KAUNAS UNIVERSITY OF TECHNOLOGY
MECHANICAL ENGINEERING AND DESIGN FACULTY

Dhanraj Allepalli

THE RESEARCH OF TUBE TYPE WORKPIECE OF STEEL S355 PREPARATION INFLUENCE ON LONGITUDINAL ORTHOGONAL TURNING

Master's Degree Final Thesis Project

Supervisor
Assoc. prof. Virginija Gyliene

KAUNAS 2018

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Industrial Engineering and Management (621H77003)

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KAUNAS 2018

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The Research of Tube Type Workpiece of Steel S355 Preparation Influence on Longitudinal Orthogonal Turning

DECLARATION OF ACADEMIC INTEGRITY

05 January 2018

Kaunas

I confirm that the final project of mine, **Dhanraj Allepalli**, on the subject "the research of tube type workpiece of steel s355 preparation influence on longitudinal orthogonal turning" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis. I fully and completely understand that any discovery of any manifestations/case/facts of dishonesty inevitably results in me incurring a penalty according to the procedure(s) effective at Kaunas University of Technology.

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Approved: ______________________________
Head of Production engineering Department
(Signature, date)

Kazimieras Juzėnas
(*Name, Surname*)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

LT: Vamzdžio tipo plieninio ruošinio S355 paruošimo įtakos tyrimas išilginiam ortogonaliniam tekinimui
ENG: The research of tube type workpiece of steel S355 preparation influence on longitudinal orthogonal turning

Approved by the Dean Order No. V25-11-12, 11 December 2017

2. Aim of the project

To determine the machinability of the steel S355 undergoing the longitudinal orthogonal turning process with varying cutting speed

3. Structure of the project

Introduction, literature review, constrained turning experiment and results, comparison of results, microsection analysis results, chip hardness test results, conclusion and references.

4. Requirements and conditions

Workpiece material S355JRG3. The cutting tool should be used for longitudinal turning operation. Bump test on workpiece and cutting tool before the vibration analysis. The orthogonal turning process experiments should be conducted in CNC machine according different cutting speed. Chip segmentation processes, microsection to the chips. Conducted chip hardness test.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 21 December 2017

Student ______________________________ ______________________________
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor Lect. Virginija Gyliene______________ ________________
(*Position, Name, Surname*) (*Signature, date*)

Dhanraj Allepalli. VAMZDŽIO TIPO PLIENINIO RUOŠINIO S355 PARUOŠIMO ĮTAKOS TYRIMAS IŠILGINIAM ORTOGONALINIAM TEKINIMUI. Magistro Pramonės inžinerijos ir vadybos baigiamasis projektas / vadovas doc. Virginija Gyliene. Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultete, Gamyba inžinerijos katedroje

Mokslo kryptis ir sritis: Technologijos mokslai, Gamybos inžinerija

Reikšminiai žodžiai: *Ortogonalinis tekinimas, Drožlės formavimas, Pjovimo mechanika, Drožlės mikrošlifai, Kietumo testai, Drožlės segmentacija, Plastinis deformavimas, plienas S355*

SANTRAUKA

Šios eksperimentinės analizės pirminis motyvas yra parinkti "vamzdžio formos plieno" S355 "pasirinkto apdirbimo detalės vertes dėl ortogonalinio pjovimo su išorine šiluma arba be jo, priklausomai nuo reikalaujamų atitinkamų rezultatų ir tokiu būdu minimalizuojant potencialą ir galimi traukuliai faktinio apdirbimo metu.

Siekiant sustiprinti bet kokio atsitiktinio ruošinio tiesiosios pjovimo procedūrą, pavyzdžiui, "S355", šiuo atveju vibracijos, sukurtos įrankio "STGCR / L" sąsajos metu, kuris buvo pasirinktas remiantis bandymų ir klaidų formomis, atliktomis naudojant ruošinio dalis turi būti panaikinta taip sumažinant likutinį stresą, sudarytą iš paties ruošinio per faktinį apdirbimo procesą.

Šis eksperimentas yra gyvybiškai svarbus šilumos panaudojimo pavyzdys, per kurį neparodžiamas ir reikalaujamas ruošinio pjovimas pasiekia maksimalią 840 ° C temperatūrą. Garsus ortogonalinis pjovimas sukuria ruošinio dugną pagal dešimt pjovimo kanalų ir tokiu būdu paverčia ruošinį į norimą objektą su nereikšmingu paviršiaus šiurkštumu.

Išskirtinio ruošinio pakėlimo bandymo metu išdėstytos "vibracijos ir dažnių" "pikoskopo 6" pavyzdžiai yra įvesties terpė, kuri turi būti sumažinta per milžinišką dydį, todėl atliekami eksperimentinio pjovimo šildymo ir nekaitinimo variantai. Buvusi mikrogyslių poliravimo metodika pageidaujamose tūrinėse ir kubinėse sekcijose yra imperiali svarba ir atlieka dominuojančią eksperimento dalį, kad būtų galima apskaičiuoti lusto segmentaciją, įtaką nustatant galutinį lusto kietumą.

Dhanraj Allepalli. THE RESEARCH OF TUBE TYPE WORKPIECE OF STEEL S355 PREPARATION INFLUENCE ON LONGITUDINAL ORTHOGONAL TURNING. Master‘s thesis in Industrial Engineering and management / supervisor assoc. prof. Virginija Gyliene, Kaunas University of Technology, The Faculty of Mechanical Engineering and Design, Department of Production Engineering.

Research area and field: Technological science, Production engineering

Keywords*: Orthogonal turning operation, Chip formation, Mechanics of cutting, Chip microsection, Hardness test, Chip segmentation, Plastic deformation, material S355.*

Summary

The ulterior motive of this experimental analysis is to provide values par excellence in the chosen workpiece of a tube-shaped steel ‘S355’ in terms of orthogonal cutting with or without the application of external heat, depending upon the relevant results required and thus minimalizing potential and possible convulsions during the actual machining process.

To enhance the procedure of orthogonal cutting of any random workpiece, for instance ‘S355’ in this case, the vibrations produced during the interface of the tool ‘STGCR/L’ which has been selected based on trial and error formulations carried upon the workpiece, has to be nullified thus reducing the residual stress constituted in the workpiece itself during the actual machining process.

This experiment proves to be a vital illustration of heat application through which non-disastrous and demanded cutting of the workpiece is achieved a peak temperature of 840 c. The ‘picoscope 6’ application readings of vibrations and frequencies tabulated during the bump test on the exclusive workpiece serves as an input medium that has to be reduced through a colossal magnitude and thus heating and non-heating versions of the experimental cutting are accomplished.

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INTRODUCTION

The factors that evidently constitute cutting stability include cutting conditions, robust properties corresponding to the cutting tool and also depends upon the workpiece along with the actual machine itself. In most cases, the dynamic properties cannot be changed. The key to cost effectiveness and expanded productivity is proper cutting conditions which can achieve higher disposition of metal and make sure of a firm and stable cutting process. As vibrating cutting forces kick in tool vibrations, producing a process known as regenerative chatter. If the vibrations are not stable, which in result cause a bad surface finish and can damage the cutting tool, the workpiece and the machine. For stability, precisely predicting the stability of the cutting operation is key. In an aim to increase the productivity and reduce the costs in metal cutting operations, metal removal rates are pushed to the bounds of instability. Vibrations caused due to contact of the tool and the workpiece results in further vibrations to happen in the cutting forces.

In orthogonal turning process we have done total ten different cuts to the workpiece with different speeds, and the cutting speed details and the rpm is shown (table 11.2). During orthogonal cutting process, the findings will be examined considering different cutting speeds. Tried various speeds for cutting to obtain better outcomes.

When we perform orthogonal cutting process, we received different types of chips as an outcome and outcome chips are shown (table 11.2). Therefore, cutting can be considered as a chip formation approach and stimulate chip segmentation, plastic deformation and chip hardness test. The best advised viewpoint of such partner degree method is to be inclined to expect chip flow, cutting strengths, instrument temperatures and stresses that results in shifted cutting conditions. In any case, material flow qualities, or flow worry, at heating and deforming rates square measure expected to lead such augury. The outcome of chips from the workpiece after the orthogonal cutting process, the chips thickness is calculated and analysed in the table 14.11. Total six chip thickness measurements are taken in order to get the proper average thickness of the chip. There square measure just a few of material flow push particulars available for the twisting conditions that exist in machining.

1.1 Aim of the report:

The main aim of this report is to define the vibrations which are occurring in the orthogonal turning process by removing residual stress to the material steel S355. And also, to analyse the chip hardness and chip thickness. The results and calculations are clearly mention in detail in this report.

Figure1.1 Orthogonal cutting process [13]

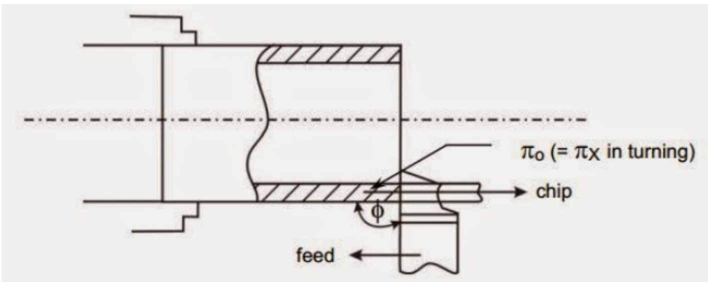


Figure1.2 Orthogonal Oblique cutting [5]

1.2 Objective:

- A bump test conducted on the cutting tool and on the workpiece in the experiment.
- Vibration analysis of the orthogonal turning process results must be compared to the material steel S355 without heating the work piece in order to conclude which material giving better results.
- The preparation of a special tube – type workpiece for orthogonal turning experiments and heat treatment of workpiece in order to remove residual stresses after the cutting
- By coming to the end of the process we will be getting some different results according the different cutting conditions.

1.3 Future aspect:

The result of this research work can be used for the further investigation of the material with different experiments with changing input parameters. The behaviour pattern of the material S355 can be observed and analysed by making a chart or table of the results investigated with different experiments.

LITERATURE REVIEW

2. ORTHOGONAL TURNING PROCESSES

Orthogonal turning process is the most widespread and fundamental machining operation in the manufacturing industries.

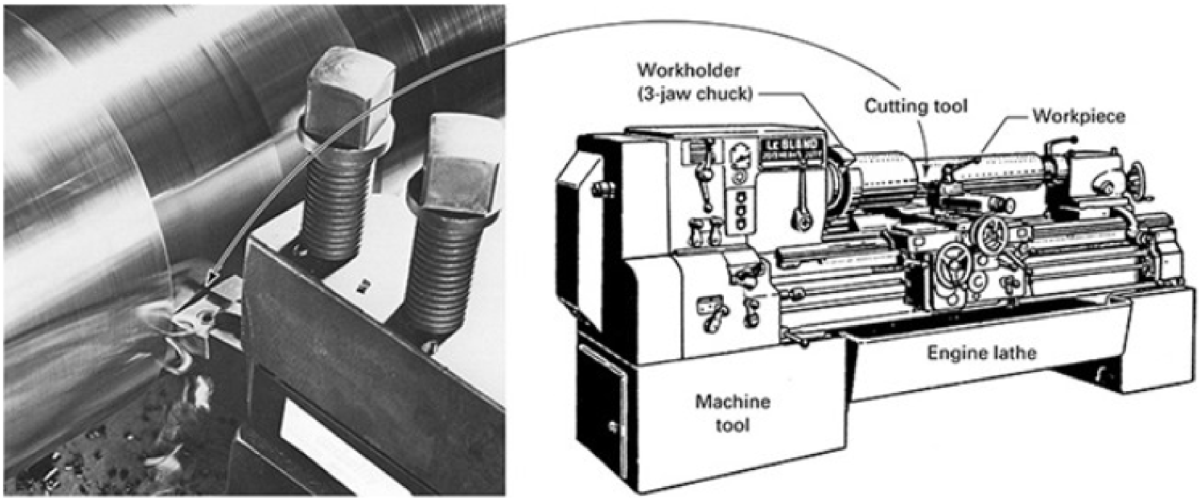


Figure 2.1 Lathe machine [3]

The prime nexus of the experiment is the turning process function, it is very necessary and requisite to interpret the primary mechanics of the turning operation. A cutting tool is located at post of the lathe machine so that it helps to remove the material from the workpiece. The cutting edge of the cutting tool should be perpendicular to the direction of relative motion between tool and workpiece which is called as cutting motion, cutting edge length should be greater than or at least equal to the width of workpiece [3].

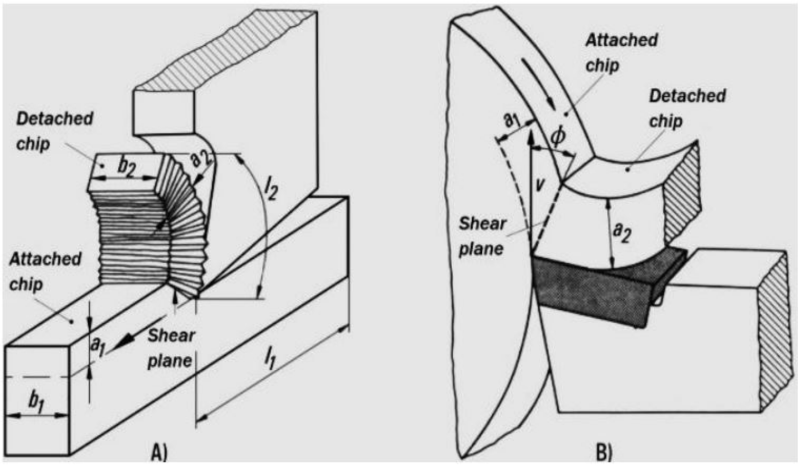


Figure 2. 2 orthogonal turning process A) Plane Surface B) Rotating disc [3]

The figure 2.2 shows the two types of cutting angles. One is about the place surface orthogonal cutting process and the other defines the rotating disc orthogonal turning process. The two methods as shown in the figure are completely different from each other. In this experiment we are using the rotating surface process.

In this experiment the cutting angle is shown in the figure 14.2 as it is conducted. The workpiece is heated to remove residual stress and the experiment of cutting process is started. The removed chips from the workpiece is collected in order to check the chip measurements.

3. CHIP FORMATION PROCESS

In cutting and abrasive processes, the cutting edge pierces the workpiece, which in turns causes it to be plastically disfigured and slips off along the face of the cutting edge, known as chip formation. These formations within chip structuring can be inspected inside the orthogonal plane in view fundamental parts of the material flow occur inside this plane. That two-dimensional may be aggravated during the edges of the cross-segment of the un-deformed chip, at that free surface and in front of the front-line corner, as there is material flow at an angle towards the orthogonal plane, which is caused by linkage to the un-deformed material by the free surface respectively. Depending on the deformation behaviour of the workpiece material, there are different mechanisms of chip formation with either continuous or discontinuous chip formation [7].

