STUDY OF MACHINING PARAMETERS OF SURFACE ROUGHNESS IN ELECTRO DISCHARGE MACHINING OF TOOL STEEL

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurently submitted for award of other degree.

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ABSTRACT

This thesis presents the study of machining parameters on surface roughness in Electro Discharge Machining (EDM) of tool steel. The operation of EDM is based on removing material from the workpiece by a series of repeated electrical discharges, produced by electric pulse generators at short interval, between an electrode and workpiece that being machine in dielectric fluid medium. The Full Factorial Design of Experiment (DOE) from software STATISTICA was used to formulate the experiment layout, to analyze the effect of each parameter on the machining characteristic, and to predict the optimal choices for each EDM parameters. The selected EDM parameters were Peak Current, IP (8 and 16 A), Pulse ON-time (2 and 24 μs), Pulse OFF-time (2 and 3 μs) and Servo Voltage, SV (30 and 40 V). Machining is performed on EDM Sodick AQ55L model. The Surface Roughness Tester Series Mahrsurf XR 20 is used to measure R_a. From the analysis by Full Factorial DOE, it shows that Peak Current and Pulse ON-time have significant effect to surface roughness. The analysis also determined the optimum condition of the machining parameter. The lower values of these parameters the lower surface roughness. The confirmation tests and comparison test were performed for the optimum condition for the machining characteristic. The result of comparison tests showed that the percentage of performed is not accurate but this result can be accepted because the error percentage is below 10%.

ABSTRAK

Tesis ini membentangkan pembelajaran parameter mesin ke atas kekasaran permukaan dalam electro nyahcas mesin (EDM) pada alatan besi. Proses EDM berlaku dengan menyingkirkan bahan dari bahan kerja oleh beberapa siri ulangan nyahcas elektrik yang dihasilkan daripada penjana denyutan elektrik pada sela waktu pendek di antara satu elektrod dan bahan kerja yang dimesin dalam medium cecair dielektrik. Kaedah Faktorial Penuh Rekabentuk Eksperimen (DOE) dari program STATISTICA digunakan bagi merekabentuk eksperimen, menganalisis kesan setiap parameter terhadap kriteria selepas pemesinan dan jangkaan keputusan yang optimum kepada setiap EDM parameter. EDM parameter yang telah dipilih adalah Arus Puncak, IP (8 dan16 A), Tempoh Hidup Denyutan (2 dan 24 µs), Tempoh Mati Denyutan (2 dan 3 µs) dan Voltan Servo, SV (30 dan 40 V). Kerja pemesinan dilakukan dengan EDM model Sodick AQ55L. Penguji kekasaran permukaan iaitu Mahrsurf XR20 digunakan untuk mengukur R_a. Daripada analisis Faktorial Penuh DOE, ia menunjukkan bahawa Arus Puncak, IP dan Tempoh Hidup Denyutan memberi kesan utama pada kekasaran permukaan. Analisis juga dapat menentukan keadaan optimum pada paramater mesin. Semakin rendah nilai parameter ini semakin berkurang kekasaran permukaan. Ujian pengesahan dan ujian perbandingan telah dijalankan mengikut keadaan optimum yang telah ditentukan untuk kriteria pemesinan. Keputusan ujian perbandingan menunjukkan peratusan ralat perbezaan yang diperoleh tidak begitu tepat tetapi keputusan masih boleh diterimapakai kerana perbezaan peratusan ralat di bawah 10%.

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LIST OF SYMBOLS

IP	Peak Current, ampere
SV	Servo Voltage, Volt
SR	Surface Roughness
MRR	Material Removal Rate
SF	Surface Finish
SQ	Surface Quality
R_a	Coefficient for surface roughness
SS	Statistical Significant
df	Degree of Freedom
p	Probability
F	Function
C	Constant

LIST OF ABBREVIATIONS

EDM	Electro Discharge Machining
HAZ	Heat Affected Zone
PM	Powder Metallurgy
HF	High Frequency
RF	Radio Frequency
AISI	American Iron and Steel Institute
DOE	Design of Experiment
ANOVA	Analysis of variance

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE PROJECT

Nowadays, the application of advanced machining processes in manufacturing industry is become more important for company to produce the better or good products that satisfy the customer. This machining will solve all the problems that happened such as in machining high hardness and the strength of the material, creating complex shape, obtains the better surface finish and dimensional tolerances.

