



# **Machining Analysis in Mould Making**

Master degree in Product Design Engineering

**Karthik Ravichandran**

Leiria, March,2019



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Internship Report developed under the supervision of Professor Henrique Amorim Almeida and Professor Mário Simões Correia, professors at the School of Technology and Management of the Polytechnic Institute of Leiria.

Leiria, March,2019

## **Originality and Copyright**

This internship report is original, and made to understand roughness characteristics of steel 1.2316, and all authors whose studies and publications were used to complete it are duly acknowledged.

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## **Dedication**

I would like to dedicate the work to my beloved parents who made all the struggle and efforts to make me become who I am today, Also I would like to thank all my friends and professors who kept me engaged and motivated throughout my career.

## **Acknowledgements**

First of all, thanks to my professors Mr. Mario Correia and Mr. Henrique Almeida with the thorough knowledge and their help gives me space to learn more about the moulding industry. Like to Thank Mr. Vitor Batista Chairperson of Batista Group who give me opportunity to do my Internship in VB Fresagem. Special thanks to my supervisors of company Mr. Carlos Alexandre and Mr. Diogo Batista who keeps motivated and helpful and passed their knowledge throughout my Internship period and all the co-workers of VB Fresagem who teaches me good qualities and professionalism.

# Resumo

Este documento é o relatório de estágio do curso de Mestrado em Conceção e Desenvolvimento de Produto realizado na empresa V.B Fresagem S.A. A empresa V.B. Fresagem S.A., é dedicada à prestação de serviços de fresagem para o sector dos moldes e metalomecânica. Tem a capacidade de maquinar peças pequenas e de médias dimensões, em diversos materiais, tais como aço, inox, alumínio, madeira e *nylon*. A V.B. Fresagem S.A. é uma sociedade anónima com início de atividade em 1991, sediada na Marinha Grande, especializada na prestação de serviços na área dos moldes, mais concretamente na fresagem.

Com este estágio foi possível concretizar a imersão industrial que era um dos objetivos do estudante para este estágio. Na empresa depois de um enquadramento inicial, foi possível desenvolver trabalho nos diversos equipamentos com diferentes materiais para moldes que a empresa maquina.

Foi também definido como objetivo, a realização de uma análise ao processo de maquinação de superfícies moldantes. Com esta análise foi possível comparar parâmetros de processo de maquinação, ferramentas e um aço para moldes com o estado superficial em termos de rugosidade. Também foi possível comparar a estabilidade do processo em diferentes equipamentos. A velocidade de rotação e o diâmetro da ferramenta são dois dos parâmetros que mais influenciam a rugosidade superficial, porque efetivamente também estes influenciam de forma genérica os restantes parâmetros de maquinação.

Este trabalho ainda concluí que é fundamental que as ferramentas utilizadas nos trabalhos de maquinação, sejam utilizadas dentro das gamas de funcionamento recomendado pelos fabricantes. Assim, deste modo, é possível garantir um acabamento superficial dentro do definido no projeto das cavidades moldantes e também uma estabilidade no processo de maquinação para assegurar um tempo de vida superior para as ferramentas.

Palavras-chave: Máquinas CNC, ferramentas de corte, rugosidades, fabrico de moldes

# Abstract

This document is the internship report of the Master in Product Design Engineering carried out at V.B Fresagem S.A. The company V.B. Fresagem S.A., is dedicated to the provision of milling services for the sector of moulds and metal machining. It has the ability to machine small and medium sized parts in various materials such as steel, stainless steel, aluminium, wood and nylon. V.B. Fresagem S.A. is a company started in 1991, based in Marinha Grande, specialized in the service of moulds, in milling operations.

With this internship it was possible to concretize the industrial immersion that was one of the objectives of the student for this stage. In the company after an initial inclosing, it was possible to develop work in the different equipment's with different materials for moulds in the company machines.

It was also defined as an objective, the accomplishment of an analysis to the machining process of moulding surfaces. With this analysis it was possible to compare parameters of machining process, tools and steel for moulds making with the surface state in terms of roughness. It was also possible to compare the stability of the process in different equipment. The speed of rotation and the diameter of the tool are two parameters that most influence surface roughness, because they also influence the other machining parameters in general.

This work also concluded that it is fundamental that the tools used in the machining works, are used within the ranges of operation recommended by the tool's manufacturers. Thus, it is possible to ensure a surface finish within that is defined in the design of the moulding and also a stability in the machining process to ensure a longer tool life.

Keywords: CNC machines, cutting tools, roughness, mould moulding

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# 1 INTRODUCTION

This is an internship report developed on VB Fresagem at Marinha Grande. The report is mainly focused on analysis of roughness characteristics of steel 1.2316 by milling with different set of tools and it is explained how it work with the CNC machines with different parameters. Starting with the history of CNC machines, report explain the machining processes which is generally used in mould making companies. Types of machining equipment were described and identified which were available in the company.

In mould making industry, material selection plays a huge factor to make a final mould, each characteristic and criteria for various material index of moulds has been also showed in this study. To find roughness value, measurements were made on 1.2316 steel after several milling process. Different cutting tools and cutting parameters were used to find the different surface texture. Previous discussion concerning roughness parameters were showed.

## 1.1 Company Presentation

VB Fresagem is a company located in Marinha Grande established in the year 1991 specialized mainly for milling services and making tool bases. Mr. Vítor Batista the chairperson through his hard work and dedication developed the company with tremendous efforts and self-belief, elaborated the company in different zones of Marinha Grande. VB Fresagem is part of the Batista Group of composed of three companies, being the other two Batista Moldes (mould manufacturing to develop plastic parts) and Batista Moldes 2 (specialized in mould bases). As service provider for milling for the mould and metalworking sector that company is committed to meet the requirements of every customer and continuously satisfying all needs. The VB Fresagem company is well equipped with latest technology CNC machines and relied mostly on dynamic team, which works tremendously with new and creative ideas. In Figure 1 it is possible to observe an overview of the company from top view.



**Figure 1 VB Fresagem**

VB Fresagem holds fundamental values such as humility, honesty, accuracy and sense of responsibility and of all those in company mission and vision of company, company recognizes and appreciates the respect and ethics in human relationships and activities, spirit of teamwork, the dynamism and initiatives of its employees in continuous quest for improvement of organisation.

One of the company issues is to provide a quality milling for the clients and the mission is to satisfy the customer which is the primary motive.

Be competitive in the moulding industry provided better customer satisfaction, and also belongs to the main market players and be the reference supplier in our market, thus providing continuous improvement of VB Fresagem organization.



**Figure 2 Design room of VB Fresagem**

In Figure 2 it is showed the design room of VB Fresagem where programming for all the machines are done with well-trained persons in the programming field. Around 15 employees are working in VB Fresagem where in the other two companies of the group are around 150 employees.

## **1.2 Structure of the internship report**

The main issue of work developed in this internship were to find the roughness characteristics on steel 1.2316 by using different tools and cutting parameters.

The manuscript is divided in five chapters. On chapter 1, a brief introduction about the company and the machining processes which is generally used in company VB Fresagem is presented. On chapter 2, explains the history of CNC Machines and also described types of process such as milling. Also, a brief description on drilling process is made in this chapter.

On chapter 3 a description of equipment's available in the company VB Fresagem is made.

On chapter 4 the case study is presented. It is explained the main characteristics of 1.2316 steel and also explained the reason for selecting that steel. References concerning heat treatment process, polishing processed in machined material were made. Tools, type of inserts used for the milling operation, equipment's and study parameters were showed. Milling process and roughness analyse characteristics. Roughness parameters and measurement device used is described. Results are showed on this chapter and the relationships between tools, cutting parameters and roughness are showed.

To finalize the report, chapter 5 presents the conclusions that were obtained from the performed work.

## 2 Machining processes

CNC Machine is generally defined as Computed Numerical control, which performs the automated tools of the machine into operation by a predefined programmable sequence. This is generally developed by the Computer-aided Design (CAD) software, and then imported to the Computer-aided Manufacturing (CAM) by the manufacturing directives, this operation will help to initiate the necessary programs required to perform the particular operation for milling. This machine can perform different operations according to the commands given prior to the operation. Generally, CNC machines can be used for various process like milling, drilling, surface cleaning and finishing.

### 2.1 History of CNC Machines

The First Numerical Control machines were developed in the early 1940s, this system is a primary version of the existing CNC Machines. It has very complex systems, as like present CNC Machines developed by a scientist named John Parsons, this particular machine was generally used to produce complex aircraft parts during its initial stage. Parsons who is working with his father during his initial stages in Michigan has collaborated the idea of making the rotor of helicopter wing templates by using the IBM 602A multiplier to calculate air foil coordinates and input this data into a Swiss jig borer.

Parson's work and research leads to Air Force Research projects in Massachusetts Institute of technology in the year 1949, with his intensive research and dedication he has developed the new milling machines in the Servomechanism laboratory. A 28- inch Cincinnati Hydro Tel vertical spindle machine was formed the base for the experimental system. External modifications of the system like table, head, spindle has been made along with the three variable speed hydraulic transmissions which was connected with the leadscrews. A feedback system was added to the machine to ensure that the machine is running as directed.

By the year 1953 research of this machines have been indicated the practical possibilities of this technology through various research applications. However, in MIT a different, less accurate Numerical controller machine was developed that utilized a tape reader, Flex writer, has paved the way laterally to become a prototype model of CNC Machines.

In General, CNC Machines has evolved of different types and it was purely depending on the computer commands rather than the human to perform works. This machine was generally using drives, actuators, and software commands and programs.

Different types of CNC machines existing in the production industry and the number of manufacturers which are involved in production of CNC machines. The CNC's are making most of the mechanical production faster and easier and the manufacturers who are developing the CNC machine are developed and innovated the various new innovations in the CNC equipment's some of the CNC manufacturers namely Doosan, Deckel, Hartford, AWEA mechatronics, Sun mill, Mill star, Mazak, etc. Moreover, the involvement of CNC's in automobile, industrial, packaging is immense, and it continue to advanced day by day as the technological innovations improved tremendously.

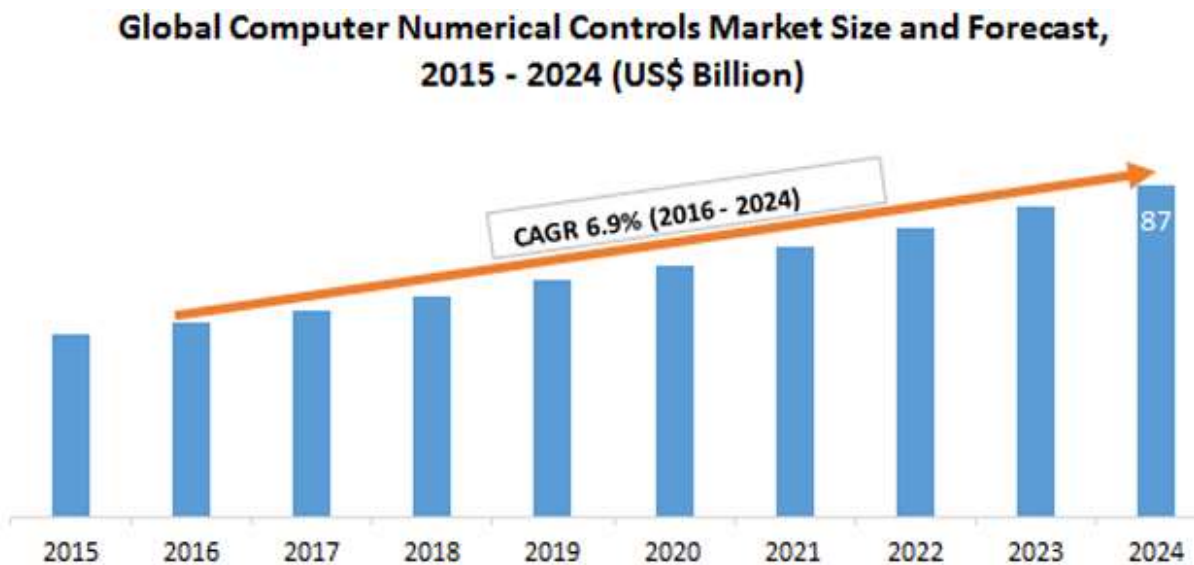


Figure 3 Market Value of CNC Machines [5]

In figure 3 we can see the global market share of CNC machines by each year which is expected to grow around (6.9%) from the year 2015-2024 which denotes that the necessity of the machines is increased every day and the usage of the machines and the buyers of CNC equipment's tends to increase.

## **2.2 Processes and equipment's**

In manufacturing process there are various number of cutting technologies involved, some of them are planning, milling, boring, drilling, threading and finishing. In order to make all these processes an engineer or designer should analyse the requirement needed to cut the raw materials it may be different type of steels, aluminium or others. First of all, to the process selection is given more importance as this manufacturing production process, involves time and cost to the company. The designing or programming of milling operations has to be developed concerning materials which are readily available in the company.

Most of the moulding industries have their Work Strategy based on minimum production time making the company competitive and more profitable, in other words, if the work is finished on time or before time so that the Company can save more time and money. Time consumption is the huge factor in making the process strategy which includes right selection of parameters, machines, availability of tools stocks etc., mostly there are various number of techniques available for milling operations the product designer or manufacturer should select most effective and time-consuming strategy. Let us discuss in below topics the number of milling operations which are available in the company where internship occurs.

### **2.2.1 Milling**

Milling is the process done with the multiple tooth cutter more specifically each tooth has the tendency to cut the steel along each direction it moves along. Milling can be done in many types of materials like steel, cast iron, aluminium and others. The hardness level of the steel can also play a role in selection of cutting tools. Higher the hardness of the material to be machined, it can produce severe wear and cracks on tools. The hardness range of steel usually around 35-55HRC can be successfully milled.

The company has been specialized in milling operations. Company is specialized on face milling, high feed milling and shoulder milling. Usually, company initially receive the order from clients with the specific requirements to be done on the steel. The milling operations and selections of tools is mainly depending upon the size, shape and resistibility. In Figure 4 it is possible to observe the different milling operations.

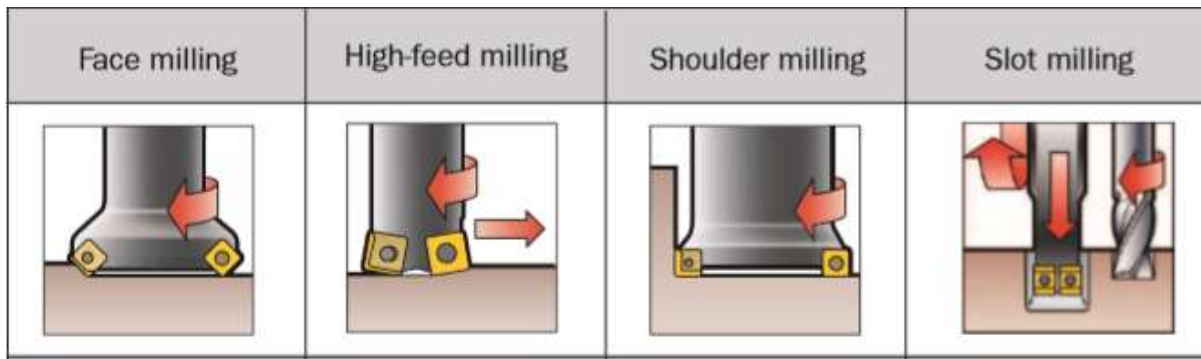


Figure 4 Milling operations [6]

### Face milling

The milling operations in raw steel is initiated with face milling where all the metal inserts are of different angles with  $10^\circ$ ,  $45^\circ$ ,  $90^\circ$ . The tools are of generally larger diameter 40-50 mm and the cutting capabilities of this tools are relatively larger with depth of cut in both radial and axial directions. In these cutting speeds is generally around 1000-1400 rpm where generally used to make the planned surface. On Figure 5, it is possible to observe high feed face milling.