The shape and geometry of the chips investigated using the optical-microscope Fig.3.1 In this analysis, the chip shapes are mostly continuous (Type II). However, saw-tooth-shaped chips are observed at conditions with cutting speed of 300 m/min and un-deformed chip thickness of 0.100 mm. Nevertheless, it can be stated that the chip formation indicates a continuous type of chips at the lower feed rates and at the lower cutting speeds (60 m/min) when high-speed cutting of P20 mould steel. This observation supports the shear localization behaviour of hard steels in the secondary deformation zone due to runaway thermo-mechanical deformation at high feed and cutting speeds postulated by Zhanga et al (2006) [8].

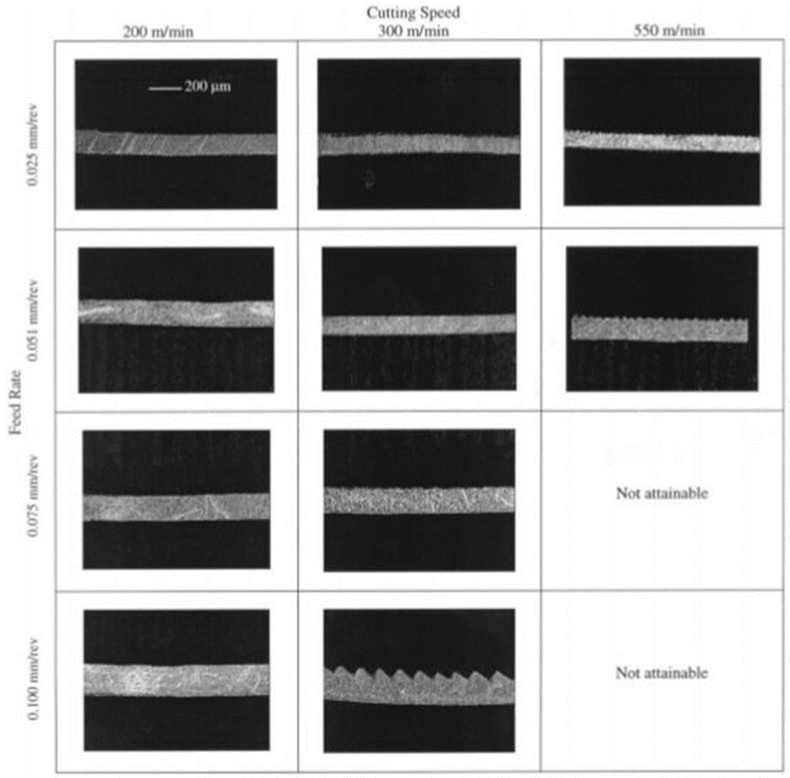


Figure 3.1 Chip geometries observed under microscope with different cutting speed and feed rate [8]

3.1 The mechanisms of chip formation

On the bases of workpiece material and condition of the cutting methods, the following mechanisms of the chip is explained below

- Continuous process of the chip formation
- Lamellar chip formation
- Chip formation segmentation
- Discontinuous of chip formation

In continuous process of chip formation, the chip will slide along the rake face on a stabile speed in a stationary flow. This method of chip formation is promoted by a consistent, fine-grained structure and ductility on the work material, by high speed and low friction within the rake face, by positive rake angles and chip thickness with a low un-deformed [10].

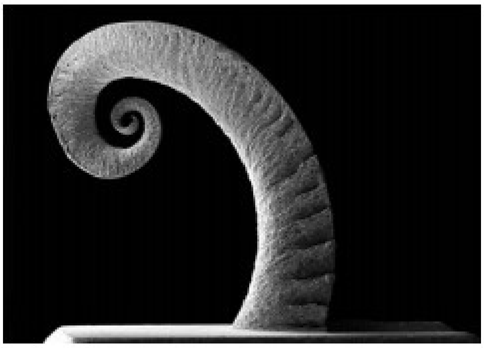


Figure 3.2 Electron micrographs of chip formation [13]

Lamellar chip formation could be a continuous, periodic chip formation process similar to pure continuous chip formation. However, their square measure variations within the deformation method can cause additional or lesser cleavages or perhaps targeted shear bands. The lamellae square measure created as a result of thermal or mechanical processes with a high formation frequency at intervals of kHz range. Lamellar chips occur with extremely ductile workpiece materials with associate raised strength, particularly at high cutting speeds (q. v. high-speed cutting) [10].

Segmented chip formation is that the discontinuous formation of a chip with still more or less connected components, nevertheless with important variations within the degree of deformation on the flow path. It primarily happens with negative rake angles, lower cutting speeds and a better chip thickness [11].

Discontinuous chip formation occurs if the plastic malleability of the workpiece material is extremely low or if predefined slide methods are shaped as a result of high inhomogeneity (e. g. if cast iron with lamellar graphite is machined) components of the workpiece material are ripped out of the compound material without major deformation. The workpiece surface is then created by the rending out process within the chip formation, then by the tool traces [11].

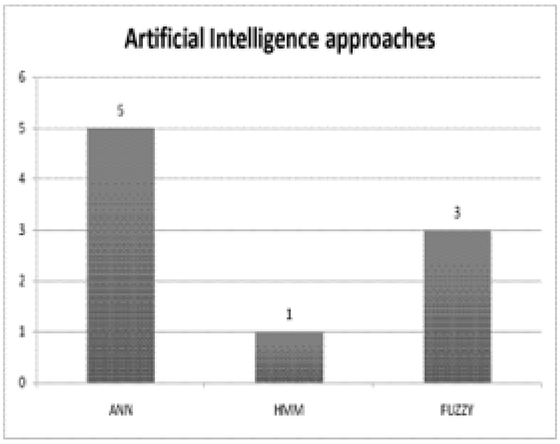
4. CHIP ANALYSIS APPROACH

Specialists bring broken chips to analyse the chip segmentation and plastic deformation. What's more recognizing is the occurrence of chatter. However, that dissection of chip arrangement might best furnish most of the data around chatter. So, this kind of methods is unable to predict chatter onset in an advance. Nurulamin in 1983 has focused and studied about the mechanism of instability of the chip formation on micro section metallographic specimens of chip roots, which is received by instantly stopping the cutting process at different phases of the full cycle of instability as well as on the micro-section metallographic specimens of the chip [11]. On such specimens, with the help of a metallographic microscope and micro hardness measuring instruments, the grain orientation, borders of different zones and contact areas and also the time of each phase of the cycle were determined. It was discovered that the physical cause of chatter is the instability of chip formation and by self-excitation between tool and workpiece at the resonant frequency [13].

Some researchers associate chip formation with the dynamics of the turning process and to decide chatter conditions. However, chip analysis would merely remain the post mortem of the process/behaviour as it cannot predict the stability of the process in advance, but it is still very useful in understanding the behaviour of the turning process during stable and unstable conditions [11].

Artificial intelligence approaches:

A few scientists have done experiments on orthogonal turning process and the number of experiments are done in every year as shown in the below figure 4.1. We can notice the number experiments are increased slowly to bring the changes and improve the methods. These computerized reasoning systems are reviewed in this detail are explained in the below figure. 4.1 gives data over publications to each procedure.

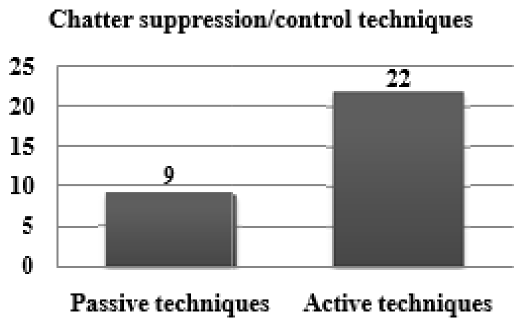


Years	ANN	HMM	FUZZY	Total
1971-1980	0	0	1	1
1981-1990	0	0	0	0
1991-2000	1	0	1	2
2001-2010	4	1	1	6
TOTAL	5	1	3	9

Figure 4.1 Number from claiming publications emphasizing counterfeit consciousness methodologies and the table indicating rundown judgment of the chosen publications between a considerable length of time 1978 What's more 2010. [13]

Chatter suppression/control techniques

Chatter suppression/control will be a testing issue to turning. Create finer strategies for chatter concealment what's more control may be developing stronger over. At any point because of the weight with respect to manufacturing commercial enterprises to secondary productivity, helter-skelter. Systems could be suppression/control. Arranged under two primary categories, namely, indifferent chatter also animated chatter suppression/control.



Years	Passive	Active	Total
1961-1970	1	0	1
1971-1980	0	1	1
1981-1990	2	0	2
1991-2000	2	10	12
2001-2012	4	11	15
TOTAL	**9**	**22**	**31**

Figure 4.2 Number of publications emphasizing chatter control strategies and the table demonstrating to outline judgment of the chosen publications between mentioned years in the above table. [13]

In the latent technique, those destinations will be will smother chatter toward evolving those framework conduct. The framework conduct might make transformed or changed Toward Possibly. Indifferent vibration concealment systems show various preferences like simple implementation, low expense and no have for outer vitality. Be that as for great performance, a percentage indifferent damper oblige really exact tuning, which is difficult, because of uncertainties in the machine-tool structure.

5. CALCULATION OF CHIP THICKNESS

Concerning illustration, the base chip thickness relies on the machined material properties, recognized those effect of the friction between the workpiece and the tool (in diamond). They provide for an explanatory outflow of the base chip thickness (tu), contingent upon the device around edge radius (Re) [23].

$$tu = Re[\ 1 - \cos(\Pi/4 - \beta/2)]$$

It may be additionally watched that the roughness of the machined surface might have been the best during those base chip thickness; those chips produced might have been afterward continuous [7]. The calculation of the chip thickness is analysed by the chip microsection process. In that following process the chips are prepared into a cube solid material, for more information that process the procedure is explained in detail in the chapter chip microsection process.

6. TURNING TOOL

In the experiment for the turning operations, there are going to be one tool used to conduct the experiment. The schematic diagram of the tools STGCR/L and STFCR/L is shown in the figure 6.1. The tungsten carbide insert is used for this tool which is TCMT 11 x 02. The dimension of the tool is shown in table 6.1.

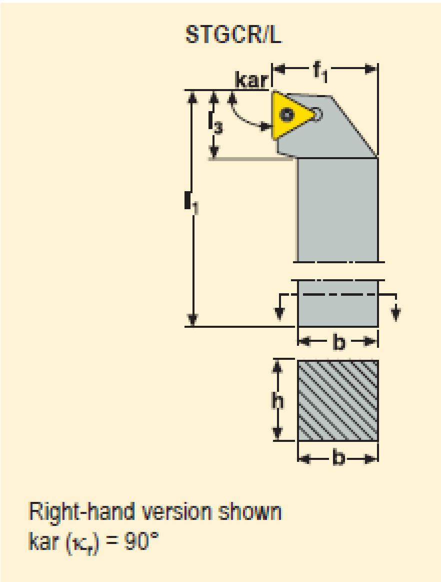


Figure 6.1 Right hand turning tool holder [7]

Table 6.1 Dimension of Turning tool holder

	Dimensions in mm						
Tool	**h**	**b**	l_1	f_1	l_3	**Rake angle**	**Inclination angle**
STFCR 1616H11	16	16	100	20	16	0°	0°

Application:
The tool STGCR/L would be used for the operation of removing material in the horizontal direction which is shown in figure 6.2. The insert used is tungsten carbide.

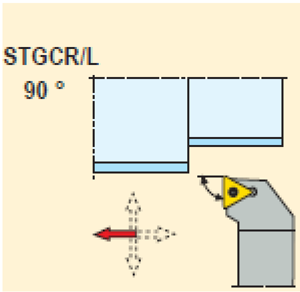


Figure 6.2 Operation direction of tool STGCR/L and STFCR/L [9]

Table 6.2 Tool material details

	Part No.	Dimensions in mm								
		h	b	l_1	f_1	l_3	γ_o°	λ_s°	KG	
11	STGCR 1616H11	16	16	100	20,0	17	0	0	0,2	TC..1102..
	1212F11	12	12	80	16,0	17	0	0	0,1	TC..1102..

6.1 Workpiece information

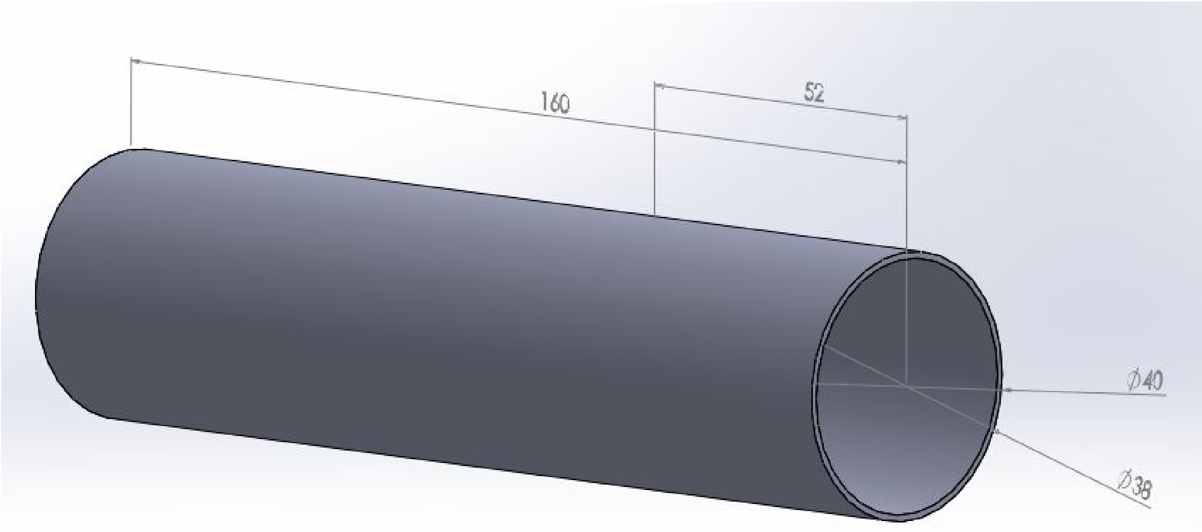


Figure 6.3 Workpiece with dimension

The workpiece going to be used is a disc. The workpiece material is S355 which is a medium carbon steel. It has a property of good weldability and machinability. The chemical composition of the material is shown in table 6.3. The tensile and the yield strength of the material is 470 – 630 MPa and 355N/mm2 respectively for the thickness below 16mm.