One of the advanced machining processes that become the most important accepted technologies in manufacturing industries is electro discharge machining that also called die sinking EDM. Electro discharge machining (EDM) is one of the most accurate manufacturing processes for creating complex or sample shape and geometries within parts and assemblies. EDM has become a basic machining method for the manufacturing industries such as automotive, aerospace and mostly use in die-mold production.

EDM works by removes material by creating controlled sparks between a shaped electrode and an electrically conductive work piece [1]. As part of the material is eroded, the electrode is slowly lowered into the work piece, until the resulting cavity has the inverse shape of the electrode [1]. Dielectric fluid is flushed into the gap between the electrode and work piece to remove small particles created by the process and to avoid excessive oxidation of the part surface and the electrode [1].

However, not all the melted material is flushed away completely and the remaining material resolidifies to form discharge craters. As a result, machined surface has microcracks and pores caused by high temperature gradient which reduces surface finish quality [2].

There are many published studies to determine surface finish of machined materials by EDM. From that, it was noticed that many machining parameters affect surface roughness and the combination of these parameters was difficult to produce optimum surface quality. The effect of some machining parameters such as pulsed current, pulse time, pulse pause time, voltage, dielectric liquid pressure and electrode material have been examined [2] and [3]. Previous study examined P20 tool steel and provided useful information the effects of some machining parameters on surface roughness, but the selected of pulsed current values was very low 1–8 A [4].

The aim of this project is to study the effect of machining parameters of surface roughness in EDM of tool steel (AISI D2). In this study, the surface roughness will be determined in tool steel (AISI D2). Tool steel (AISI D2), one of the carbon steels alloyed with Mo, Cr, and V, is widely used for various dies and cutters for its high strength and wear resistance due to formation of chrome carbider in heat treatment [5]. The effects of Peak Current, Pulse ON-time, Pulse OFF-time and Servo Voltage will be use to examine the surface roughness of tool steel (AISI D2).

1.2 OBJECTIVES

The aim of this study is to know more about the influences of EDM parameters on surface roughness for machining of tool steel (AISI D2) which is widely used in the production of plastic mold and die. From previous study, it was noticed that there are many machining parameters influenced surface roughness and these parameters was difficult to produce optimum surface quality. By using the different parameter such as pulse current, pulse time, pulse pause time, voltage, dielectric liquid pressure and electrode material, we will know how to obtain or produce optimum surface quality [2]. Beside, this study will generate more knowledge and experience during operating EDM.

These are summarizing of the objectives:

1. To study more about Electro Discharge Machine process.
2. To analyze the surface roughness of tool steel (AISI D2) using Electro Discharge Machine.
3. To determine the most suitable set up parameter in EDM for obtaining the good surface quality.

1.3 PROJECT SCOPES

The scopes of the project are to embrace us about machine and the material that have to cut and do the analysis. There are several scopes that will be carrying out with some result:

1. To do literature study about Electro Discharge Machining (EDM).
2. To design the experimental procedures in machining tool steel (AISI D2)
3. To conduct the experiment based on Design of Experiment (DOE).
4. To do analysis on surface roughness.

1.4 PROBLEM STATEMENT

The major research of EDM is about the ability for creating complex or sample shape parts that are mostly use in producing die and mold that require good accuracy in dimension. Moreover, the selections of parameter play an important part for obtaining good surface finish. The selection of improper parameter may result in serious consequences like produces damage such as microcracks, pores and craters on the machined surface which reduces surface finish quality.

In producing better surface quality and good accuracy in dimension, to reduce all the damage by controlling the setting of pulsed current, pulse time, pulse pause time, voltage, dielectric liquid pressure and type of electrode material [2]. In providing a variety of information in machining process, the Design of Experiment (DOE) will be performed as the methodology.