Figure 5 High feed Face Milling [6]

### Shoulder milling

These type of milling are always done with the metal insert angle of  $90^\circ$  and there are generically used to mill the surface corners and they are specialized with cutting tool diameter around 40-50mm, in Figure 6 we can see the shoulder milling. This milling operation can be generally used for higher depth of cut and finishing is very appreciable in this milling operation.



Figure 6 Shoulder Milling [6]

### Profile Milling and Solid Carbide End mill

The profile milling is always made of round inserts or circular and these types of tools are having strongest cutting edges with multiple index, and they also have the milling cutters with bull nose. And another material used on milling is the solid carbide end mill this can use be cutting with higher depth and smaller width, this is generally used to make the cutting zones deeper. In Figure 7 we can see the end milling tools.



Figure 7 End Milling Tools [6]

### 2.2.2 Drilling

Drilling is generally defined as making the holes in the steel with the requirement diameter. There are various number of drilling tools available on company. Materials used on drilling tools are high speed steel and carbides. Drilling are available in different dimensions from 3.3 mm to 40 mm in fabrication section. And all of these are drilling tools are used combine with cutting fluids in order to resist the heat created by the tool.

#### High Speed Steel Drill (HSS)

High speed steel drillers are generally used to make the hole deeper in the steel. And main significance of this material, that can work for deep holes drilling and operations without losing its hardness level. Also, this can be more effective and faster than high carbon steel so

is used high speed steel (HSS). In Figure 8 we can see the image of high-speed steel tool which can be milled in materials like steel and other metallic alloys.



**Figure 8 High speed drilling tool (HSS)**

### **Speed Drilling**

Speed Drillers are generally used to drill the hole faster with highly efficient way, and these tools are generally having the capacity of cutting the hole faster and they are relatively smaller drillers (3.3mm to 14.5mm) and also larger drillers which are available (17.5 mm to 40 mm). In figure 9 we can see the drilling tools which we are using.



**Figure 9 Speed Drilling**

## Deep Hole Drilling

Also, the speed drillers available in the company are for larger diameters from 17.5 mm to 40 mm. These drillers are used generally in the drilling tool which are able to provide cutting fluid and used for finishing operation. Also to these deep hole drilling it is also necessary make with internal fluid flow option, because the deep hole drilling tools generally cut large quantity of steel and provides big quantity of chip formation, so the internal fluid flow during drilling can ejects out the chip, moreover if used external cutting fluid for deep hole drilling in some cases occurs breakage of metal inserts or tools. Even the vibrations provided in the work piece can happen and major faults will occur in the result of machined surface final. So, the use with more efficient way internal cutting fluid helps on a good surface finishing. These drilling tools are more efficient and normally a faster way to make the drilling operation in many Industries. In Figure 10 we can see the deep holes drilling tool.

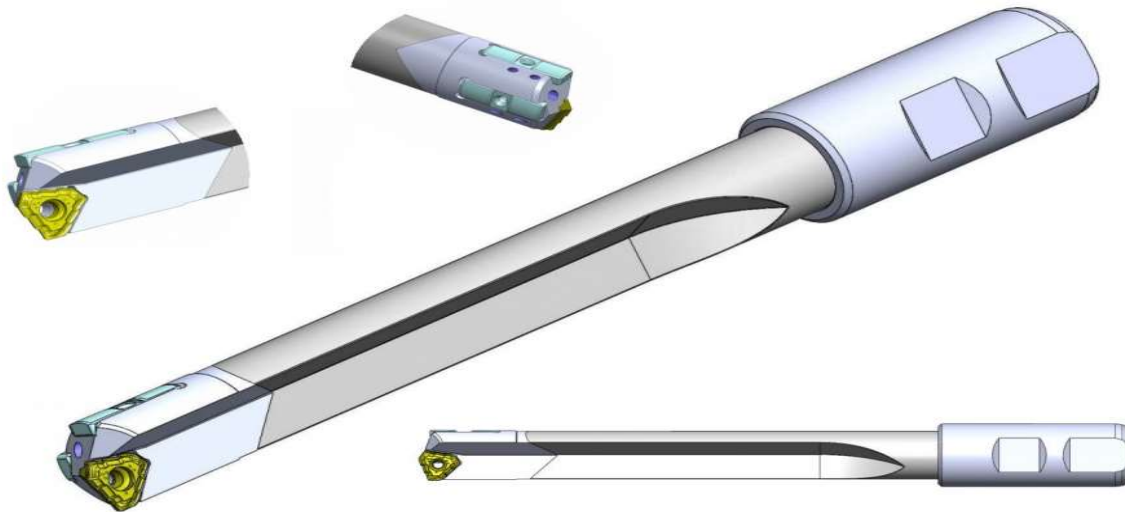


Figure 10 Deep Hole Drilling Tool [9]

So, these are some of the milling and drilling operations which are done in company. Different milling inserts are used on the company. For milling operation tools from Palbit, Dijet and Hitachi and for drilling Palbit.

### 2.3 Machining parameters and strategies

In milling operations, it is necessary to define a typical procedure to involve members of the company to have teamwork and pre-planning. The machining parameters and strategies will be described with the help of figure 11.

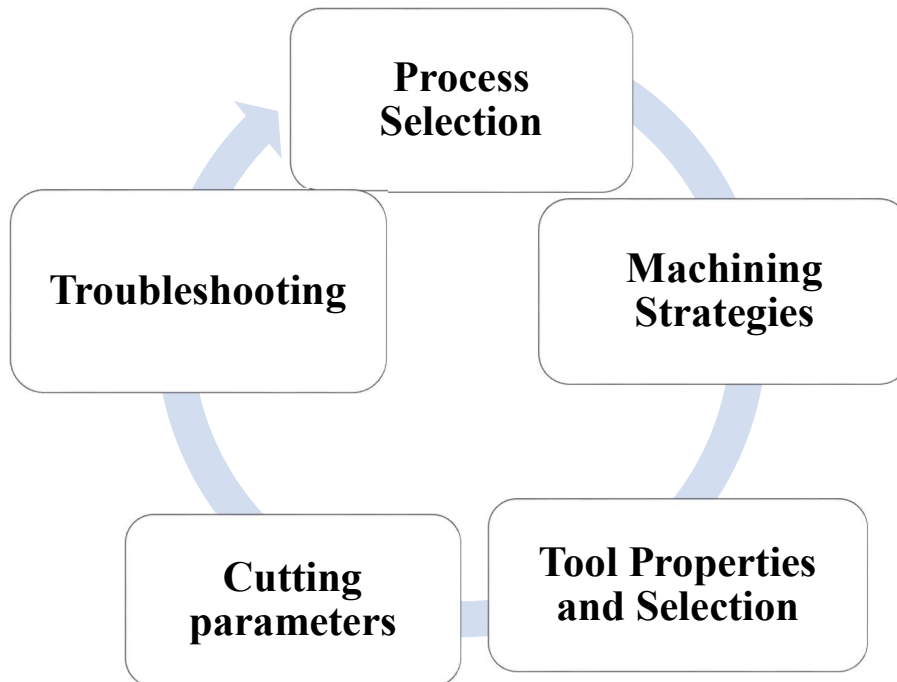


Figure 11 Machining Strategies Cycle

#### Analysis of Machining Parameters

Surface roughness influences the relationship between cutting tool and work piece. This will be most important analyse because it has influence on various properties such as, aesthetic appearance, wear, lifetime of the product [1]. It is possible to observe the conditions that affect the productivity in terms of surface conditions (roughness and hardness). Furthermore, the parameters which are chosen for machining decides the quality of final part product and also the cost. Chen Lu and Ning Ma [3] insisted that the influence of the conditions and parameters has important factor in maintaining the quality of final product. So, the knowledge of the various machining parameters for different tools should be evaluated. Different depth of cut, spindle rotation, feed rate will be discussing later on with the classification how each parameters and strategy hade influence on the characteristics of the surface roughness.

## Process selection

Before making the machining process, it is important to do the selection of the standard working procedure which will make the productivity faster and better. In other means it is necessary select the right machine which has a good geometrical flat surface or good surface table with slots to ensure that that work piece holds well in the machining zone. Before ensuring the right process selection, process requirements like drilling, tapping, milling, boring and finishing, must be well defined including the machined parameters. Because each machine has its own characteristic which influences the impact on final results, the selection and right working strategy will provide better results for the manufacturer.

## Machining Strategies

The strategies are very important to deliver the product right on time while explaining this briefly we should consider the right machines which has a good specification like rotation of spindle, cutting tool, metal inserts, feed rate (depends on processes), this also requires team work from employees of company in order to achieve higher production rate. In figure 12 we can see how the time is consuming in an industry.

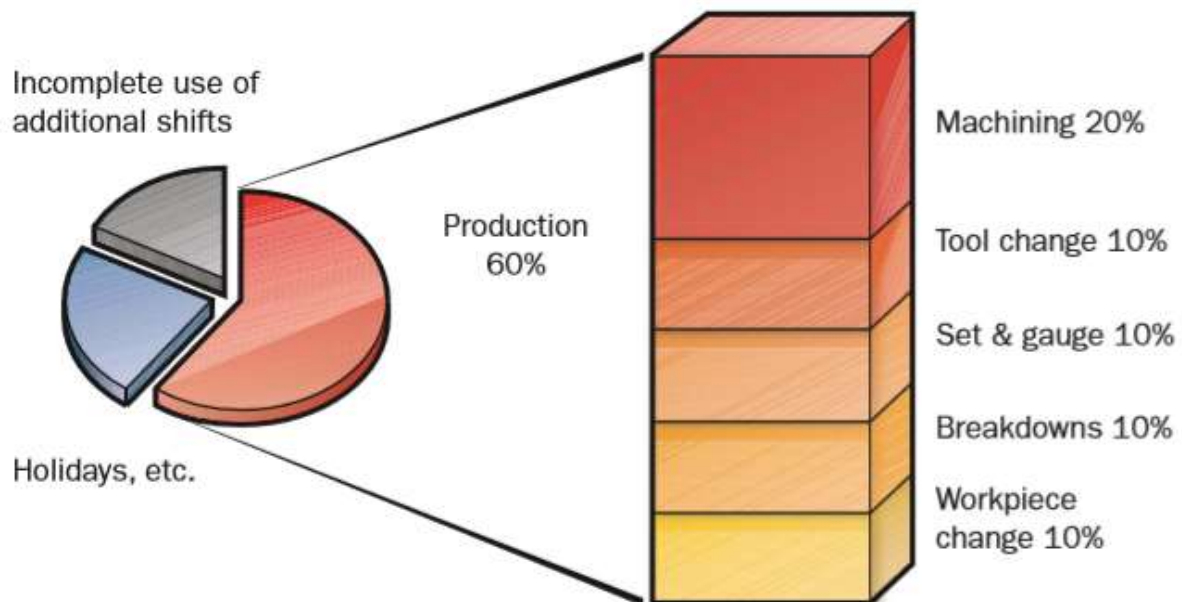


Figure 12 Time Consumption In Industry [6]

## Tool Properties and Selection

Even the cutting tool temperature can make some influences on the surface roughness [1], proper coolant should be provided in order to avoid these sorts of problems. There are various tools available to optimize the better cutting like tool cutters with round inserts which provides high performance milling operations and well suitable for face milling and profiling. This type of inserts requires stable machines as it has less capabilities of absorbing vibrations and sudden failure of machines (power supply, high depth of cut).  $45^\circ$  face milling is generally best suitable for face milling operations, smooth cutting and well balanced generally for axial and radial forces.  $90^\circ$  metal inserts have four inserts which provides better depth of cut and good low axial forces and also this have tendency to finish the cutting of work pieces faster. Figure13 represents cutter with round inserts, and Figure 14 represents shoulder face mill operation.

## Thermal Parameters

Durmus Karayel [4] considered that the cutting tool will promote higher level of surface roughness when using cutting fluid instead of coolant, because the fluid will reduce the friction between the flank and tool rake. In other hand, also removes dirt and wear particles create during the cutting process. So, the use of cutting fluid should be recommended when the machine will be working in high temperature conditions.



Figure 13 Round Inserts[6]

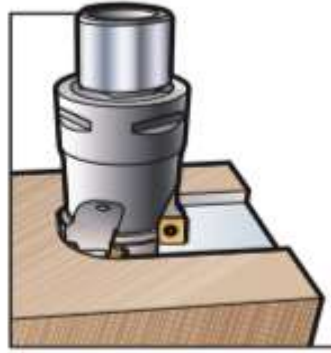


Figure 14 Shoulder Face mill

### Machining Parameters and Tool Properties

The parameters are generally rotation of spindle, metal inserts, feed rate and depth of cut. Programmer should ensure that the right parameters and cutting conditions are selected to make the milling faster with right surface finish. Discussion concerning parameters which will be recommended will be explained later. The Figure 15 explains the usage of right parameters for milling operations. Azouzi and Guillot [2] analyse that for higher feed and depth of cut the surface roughness will be higher. They have also insisted the quality of surface roughness will be increased with increasing the rotation of spindle and decreasing the feed rate.