Table 6.3 Chemical composition for the material

Grade	C	Si	Mn	P	S	Mn
S355	0.2	0.55	1.6	0.025	0.025	1.6

7. EXPERIMENT TEST SCHEMATIC DIAGRAM

There would aggregate 10 analyses would set off to a chance to be directed on the example workpiece. Those cutting speed will make changing with each analysis. Demonstrated beneath is the schematic outline of the test setting off will make led on the workpiece of material S355

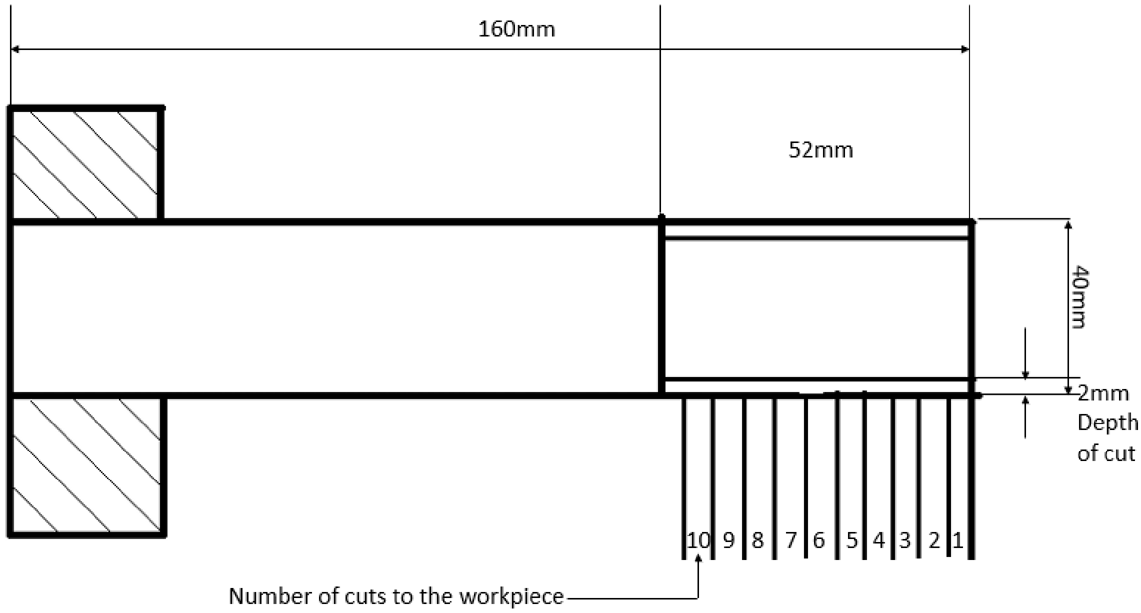


Figure 7.1 Experiment test schematic diagram

8. RESIDUAL STRESS

In this chapter we discus about the residual stress and how it shows the impact on the workpiece material.

The stress which is contained in the material in the locked position is called as residual stress. The stress which remains in the body when there is no external load applied. To improve the mechanical properties of steel thermal treatment is used and not only the mechanical properties we can also improve the toughness, resistance and tenacity [16]. In a short thermal treatment shows good results in the residual stress. The heating treatment has been used traditionally as a way for raising the strength and making the material much stronger as compared to the previews condition of the steel, by normalising and termination. This can be lead to undesirable residual stress, which can successively cause to crack the distortion of the components being heat treated. Commonly residual stress is caused in the manufacturing process [17].

Residual stress is removed for the workpiece in this experiment at the temperature of 840℃ as shown in the figure 10.2. The observation on the workpiece is studied that the workpiece reached quickly to the high temperature to 840℃. And we have studied that the workpiece cool down faster within 15min to the normal temperature.

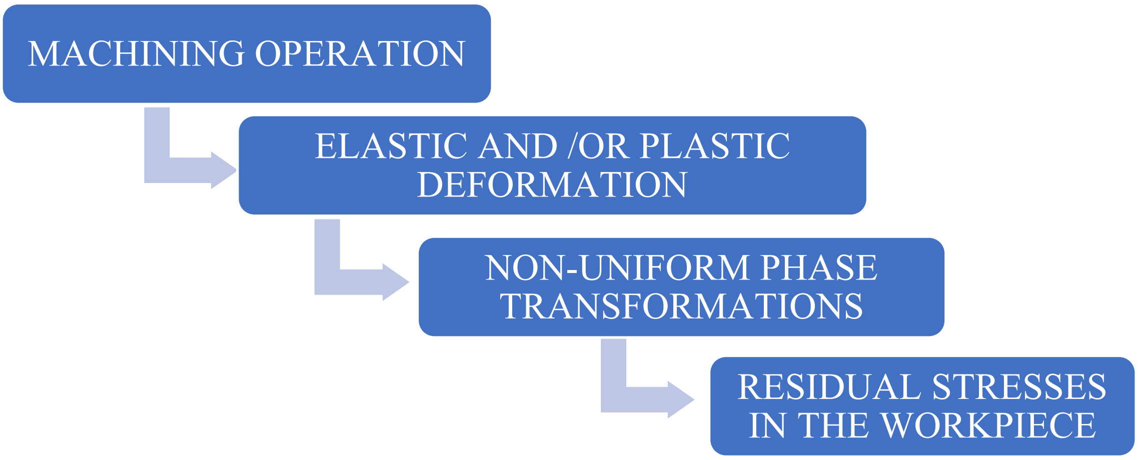


Figure 8.1 The operation explains the machining process of the residual stresses and its function [17]

Whereas, the existing residual states of the properties might make changed because of the mechanical, thermal, alternately compound factors. The mechanical factors are the material evacuation procedure itself. Mechanical impacts of the machining methods progress the change of surface and the microstructure and there will observation of the plastic deformation also. In general, the pattern of the residual stress will be opposite to the pattern of the plastic strain that is produced it. Orthogonal cutting process is another common chip-forming machining process which induces residual stresses on the workpiece. It's known that when a plain carbon steel cutting process in different ways, the resultant residual stress depth profiles could be different, depending on the way of cutting [16, 17].

Experimentation process in detail

9. THE MACHINING OF WORKPIECE FOR ORTHOGONAL TURNING

For this process, we used turning lathe machine. The drilling speed is 500rpm and 0.1mm/rv. The drill to the workpiece is 16mm. The workpiece is fitted to the machine to avoid the beet and the vibrations as it is presented in figure 9.1.

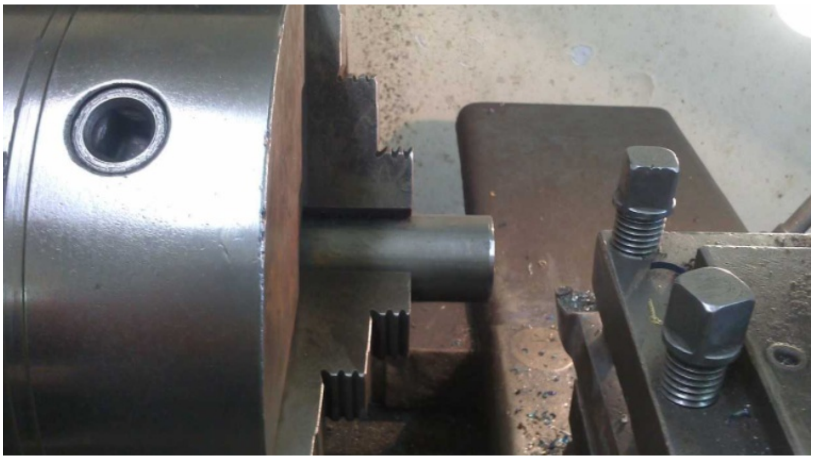


Figure 9.1 chuck of the lathe machine

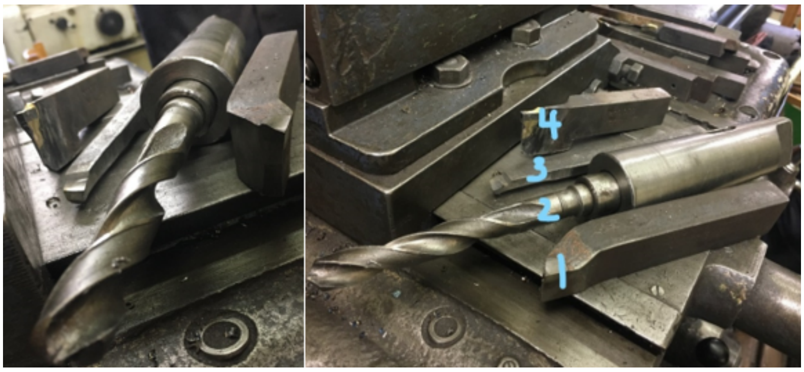


Figure 9.2 Cutting tools for drilling

Figure 9.2 shows the tools which are used to prepare the workpiece for the experiment. The tools which are shown in the figure 9.2 are numbered according to the cutting processes which are used.

After heating treatment procedure oxidation will be removed which were formed on the workpiece by using sandpaper or carbon paper. Below figure 9.3 shows the workpiece after removing the oxidation which formed to the workpiece.

Figure 9.3 Workpiece for the orthogonal cutting process

10. HEAT TREATMENT OF WORKPIECE FOR ORTHOGONAL TURNING

In the first experiment, the material which is selected to conduct the test is steel S355JRG3. The main aim of selecting this material is to analysis the chip thickness for better results.

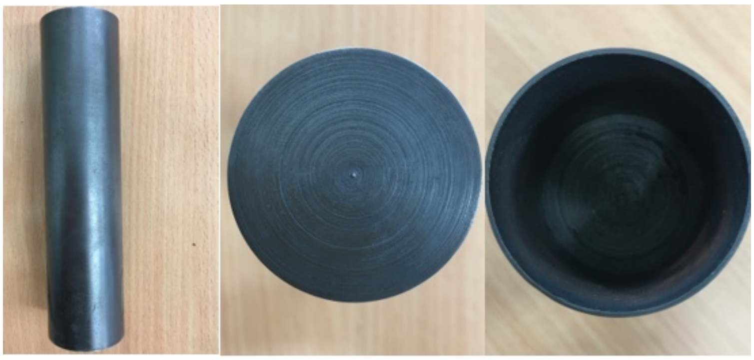


Figure 10.1 Steel S355JRG3 before the cutting process of orthogonal turning process

Observation

In this above figure we can observe that the steel workpiece is in normal condition. This was the first view of the workpiece before starting the experiment and this material is processed to the heating treatment. The workpiece is heated up to 840℃ and this process is done in the machine called Naber thermal heating machine. This machine is provided by the university in their laboratory to conduct the experiment. When the heating treatment started we have observed the workpiece dropping its temperature very quickly.

The process of heating treatment

Heating the workpiece till 840℃. For this process, the heating process took 14 minutes to the temperature from 820℃ to 840℃. While material observing the heat, we can clearly watch the workpiece how it is turning to 840℃. It is clearly visualized while it is heating. In this heating process, few precautions are to be taken because the workpiece will be at high temperature. Safety precautions should be taken using hand gloves or some other safety measurements.

Figure 10.2 Heating Treatment Temperature

The rules and conditions for this process as followed according to engineer's direction. As per the engineering rule, the heating time is 1minite for 1mm of thickness. The workpiece constantly heated 5 minutes in the temperature 840℃ and after heating the process is stopped to bring the material to normal temperature. After this process, workpiece reached the normal temperature. The heat dropped to the normal temperature in less minutes and quickly.

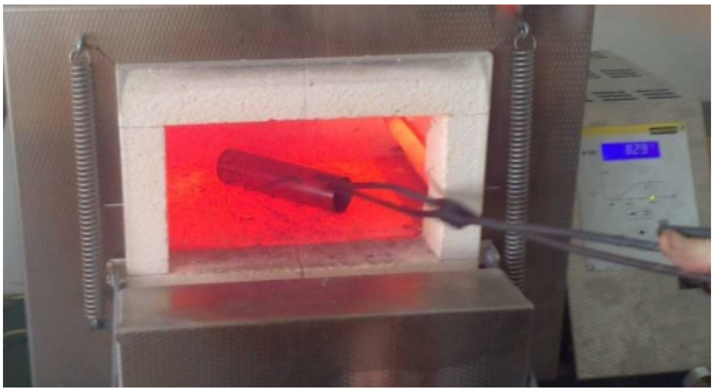


Figure 10.3 Keeping workpiece for Heating Process

11. ORTHIGONAL TURNING EXPERIMENTS

This chapter covers the main cutting process of an experiment and its following processes.

The cutting process is done in the machine name called CNC machine Rayo CNC 165 – 750/1000. 10 experiments are scheduled to perform, according different cutting speed. The cutting speed will be changed for every cut of the workpiece. Cutting speed is started from 60m/min for the first cut and the cutting speed increased slowly for every cut. Feed rate is

0.1mm/rev and the depth of the cut is 1mm for every cut. The cutting speed is increased till 240m/min for the 10th cut of the workpiece. In this operation, the feed rate and depth of the cut are constant for all ten cuttings.

Figure 11.1 CNC machine (Rayo CNC 165- 750/1000)

From the (figure 11.1), we can notice the total setup of the process which we have done in the experiment. Attention while cutting process is running in the machine the door of CNC machine should be closed to avoid any kind of accidence. The cutting speed, the angle of the tool and feed rate is completely operated by the electronic operation board which is connected to the machine as shown in (figure 11.1).