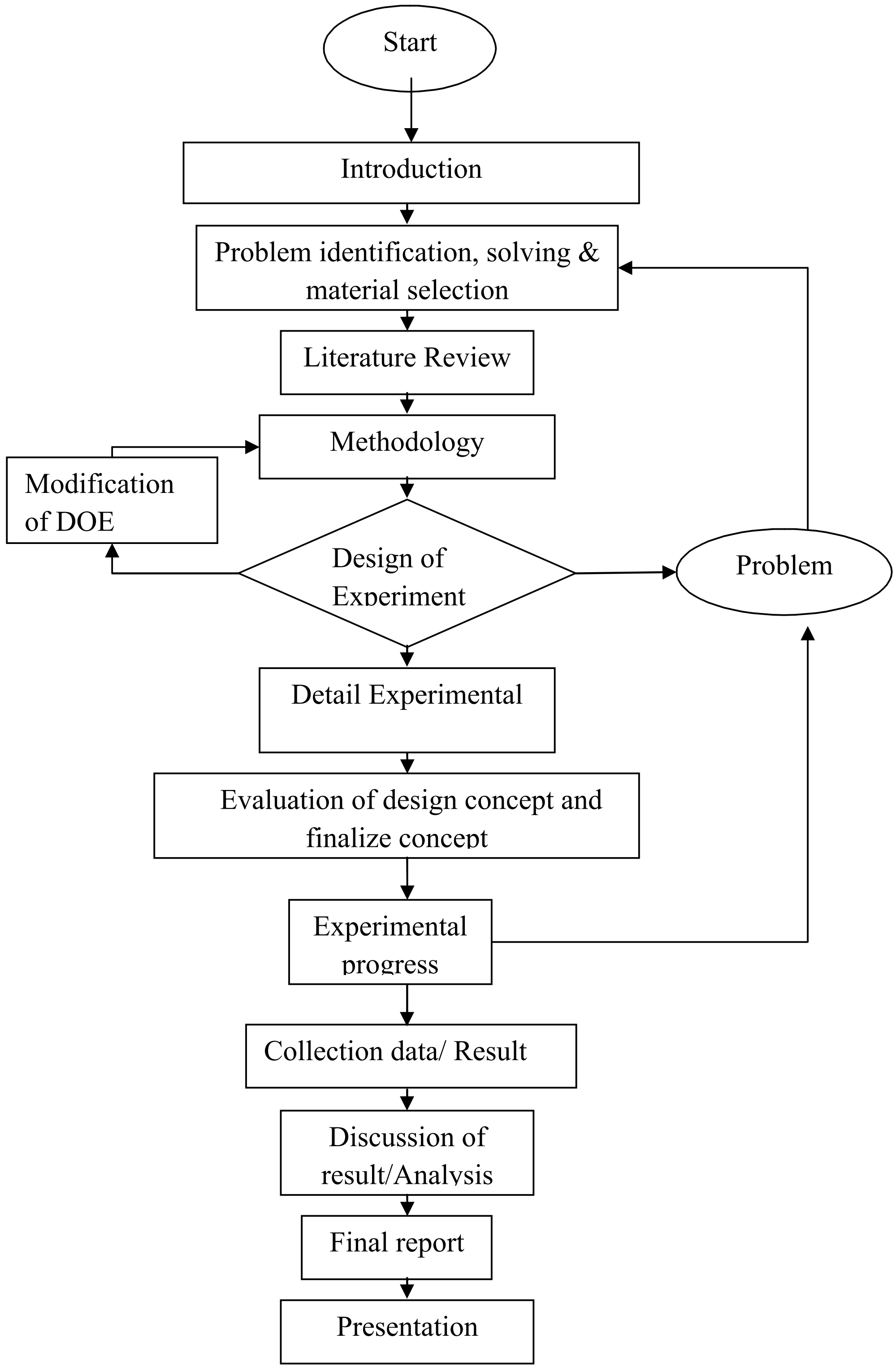

Figure 1.1: Project flow chart

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In manufacturing industry, Electro Discharge Machining (EDM) is commonly used for producing mold and die component. This machine is use because the ability of the machining process that is very accurate in creating complex or simple shape within parts and assemblies. The cost of machining is quite high payable to its initial investment and maintenance for the machine but very desirable machining process when high accuracy is required.

