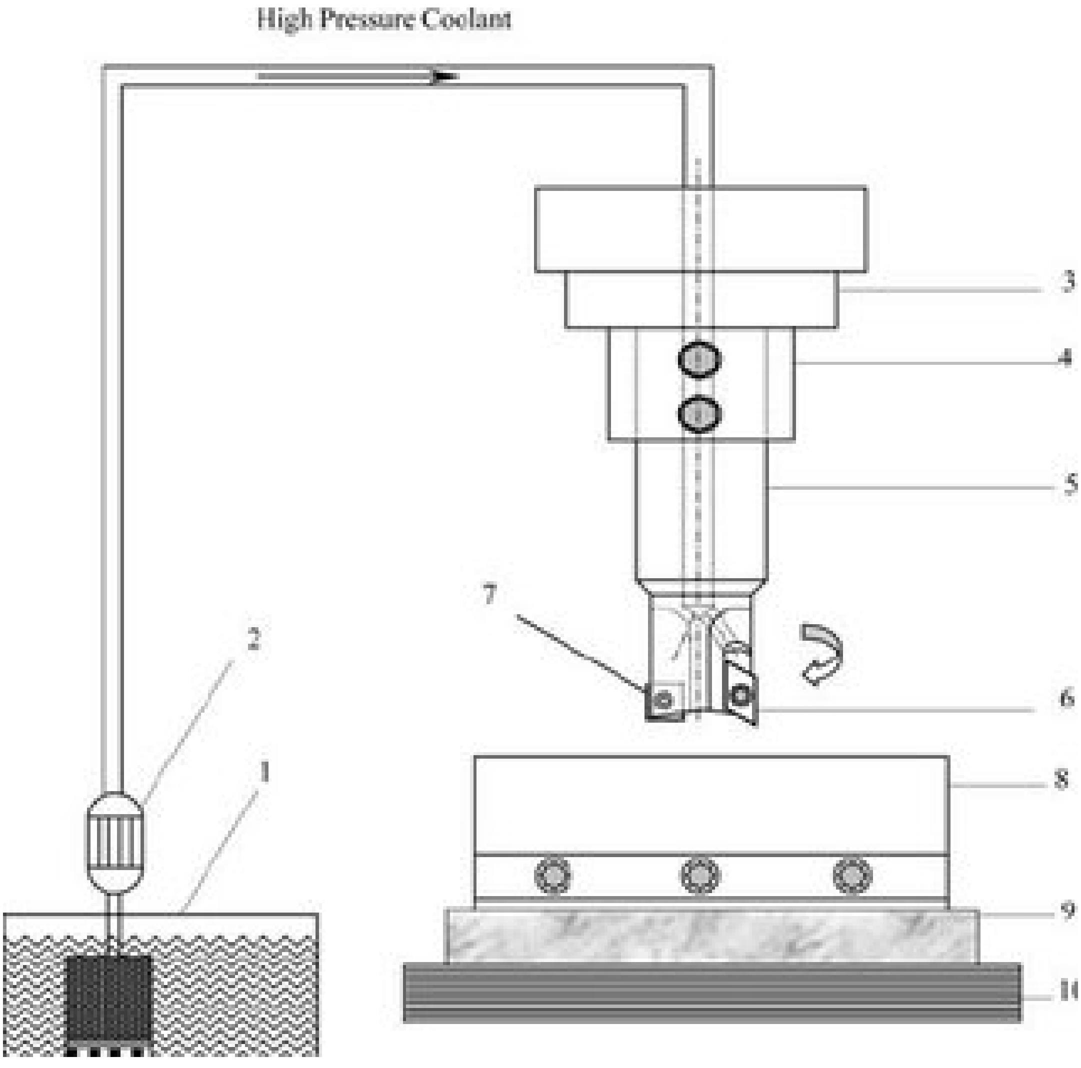

Fig. 1.19:High-Pressure Cooling [Senthil Kumar et al.,2002]

1.8 Optimization Tools and Techniques

Optimization aims to produce the best outcomes feasible in a given situation. The main goal might not be to optimize perfectly but rather to compromise well and hence provide the optimal formulation within a set of constraints. There are two different categories of optimization approaches, such as traditional and non-traditional techniques. The schematic depiction of optimization strategies is shown in Figure 1.20.