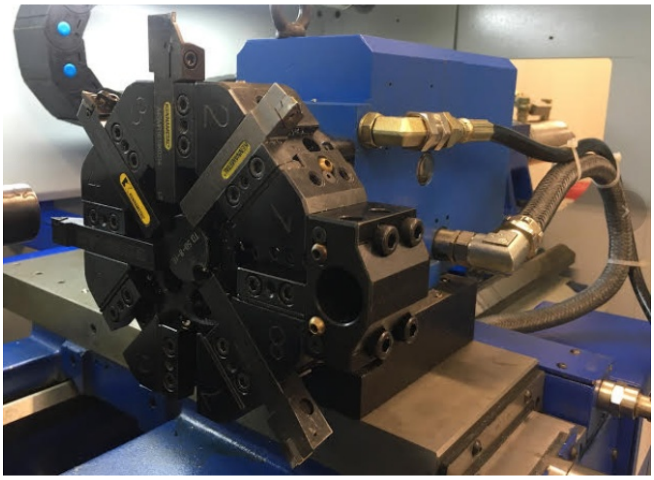


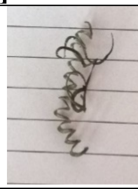
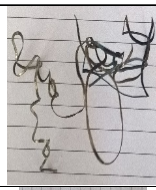
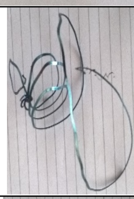
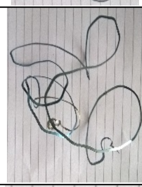
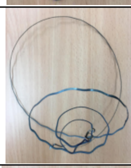
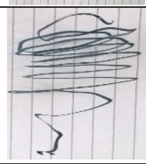
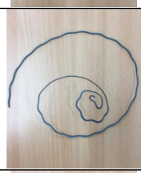
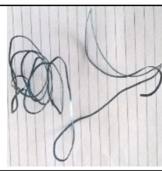
Figure 11.2 Cutting tool

11.1 Properties of the workpiece

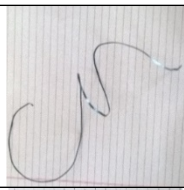
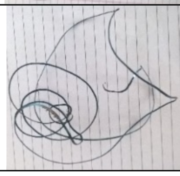
S355JRG3 this is a steel material in detailed it's a carbon manganese steel. The characteristics of this material are very strong and powerful. S355JRG3 is also known as non-alloy structural steel. This material can be weldable, cut and drill or mill. The chemical properties of the steel material are shown in the below (figure 11.3). 470-630 MPa is the tensile and the yield strength which the material contains 355N/mm^2 respectively. This information is the regards of the workpiece 16mm of its thickness.

11.2 Experiment results

Table 11.1 The shape of chips according to the preparation of workpiece.

EXP No	Feed rate (mm/rev)	Depth of cut(mm)	Cutting speed (m/min)	Spindle speed calculation (rpm)	Chip formation Experiment (heated steel material)	Chip formation Experiment Workpiece without heating [15]
1	0.1	1	60	477.47		
2	0.1	1	80	636.63		
3	0.1	1	100	795.79		
4	0.1	1	120	954.95		
5	0.1	1	140	1114.11		
6	0.1	1	160	1273.27		
7	0.1	1	180	1432.43		
8	0.1	1	200	1591.59		

Continuation of table 11.2

9	0.1	1	220	1750.75		
10	0.1	1	240	1909.91		

Remark: The chips (workpiece without heating) which are shown in the above table are taken from the previews experimentation done by the Rohan Erava who done the experimentation of on steel S355 longitudinal orthogonal turning process in the year 2017. And the incomplete of his work is calculated by myself to improve the results and for the comparison of both workpieces with heating and without heating.

12. BUMP TEST THE WORKPIECE AND FOR CUTTING TOOL

Bump test:

Bump test is a method to analyse the structural modal response of a machine or a structure. When a machine produces or creates any broad frequency band of excitation components. When the machine forms such frequency is considered as natural frequencies. The frequencies are due to the vibration which occurs from the machine. These vibrations are measured by using sensors. These sensors are attached to the machine, cutting tool and to the workpiece. Not only for this purpose we can measure any frequencies but for the present experiment, we measured the cutting tool and workpiece. And, we took the frequency of the normal running machine vibrations.

While conducting the bump test the sensitivity will be changed and checked in different senesces to get the better results. These sensors are attached to the object which we measure the frequency of it is attached by using super glue gum. This glue gum helps to stick both the objects together.

The main concentration to conduct the bump test is to know about the impact of the object and it’s measurable with a frequency. So that we can measure the vibration which is occurred in the cutting process which leads the experiment to get better results. The main reason to conduct the bump test is to know about the mass of the object, to understand the stiffness of the object and to check the dumping ratio.

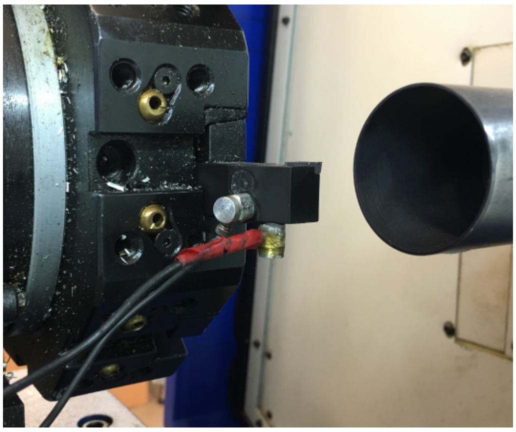


Figure 12.1 Bump test to the tool on both Vertical and Horizontal directions to check the vibrations occurring to the workpiece by using sensors.

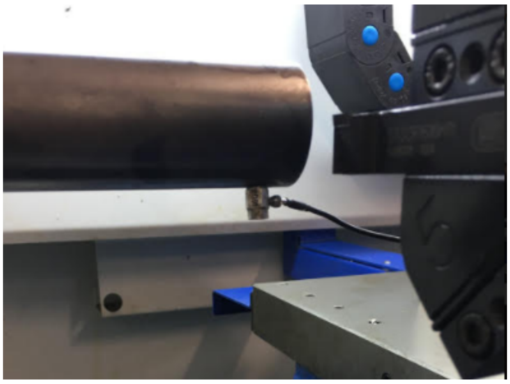


Figure 12.2 Bump test to the workpiece

Usually, in many cases, the machine vibration will be increased or decreased by its motion of the function. If we clearly search about the point of major vibration frequency, then the result will be improved by conducting repeated tests. By coming to the test process, after both sensor and the object attached together by using a small metal rod should be knocked to a workpiece and the cutting is given. So, we can clearly notice the frequency of vibration which formed from the object and this frequency are shown in the PC using a software called picoscope 6. This software helps to calculate the vibration of the tool and the workpiece. It is shown in frequencies.

Figure 12.3 PC Oscilloscope (modem)

The bump test is conducted both in vertical and horizontal directions. We measured both vertical and horizontal due to finding out the actual vibration is occurring to the cutting tool. The results we get is an accurate calculation. The measurements which are measured in this experiment is an accurate frequency which we found to be measured. The sensor's sensitivity of both vertical and horizontal are mentioned below in detailed.

Notice:

i. Sensor 1 details- Vertical direction sensor: - 5219-0.22mv/m/s^2
ii. Sensor 2 details- Horizontal direction sensor: - 5515-1.1mv/m/s^2

The value of the damping ratio(ζ) is can be taken to measure and calculate the behaviour of the system. The value of ζ =1 then it can be known as critical damping and if the value is shown as ζ < 1 then it can be considered as a system in underdamped. The damping ratio(ζ) depends on the value of logarithmic decrement (δ) which can be calculated from the equation and this formula is shown below.

$$\delta = \ln\left(\frac{X1}{X2}\right)$$

You can notice the X1 and X2 in the formula. X1 is the acceleration value of the bigger peak and by coming to the X2 is the acceleration value of the smaller peak

$$\zeta = \frac{1}{\sqrt{1 + \left(\frac{2\Pi}{\delta}\right)^2}}$$

The above formula is for calculating the dumping ratio

13. FREQUENCY CALCULATION AND THEIR RESULTS OF WORKPIECE AND CUTTING TOOL

Tests and their results

Table 13.1 Bump Test 1 for the cutting tool in vertical direction

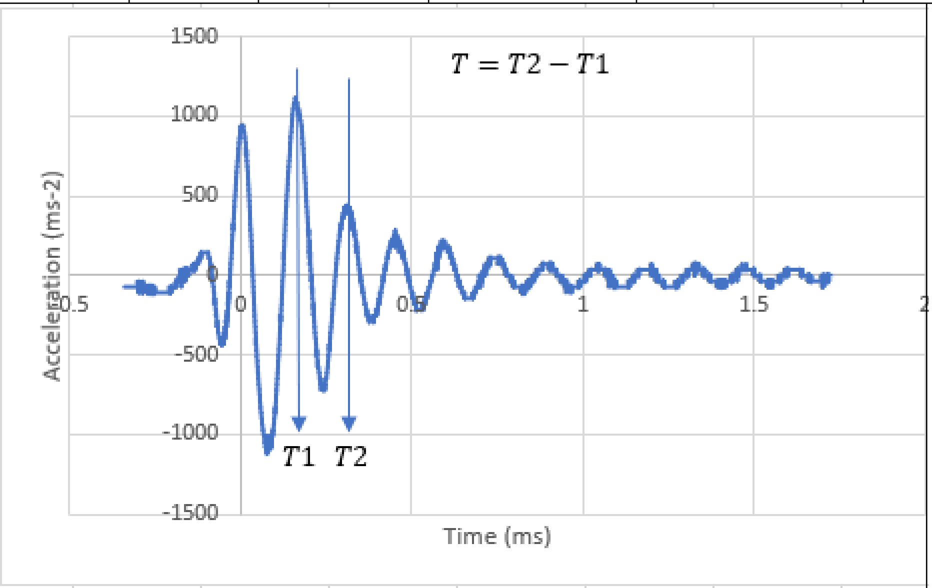
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**	**Logarithmic decrement (δ)**	**Damping ratio(ζ)**
Vertical	0.159	0.310	0.151	6.62	0.9492	0.150
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction						

Table 13.2 Bump Test 1 for the cutting tool in a horizontal direction.

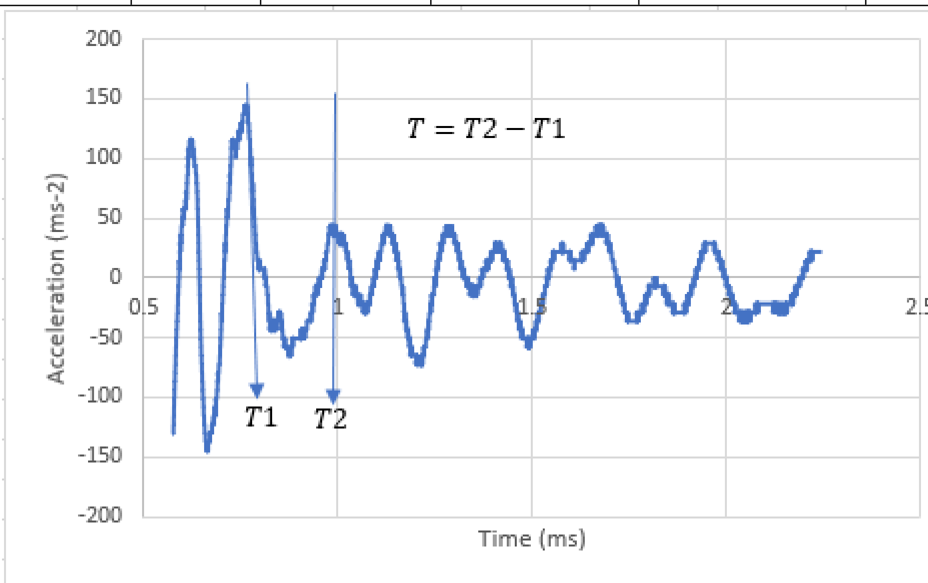
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**	**Logarithmic decrement (δ)**	**Damping ratio(ζ)**
Horizontal	0.765	0.993	0.228	4.38	1.2041	0.190
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction						

Table 13.3 Bump Test 2 for the cutting tool in a vertical direction.

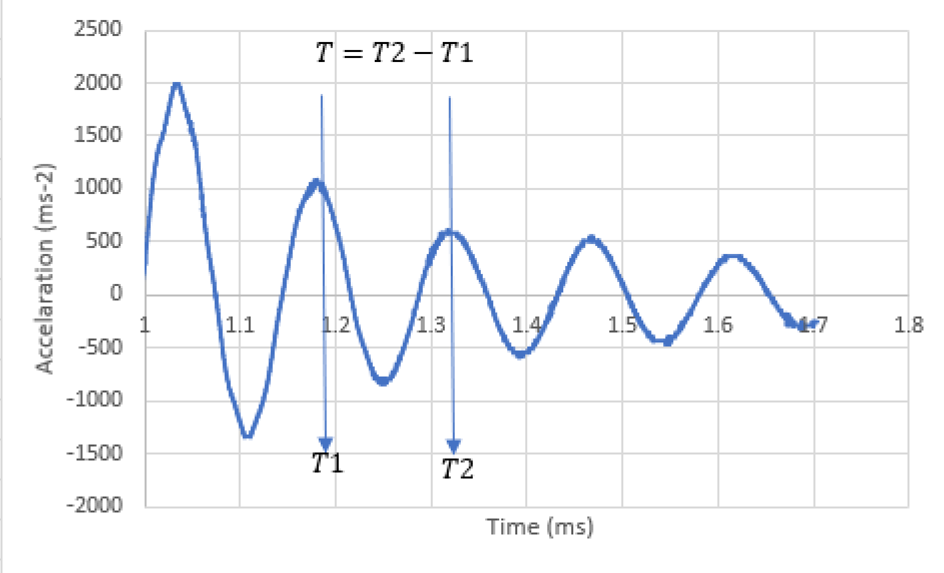
Direction	T1(ms)	T2(ms)	T=T2-T1	F=1/T(kHz)	Logarithmic decrement (δ)	Damping ratio(ζ)
Vertical	1.185	1.321	0.136	7.35	0.5948	0.0942
Graph of Acceleration (ms^{-2}) vs Time(ms) for vertical direction						

Table 13.4 Bump Test 2 for the cutting tool in a horizontal direction.

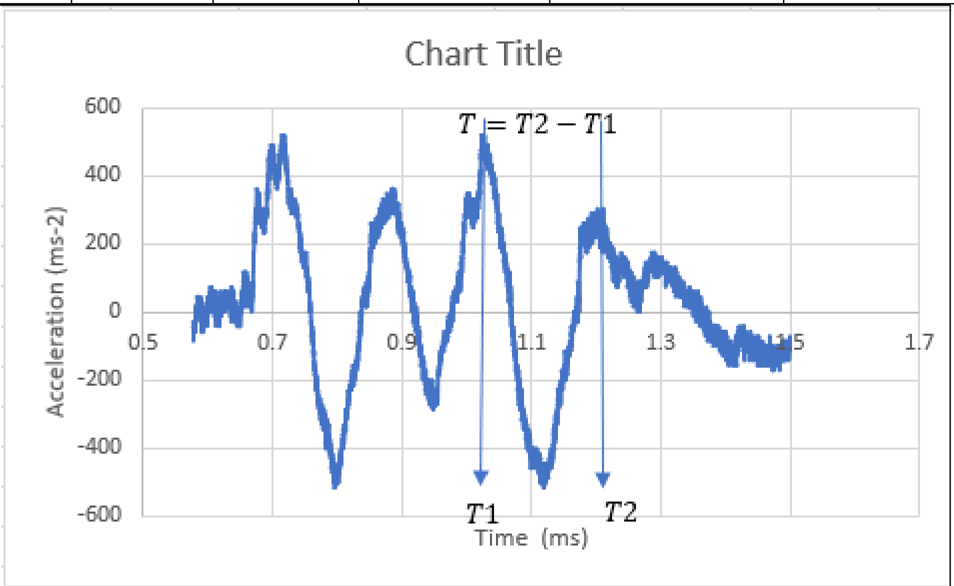
Direction	T1(ms)	T2(ms)	T=T2-T1	F=1/T(kHz)	Logarithmic decrement (δ)	Damping ratio(ζ)
Horizontal	1.025	1.211	0.186	5.37	0.5107	0.081
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction						

Table 13.5 Bump Test 3(1) of the workpiece.