Many studies have been carried out for improving or finding ways to obtain good surface quality of the EDM process [2]. From the results, these study show that the machining parameter is the most important factor in producing good surface finish on the workpiece. Hence, with the information from previous studies about the effect of machining parameters on the surface roughness, the machining parameters can be set for maximum or optimum machining.

2.2 ELECRO DISCHARGE MACHINING (EDM)

This section explains the basic information about the EDM process, the capabilities and the limitation and the variations of the process combining other material removal techniques.

2.2.1 EDM process

EDM is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool and the workpiece. There are no physical cutting forces between the tool and the workpiece [3].

EDM works by removes material by creating controlled sparks between a shaped electrode and an electrically conductive work piece. As part of the material is eroded, the electrode is slowly lowered into the work piece, until the resulting cavity has the inverse shape of the electrode. Dielectric fluid is flushed into the gap between the electrode and work piece to remove small particles created by the process and to avoid excessive oxidation of the part surface and the electrode [1].

The EDM process uses electrical discharges to remove material from the workpiece, with each spark producing a temperature of between 10,000-20,000°C. Consequently, the workpiece is subjected to a heat affected zone (HAZ) the top layer of which comprises recast material. The thickness, composition and condition of this layer depend on the discharge energy and the make-up of the workpiece, tool electrode and dielectric fluid, and both hard and soft surface layers can be produced despite perceived wisdom that the recast layer is always hard. With ferrous workpiece materials, the recast layer typically appears white and amorphous when viewed under a microscope, and is prone to tensile stress, microcracking and porosity [6].

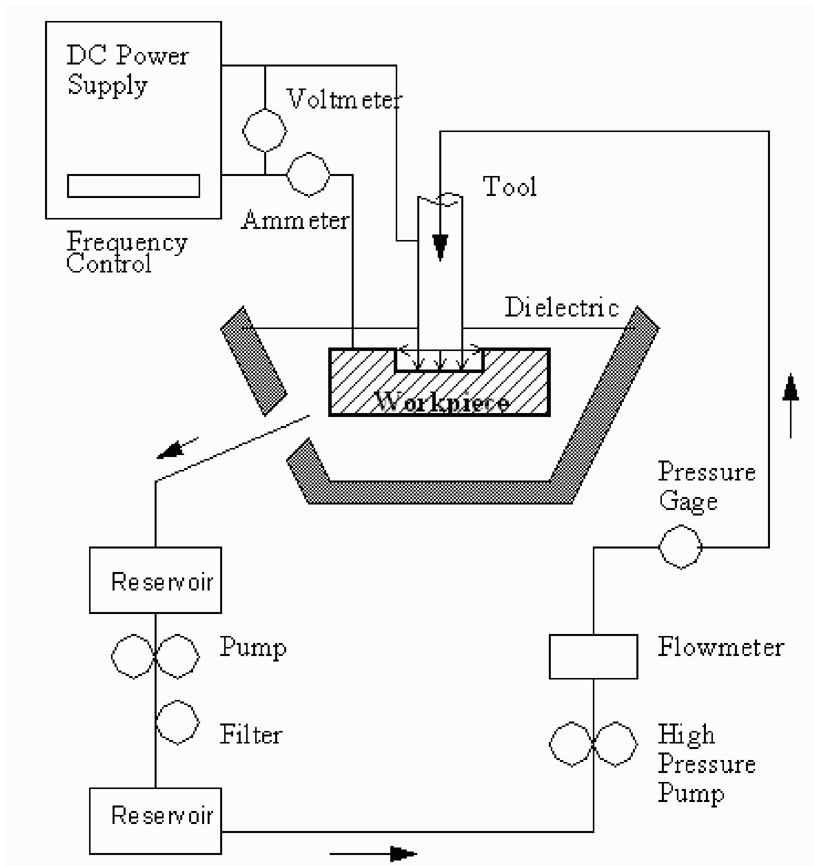

Figure 2.1: EDM process [7]