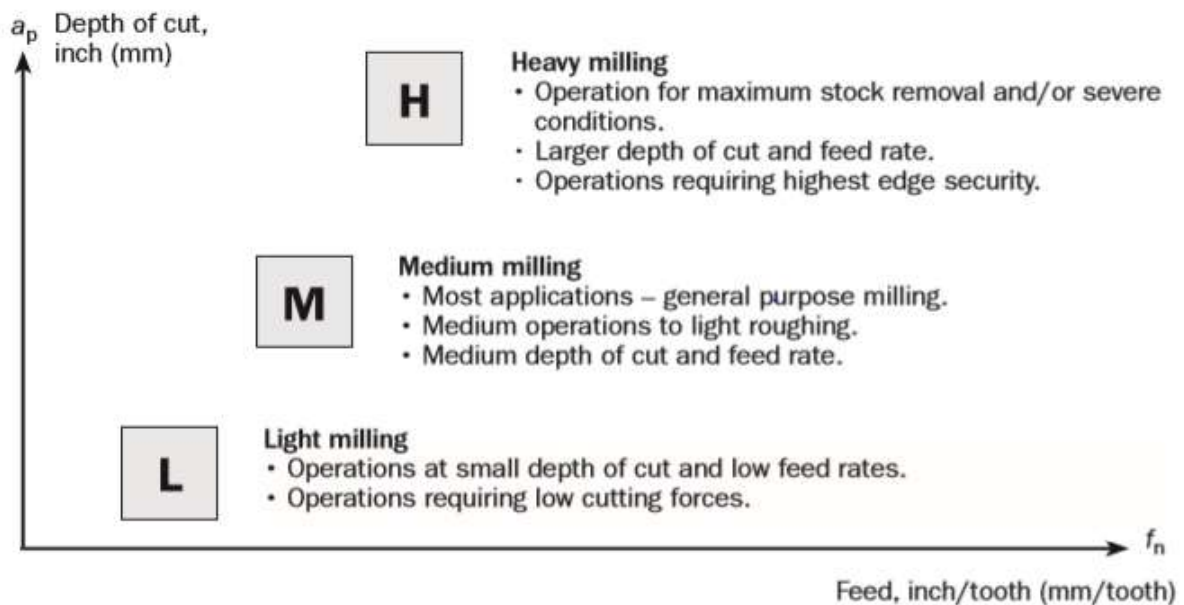


Figure 15 Implementing Right Feed Rate [6]

**S** – Rotation of Spindle (rpm)

**F** – Feed rate ( $V_f - F_z * Z_c * S$ )

**V<sub>f</sub>** – Table Feed (inch/min) (mm/min)

**F<sub>z</sub>** – Feed Per Tooth (inch/tooth) (mm/tooth)

**Z<sub>c</sub>** – Effective number of teeth (No of Inserts)

**A<sub>e</sub>** – Radial depth of cut (mm)

**A<sub>p</sub>** – Axial depth of Cut (mm)

All the above parameters are important to be considered while programming the working operations.

### **Troubleshooting**

After milling the work piece proper inspection (Troubleshooting) should be made whether the planning of surface is better according to the requirements (Dimensions, calibrations), should be proper checked before delivering the products to the client.

These are the general overview of machining strategies and parameters that should be considered while making good quality surfaces.

## 2.4 Roughness Parameters

Roughness of the material surface is usually considered as the most important aspects in the material science and in the production industry, because it influences a predominant role in manufacturing the products [12]. Moreover, the surface texture brings the lot more flexibility in makeover of many products developed in the moulding industry. As mentioned smoother the surface better the final quality of product, many factors should be considered in manufacturing of the product like corrosion, resistance, wear and tear. There are various parameters involved in the Roughness texture can be seen in Figure 16 which indicates the exact behaviour of the surface requirements, let us discuss the number of parameters which is evolved in the roughness characteristics and how it denotes the certain tendencies of the surface texture.

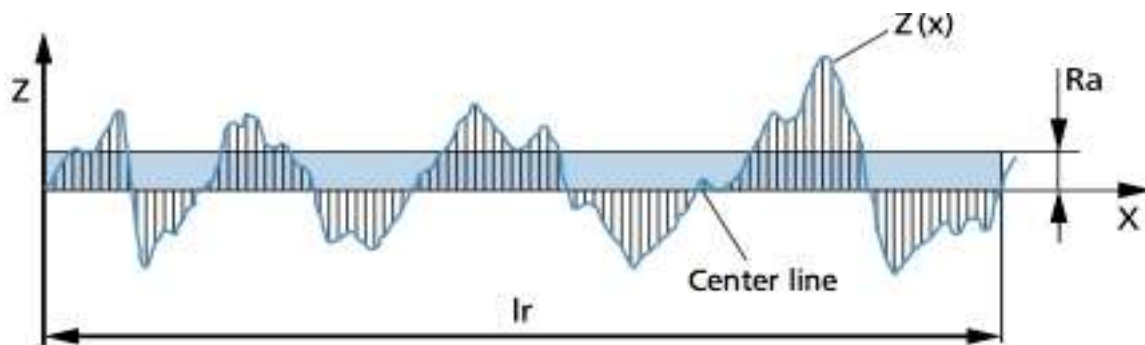


Figure 16 Roughness Average [8]

- **Ra- Roughness average** this denotes the exact arithmetic average of the roughness values of profile deviations from the mean line of roughness profile. [13]
- **Rq, RMS Roughness** is the root mean square of the average of the height of profile over its evaluation length.
- **Rp, Maximum profile peak height**, the distance this has between highest point of profile and mean line with evaluation length. Graph can be seen in Figure 17.

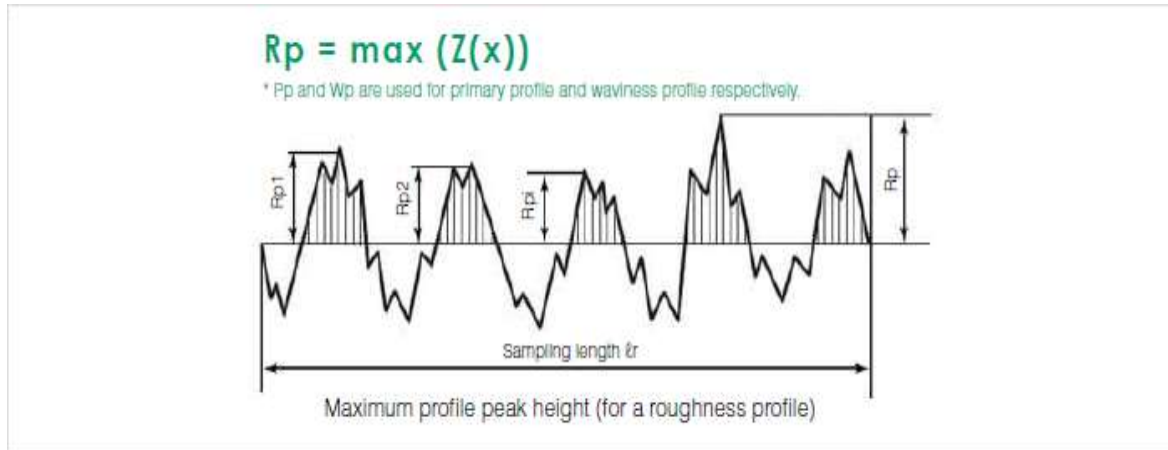


Figure 17 Maximum Profile Peak height [19]

- **Rp, Average Maximum profile peak height**, this the average of the successive values calculated over the evaluation length.
- **Rv, Maximum valley Depth of Profile**, denotes Distance between deepest valley of profile and the mean with evaluation length [22]
- **Rt, Maximum Height of Profile**, vertical distance between highest and the lowest points of the profile within the evaluation length.
- **Rz, Average Maximum Height of Profile**, denotes Average of successive values of Maximum height with sampling lengths over the evaluation length, where there are five sampling lengths within evaluation length graph can be seen in Figure 18.

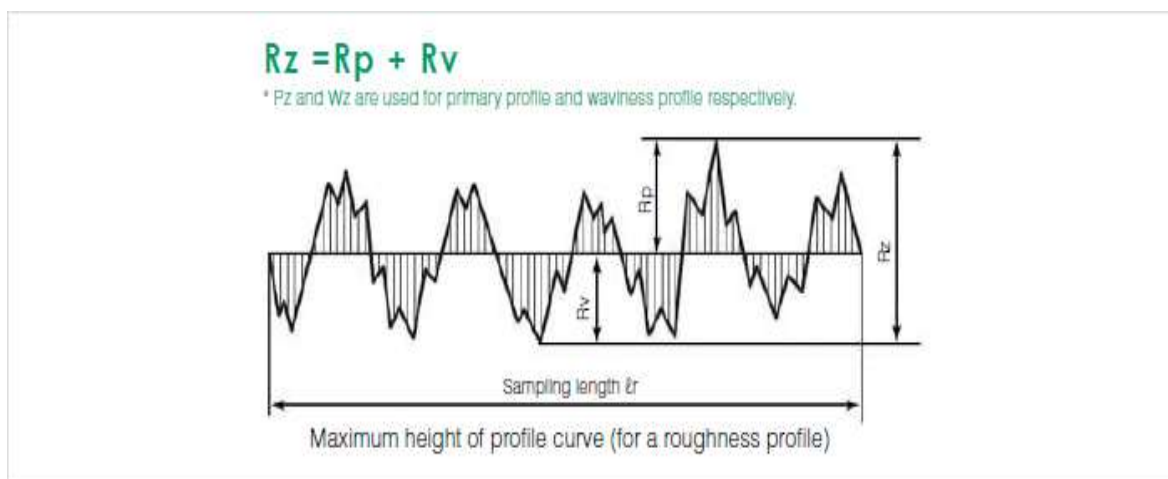


Figure 18 Average Maximum Height Of Profile [20]

- **Rmax, Maximum Roughness depth**, largest of successive values of maximum height calculated over the evaluation length seen in Figure 19.

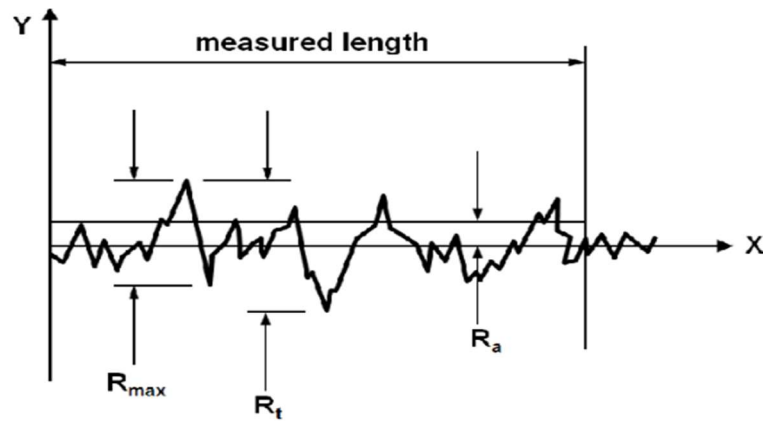


Figure 19 Maximum Roughness Depth[21]

So, these are the few parameters which are usually expressed in finding out the roughness values and this also helps the analysts to fine tune their working modes in order to provide better roughness characters in the production zones.

Table 1 Roughness characteristics [13]

Surface Finish	Types of Process
1D	Hot Rolled, heat treated, rough and dull
2D	Cold rolled, heat treated, smooth
2B	Cold rolled, heat treated, smoother than 2D
2G-(GROUND)	Grade of the grit or surface roughness can be measured, Unidirectional texture and not reflective
2R- (BRIGHT ANNEALED)	Cold rolled, bright annealed, smooth, bright and reflective
2J- (BRUSHED OR DULL POLISHED)	It is dull polished, and the surface will be not reflective

In table 1 is the roughness characteristics of steel and provides an idea how each classification can be denoted with the various surface finish grades.

### 3 VB Fresagem Milling Equipment's

Though internship career it was possible to learn and work in several CNC machines in the company. All equipment's are CNC Machines with different functions. In this chapter a description of VB Fresagem CNC machines will be made. The Company VB Fresagem has various types of machines such as 3-axis and 5-axis equipment's.

#### 3.1 HARTFORD OMNIS VMC-1270

Hartford Omnis is the vertical milling machine which has the capacity to hold 950 kg in the machining bed, the machine has the moving table in either direction with the dimensions of 1370\*600 mm. This CNC machine is equipped with the 24 tool savers with one tool changer in both ways. Detailed specifications can be seen in Table 2, the machine has fixed head on the vertical pointed tool operations and moving longitudinal direction on cross slide ways. The Figure 20 illustrates the front View of HARTFORD Omnis machine.

**Table 2 Specification of Hartford Omnis Machine**

Working Surface	1370*600mm
Maximum Capacity of Table	950 kg
Longitudinal Course (X-Axis)	1270mm
Transversal Course (Y- Axis)	635mm
Vertical Course (Z-Axis)	635mm
Maximum rotation of spindle	8000 rpm
T Grooves(N*Width*Distance)	18*5*100mm



**Figure 20 Front view of Hartford Machine**

The machine has the rotation of 8000 rpm and has the capacity to solve many milling operations like planning, drilling, surface finishing. As like most of CNCs this machine is well equipped internally and externally with the dust conveyor in built in the machine to take the steel chips out of the machine, water flash gun inbuilt with the water tank to clean the working area after the milling. The inbuilt water tank is basically helping in many of the drilling operations where the internal hole can hold some chips and can cause damage to the workpiece and also the tools. To avoid wear and tear, the tool and the machine requires overhauling and maintenance in the form of Oil and recycling of water. Figure 21 represents the working surface of HARTFORD Machine.



Figure 21 Working surface of Hartford Omnis

### 3.2 DECKEL MAHO DMU 125P

DECKEL MAHO is a German Based Manufactured CNC Machine which is a 5- Axis machine which can help us to produce complex structured parts in a slightly easily manner, this ,machine generally has a tendency of the Three Axis X,Y, and Z, with the rotating table and moreover with the rotating head, this machine is one of the most advanced and equipped Machine in the company which can make complex parts of different set of steels with the help of the CAD software, our company, VB Fresagem generally use the HEIDENHAIN software for all the machines. As mention in table 3 this machine has the working hold capacity 2.5 tonnes. And can rotate and cut the tools with 8000 Rotation per minute, and the Table of the working surface with 1250\*1000mm.

Table 3 Specification of Deckel Maho

Working Surface	1250* 1000mm
Maximum Capacity of Table	2500 kg
Longitudinal Course (X-Axis)	1156mm
Transversal Course (Y- Axis)	880mm
Vertical Course (Z-Axis)	800mm
Maximum rotation on Horizontal Axis	8000 rpm
Fast Forward Speed	X, Y, Z- 30000mm



Figure 22 Front view of Deckel Maho

This machine has the capacity to hold 40 tools at the same time in the tool magazine, with a double tool change gripper. It has the coolant supply of 40 bar pressure through the spindle centre which will help to blow in the air, when cutting hard steels, it creates more heat

in the machined zone, so to make sure that the work piece not elongates due to overheat it must be ensure the necessary required air has blown to the work piece and the tool these will help to save the tool and can expands the lifetime of tools. Figure 22 represents front view of DECKEL MAHO DMU 125P machine.

Machine has the coolant system which can hold a capacity of 500 litres, mostly are used oil mixed with water to make sure that tools not broken. During drills generally is used coolant all time because of the high-speed rotation of the spindle in contact with the work piece. In this case there are a maximum chance that the tool can make the damage either the work piece or the drillers, so in order to avoid the circumstances we use all time the coolant for all drillings operations to increase the tool life. Also, to take the metal chips out of the machine it has the integrated chip conveyor with Fabric Belt Filter.

### 3.3 MIKRON VCP710

MIKRON is a Swiss Based CNC machine, this is one of the smallest CNC machines in the company which was mainly used to manufacture very minute and small complex structured parts, with the fixed table base this has the spindle rotation of 20000 rpm with the capacity to hold to 30 tools at a time. In Table 4 we can see the specifications of MIKRON machine. This is a vertical positioned machine that can hold up to 1.6 tonnes at a time, has the fed rate of 30 m/min. it is possible to observe the working machine MIKRON VCP710 in the Figure 23.