T1(ms)	T2(ms)	T=T2-T1	F=1/T(kHz)	Logarithmic decrement (δ)	Damping ratio(ζ)
0.000	0.894	0.894	1.11	0.1520	0.0241

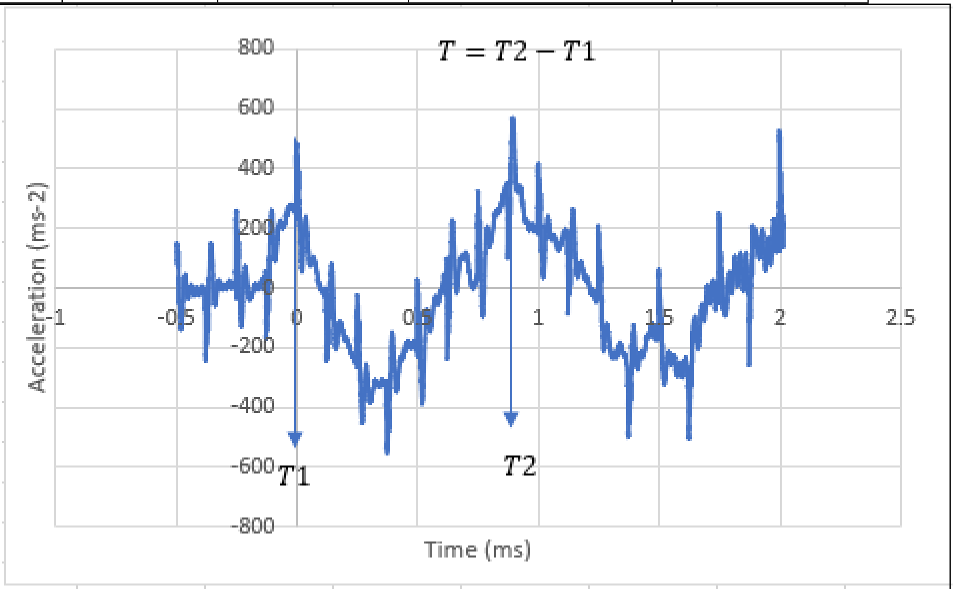
Graph of Acceleration (ms^{-2}) vs Time(ms)	

Table 13.6 Bump Test 3(2) of the workpiece.

T1(ms)	T2(ms)	T=T2-T1	F=1/T(kHz)	Logarithmic decrement (δ)	Damping ratio(ζ)
1.226	2.350	1.124	0.88	0.4261	0.0676

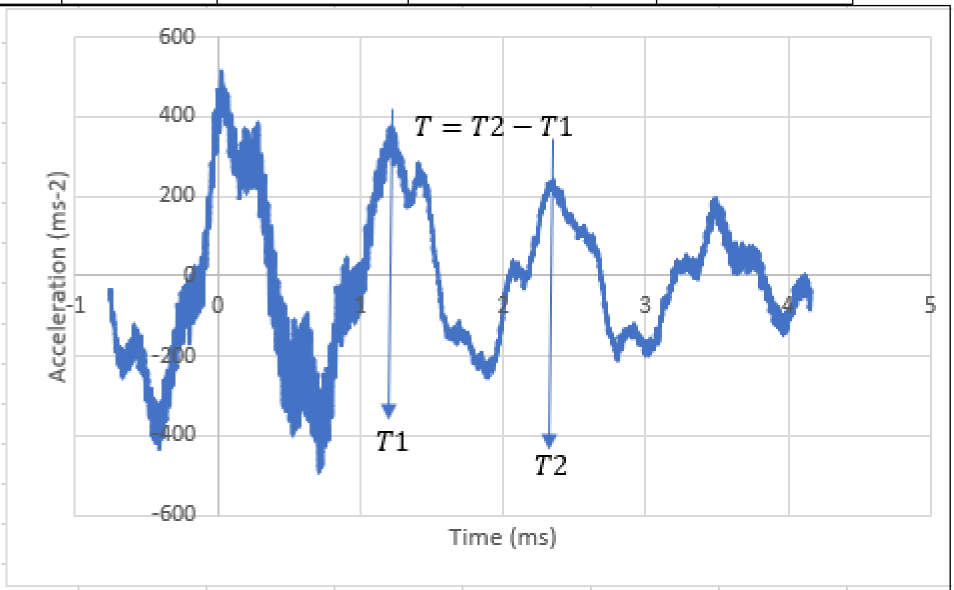
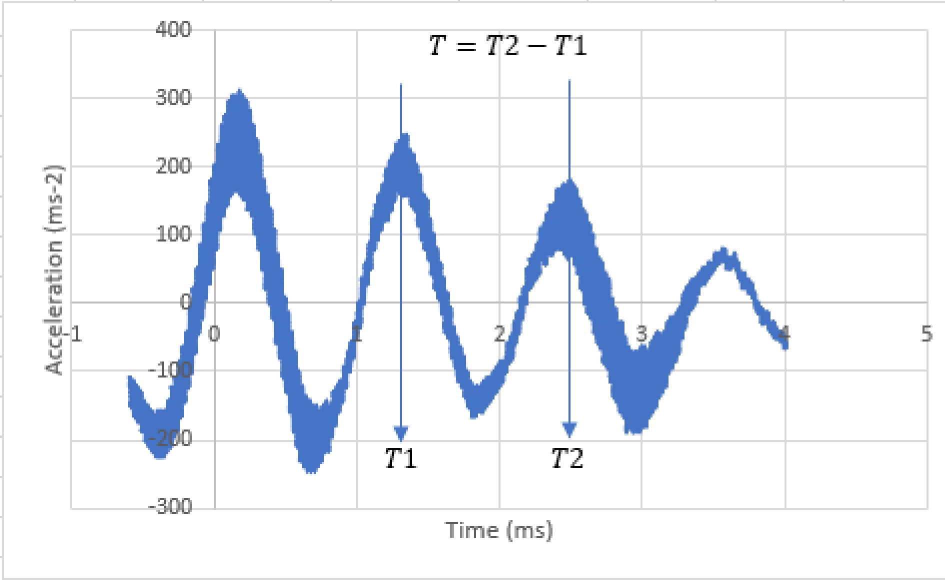
Graph of Acceleration (ms^{-2}) vs Time(ms)	

Table 13.7 Bump Test 3(3) of the workpiece.

T1(ms)	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**	**Logarithmic decrement (δ)**	**Damping ratio(ζ)**
1.347	2.490	1.143	0.87	0.3609	0.0573
Graph of Acceleration (ms^{-2}) vs Time(ms)					

14. Frequency calculation of turning process

In this experiment, there are ten cuts to the workpiece. For every cut the feed rate and the rotation speed is constant. The cutting speed details are rpm and 0.1mm/rv for the internal cutting of an experiment.

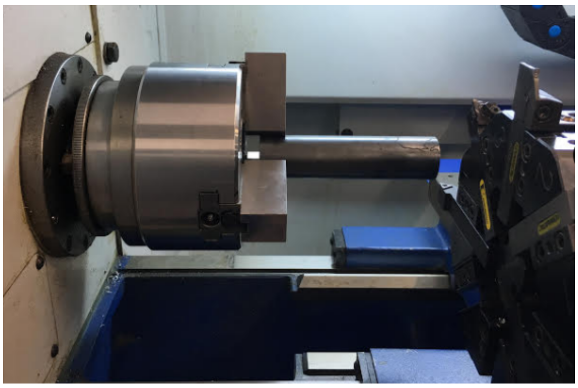


Figure 14.1 workpiece before cutting process

In the above figure 14.1, you can notice that workpiece is fixed to the chuck strongly to avoid the vibrations occurs from the workpiece. And, you can notice the cutting tool direction of the cut.

Table 14.1 Experiment 1 (test1)

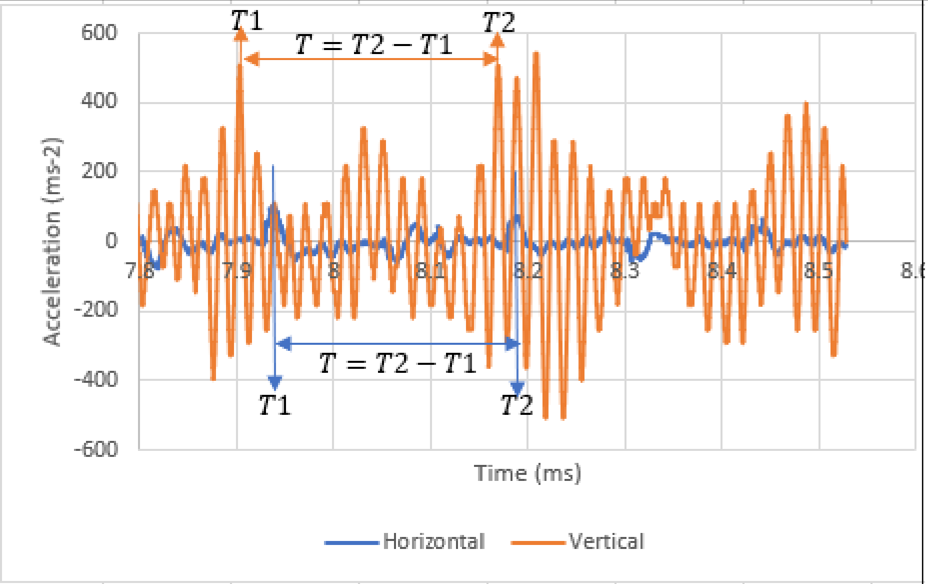
<table>
<tr><th>Direction</th><th>T1(ms)</th><th>T2(ms)</th><th>T=T2-T1</th><th>F=1/T(kHz)</th></tr>
<tr><td>Horizontal</td><td>7.939</td><td>8.193</td><td>0.254</td><td>3.93</td></tr>
<tr><td>Vertical</td><td>7.902</td><td>8.170</td><td>0.268</td><td>3.73</td></tr>
<tr><td>Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction</td><td colspan="4">
</td></tr>
</table>

Table 14.2 Experiment 1 (cutting test 2)

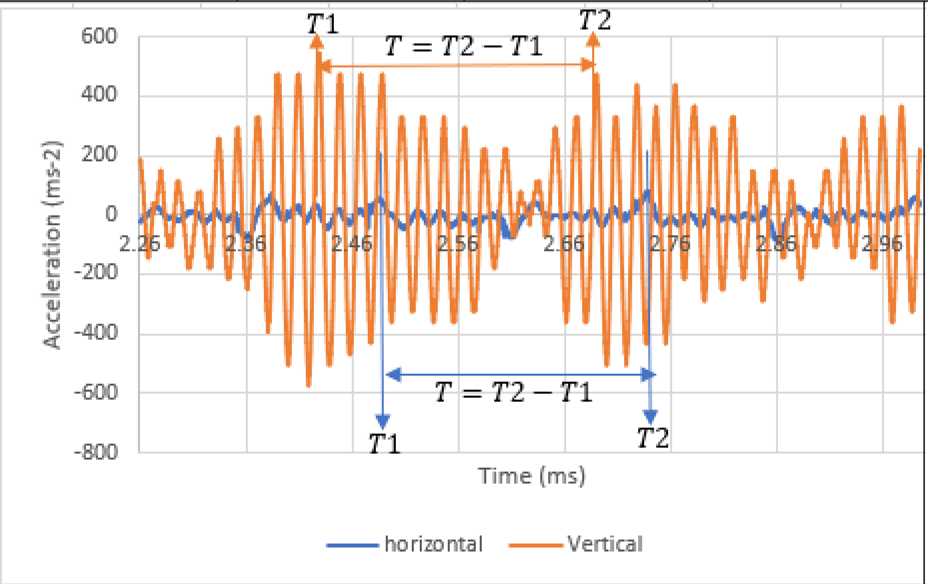
<table>
<tr><th>Direction</th><th>T1(ms)</th><th>T2(ms)</th><th>T=T2-T1</th><th>F=1/T(kHz)</th></tr>
<tr><td>Horizontal</td><td>2.493</td><td>2.742</td><td>0.249</td><td>4.01</td></tr>
<tr><td>Vertical</td><td>2.428</td><td>2.689</td><td>0.261</td><td>3.83</td></tr>
<tr><td>Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction</td><td colspan="4">
</td></tr>
</table>

Table 14.3 Experiment 1 (cutting test 3)

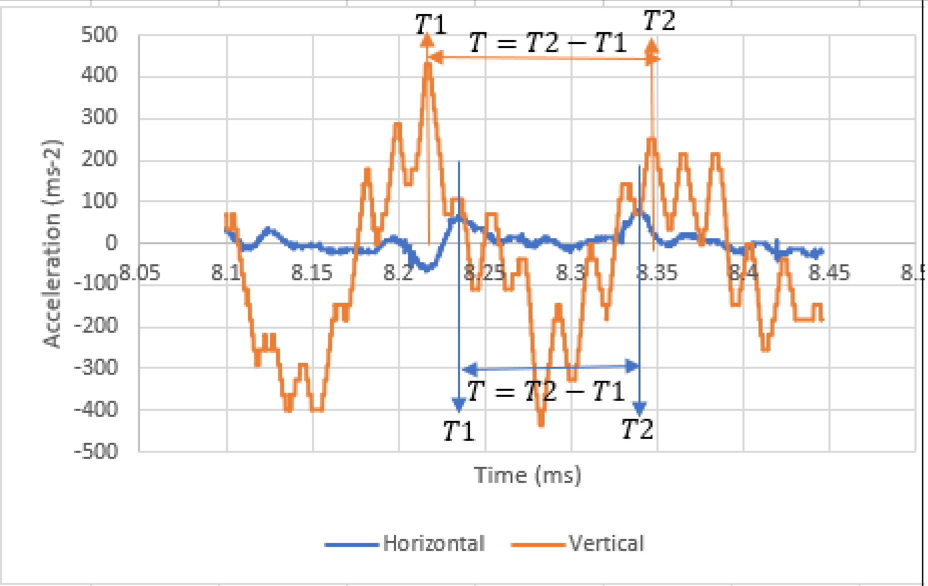
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	8.238	8.339	0.101	9.90
Vertical	8.217	8.347	0.13	7.69
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction				