2.2.2 EDM capabilities and limitations

Capabilities

- Material of any hardness can be cut
- High accuracy and good surface finish are possible
- No cutting forces involved
- Intricate-shaped cavities can be cut with modest tooling costs
- Holes completed in one "pass"

Limitations

- Limited to electrically conductive materials
- Slow process, particularly if good surface finish and high accuracy are required
- Dielectric vapor can be dangerous
- Heat Affected Zone (HAZ) near cutting edges
- Die sinking tool life is limited

2.3 MAJOR AREAS OF EDM RESEARCH

In this section, the authors have arranged the research areas in EDM under two major headings. The first relates to machining performance measures such as surface quality (SQ) and also surveys them. The second area describes the effects of process parameters including electrical and non-electrical variables.

2.3.1 EDM process optimization

This section provides the study about the effect of the parameter in EDM process and various machining strategies. In this study, identifying the different factors and finding the different ways of EDM process play a major role to obtain the optimum machining condition and the performance. From the effective machining strategy, the result such as for producing good surface quality will be easily obtained.

2.3.1.1 EDM performance measures

Some effects of the parameters on the typical of EDM performance measures such as surface quality will be explained here. The setting and strategy for the various parameters required in EDM process play important part to produce an optimal machining parameter.

2.3.1.1.1 Surface quality analysis

The electrical discharge machined (EDMed) surface is made up of three distinctive layers consisting of white layer/recast layer, heat affected zone (HAZ) and unaffected parent metal [8]. Lim et al. [9] provided a review on the metallurgy of EDMed surface, which is dependent on the solidification behaviour of molten metal after the discharge stop and follow by phase transformation. The thickness of the recast layer formed on the workpiece surface and the level of thermal damage suffered by the electrode can be determined by analyzing the growth of the plasma channel during sparking [8].

Several authors discovered the presence of micro-cracks and high tensile residual stresses on the EDMed surface caused by the high temperature gradient [8]. The undesirable effect of discharge energy also provided some insights on the fatigue strength of the workpiece, which propagates from the multiple surface imperfections within the recast layer [8].

The EDMed surface has a relatively high micro-hardness, which can be explained by the emigration of carbon from the oil dielectrics to the workpiece surface forming iron carbides in the white layer [8]. The concentration of carbides, both as surface layer on the workpiece and as fine powder debris, is dependent on the frequency and polarity of the applied current together with other processing parameters such as pulse shape, gap spacing and dielectrics temperature [8].

However, Thomson [10] argued that the pulse duration and type of electrode material under a paraffin dielectric has little effect on the amount of carbon contamination. Thomson also suggested that the number and size of micro-cracks increase with pulse duration when machining with copper electrode.

2.3.1.1.2 Methods of improving surface quality

(i) Surface alloying:

Several authors [11and12] have reported about the surface alloying method using the composite electrode to improve the surface properties of the workpiece. The composite electrode is also known as the green compact or powder metallurgy (PM) electrode. It has low thermal conductivity allowing the composite material to disintegrate from the electrode and alloy onto the workpiece surface producing less cracks, high corrosion and wear resistance.

(ii) Ball burnish machining:

The studies of using EDM with ball burnish machining (BEDM) have been experimented to improve the workpiece surface integrity. BEDM uses hard smooth balls attached to the electrode to form a plastic deformation layer on the workpiece surface during sparking yielding a hardened and modified surface micro-structure [8]. It also improves the corrosion resistance, fatigue strength and surface roughness of the workpiece surface [8].