Table 4 Specification of Mikron VCP-710

Working Surface	900* 600mm
T Grooves (N * Width * Distance)	6* 14H12* 63mm
Maximum Capacity of the table	1600 kg
Longitudinal Course (X- Axis)	710 mm
Transversal Course (Y- Axis)	550 mm
Vertical Course (Z- Axis)	500 mm
Rotation of Spindle	20000 rpm



Figure 23 Front View of Mikron Machine

Unlike other machines this machine has the unique configurations in the sense it has the fixed bed table whereas head of the table can move on to 3-axial positions X, Y, and Z. the machine has always used to mill very small dimensioned parts which has very complex requirements to fulfil, this machine has basic amenities like lubrication tank, hydraulic tank and the dust conveyor, in built to take out the steel from machining areas.

### 3.4 AWEA VP2012

AWEA is the one of the 3-axis machine in the company it has the working surface 2000\*1200mm which has the moving table on the X-axis. It was the machine which has tendency to cut at a speed at 5000 rpm, with high-speed milling tools, drilling operations can be easily made and the multi capabilities of the machine make it so innovative and with the newest CNC technologies. Detailed specifications can see in Table 5. This machine can hold up to 3.5 tonnes at a time. This machine has a rapid feed rate of about 24m/min and cutting feed of 12m/min. The Figure 24 represents the front view of AWEA VP 2012 machine.

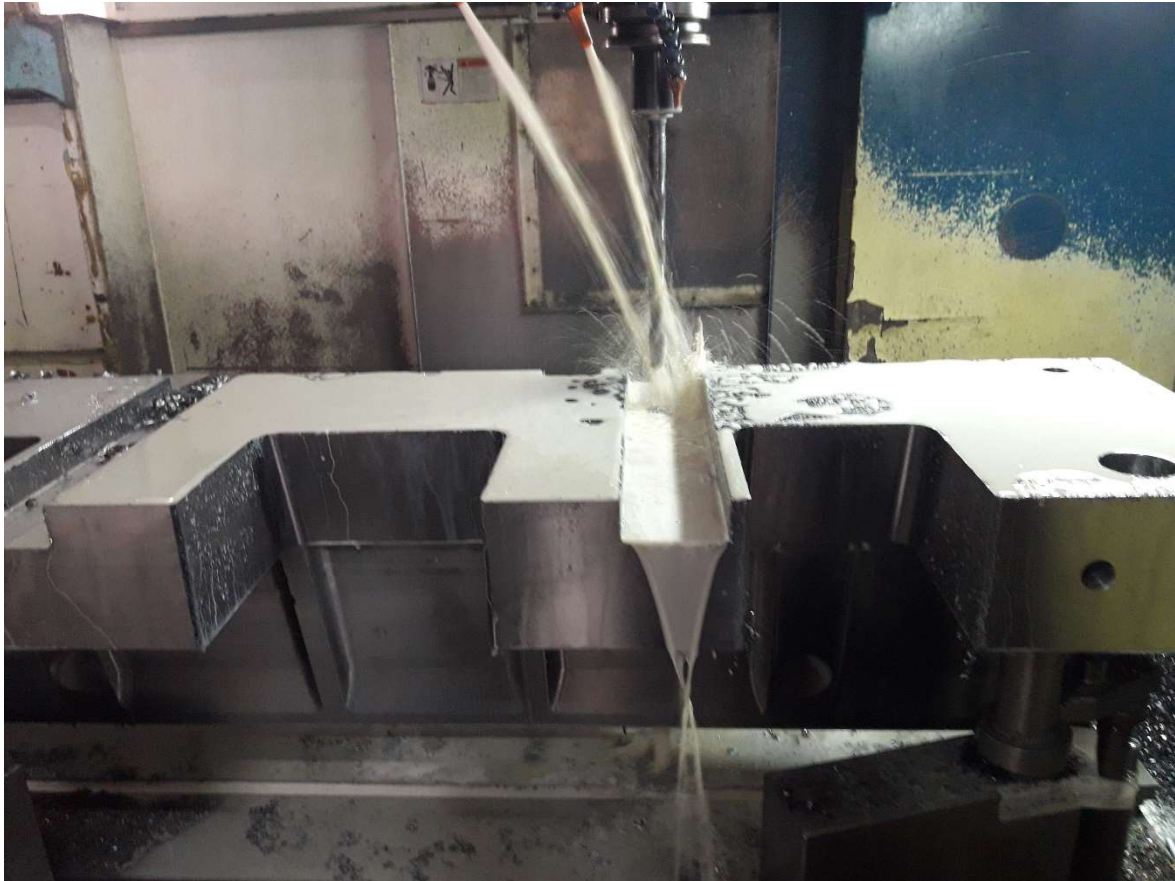
Table 5 Specification of AWEA VP2012

Working Surface	2000* 1100mm
Capacity of Table	3500 kg
Longitudinal Course (X- Axis)	1550 mm
Transversal Course (Y- Axis)	1200mm
Vertical Course (Z-Axis)	760mm+ 200mm
Rotation of Spindle	5000 rpm



Figure 24 AWEA Machine

The maximum weight of the tool it can hold the spindle is about 15 kg, it has a lubrication oil tank of about 4.5 litre, and the hydraulic tank of 120 litre capacity which we use for many of the drilling operations, and the coolant tank capacity of 370 litres. As like the other machine in the company, use HEIDENHAIN software for the machines to do all the milling operations. In Figure 27 it is showed the working surface of AWEA VP2012 with deep hole drilling in the work piece.



**Figure 25 Machining Surface of AWEA**

### **3.5 AWEA HSC200120**

The Figure 26 represents the front view of AWEA HSC 2001020, machine is the very latest equipped machine of the company which was equipped and commissioned during my tenure of the training. This machine has the similar kind of technical features as same as the AWEA VP, but the rotation capacity of the spindle is much higher than that of the machine of about 8000 rpm. Detailed specifications on table 6. This CNC has the moving bed conveyor on the X-axis and the spindle can move on Y-axis, so it can make the adjustments whenever it need to machine on the either axis in the fixed table. This can hold up to 32 tools at a time with the tool spindle exchanger in operation. Figure 27 illustrates the working zone of AWEA HSC 2001020.

**Table 6 Specification of AWEA HSC 200120**

Working Surface	2000* 1100mm
Capacity of Table	3500 kg
Longitudinal Course (X- Axis)	1550 mm
Transversal Course (Y- Axis)	1200mm
Vertical Course (Z-Axis)	760mm+ 200mm
Rotation of Spindle	8000 Rotation Per Minute



**Figure 26 Front view of AWEA Machine**



**Figure 27 Working surface of AWEA HSC2001020**

### **3.6 CME BF-04**

Table 7 gives specifications of CME Machine. CME is the multiaxial configured machine in the company which has the working surface of 2700\*1000mm, this machine can hold up to 6.5 tonnes at a stretch where the it has the machining head can make the rotations and can mill in horizontal and vertical directions. So according to the work piece requirements we always predisposition the head position of the machine whenever required. This machine has moving bed conveyor on the X axis position and the head can make two positions either Y and Z axis. The Figure 28 represents front view of CME Machine.

Table 7 Specification OF CME-BF04

Working Surface	2700* 1000mm
T Groove (N* Width* Distance)	7* 22H7* 140mm
Maximum Weight of Table	6500 kg
Longitudinal Course (X- Axis)	2500mm
Transversal Course (Y- Axis)	1200mm
Vertical Course (Z- Axis)	1600mm
Rotation of spindle	3000 rpm



Figure 28 Front View of CME Machine

The machine is equipped with the 30 pocket of tool saver, with one exchanger in positioned internally. The machine can make the maximum rotation of about 3000 rpm, with the spindle coolant pressure of 15 bar, with the chip conveyor inbuilt to take the steels and the dust out of the machine. It is possible to make the movement of the axial positions either with the monitored keypad or with the electronically hand wheels. As it has significance of milling

it in both axis horizontal and vertical, this machine has tendency to make precision milling. The horizontal milling of the machine CME in has been illustrated in Figure 29.



Figure 29 Machining of CME machine

### 3.7 VTEC VB-2515- Series B1-0051

VTEC 2515 is the one of the biggest capacity machines in the company which can hold up to 9 tonnes in the company. The dimension of the machine is quite bigger in size when compared to the other machines 2500\*1300 mm, spindle rotation of machine of about 10000 rpm. It has a moving table on the X-axis, and fixed head on Y-axis and Z-axis. The machine has total of 40 tool savers, with one tool exchanger, generally it takes about 2.5 secs of minimum time for a tool change in between the operation. Figure 30 represents front view of VTEC Machine. Detailed specification of machine in Table 8.

Table 8 Specification of VTEC-2515

Working Surface	2500* 1300mm
Maximum Weight of Table	9000 kg
Longitudinal Course (X- Axis)	2500mm
Transversal course (Y- Axis)	1500mm
Vertical Course (Z- Axis)	800mm+150mm
Rotation	10000 rpm



Figure 30 Front view of VTEC Machine

This machine is equipped with the internal chip conveyor to take the chips out of the machine, also with a splashing gun for cleaning the mill zone. The machine has the lubricated

water tank for make the deeper drills, this is usually the head of the tool magazines relate to the water tank which is interconnected with the machine in above Figure 30 there is the front view of the machine VTEC. These machines are vertically placed machine from origin, but whenever it is required to mill the work piece in the horizontal direction, it always have horizontal header near the machine which can be connected whenever necessary, used by the HEIDENHAIN Software this machine always tend to make all the milling operations. Figure 31 represents the working surface of the VTEC Machine.



**Figure 31 Working Surface of VTEC**

Machine is equipped with footswitch for clamp and unclamp the tools, the coolant system of air for the milling with certain tools can blow up to 20/70 bar pressure which in many cases helps to save the tools and the work piece from the elongation.

### 3.8 WOTAN CVCL2

This is a hand operated CNC boring Machine in the company, this is one of traditional CNC which was controlled and performed the action only by using the wheels by the operators, this machine is equipped with the rotating table one of the big significant features in the machine which helps the operations can be done in either direction on different zones of milling zone. In table 9 the detailed specification of WOTAN Machine.

**Table 9 Specification of WOTAN CVCL2**

Working Surface	1100*1250mm
Maximum Weight	12 Tonnes
Longitudinal Path (X)	700 mm
Transversal Path (Y)	1350 mm
Vertical Path (Z)	800 mm
Rotation of Spindle	1000 rpm



**Figure 32 Wotan Machine**

Figure 32 is the view of the WOTAN Machine, deep drilling of holes very much efficient to mill in this sort of machine as it has the tendency of moving in transversal and longitudinal directions, this is horizontal milling machine which have significant contributions to deliver in most of the milling operations

### 3.9 V050 DRILLING MACHINE

V050 is a drilling machine which will do all types of drilling, the machine has a fixed table in the base with the option of assembles temporary table fixations, the machine has the option of different types of rotation with the selection of buttons, so this has a hand wheel connected with the head of the machine to move the spindle across the table (X, Y, Z axis). In the table 10 we can see the detailed specification of V050 machine.

**Table 10 Specification of V050 Drilling Machine**

Working surface	1250mm (X axis)
Rotation of spindle	30- 2500 rpm
Operating Mode	Manual (Hand)
Type of Operation	All types of Drilling

It is possible to observe the front view of the V050 Drilling Machine in the Figure 33; this machine has been operated generally by hand wheels whereas the controlling of machine is been generally operated by hand mode. So, this are the numerous kinds of machines which are existing in the company and they all are of different kinds with their specifications and working nature. Schematic representation of V050 Drilling machine is shown above.

An overview of the machines and its basic functions were made. Moreover, these machines are technological advanced, so it is very useful for the production in the company.



**Figure 33 V050 Machine**

With this it was possible to describe the machines that exist in VB Fresagem company. In next chapter is described the case study developed on company during internship.

## 4 CASE STUDY

For a product designer there is always a few challenges has been posted to select the right materials in order to provide a good and better results, so to achieve this there are so many criteria to be satisfied. Apart from the functional performance the moulding is often required to match high standards of finish and tolerance for the product to have a long run, so all these requirements are often achieved by a right selection of material, this can play a huge role in producing better results and productivity.

Plastic moulding is part of everyday routines for the people all over the world in using their day to day product to say like mobile phones, glasses, automobile parts, computers, etc. Moreover, the materials which is needed to make these products often requires better quality and precision too, this is why the selection of steel became a huge aspect in order to provide good moulds. A mould making person knows the cost of excessive mould maintenance in form of cleaning, replanting, or replacing the broken parts, wear and tear should be taken into consideration. Certain facts like cost of production and downtime, late-delivering of products and loss of customer goodwill be taken into consideration.

The company VB Fresagem has been specialized in different milling operations and most often use varies materials which include steel, copper and iron. For this study, during internship period, the 1.2344 steel material were evaluated concerning hardness and roughness.

Steel 1.2316 is the classification of one type of stainless steel used for plastic moulds which was already developed from the 2083 (AISI 420). This material can increase its corrosive resistance by adding composition of molybdenum and chromium, also it comes out with quenching and tempering as the normal condition. Hardness was generally in the range 300 HB (30 HRC), which eases the way for milling operation without hardening ageing, which helps to avoid change in dimension or shape during the milling operation. The chemical composition of steel 1.2316 is explained in Table 11.

Table 11 Chemical Composition Of steel 1.2316

Type of Steel	C	Si	Mn	S	Ni	Cr	Mo
1.2316	0.33- Min 0.43- Max	Max 1.00	Max 1.00	Max 0.005	Max 1.00	15.00- min 17.00- max	1.00- min 1.30- max

This steel is very much suitable for plastic moulding because of corrosive resistance during thermoplastic material making such as PVC and thermoplastic. The main application of this steel is that it can be mostly suitable for plastic mould because of its rusty condition and corrosive resistance. The materials are generally used in plastic moulding industry such as example for plastic extrusion mould, high corrosive plastic shafts of water pump and also even in compressor parts.

The main motivation of the case study is to find the characteristic behaviour of the hardness and roughness of the material steel 1.2316 after machining with different parameters. It is possible to measure hardness and roughness with different equipment of Materials Laboratory.

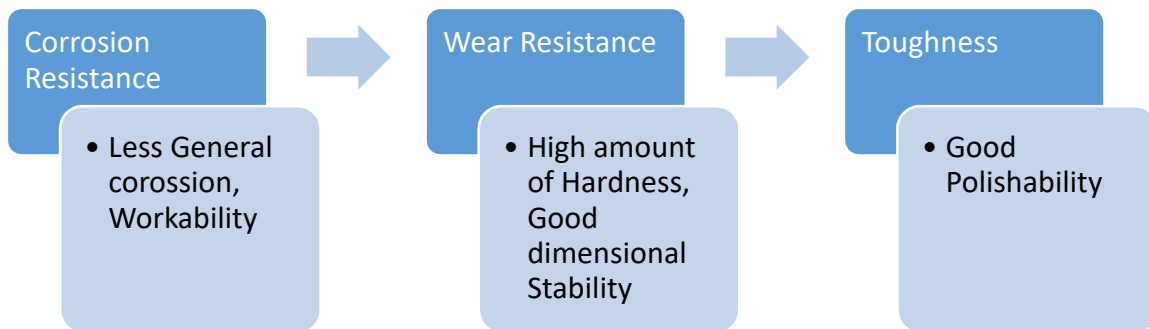
To achieve the best possible result, they are several criteria that the mould designer and the production engineer have to consider the requirement aspects, together they share the heavy responsibilities for producing a mould that gives reliable and economical production of parts conceived by the product designer. Whenever these requirements are achieved, there is no necessity make the large extent on specifying the best mould steel and hardness for mould concerned. Smarter designer should think in a fact that to produce better standards in a successful short period of time. Cost savings can be further improved by extend the thinking to select the standard steel grades, machined plates and steel grades.