Table 14.4 Experiment 1 (cutting test 4)

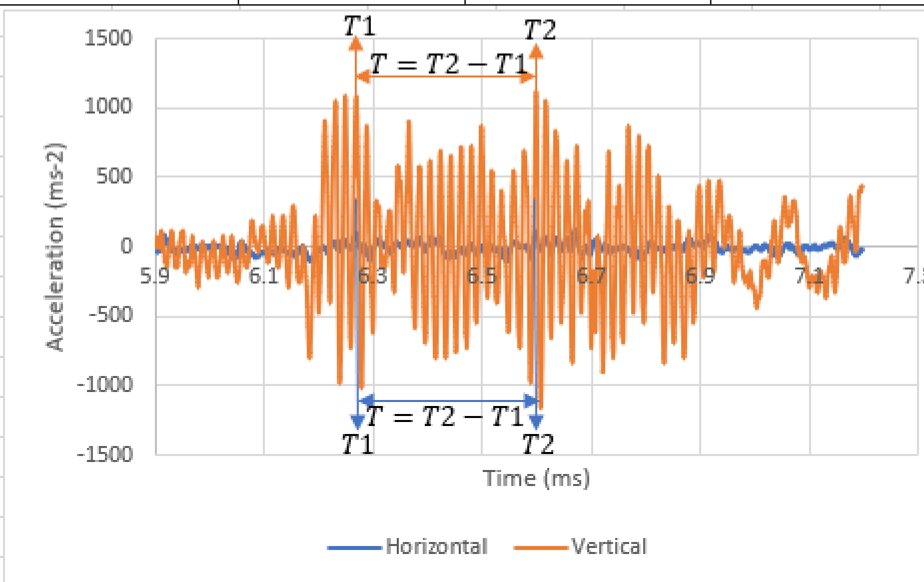
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	6.275	6.611	0.336	2.97
Vertical	6.268	6.598	0.33	3.03
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction				

Table 14.5 Experiment 1 (cutting test 5)

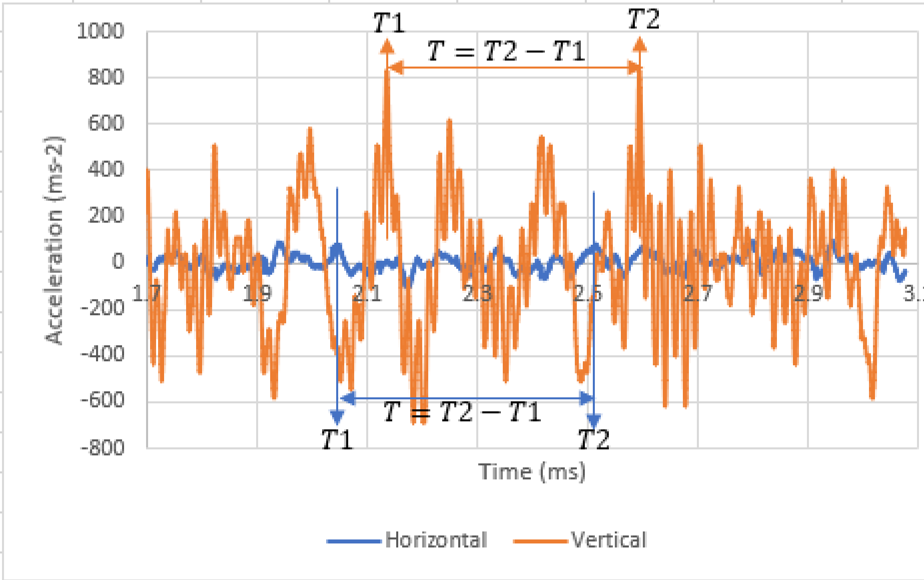
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	2.021	2.512	0.491	2.03
Vertical	2.135	2.594	0.459	2.17
Graph of Acceleration (ms^{-2}) **vs Time(ms) for horizontal direction**				

Table 14.6 Experiment 1 (cutting test 6)

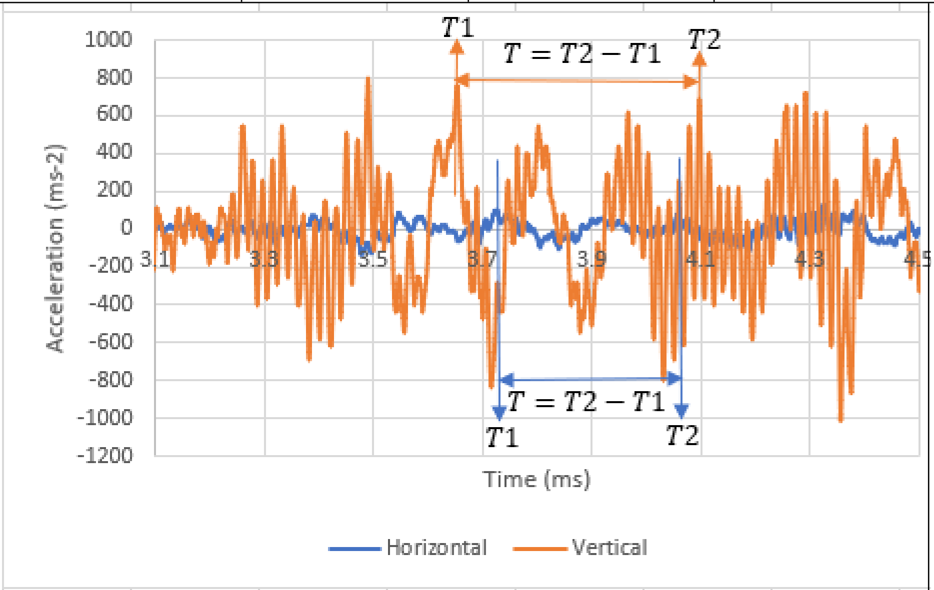
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	3.742	4.073	0.331	3.02
Vertical	3.653	4.097	0.444	2.25
Graph of Acceleration (ms^{-2}) **vs Time(ms) for horizontal direction**				

Table 14.7 Experiment 1 (cutting test 7)

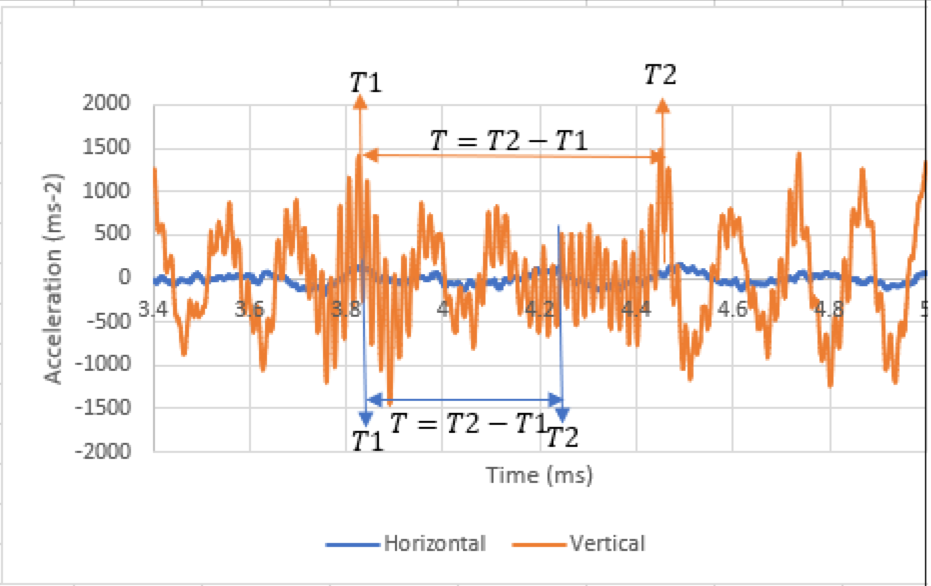
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	3.837	4.229	0.392	2.55
Vertical	3.827	4.451	0.624	1.60
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction				

Table 14.8 Experiment 1 (cutting test 8)

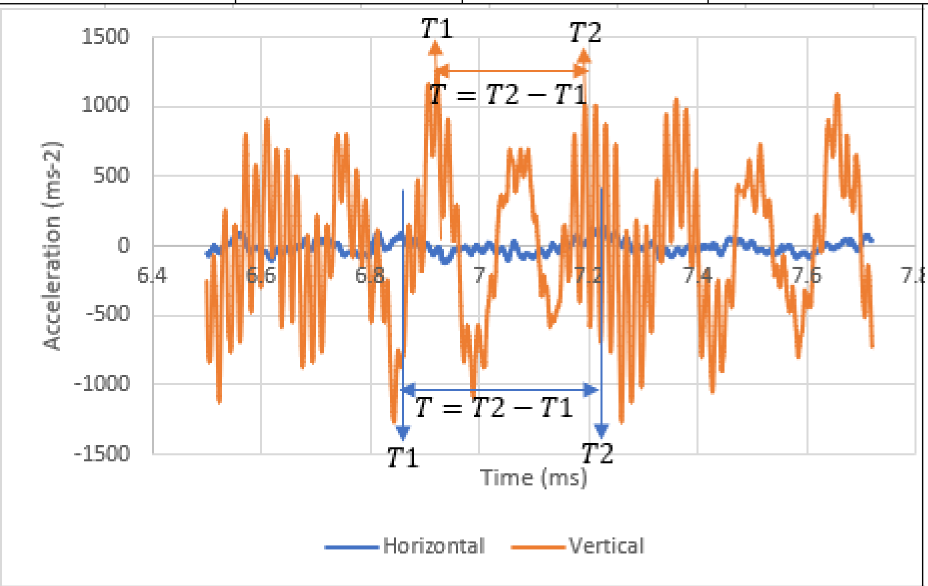
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	6.868	7.226	0.358	2.79
Vertical	6.922	7.193	0.271	3.69
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction				

Table 14.9 Experiment 1 (cutting test 9)

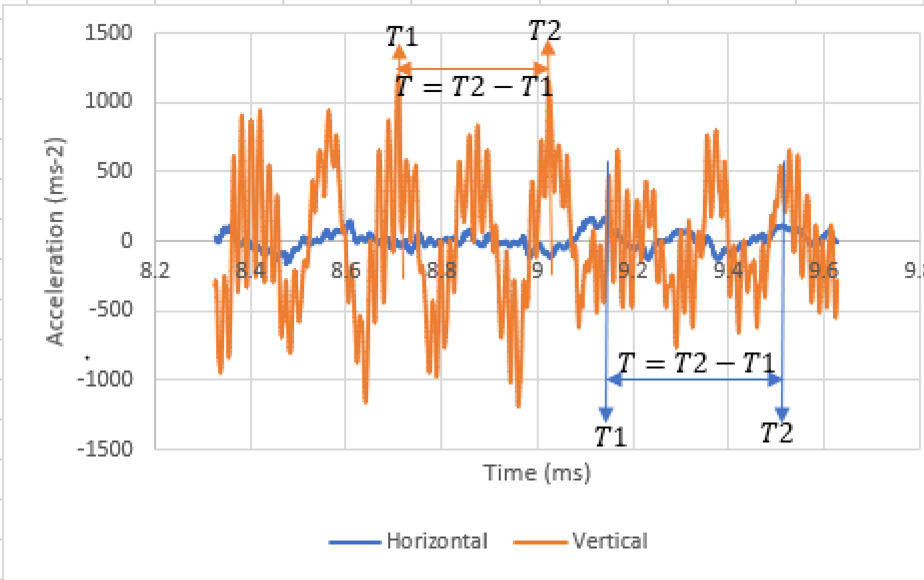
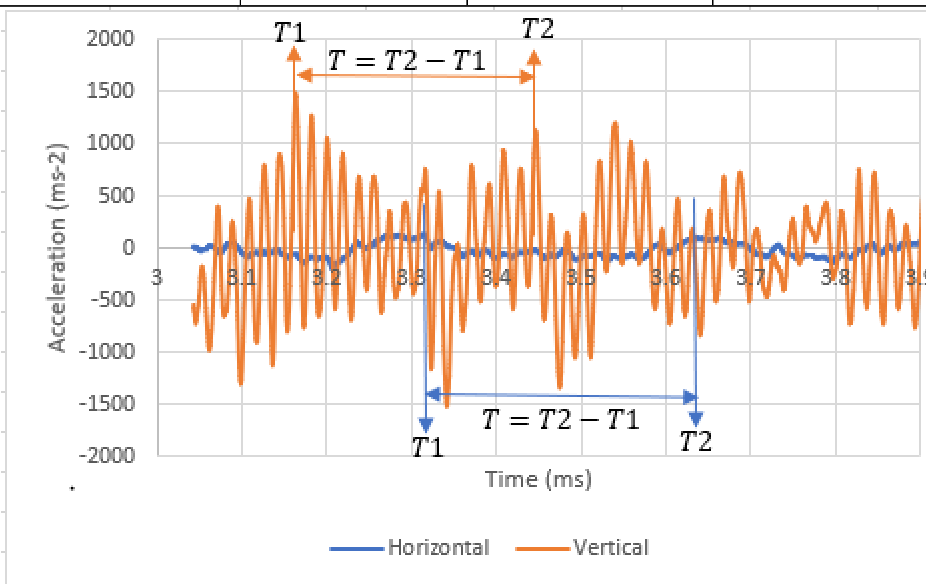
Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	9.152	9.533	0.381	2.62
Vertical	8.707	9.023	0.316	3.16
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction				

Table 14.10 Experiment 1 (cutting test 10)

Direction	**T1(ms)**	**T2(ms)**	**T=T2-T1**	**F=1/T(kHz)**
Horizontal	3.319	3.632	0.313	3.19
Vertical	3.164	3.447	0.283	3.53
Graph of Acceleration (ms^{-2}) vs Time(ms) for horizontal direction				

The below graph (fig 14.2) explains the vibration frequencies (frequency vs cutting speed). The frequency is mentioned as kHz. In this graph, you can observe the comparison between horizontal frequencies and vertical frequencies. Horizontal frequency is a bit high as compared to the vertical. And clearly, we can study from the graph.