(iii)Powder addictives:

Powders are suspended in the dielectric fluid as another means of improving the surface properties. The powder particles facilitate the ignition process by creating a higher discharge probability and lowering the breakdown strength of the insulating dielectric fluid [8]. As a result, it increases the material removal rate and improves the sparking efficiency producing a strong corrosion resistant EDMed surface [8]. The powders in the dielectric fluid also increases the micro-hardness and reduces the micro-cracks on the EDMed surface due to a reduction of losing alloying elements residing onto the workpiece [8].

(iv) Surface finish simulation:

Jeswani et al. [13] studied the effects of workpiece and electrode materials on surface roughness and suggested an empirical model, which focused solely on pulse energy. Zhang et al. [14] proposed an empirical model, built on both peak current and pulse duration, for the machining of ceramics and realized that the discharge current has a greater effect on the material removal rate while the pulse-on time has more influence on the surface roughness and white layer.

2.3.2 EDM process parameters

This section focuses on the effects of process parameters such as electrical and non-electrical parameters on the various performance measures.

2.3.2.1 Effect of electrical parameters

(i) Pulse parameters EDM:

Pulses can be classified into open, spark, arc, off or short pulses, which are dependent on the ignition delay time, and have a direct influence on the material removal rate, surface roughness and accuracy of the part [8]. Therefore, the recognition and classification of the different pulses provide a viable option of monitoring and controlling the sparking process by measuring the related gap voltage and current. Kao and Tarng [15] proposed a neutral-network method, while Liu and Tarng [16] suggested an abductive network method of classifying and regulating the EDM pulses occurring at varying machining conditions.

(ii) Time domain:

Several authors [8] argued that the gap voltage is not a good indicator of the dynamic responses taking place at the spark gap largely due to the high frequency (HF) noise component. These authors instead suggested monitoring the time ratio of transient arc measured by the pulse-on time, which shows the trend towards undesirable arcing. Yu et al. [17] also studied the time domain of different pulses and presented a wavelet transform serving as an input signal for an online monitoring and control systems.

(iii)Radio frequency:

The emitted radio frequency (RF) or HF signal generated during EDM has been used to monitor and control the sparking process. Bhattacharyya and El-Menshawy [18] developed an RF monitoring system providing a pulse control to the machine power generator by examining the RF signal created from the spark gap. The RF monitoring system detects any drop in the intensity of signals to a threshold value whenever the discharge changes from sparking to arcing.

2.3.2.2 Effect of non-electrical parameters

(i) Flushing of dielectric fluid

Lonardo and Bruzzone [19] revealed that flushing during the roughing operation affected the material removal rate while in the finishing operation, it influenced the surface roughness. The flushing rate also influences the crack density and recast layer, which can be minimized by obtaining an optimal flushing rate [8]. The possibility of using water instead of kerosene as the working fluid for micro-EDM has been experimented [8]. The result revealed a high material removal rate and low tool wear rate without any metal carbides forming on the workpiece surface.

(ii) Rotating the workpiece

Guu and Hocheng [20] provided a workpiece rotary motion to improve the circulation of the dielectric fluid in the spark gap and temperature distribution of the workpiece producing better material removal rate and surface roughness. Kunieda and Masuzawa [21] proposed a horizontal EDM (HEDM) process in which the main machining axis is horizontal instead of the conventional vertical axis. The change in the basic construction in addition to the rotary motion of the workpiece offered an accessible evacuation of debris improving the erosion efficiency and accuracy of the sparking process.

(iii)Rotating the electrode

Soni and Chakraverti [22] compared the performance measures of rotating electrode with the stationary electrode. The results showed an improvement in material removal rate because of the better flushing action and sparking efficiency with little tool wear. The result also showed that the surface roughness was high.

2.4 TOOL STEEL

Tool Steel is actually, any grade of steel that can be used for a tool. Generally the term tool steel as applied in the steel industry is a grade of steel characterized by high hardness and resistance to abrasion coupled in many instances with resistance to softening at elevated temperatures. These properties are attained with high carbon and high alloy contents and the steel is usually melted in electric furnaces to assure cleanliness and homogeneity of the product [23].