In fact, if there is availability of specifically standardized steel with the necessity is selected and ready then it is very easy for the product tool maker to produce the goods faster and make more time and money. we can see the Figure 34 with the completed finished mould.



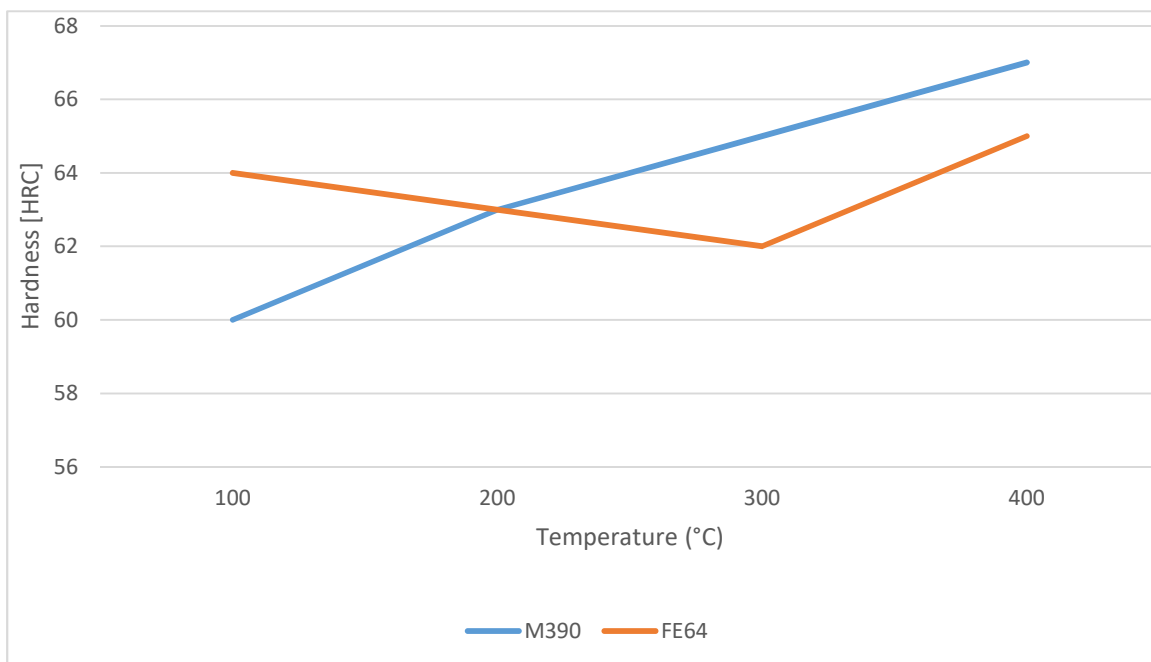
**Figure 34 Finished Mould [14]**

The manufacturer of the moulds is always gives significant importance to his product delivery, which means the clients required the product to be perfect and delivered on time which will help them to ease their works, the manufacturer in other terms gives values to the characteristics of product which is essential nowadays as various factors plays major role in reliability of tools such as performance, delivery on time, product wear resistance, compressive strength, corrosive resistance, thermal conductivity, friction, toughness of product. The properties of plastic mould steel have explained in figure 35.



**Figure 35 Requirements of Mould Steel**

The figure 36 represents the Rockwell hardness range for the materials with the certain temperature and the concern hardness range (generally use for metallic and polymer materials, there are also number of hardness types line Brinell (uses ball indent of 10mm diameter) for larger grain size or thin sheets, Vickers (for Thinner and fine grained material) use diamond indenter to measure which is lot smaller than Brinell indent.



**Figure 36 Comparison Graph (Hardness vs Temperature)**

The crack formation which happen in the mould is one of the major drawback factors, this happen mainly in the sharp corners, thin walls, smaller radii which are zones mainly affected, so the toughness of the metal is often considered [10] as the important factor for the mould steel. The major of this problem arises because of the improper heat treatment, non-structural construction, and fatigue crack. In order to optimize the toughness of the material the state of metallurgical art is used like vacuum degassing, special refining, and electro slag melting. By emulating this procedure there is improvement in the toughness and also throughout the material of the steel.

The tool maker has the importance of selecting right material and also the certain factors which are more importance than considering the final quality of the product, so in this case it is necessary we need to consider how good the steel can be more effectively produced with the higher amount of quality and no defects. Also, we have the responsibility to satisfy the clients according to their necessity. There are few things which is most important to select the material and it is finding its properties like polish ability and heat treatment.

### **Polishing**

Polishing is one of the most important factors to be considered in the steel productivity it almost consumed 1/3 of the total mould cost, so it is more time-consuming process during the tool making procedure and expensive. The results obtained in polishing processes is mainly dependent on the steel and its cleanliness. This process also increases the tool's life durability and, stability as compared to the non-polished steels. Its factors give the mould maker the higher amount of precisions in developing the prototype and various production process.

### **Heat treatment**

The heat treatment is utmost a very important factor in making the tool for moulds, because it plays a huge factor to attain a mechanical property such as hardness, toughness, but has some few drawbacks [10] in the form of distortion and dimension changes which can be solved involving different processes. The tool after the machining process should be completely relieved of stress, this is the one way that can be successful in making the heat treatment. When using the hardness steel at the maximum hardness levels, the minimum distortion has tended to happen, this is because of very higher temperatures on the material, in order to avoid this, it is important that pre-hardened steel should be use.

Also, it is usual that the when heating treatment goes on it may cause some dimensional changes which is inevitable, but it is possible to limit this cause by limiting the slow uniform temperature like medium temperature or by a suitable quenching procedure, for the steel not to make dimensional difference. Figure 37 denotes the heat treatment machine. There are certain types of heat treatment procedures involved in the mould making namely stress relieving, annealing, normalizing, nitriding and carburizing.

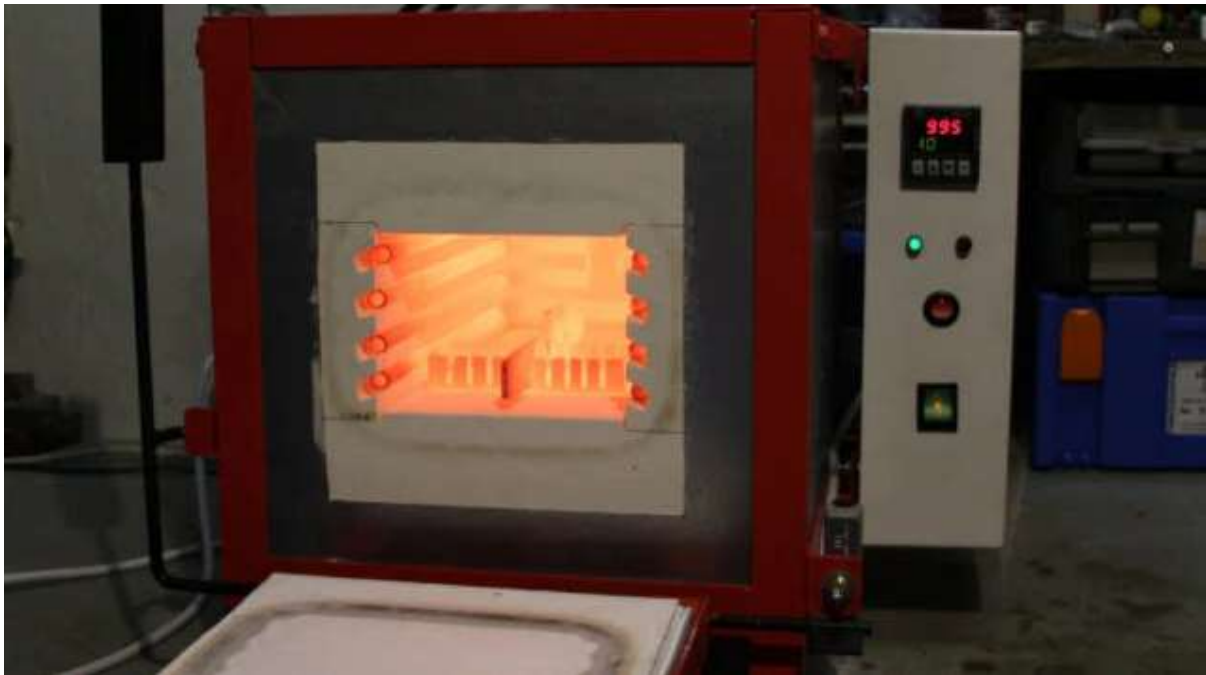


Figure 37 Heat treatment [15]

- I. **Stress relieving** - The main aim of this procedure is to decrease the stress after the cutting, in this process the heating and cooling of the steel is very slow.
- II. **Annealing** - This procedure is to remove the internal stress and toughen the metals, this can be making the metal heated and allowed it to do cool down slowly, this can improve its ductility and reduce the hardness of the metal and makes the product workable.
- III. **Normalizing** - This type of process relieves the stress on steel, by heating the metal above its critical point, and then slow uniform cooling by air, until it attains the room temperature.
- IV. **Hardening** - This process generally takes place to harder the metal, this will be taken down primarily by annealing which will be followed by hardening

process. This makes the metal more brittle and could not break or distort when its subjected to use.

- V. **Tempering** - Generally to remove the brittleness this process is takes place after hardening process, heat the metal slightly and let it cool slowly this is the basic principle of tempering, this makes the metal improve ductility and brittleness. In Figure 38 have the tempered steel from my company.
- VI. **Nitriding** - The main purpose of nitriding is to improve the surface hardness of the steel and improve its wear properties.



Figure 38 Tempered Steel

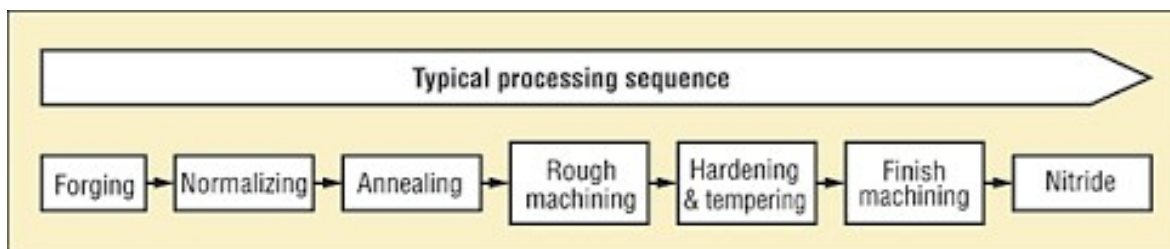


Figure 39 Sequence Of Heat Treatment [16]

The sequence of heat treatment is explained in figure 39. In general heat treatment procedures are mainly based upon the type of the requirement of the mould and the kind of the steel which we initiated to use, most of the mould processes generally goes through hardening before machining which makes the steel stronger and avoids distortion. And also, after the machining process the steel is sent for nitriding procedure this will make the uniform structure of the steel and increases its abrasion resistance and also for better mould characteristics. There are certain types of standards and grades of steel used in the moulding industry let us see few kinds of steel in table 12 and the types of heat treatment takes place in the steel and its actual temperatures.

**Table 12 Heat Treatment on Various Steel [7]**

<b>Steel-1.2311</b>	<b>Steel-1.2316</b>	<b>Steel-1.2343</b>
<b>Annealing-</b> 710-740°C in Furnace	<b>Annealing-</b> 760-800°C In Furnace	<b>Annealing-</b> 750-800°C in Furnace
<b>Hardening-</b> 840-870°C in Oil Hardness	<b>Hardening-</b> 1020-1050°C in Oil Hardness	<b>Hardening-</b> 1000-1030°C
<b>Tempering-</b> 100°C-51HRC 200°C-50HRC 300°C-48HRC 400°C-46HRC 500°C-42HRC 600°C-36HRC 700°C-28HRC	<b>Tempering</b> 100°C-49HRC 200°C-47HRC 300°C-46HRC 400°C-46HRC 500°C-47HRC 600°C-32HRC	<b>Tempering</b> 100°C-52HRC 200°C-52HRC 300°C-52HRC 400°C-52HRC 500°C-54HRC 600°C-48HRC 650°C-38HRC

Several steel materials are used for mould making, for this study it was used the 1.2316 steel described previously.

## 4.1 Tools Geometry and Materials

When concerning tools geometry, it is important for any manufacturer to have the right tool (demanded requirements), usage of metal inserts, productivity concept, machining strategies and time consumption.

The percentage of production rate can be increased by implementing the working strategies by following the right tool geometry. Increasing the production rate and tool life by decreasing the wear and tear, this leads to maximum productivity and time consumption in working conditions. Tools are generally the main cost factor in many of the production industry. The next chapter will present the discussion of factors which leads to damage the tools and machining strategies which should be followed in order to avoid the damage.

### Tool wear and Maintenance

The tool wear generally happens for different reasons. High feed rate, unusual cutting speed, wrong selection of inserts, fault in machines and damaged of tool holders. It is necessary for the selection of right conditions in order to avoid these kinds of wear and tear. In Figure 40 we can see the breakage impression in the tool, this can be of tool breakage and it should be rectified when used for further milling operations, because this can lead to change in feed depth and cause irregularity in the work piece. Figure 40 represents tool breakage on corners of metal inserts.

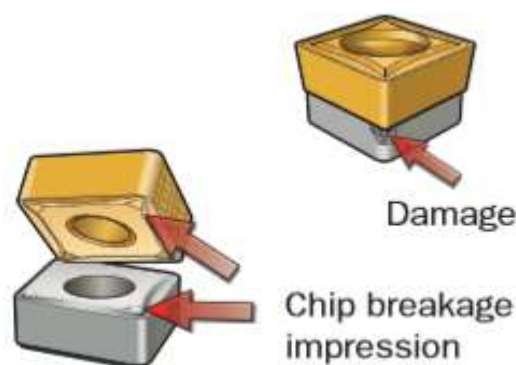


Figure 40 Insert Breakage [6]

The metal insert should be always verified because the small gap between pockets and inserts could lead to fails. When fixing the metal insert with screw some small metallic particles could leads to improper insertion of tools which leads to breakage of inserts. In order to avoid

this kind of faults, proper checking should be implemented during the change of metal inserts. In Figure 41 it is possible to observe the hole in cutting tool head.

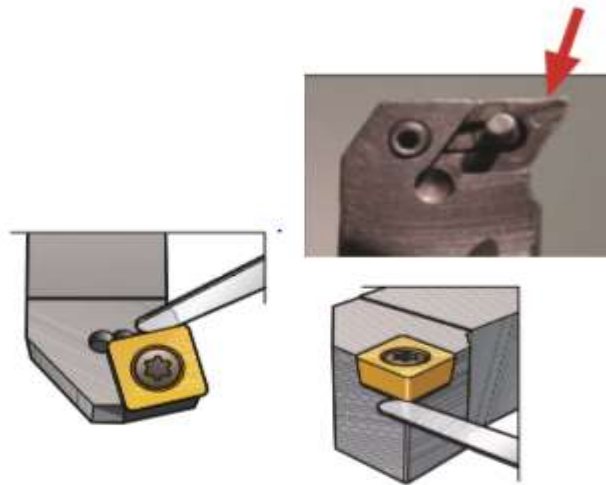


Figure 41 Metal Insert Pockets [6]

Whenever the metal insert is being replaced it is necessary that is used the right wrenches (keys) for the screws and make sure it should not be damaged, because if the screw not hold the metal inserts well can make angular differences and produce error results during milling operation or also possibility of breakage. In order to avoid this sort of mistakes we can use lubricant (molykote from Dupont) to grab the screw with metal insert. Figure 42 represents the keys and screws which we use for metal inserts.