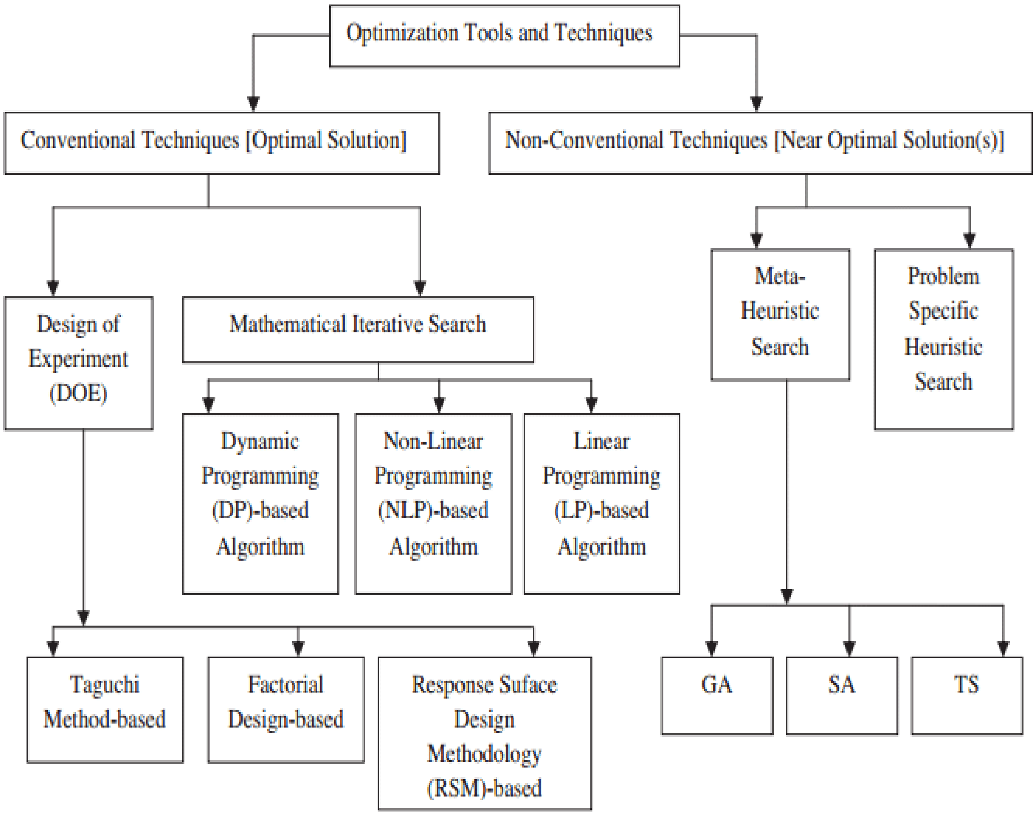

Fig. 1.20:Schematic presentationtypes of optimization techniques [Mukherjee et al.,2006]

1.9 Organizations of The Thesis

The thesis is organized into five chapters with references as enumerated below:

Chapter 1 Introduction

The notion of drilling on duplex stainless steel 2205, along with its applications and machinability of the material, is introduced in this chapter. This chapter also discusses the impact of process factors on response variables as well as an overview of environmentally friendly cooling techniques such dry, MQL, n-MQL cryogenic, and high-pressure chilling. The review of optimization approaches, both conventional and non-conventional, is also included.

Chapter 2 Literature Review

The machinability inquiry under environmentally friendly cooling ways on the difficulty to cut machine material was covered in this chapter's literature review. The objectives eventually as a result of the study or knowledge gaps.

Chapter 3 Research Methodology

This chapter included the research methodology, e.g. Taguchi method, RSM method, GA, ANN, FLS, ANFIS, and TOPSIS.

Chapter 4 Experimental Work

This chapter included the details of the experiment setup, measuring instrument, cutting tool, workpiece material, cooling conditions, experimental plan, and used optimization techniques.

Chapter 5Results & Discussion

This chapter included results and a discussion of machining on DSS 2205 under different environmental conditions, ANOVA analysis, regression analysis, and confirmation test. Furthermore, the comparison of experimental results to predicated model results e.g. artficial neural network (ANN), fuzzy logic system (FLS), ANFIS and RSM.