2.4.1 Types of tool steel

High-Speed Tool Steels: High-speed alloys include all molybdenum (M1 to M52) and tungsten (T1 to T15) class alloys. High-speed tools steels can be hardened to 62-67 HRC and can maintain this hardness in service temperatures as high as 540 °C (1004°F), making them very useful in high-speed machinery. Typical applications are end mills, drills, lathe tools, planar tools, punches, reamers, routers, taps, saws, broaches, chasers, and hobs [24].

Hot-work Tool Steels: Hot-work tool steels include all chromium, tungsten, and molybdenum class H alloys. They are typically used for forging, die casting, heading, piercing, trim, extrusion, and hot-shear and punching blades [24].

Cold-work Tool Steels: Cold-work tool steels include all high-chromium class D, medium-alloy air-hardening class A alloys, water hardening W alloys, and oil hardening O alloys. Typical applications include cold working operations such as stamping dies, draw dies, burnishing tools, coining tools, and shear blades [24].

Shock-Resistant Tool Steels: Cold-work tool steels include all class S alloys. They are among the toughest of the tool steels, and are typically used for screw driver blades, shear blades, chisels, knockout pins, punches, and riveting tools [24].

Mold Steels: Mold steels include all low-carbon and one medium-carbon class P tool steels. They are typically used for compression and injection molds for plastics, and die-casting dies [24].

Special-Purpose Tool Steels: Special-Purpose Tool Steels include all low-alloy class L Tool steels. They are usually quenched, which makes them relatively tough and easily machinable. They are typically used for arbors, punches, taps, wrenches, drills, and brake-forming dies [24].

Water-Hardening Tool Steels: Water-Hardening Tool steels include all class W tool steels, and while they do not retain hardness well at elevated temperatures, they do have high resistance to surface wear. Typical applications include blanking dies, files, drills, taps, countersinks, reamers, jewelry dies, and cold-striking dies [24].

2.4.2 AISI Designations

W: Water-Hardening
S: Shock-Resisting
O: Cold-Work (Oil-Hardening)
A: Cold-Work (Medium-Alloy, Air-Hardening)
D: Cold-Work (High-Carbon, High-Chromium)
L: Low-Alloy
F: Carbon-Tungsten
P: P1-P19 Low-Carbon Mold Steels
P20-P39 Other Mold Steels
H: H1-H19: Chromium-Base Hot Work
H20-H29: Tungsten-Base Hot Work
H40-H59: Molybdenum-Base Hot Work
T: High-Speed (Tungsten-Base)
M: High-Speed (Molybdenum-Base)

2.4.3 General Properties of Steels

The following table lists the typical properties of steels at room temperature (25°C). The wide ranges of ultimate tensile strength, yield strength, and hardness are largely due to different heat treatment conditions.

Table 2.1: Properties of steels at room temperature (25°C) [24]

Properties	Carbon Steels	Alloy Steels	Stainless Steels	Tool Steels
Density (1000 kg/m^3)	7.85	7.85	7.75-8.1	7.72-8.0
Elastic Modulus (GPa)	190-210	190-210	190-210	190-210
Poisson's Ratio	0.27-0.3	0.27-0.3	0.27-0.3	0.27-0.3
Thermal Expansion (10^{-6}/K)	11-16.6	9.0-15	9.0-20.7	9.4-15.1
Melting Point (°C)			1371-1454	
Thermal Conductivity (W/m-K)	24.3-65.2	26-48.6	11.2-36.7	19.9-48.3
Specific Heat (J/kg-K)	450-2081	452-1499	420-500	
Electrical Resistivity (10^{-9}W-m)	130-1250	210-1251	75.7-1020	
Tensile Strength (MPa)	276-1882	758-1882	515-827	640-2000
Yield Strength (MPa)	186-758	366-1793	207-552	380-440
Percent Elongation (%)	10-32	4-31	12-40	5-25
Hardness (Brinell 3000kg)	86-388	149-627	137-595	210-620