Figure 42 Wrenches and keys[6]

For ensuring the tool is safer we should choose the right parameters (insert size, radius and cutting speed) for the good chip flow which ensures that the better cutting is made on the work piece. The contact face and support face of tool as seen in Figure 43 should be verified to ensure there is no dirt or steel particles stuck between them.

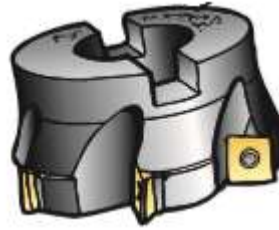


Figure 43 Tool Head [6]

So, these are the tools geometry which are taken into consideration when we are milling the work piece because this plays a huge role as part of companies' productivity. In the case study while making the roughness test by using five set of tools which are of unique. There are certain considerations while choosing the right metal inserts for milling operations like conditions suited, hardness range, cutting feed and velocity.

### Selection of Inserts

Metal inserts are of various types and of different materials it is our decision and choice of selecting the right insert for milling operations. Inserts can be of different angles  $10^\circ$ ,  $45^\circ$ ,  $90^\circ$  and each insert have different chip removal rate depend upon the type of material, for milling operation. For example, hardened raw steel metals cannot be milled with insert of  $45^\circ$  because it can easily wear the insert and provides irregular cutting impression on the work piece. In Figure44 it is possible to observe different grade type for inserts for efficient work.



Figure 44 Grade of Metal Inserts

#### 4.1.1 Tool -42-R-3

The tool initially used was 42-R-3 which is generally used to make the face milling in all the working CNC's. This tool is very suitable for face milling and the inserts are type JP4020 (Grade code for Pre-hardened steel) and this modular type insert is well made for highly efficient pre-hardened steel. In Figure 45 we can see the type of insert used for Milling the steel grade.



Figure 45 Radius Insert

The Table 13 below shows the description of metal Insert made of Mitusbushi Hitachi tools.

Table 13 Description of Insert 42-R3

<b>Tool</b>	42-R-3
<b>Material</b>	Tungsten Carbide
<b>Model</b>	JP 4020
<b>Suited</b>	Well suited for Pre- Hardened Steel
<b>No of Inserts in Tool</b>	6 Inserts
<b>No of Sides(Milling Faces)</b>	2 Sides

#### 4.1.2 Tool 66-R1

This tool is more suitable for milling steel grade with the qualities of milling higher depth of cut and also is suitable for face milling operations and for all kinds of metals. This tool has 4 sides of cutting faces and the Palbit Cutting Tools specifications can be seen in table 13. The cutting operation were made on two machines CME-BF04 and AWEA-VP 2012 the cutting parameters and achieved roughness values are detailed in the topic 4.4.2. In Figure 46 it is possible to observe the tool used for making the roughness test.



Figure 46 Tool Used 66-R1

Table 14 Description Of insert 66-R1

<b>Tool</b>	66-R-1
<b>Material</b>	Tungsten Carbide
<b>Model</b>	PH 7920
<b>Suited</b>	Well suited for steel, iron, cast iron, aluminium
<b>No of Inserts in Tool</b>	5 Inserts
<b>No of Side( Milling Faces)</b>	4 Sides

#### 4.1.3 Tool 42-R1

Third tool selected to mill is 42-R-1 this tool with the capacity of milling in two faces and capacity of holding four metal inserts. The manufacturer is DIJET cutting tools and is mostly used for making the face milling and planning of the surface. The insert is made up of Tungsten carbide (DH-103). Tool used can be seen in Figure 47 and the specification can be seen in Table 15.



Figure 47 Tool used 42-R1

Table 15 Description of Insert 42-R1

<b>Tool</b>	42-R-1
<b>Material</b>	Tungsten Carbide
<b>Model</b>	DH-103
<b>Suited</b>	Well suited for steel, iron, cast iron, aluminium and hardened material
<b>No of Inserts in Tool</b>	4 Inserts
<b>No of Sides( Milling Faces)</b>	2 Sides

#### 4.1.4 Tool 42-R5

This is the metal insert of type JC 5040 with maker of DIJET Industrial tools this insert have the radius of 5 mm and it can be circular type, the main significance of this insert is that has no sides and we can rotate the insert by adjusting the screws. Figure 48 illustrates a detail of tool 42-R-5 which was used for cutting the steel 1.2316 and detailed specification explained in Table16.



Figure 48 Tool Used 42-R5

Table 16 Description of Insert 42-R5

<b>Tool</b>	42-R-5
<b>Material</b>	Tungsten Carbide
<b>Model</b>	JC-5040
<b>Suited</b>	Well suited for steel, iron, cast iron, Aluminium
<b>No of Inserts in Tool</b>	5 Inserts
<b>No of Sides (Milling Faces)</b>	Circular

#### 4.1.5 Tool 42-R-6

The final tool used was 42-R-6 where the main difference is the radius between tool 42-R5 and 42-R6. Is made of tungsten carbide filament and generally used for planning and good finish of the surface. In Figure 49 and table17 we can see the tool and the specifications inserts used to mill the surface.



Figure 49 Tool Used 42-R6

Table 17 Description of Insert 42-R6

<b>Tool</b>	42-R-6
<b>Material</b>	Tungsten Carbide
<b>Model</b>	JC-8118
<b>Suited</b>	Well suited for steel, iron, cast iron, Aluminium
<b>No of Inserts in Tool</b>	4 Inserts
<b>No of Sides( Milling Faces)</b>	Circular

## 4.2 Perthometer equipment

This is the instrument which was developed specially to find out the characteristic behaviour of the material about the roughness and its surface texture parameters. It was used this Instrument Mahr Perthometer (Figure50) to find out the roughness of the steel (1.2316). This Instrument has very innovative characteristic which is very helpful for any user to make the way of work very easier and technically right. This machine is a portable compact instrument which can either can connected to the mobile use. It has the data backup in the form of PDF file, X3P, TXT, with the adjustable 4.3” TFT display. This machine is the error free machine so even the person who is unfamiliar with the machine can make out the exact results as it has very accurate behaviour, with a short time activation. Results are presented within seconds and it can be transferred into a PDF format which helps to find and analyse the characteristic behaviour. In table 18 can see the detailed specifications of the machine.



Figure 50 Perthometer

Table 18 Specification of PERTHOMETER [23]

Measuring principle	Stylus method
Probe	Inductive skidded probe
Measuring Units	Metric/inches
Measuring range	0,350
Profile resolution	8nm
Short stroke under ISO/JIS	Selectable
Traversing length	1mm,2mm,4mm,8mm,12mm,16mm
Evaluation Length	1.25mm,4.0mm,12.5mm
Number of N sampling	Selectable 1 to 16
Stylus	5 $\mu$ m
System of Protection	IP40
Rechargeable Batteries	Lithium-ion batterymin1200 measurements
Wide range supply	100 to 264 V
Dimensions in mm	160mm*77mm*50mm
Calibration Function	Dynamic; Ra, Rz, Rsm
Storage Capacity	Min 1350 profiles, min 500000 results, 250 PDF Records, expandable to 32 Gb

Table 18 is the basic technical features of the roughness tester machine Mahr PS 10, this is a portable device which is fit to pocket size (160mm in length, 77mm in breadth, 50mm in width) and can give very precise measurements as needed. It has inbuilt lithium battery and can measure around 1200 measurements and can give 500000 results with the integrated memory, which is the highlight of this roughness tester machine.



**Figure 51 Perthometer with Stylus needle [23]**

Perthometer has different salient features which provides the user more technical details and free to use facilities, it has large illuminated 4.3'' TFT display as seen in Figure51 which can be rotated either directions, this is as much simple as using a smartphone, this have more flexibility due to the removable driving unit. Evaluation process and values are more standard and are in accordance to ISO/JIS standards. The device has a dynamic calibrated function, with the automatic cut-off section to ensure and provide better ad accurate results. We can protect the device in form of lock settings or with the password protection provided with the date and time of measurements.

Surface roughness is the measurement of the surface and the texture of the surface, so this test had been taken out in the laboratory. The surface roughness tester Perthometer, denotes the different Roughness Measures Ra, Rq, Ryj. In general, the roughness is measured by the vertical deviations of real surface. It has been analysed that if the surface is rough the deviations denotes will be greater and larger, and if the surface is smoother the graph tends to be smaller. In general practice it is often measured to find out whether the surface is typically fit for use. The roughness of the surface is generally measured with the Perthometer with the stylus moves along the surface, the movement is then measured in accordance with the length of the steel.

The value of the roughness is generally measured in micrometres ( $\mu\text{m}$ ). Ra is principle of measuring range; it can be found that the various surface profiles denotes the same Ra value. For requirements the roughness of the steel in general can be around  $\leq 0.6 \mu\text{m}$  which denotes that the steel is fit and practically good for use.



Figure 52 Roughness test on steel 1.2316

Another factor for the measurement Rq which means the root mean square deviation of the profile which has been also measured, the test which I have found is that finding the roughness of the surface along with the mean deviation. Measurements made in the school laboratory as seen in figure 52.

There are certain surface finishes which are often exceeds the maximum Ra value offered which in case has been done by the specific irregular (Roughness test on variety of steels) surface finish which leads to the fault in the construction of the tools, so this can be either solved out by the certain mechanical procedures, the criteria shown that the each kinds of roughness range denotes that the different procedures can be taken out.

Surface roughness which has range of ( $0.6 \mu\text{m} - 1 \mu\text{m}$ ) can be makes a change out in the textures by emulating the process of rolling or mechanical polishing this can brings out the linearly textured finish of the surface, a skilled professional operator can be efficient enough

to bring out these surface finish. There are some transverse values which ranges around (0.5  $\mu\text{m}$ ), as a result of architectural finishes and this texture cannot be a major drawback in the form of surface finish.

### **4.3 Marcom Software**

Marcom software is basically using to transfer the files directly from the machine and can be transferred in the form of MS Excel sheet or into a text file or key code, each measurement we make can be made into a separate folder, the data can be transmitted into USB or 2 serial COM Interfaces. The software provides us a flexible and comfortable data transmission, we can either press the Data button or with data cable, otherwise with activating a foot switch connected to an USB Interface.

The software provided us a catalogue for the users which helps us to follow instructions and make the test easier and more accurate. Once we have installed the marcom software it has shown the options whether to make the directory public documents, After the selection, the program is ready to start once we have connected the measuring device to the USB , green light on the status window icon will be displayed which denotes that the measuring instrument values are ready to measure and transfer to the directory which has been selected. This software has the options with password protection to save your measures so that your documents are protected. It is possible to save the documents to the directory with the “Save As” option for the data acquisition process, the data can be saved in the Excel format and provides as the results with the tabulation.



**Figure 53 Marcom Software [25]**

The software has the different language options provides the users more significant option to work with the software. For each of the measurement the software indicates the beep sound which is audible to the users and denotes the indication that the value is saved. Wireless transmission and measurement can be also possible in this software; it has the RF Connection settings denoted in the tabulation. The settings have to make when the Wi-Fi of device is Turned ON and the Marcom Software will connect to the measuring instrument automatically. Subsequently if the Disconnect Wi-Fi option is given in the settings, the measuring professional disconnects automatically.

## 4.4 Machining Methods

There are various methods available to make the cutting operation on steel 1.2316, it was selected face milling method to make the milling. The generic use of this tool is planing of the surface on irregular surfaces. Also, this tool provides surfaces with good roughness value.



Figure 54 Face Milling [6]

In Figure 54 denotes the face milling on work piece. The machining has been done in different parameters on both the machines and the results achieved has been detailed on the chapters below.

### 4.4.1 Machining Equipment's

For machining process, it was used two equipment's from VB Fresagem company CME-BF 04 and AWEA-VP 2012 this both machines are generally 3-Axis machines moving only (X, Y, Z). The detailed specifications of this machines are available above in chapter 3.4 for AWEA Machine and 3.6 for CME machine respectively. In figure 55 we can view the image of CNC press which I have used to hold the work piece. This can be tightened by the fixtures and screws on both sides in T-slots.



Figure 55 CNC Press [18]

#### 4.4.2 Machining Parameters

In this topic it was elaborated the roughness test made with the different set of tools and various kinds of inserts used. The description will be made for each tool concerning roughness parameters. Also, there are set of graphs for each tool where the Perthometer (Roughness test measurer) gives us the final value that can be also discussed. The surface condition in general can be generally analysed by the type of feed rate, depth of cut [11].

##### Parameters of 42-R-3

Tool - (42-R3), Height -190mm, Inserts – Tungsten Carbide (Mitsubishi Hitachi Tools)

Table 19 Parameters of 42-R3

Machines used	CME-BF04	CME-BF04
Parameters	Test 1 (line of Cut)	Test 1 (Transverse)
Rotation of Spindle (rpm)	1400	1400
Feed Rate(F)(mm/min)	250	250
Depth of Cut(mm)	0.3	0.3
Roughness values Ra ( $\mu\text{m}$ )	0.639	0.322

In Table 19 it is possible to identify the parameters used to mill the steel 1.2316. After machining the work piece has been taken to the school Laboratory to find out the roughness texture, the results have been carried out by passing out the Perthometer on the finished surface of the steel. It was choosing this parameter because generally when using this tool for milling operations in the company always prefer to use this parameter. This tool generally used to mill feed rate of 1200 (mm/min) but for roughness test the parameters has changed means the feed rate of about 250 (mm/min) because the steel used has a very small dimension and it was needed the surface with good surface finish.

### Consideration for 42-R-3

1. For good surface finishing and roughness value minimizing the feed rate can provide better results. Because maximizing the feed rate can make the surface little bit rougher.
2. Metal inserts should be verified for achieving right surface finish and good chip removal rate.
3. Selection of right tool parameter is very important while make the planning and milling operations.