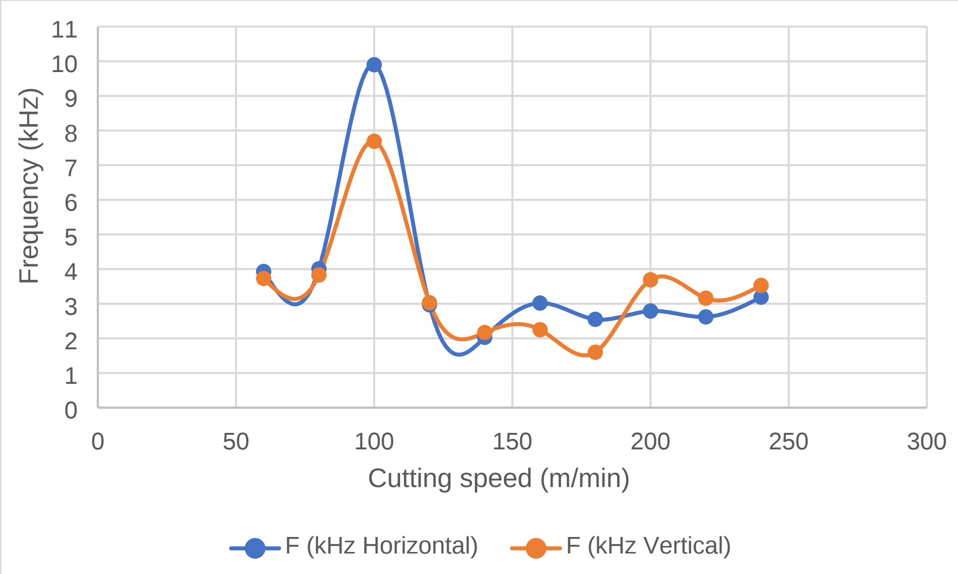


Figure 14. 2 Frequency vs Cutting speed

14.1 The calculation and determination of deformation ratio of an experimentation.

The below calculation is done with the measurement of chip thickness. The following calculation is done from the inspection for plastic deformation. These chips are formed during the orthogonal turning process. And the chips are collected from different speeds of rotations cut. The plastic deformation coefficient is considered as (Ka) and it is determined from the measured ratio of chip thickness. Average value of the chip thickness is taken from six different measurements and it is shown as (a_{avg}). And the uncut chip thickness value is mentioned as (a_0) which is mentioned below [23].

$$K_a = \frac{a(avg)}{a0}$$

The uncut chip thickness = a_0 = s.sinφ

= 0.1 sin (90°)

= 0.1

The main approach angle is considered as φ

Table 14.11 Plastic deformation results

Experiments	a_1 mm	a_2 mm	a_3 mm	a_4 mm	a_5 mm	a_6 mm	a_{avg} mm	K_a
1	0.26	0.27	0.29	0.32	0.55	0.52	0.368	3.683
2	0.64	0.59	0.63	0.60	0.63	0.64	0.621	6.216
3	0.55	0.50	0.57	0.40	0.53	0.56	0.518	5.183
4	0.60	0.54	0.49	0.60	0.56	0.57	0.56	5.6
5	0.50	0.51	0.70	0.48	0.65	0.71	0.591	5.91
6	0.54	0.46	0.50	0.52	0.48	0.55	0.508	5.083
7	0.50	0.48	0.51	0.49	0.47	0.43	0.48	4.8
8	0.46	0.53	0.60	0.56	0.61	0.47	0.538	5.383
9	0.48	0.50	0.52	0.49	0.54	0.51	0.506	5.066
10	0.40	0.43	0.50	0.44	0.47	0.49	0.455	4.55

Figure 14.3 graph explains the coefficient plastic deformation of thickness (Ka) vs Cutting speed as mentioned in the below graph. The first cut is started from the 60 m/min as mentioned in the below graph. The value is raised at the point of 80 m/min. And later it decreased in the cut of 80 m/min and again it raised at 140m/min but not as high as in the cut of 80 m/min. And we can observe that in the cut of 240 m/min is less as compared to all cuts but not the first cut.

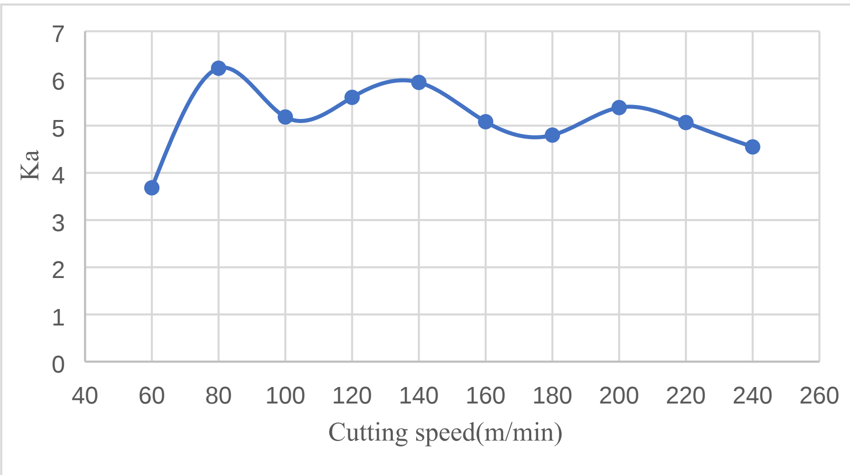


Figure 14.3 coefficient plastic deformation of thickness Ka vs Cutting speed

14.2 The chip thickness ratio (r_c) and the shear angle (Ø)

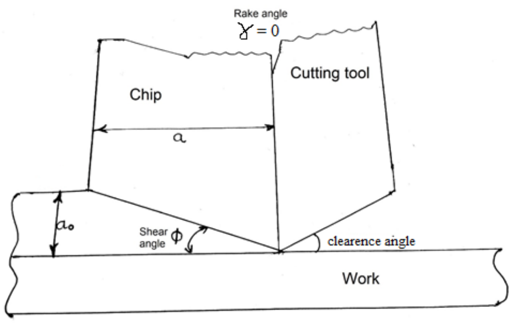


Figure 14.4 schematic diagram of the chip removed from the orthogonal turning process [22]

The shear angle of the chip thickness ratio is based on (r_c). And this equation is taken from the below equation as mentioned. The shear angle is considered as (Ø). The shear angle and the chip thickness are taken from the experimentation. The equation is explained in detail in the below [23].

$$(r_c) = \frac{a0}{a(avg)} = \frac{1}{Ka}$$

$$Ø = \tan^{-1}\left(\frac{rc\ Cos\Box}{(1 - rc\ Sin\Box)}\right)$$

As per the condition, □ = rake angle

Table 14.12 This table shows the chip thickness ratio and the shear angle from the experimentation.

Experiments	Cutting Speed (m/min)	Chip thickness ratio(r_c) (mm)	Shear angle (Ø)
1	60	0.2715	15.189
2	80	0.1608	9.134
3	100	0.1929	10.918
4	120	0.1785	10.120
5	140	0.1692	9.603
6	160	0.1967	11.128
7	180	0.2083	11.766
8	200	0.1857	10.519
9	220	0.1973	11.161
10	240	0.2197	12.391

The below graph (fig 14.5) shows the shear angle vs cutting speed

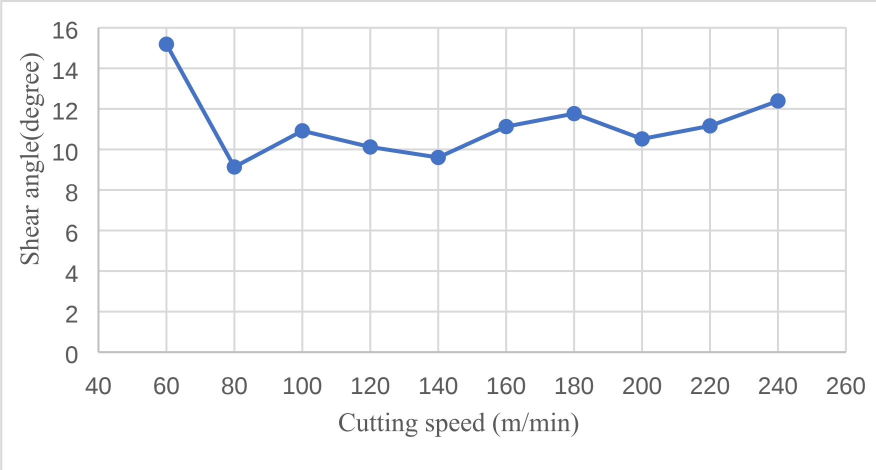


Figure 14.5 This figure shows the shear angle vs cutting speed

Longitudinal orthogonal cutting process diagram is shown in the below as per the following.

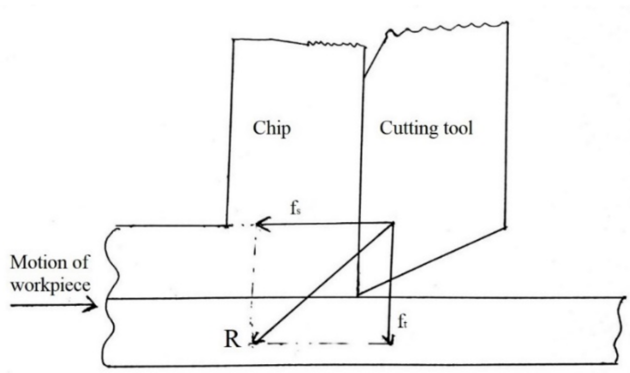


Figure 14.6 Orthogonal cutting process longitudinal of cutting force diagram [6]

The following are the explanation of the shear force and the resultant force calculation.

The resultant force is considered as (R)

The resultant force is calculated from the shear force (f_s). The equation is explained in detail below [23].

$$f_s = a_0 \, bk/\sin Ø$$

Hence the depth of the cut (mm) = b

k = yield strength = 345N/mm^2 for the thickness of workpiece 40mm

$$R = f_s / \cos (Ø + \beta - □)$$

Hence angle of the friction is = β

The observation of the equation, the value of the β is using the theory which is considered by the Ernst and Merchant [23].

$$Ø = \frac{\Pi}{2} - \frac{(\beta - \square)}{2}$$

Table 14.13 Below table shows the calculation of shear force (N) and the resultant force (N)

Experiments	Cutting Speed (m/min)	Shear force(N)	Resultant force(N)
1	60	131.677	1076.611
2	80	217.331	632.422
3	100	182.150	215.5315
4	120	196.345	201.8467
5	140	206.809	282.9093
6	160	178.755	249.9658
7	180	169.188	1069.953
8	200	188.977	191.5794
9	220	178.233	257.6869
10	240	160.777	367.68

The below graph shows the resultant force vs cutting speed

Below graph observation: In this graph, we can observe that the resultant force is dropped after first cut (60 m/min). And the resultant force is raised in the cut of 160 m/min. We can notice that the 60 m/min and 160 m/min cut is similar in the resultant force. And the resultant force dropped in the cut of 200 m/min as shown in the below graph.

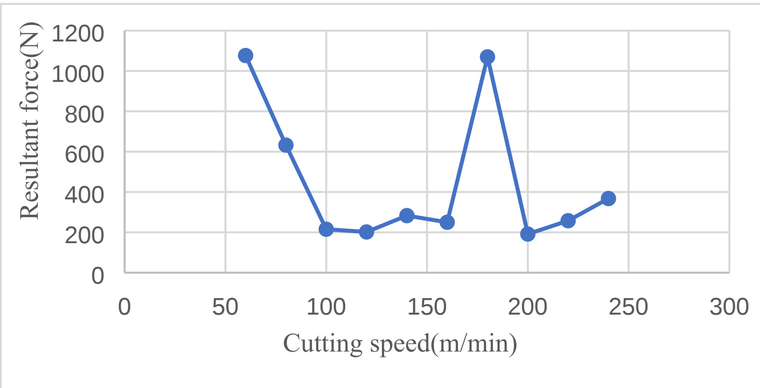


Figure 14.7 Resultant force vs cutting speed from the experimentation

15. COMPARISON BETWEEN THE FREQUENCIES OF STEEL S355 LONGITUDINAL ORTHOGONAL TURNING PROCESS WITH HEATING THE WORKPIECE AND WITHOUT HEATING THE WORKPIECE.

The below graph shows the comparison between the two different experiments. One experiment is done without heating the workpiece and another experiment is done with heating the workpiece in the temperature of 840℃. Clearly, you can observe that after heating the workpiece the frequency is dropped as compared to the workpiece frequency without heating. It shows the true variation after heating the material the flexibility of the cut is more comfortable as compared to the material without heating. By heating the material, we are removing the residual tension to the material, so it helps to the material to be flexible to cut and easy to remove the vibration occurring in the orthogonal turning process. Hence it is proved that after heating the workpiece is easy to cut with a less vibration.

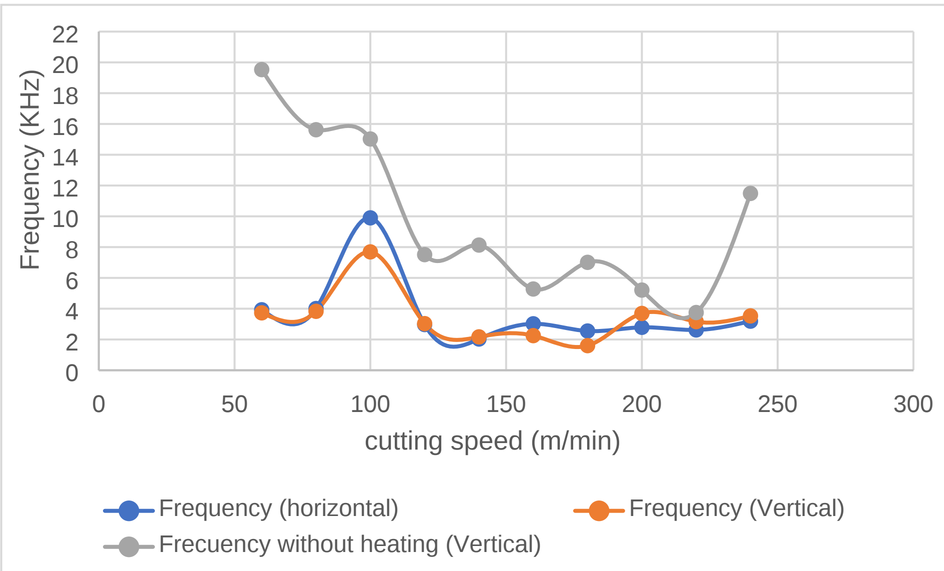


Figure 15.1 The comparison between horizontal and vertical of workpiece with heating and without heating the workpiece

Figure 15.2 graph shows the comparison between the Ka value with heating and without heating the workpiece

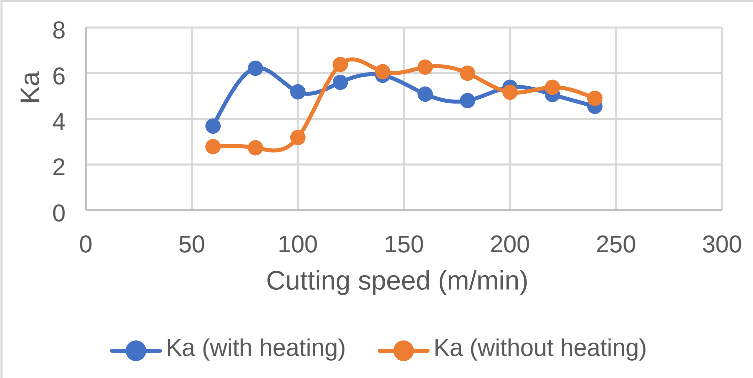


Figure 15.2 Comparison coefficient plastic deformation of thickness (Ka) between the workpiece with heating and without heating

Figure 15.3 graph shows the comparison of resultant force with heating the workpiece and without heating the workpiece

In this graph, we can observe that the workpiece after heating the resultant force is not much raised as the workpiece without heating. The resultant force is high at the beginning of the cut (60m/min) and it was dropped in between the 100m/min. The raise is similar as compared to the cut of 60m/min and 180m/min as shown in the below graph. But as compared to the resultant force without heating the material, the rise of resultant force is low is compared to the material without heating as can be studied from the below graph.