Chapter 6 Conclusions and future scope

This chapter presents the conclusion during machining on DSS 2205 under environmental friendly cooling methods e.g. dry & wet, dry, MQL, & LCO_2, and hybrid MQL-LCO_2. Further, the scope for future research is outlined.

1.10 Plan of Action

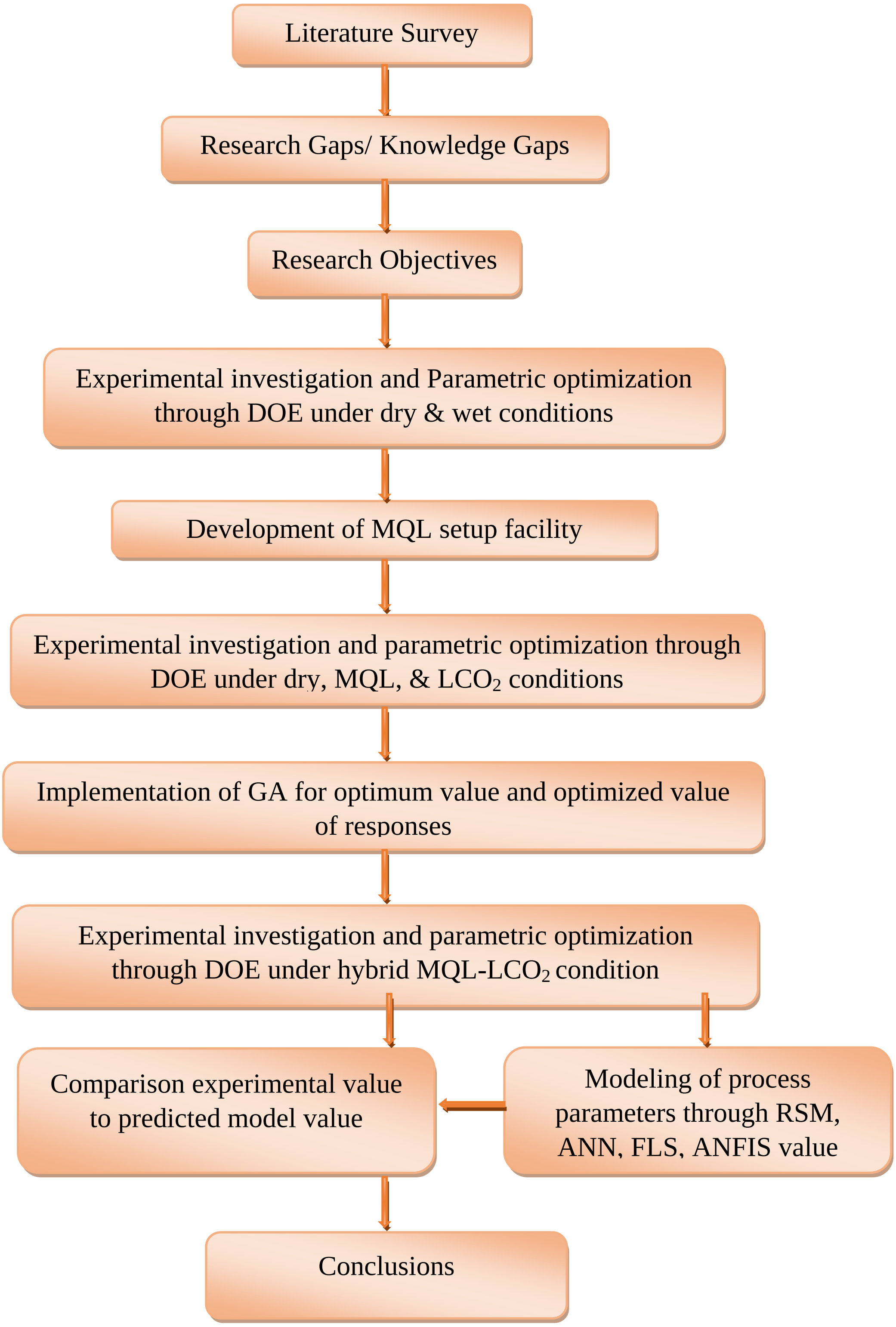

Fig. 1.21: Plan of action