### Parameters of 66-R1

Tool - (66-R1), Height -185mm, Inserts – Tungsten Carbide (**Palbit Cutting TOOL**)

Table 20 Parameters of 66-R1

Machine used	CME- BF04	CME- BF04	AWEA- VP2012	AWEA- VP2012
Parameters	Test1(line of Cut)	Test1(Transverse)	Test2(Line of cut)	Test2 (Transverse)
Rotation of Spindle (rpm)	900	900	800	800
Feed Rate(F)(mm/min)	400	400	300	300
Depth of Cut(mm)	0.4	0.4	0.3	0.3
Roughness values Ra ( $\mu\text{m}$ )	<b>3.903</b>	<b>4.474</b>	<b>0.478</b>	<b>0.372</b>

### Consideration for 66-R1

1. The parameters in table 20 shows the parameters for this tool in both machines (AWEA and CME). It possible to observe slight variations in rotations, feed rate and depth of cut. Because the values in roughness test provides higher number which makes to analyse different possibilities in order to achieve good roughness values.
2. The diameter of tool is very high when compared to other milling tools, so higher the diameter of tool the rotations tends to be lower. Tool used is 66-R1 with rotation below 900 rpm are ideal with better cutting depth and feed. So, on Test 1, it was used the maximum permissible rotation of 900 rpm with feed rate and depth of cut (400mm/min and 0.4mm respectively). In test 2, rotation was 800 rpm, feed rate and depth of cut 300mm/min and 0.3mm respectively. By analysing the best parameters Test 2 shows better results than Test 1.
3. Higher diameter and lower rotations make the conditions ideal and well suited for harder working surfaces.

### Parameters of 42-R1

The next tool used to machine was 42-R-1 which is the tool generally used to sort out the irregular surface in the steel. The tool is mainly used to make regular surface in the work piece, let us see in the table 21 the parameters used by tool 42-R1.

Table 21 Parameters of 42-R-1

Tool - (42-R1), Height -190mm, Inserts – Tungsten Carbide (DIJET 5040 Cutting TOOL)

Machines used	CME-BF04	CME-BF04	AWEA-VP2012	AWEA-VP2012
Parameters	Test 1 (line of Cut)	Test 1 (Transverse)	Test 2 (Line of cut)	Test 2 (Transverse)
Rotation of Spindle (rpm)	1800	1800	1800	1800
Feed Rate(F)(mm/min)	300	300	250	250
Depth of Cut(mm)	0.3	0.3	0.3	0.3

<b>Roughness values Ra (µm)</b>	<b>0.847</b>	<b>5.732</b>	<b>1.685</b>	<b>1.330</b>
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### Considerations for 42-R1

1. For this tool analysing the best possible parameters the rotation can be of 1800 rpm and depth of cut will be 0.3 mm (for test 1 and test 2). The difference between was the feed rate 300 mm/min for CME Machine and 250mm/min for AWEA-VP 2012. Results below on chapters 4.5.3 proven that the milling conditions of AWEA seems to slightly better with minimal fast forward feed.
2. Ideal rotations for this tool are 1800 rpm.

### Parameters of 42-R-5

The next machining test was taken place in other steel 1.2316 with similar dimensions' part machined This has been made out with the tool 42-R-5 and make in two machines as like the other tests, in table 22 are presented results and parameters evaluated.

**Table 22 Parameters of 42-R-5**

Tool - (42-R5), Height -190mm, Inserts – Tungsten Carbide (**DIJET Cutting TOOL**)

<b>Machines used</b>	<b>CME-BF04</b>	<b>CME-BF04</b>	<b>AWEA-VP2012</b>	<b>AWEA-VP2012</b>
<b>Parameters</b>	<b>Test1(line of Cut)</b>	<b>Test1(Transverse)</b>	<b>Test2(Line of cut)</b>	<b>Test2 (Transverse)</b>
<b>Rotation of Spindle (rpm)</b>	2000	2000	1800	1800
<b>Feed rate(F)(mm/min)</b>	300	300	250	250
<b>Depth of Cut(mm)</b>	0.35	0.35	0.3	0.3
<b>Roughness values Ra (µm)</b>	<b>1.069</b>	<b>1.478</b>	<b>0.326</b>	<b>0.408</b>

### Considerations for 42-R-5

1. As said previously in other tool parameters considerations, this tool has same ideal rotation conditions higher the value of rpm as shown in table 23 on Test 1 that is 2000 rpm in CME Machine provides average surface finish. When reducing the rotations around 1800 rpm can provides better results.
2. Depth of cut should be minimized in these sorts of tools, because this tool has less vibrations absorber (unsuitable for higher depth of cut) and also for making the surface with minimal roughness should be depth of cut in the range 0.05 to 0.3mm which provides better results.

### Parameters of 42-R-6

Table 23 Parameters of 42-R-6

Tool - (42-R6), Height -185mm, Inserts – Tungsten Carbide (**DIJET Cutting Tools**)

Machines used	AWEA-VP2012	AWEA-VP2012
Parameters	Test1(line of Cut)	Test1(Transverse)
Rotation of Spindle (rpm)	1800	1800
Feed Rate(F)(mm/min)	250	250
Depth of Cut(mm)	0.25	0.25
Roughness values Ra ( $\mu\text{m}$ )	<b>0.230</b>	<b>0.252</b>

### Considerations for 42-R-6

1. Finally, for tool 42-R6 the parameters used were 1800 rpm and feed rate of 250 mm/min and depth of cut 0.25 mm which final result on proves this is well suited parameters for this tool.
2. Even reducing the feed rate and rotations steel which makes surface finish average. Table23 is specification is used to mill the surface.

## 4.5 Results

### 4.5.1 Tool-42-R3 Roughness Results

Tests made on Steel 1.2316 which usually provides better surface finish is of smaller dimension (61mm\*61mm\*38mm) and it is generally used as it has tendency of providing good surface finish. In the company VB Fresagem use a large quantity of different tools to make the surface finish, so initially it was used the tool 42-R-3 to find out the roughness behaviour. This has been done out in the CNC Machine CME-BF-04 which has the maximum rotation speed of 3000 rpm. For, machining process it was placed the work piece steel 1.2316 in the CNC Precision press and tightened the work piece with the holder.

The machining has been done by passing the tool (42-R3) with the rotation of 1400 rpm and with fast forward advance of about 250 mm/min and with the depth of cut of 0.3 mm. The factors that are mainly important to bring out in these sort of machining is that the tool should be in very good working conditions which also includes the metal inserts, this plays a major factor in making a work piece more precision and good surface finish This metal insert used is the R3 (JP4020 Mitsubishi Hitachi Tool) made in Japan, which are made of Tungsten carbide with the Titanium Coating. This metal inserts can be also used to mill in steel, stainless steel, cast iron, aluminium, heat resistant and titanium alloy, and also for hardened material. And the other test which are discussed in tabulation concerning the mentioned parameters with different tools (66-R-1, 42-R-1, 42-R-5, 42-R-6) and for all those tools it was used the tungsten carbide metal inserts which provides good surface finish, better stability and dimension.

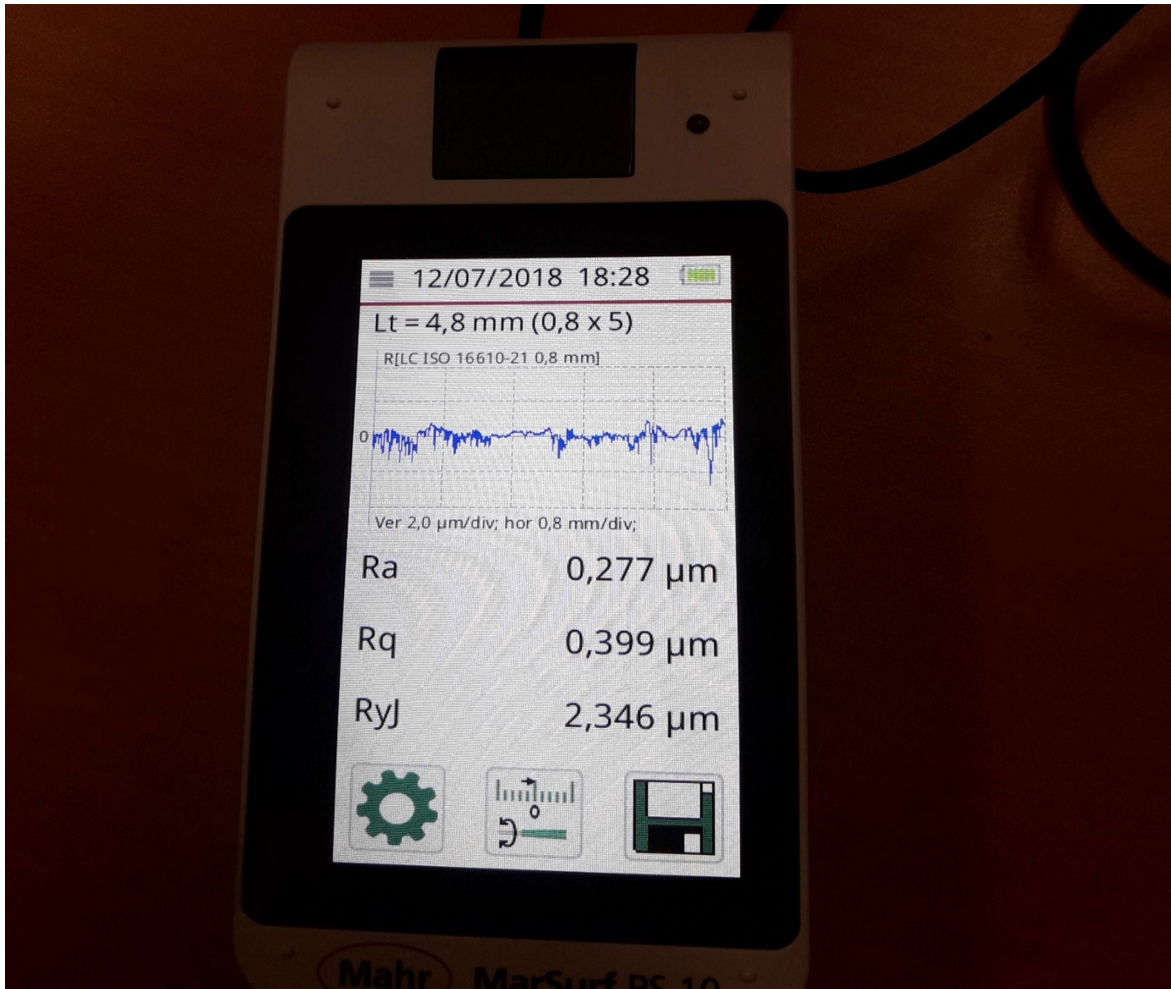


Figure 56 Measurement Of roughness on Perthometer

The measurement has been made on the transversal length of 4.8mm,  $L_t=4.8\text{mm}$  ( $0.8 \times 5\text{mm}$ ), we can select in the roughness tester with the measurable variable we require to say the measuring principal parameters ( $R_a$ ,  $R_q$ ,  $R_{y_j}$ ) so after the selection of parameters the view on the graph should be selected, the stylus probe will be passed on to the surface and within few seconds the results of the roughness can be found out as the figure shown above. As, mentioned in the roughness criteria above the value of the  $R_a$  has been  $0.277\ \mu\text{m}$  which denotes that the surface finish is very precise. Also, the values of  $R_q$  and  $R_{y_j}$  parameters has been found ( **$0.399\ \mu\text{m}$  and  $2.366\ \mu\text{m}$** ) respectively seen in figure 56. The values have been found satisfactory as the value of the roughness is proven that it can be good enough for working modes in the tool making.

The main motive of the case study is to find out the surface roughness by passing the different tools on the Steel (1.2316) so it was used different tool as a part of the Roughness measure, the surface Roughness was measured in two different machining conditions.

#### 4.5.2 Tool 66-R1 Roughness Results

As a part of roughness measure the first and second test was made out in different machines with the different parameters changed, that brings out lot of difference values to the surface. The preliminary test was made in CME-BF-04 with the tool (66-R1) with rotation of 900 rpm, with feed rate of about 400 mm/min, for one increment it has been made machined by 0.4 mm, as a result it gives the roughness values **3.903  $\mu\text{m}$**  and **4.474  $\mu\text{m}$**  (line of cut and transverse) which denotes that it has the lot of roughness tendencies which the surface finish leads to average finish as the value is not satisfactory. The reason could be addressed to rotation, Fast forward and depth of cut which was made out in the machining. The motivation of case study is to bring the right values for each tool and how it behaves with different parameters. In order to find the better surface finish, it was changed the parameters of the tool for Test 2. Milling in the other machine AWEA VP2012 with the rotation of 800 rpm and feed rate of 300mm/min with depth of cut 0.3mm, as final roughness value is in range from **0.478  $\mu\text{m}$**  and **0.372  $\mu\text{m}$** , line of cut and transverse direction respectively. This brings that the surface finish is very much higher, and it is good for industrial use.

The test was measured in the school laboratory by using device perthometer and the tabulation with graph below illustrates the texture of the surface, it has been selected prior to the test the required parameters. Generally, in all roughness measurement it is considered Ra. Is usually expressed initially because it is the primary denotation of any roughness measuring progress. For tool 66-R1 roughness (Ra) is **0.372  $\mu\text{m}$**  as seen in figure 57.

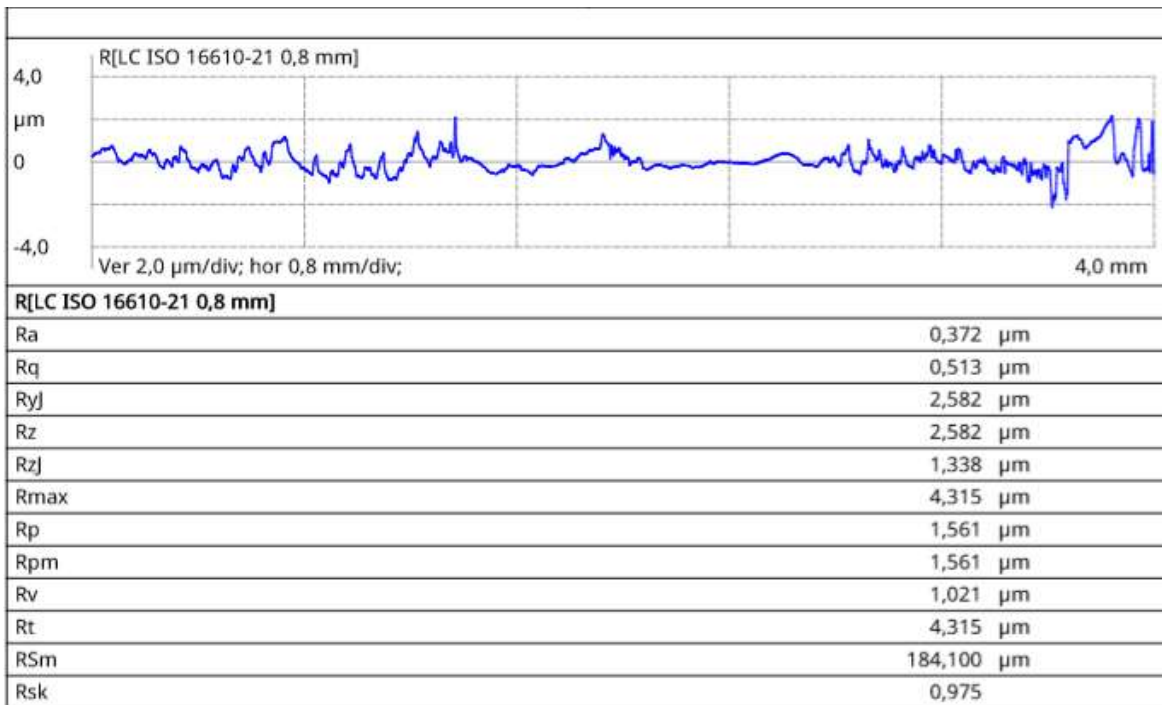


Figure 57 Roughness Graph of 66-R1

#### 4.5.3 Tool 42-R1- Roughness results

For this surface has been made the machining process with two machines. Primarily on CME-BF04 and the second tests takes place in the machine AWEA -VP2012. This happen to find out the difference in each machine. In CME-BF04 the work piece has been placed on the CNC precision Press and the rotation of the spindle is about 1800 rpm and fast forward advance of 300mm/min, with the depth of cut about 0.3mm which is the permissible value which is used in the company, and also are the right parameters to achieve the good surface finish and the perfect roughness value. The results are in range of **0.847 µm** and **5.732 µm** which shows the value are good and allowable. It was made another milling in the other machine with the similar tool with almost same parameters with slight changes in the Feed rate of 250 mm/min. The results are the opposite and gives the value of **1.685 µm** and **1.330 µm** (Feed rate and transverse) respectively seen in Figure 58, denotes that the surface finish is better in both directions. But when the value exceeds the roughness  $\geq 1\mu\text{m}$  this can be above average finish which can also be fit enough for moulding production.

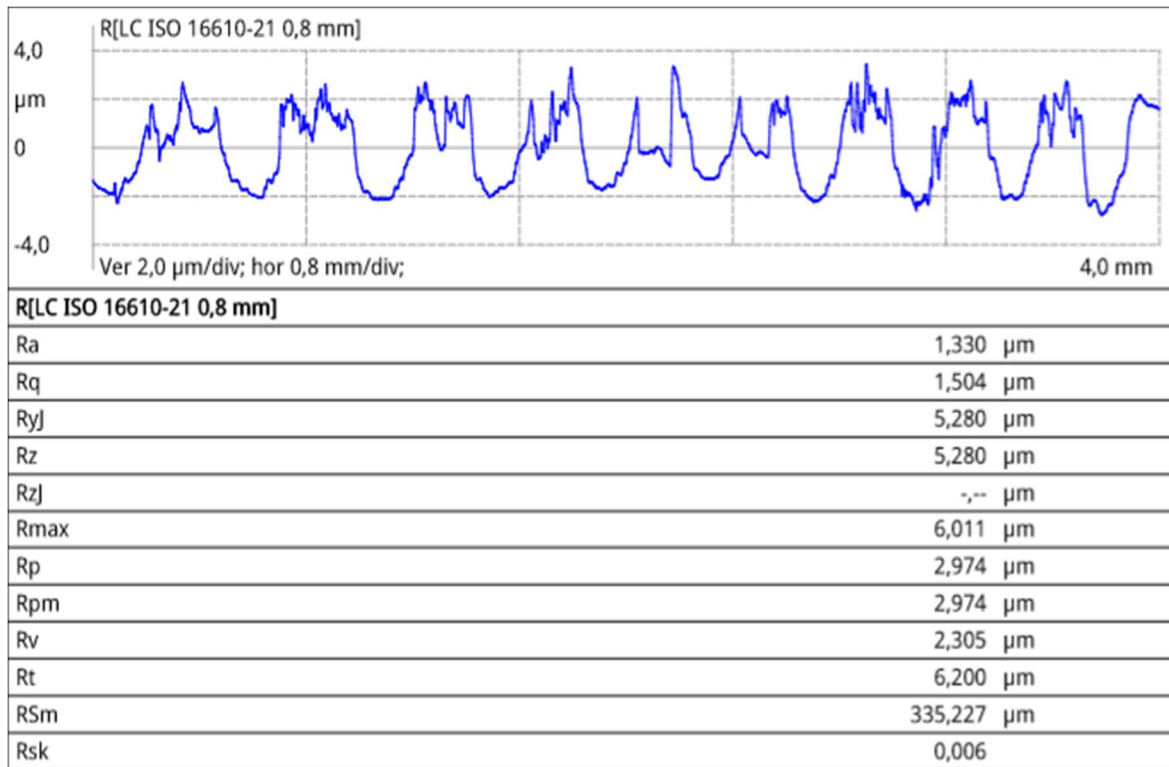


Figure 58 Roughness Graph of 42-R1

Moreover, the preliminary tests give the value above  $\geq 5 \mu\text{m}$  values it shows that has higher roughness and it will be leads to average surface finish, also it may lead to wear and tear in the work surface very quickly. More the roughness of surface faster it gets wear, which let to defect the manufacturing of concern subsidiary products. So, the tool maker has to be given more importance in make the good surface finish, the tool inserts which it was made with Tungsten carbide by DIJET Cutting tools.

#### 4.5.4 Tool 42-R5 Roughness Results

The milling was executed first in CME-BF04 with rotation of 2000 rpm, cutting speed of 300 mm/min and the depth of cut 0.35mm the results provided with the roughness values of **1.069  $\mu\text{m}$**  and **1.478  $\mu\text{m}$**  respectively. In other perspective it was made another machining test on AWEA-VP2012 with different parameters. with rotation of 1800 rpm and feed rate of about 250 mm/min with the depth of cut 0.25 mm the results provided was very reachable as per the roughness norms gives the final values of **0.326  $\mu\text{m}$**  and **0.408  $\mu\text{m}$**  respectively (Figure 59). Mainly these value gives the clarity that it is absolute necessary to follow the tool parameters in order to make out the good surface finish. The parameters of rotation 1800 rpm are the right value which we usually use in our company VB Fresagem to develop the planned surface. For this milling it was used the cutting metal insert (DIJET Cutting Tools). The value achieves in the roughness test has been seen in the figure 59.

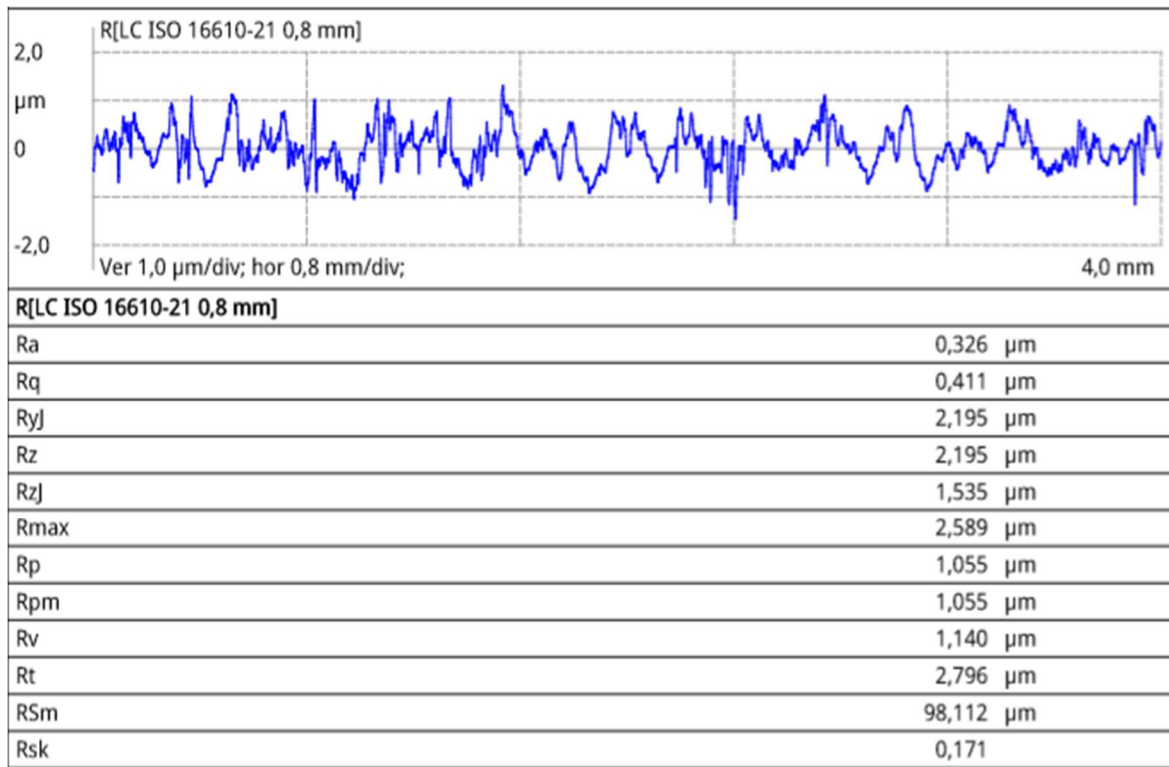


Figure 59 Roughness of 42-R5

#### 4.5.5 Tool 42-R6-Roughness Results

This test was made in the machine AWEA-VP2012 with the Tool 42-R6 of rotation 1800 rpm with the feed rate of 250mm/min, and depth of cut 0.25mm the results shown is very precise **0.230 µm** and **0.252 µm** line of cut and transverse direction and the values are very efficient enough to fit for the manufacturing and tooling purpose. The figure 60 represents the values of roughness value achieved by passing the perthometer on the worked surface of tool 42-R6. It was used metal inserts of (Radii 6) of DIJET Tools. The value achieved shows the tool has the very good roughness range and each value specified above was achieved by the surface test, this expresses that steel has very good roughness surface.

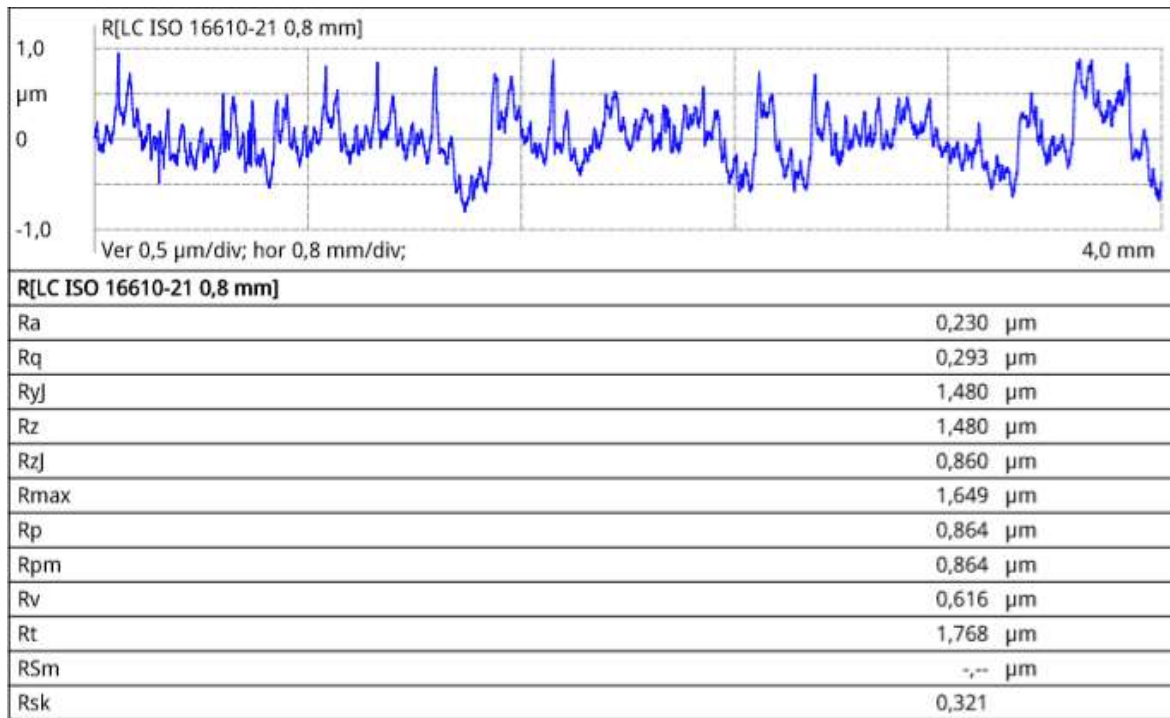


Figure 60 Roughness Graph of 42-R6

## 4.6 Relationships between tools, equipment's and parameters

Table 24 Relationship between different tools and parameters used

<b>Milling Cutter [6]</b>					
	<b>Face Milling</b>	<b>Face Milling</b>	<b>Face Milling(45°)</b>	<b>Face Milling</b>	<b>Face Milling(90°)</b>
<b>Inserts</b>	Round Inserts R5	Round inserts R6	R-1	R-3	R-1
<b>Tool/Spindle size Used</b>	<b>42-R5</b>	<b>42-R6</b>	<b>42-R1</b>	<b>42-R3</b>	<b>66-R1</b>
<b>No of Inserts used</b>	5	4	4	6	5
<b>Rotation of spindle (rpm)</b>	<b>1800</b>	<b>1800</b>	<b>1800</b>	<b>1400</b>	<b>800</b>
<b>Depth of Cut</b>	0.3 mm	0.25 mm	0.3 mm	0.3 mm	0.3 mm
<b>Final Roughness value (µm)</b>	<b>0.326 µm</b>	<b>0.230 µm</b>	<b>1.330 µm</b>	<b>0.399 µm</b>	<b>0.372 µm</b>
<b>Stability</b>	Medium	Medium	Medium	High	Very high
<b>Roughness</b>	Good	Good	Good	Very Good	Average
<b>Finishing</b>	High	High	Good	High	Medium
<b>Cutting Depth</b>	Medium	Good	Good	Good	High

The table24 represents the relationships between the tools used and parameters. In this results chapter shows the two machines from Company (CME and AWEA VP), in these we can find that the roughness value of most of the tools for the machining process:

1. AWEA VP machine provided better results as compared with CME machine and these machines are same with working surface but the capacity and spindle conditions are more suitable for AWEA VP machine.
2. Roughness value considered from **(0.2 to 5 $\mu$ m)** will be effective for working conditions, the results achieved in all the machines are seems to be appreciable and the condition of texture can be well milled.
3. Inserts can be of different kinds **(R1, R3, R5, R6)** for each tool it was discussed, and these can also give differences among the finished surface.
4. Rotations of the spindle also makes some difference in the textures.
5. For higher diameter tool, depth of cut will be higher in Tool 66-R1 (tool can work more depth at 90°) while for the same depth of cut it is not possible to do the process with Tool 42-R1. The reason for that is the tool cannot hold higher cutting forces with higher values for cutting depth.
6. Finally, for milling operations the conditions and parameters should be always followed according to the specifications given for tools and machines, which will usually provide better results and makes more precise in production.

## 5 CONCLUSION

In this internship it was possible to have contact with the mould making industry. The work developed in VB Fresagem was concerning the limitations of machining process to achieve the better roughness, concerning equipment's and tools.

In this report, an overview of equipment's and tools used in the company was made. The relationship between equipment's, tools, parameters and roughness was analysed. It was possible to conclude that AWEA VP machine provides better when comparing with CME machine. Roughness value between 0.2 and 5 $\mu\text{m}$  are in some cases acceptable for surfaces (not for cavity surfaces) especially for surface outside of core and cavity surfaces. Different inserts were used (R1, R3, R5, R6), the spindle rotations is the main factor to achieve the better surface textures.

Also was conclude that for higher diameter tool, there is some limitation in the depth of cut because will occur an increase on cutting forces and there is limitation on the tool holder of the machine, and it will occur the tendency to vibrations of the tool.

Following specifications for tools and machines will usually provide better results on surface quality due to several studies by the tool manufactures.

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