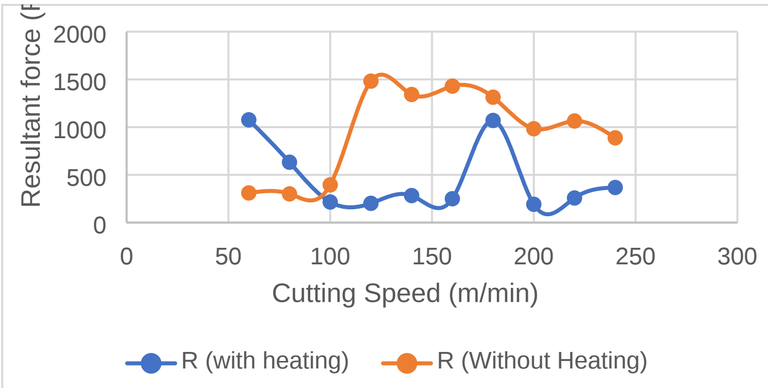


Figure 15.3 Comparison between the resultant force of workpiece with heating and without heating the workpiece

The wave of the frequency is calculated in the amplitude and the calculation is explained in detail in the below equation [23].

$$\frac{X}{(2\Pi F)^2} = A$$

X is considered as an Acceleration in m/s^2

The frequency Hz is considered as F

The frequencies of the amplitude in Horizontal and Vertical

The below graph shows the amplitude of frequency both Horizontal and Vertical directions. This graph shows the amplitude (m) vs cutting speed (m/min).

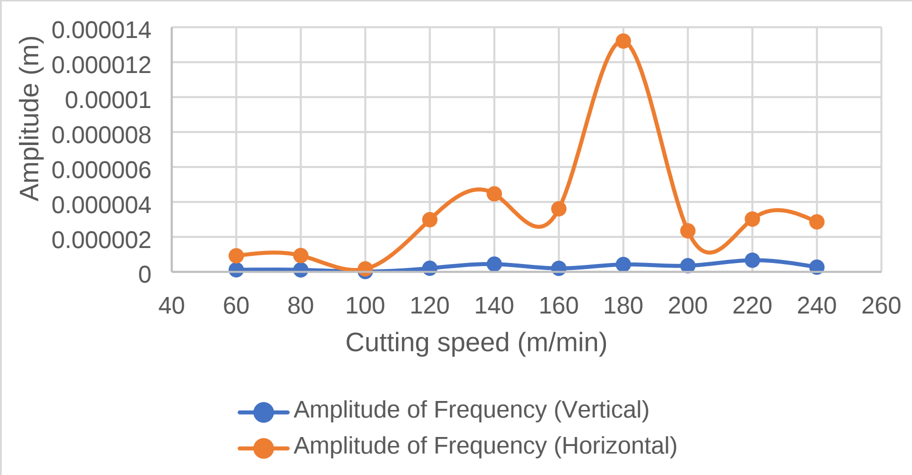


Figure 15.4 Amplitude of vibration vs cutting speed. Vertical and Horizontal directions to the workpiece (with heating the workpiece)

The below graph shows the amplitude of frequency without heating the workpiece and this graph is shown to compare the results of amplitude frequency of both heating and without heating the workpiece.

As compared to the amplitude of the workpiece with heating and without heating we can clearly study that the horizontal amplitude of frequency is less than as compared to the amplitude frequency of the workpiece without heating. The horizontal frequency (with heating the workpiece) is raised in the cut of 180m/min and as compared to the amplitude of frequency (without heating the workpiece) is raised in the cut of 220m/min as shown in the above and below graphs.

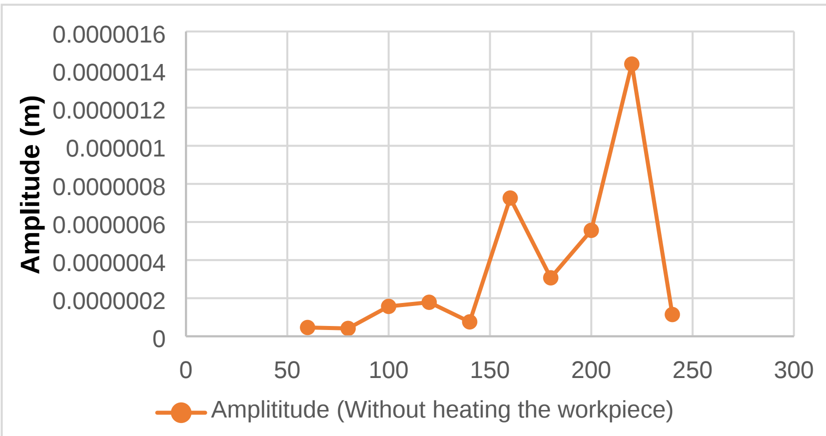


Figure 15.5 Amplitude of vibrations graph amplitude vs cutting speed without heating the workpiece kHz vs cutting speed

16. PREPARATION OF MICRO SECTION OF CHIPS

In this chapter, we cover the preparation of the micro section and in this process, there are two methods are used. First preparation of chip in the solid round cubes and the second process is about preparing the cube into fine polished to check the micro section. About the process and preparation details are explained in detail below step by step.

16.1 Preparation of solid cube

- The chip which was collected in the orthogonal turning cutting process is to be tested in the microscope to analyse the chip thickness and the hardness of the chip.
- To conduct micro section the chip is prepared into a solid cube.
- To prepare the solid cube the material used are Polyester resin and Metox-30.
- These two solutions are mixed together gently, and this solution is dropped into a small rounded PVC pipe.
- The length of the pipe is around 3-4cm. One side of the pipe is covered with the white transparent tape (for clear observation).

Figure 16.1 PVC pipe with the length of 3-4cm and open in one side of the pipe

- Collected chips from the cutting process are dropped in the pipe and after that step, the mixed solution of Polyester resin and metox-30 is poured in this pipe gently.

- After this process, the cubes are left in the open place to change into a liquid to the solid stage.
- This process takes time around one day.
- The solution will be turned into hard solid cube and after it turns solid stage it is removed from the PVC pipe.

- While removing the solid cube from the PVC pipe the cubes are removed gently because to avoid the breakage of the cube.
- After this process, these cubes are moved to the process of grinding and polishing.

- LAM PLAN (SMART LAM 2.0) grinding machine is used to process the grinding and polishing process.

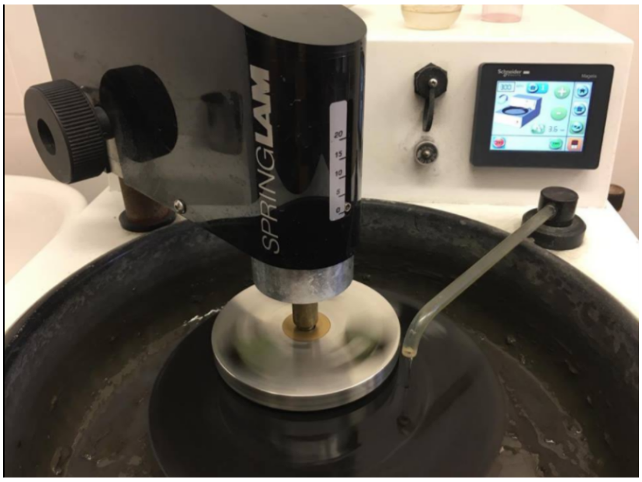


Figure 16.2 LAM PLAN (SMART LAM 2.0) grinding machine and this figure shows the process is taking place at the speed of 300rpm

- In the grinding process, the roof of the cubes is grinded.
- The rotation speed of the grinding process is 300rpm and the time period of the grinding process is 5min.
- Grinding process is done with two different emery papers. The first grinding is done with using P600 AUTO-PAPER (emery paper) and the second grinding process is done with P2000 AUTO-PAPER (emery paper).

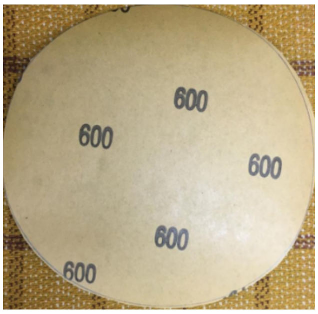


Figure 16.3 P600 AUTO-PAPER (emery paper) for the 1st operation of the grinding process

Figure 16.4 P2000 AUTO-PAPER (emery paper) for the 2nd grinding process

- Each operation takes place 5min and the total time taken to the grinding process is 10min
- After the grinding process, the cubes are polished.
- For polishing the cubes BIODIAMANT liquid is used and this liquid helps to remove the roughness of the surface and changes into a fine shining stage. The finishing of the surface will be shining and clearly visible of chips are in the cubes.
- This process is called as DIAMANT POLISHING.
- This polishing is done on the machine called LAM PLAN (SMART LAM 2.0) machine.
- The rpm of this process is raised from 20rpm to 300rpm because the DIAMANT solution which is applied to the polishing plate will take to approach the cube.
- Attention 20rpm is to be maintained for 2min and after the solution approached properly to the polishing plate then the rpm is increased to 300rpm.
- Total time taken for the polishing is 10min.
- Observation in this process is to increase the water pressure slowly to the high to get the perfect finish.
- Last 2min of the polishing process the water pressure is increased.
- After this process, the cubes are washed and cleaned with the dry tissue paper.
- And apply HNO-3٪
- On the top of the roof which they were polished to make a clear view of the micro section.
- After all this process the view of the cubes is shown in the below.

Figure 16.2 Cubes after polishing. In this figure, the chips are clearly visible after DIAMANT polishing

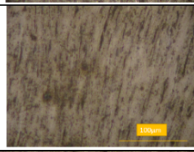
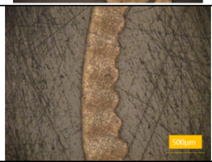
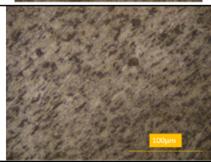
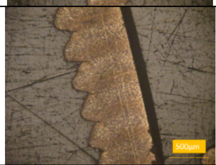
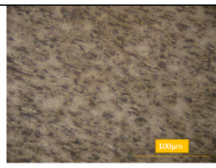
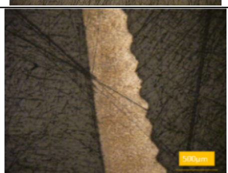
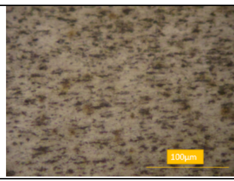
17. CHIP MICRO SECTION

In this chapter, we cover the chip micro section and its process. The process of chip micro section is clearly in detailed explained in this chapter. The observation of the chip and the thickness of the chip is explained in detailed.

The machine used for the micro section is ZEISS AXIO IMAGER2. The micro section is done with three different lances. First, lance is which is used for the micro section is 5×0.13HD. The second micro section is done on the lance 20×0.4HD. The third operation is done in the lance 50×0.7HD. The total operation is done in three HD lances to investigate for the better results. In the first lance, we found have to the observation of the chip from the long distance of the view. By coming to the second lance the chip visibility is clear to measure and in the third lance the chip thickness is clear in view and its visibility is digital to take the measurements.

Figure 17.1 ZEISS AXIO IMAGER2.This figure shows the machine used for the micro [19]

Table 17.1 Chip micro section with heating the workpiece

EXP No	Feed rate (mm/ rev)	Depth of cut (mm)	Cutting speed (m/min)	calculated Spindle speed (rpm)	Microsection Pictures Lance 5×0.13HD	Microsection Pictures Lance 20×0.4HD	Microsection Pictures Lance 50×0.7HD
1	0.1	1	60	477.47			
2	0.1	1	80	636.63			
3	0.1	1	100	795.79			
4	0.1	1	120	954.95			
5	0.1	1	140	1114.11			
6	0.1	1	160	1273.27			
7	0.1	1	180	1432.43			
8	0.1	1	200	1591.59			
9	0.1	1	220	1750.75			

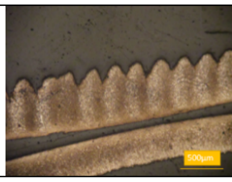
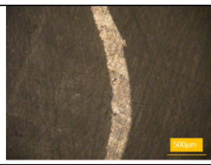
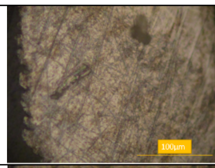
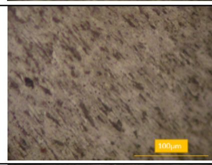
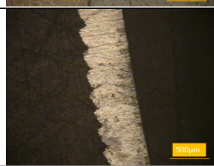
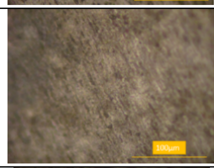
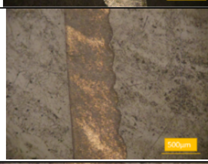
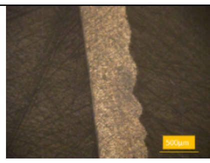
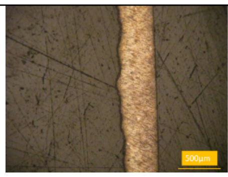
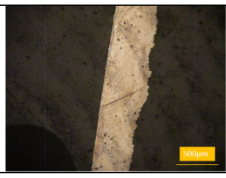
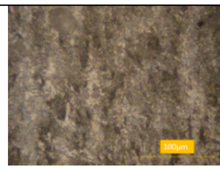
10	0.1	1	240	1909.91			

Table 17.2 Chip Microsection of the workpiece without heating the workpiece

EXP No	**Feed rate (mm/ rev)**	**Depth of cut (mm)**	**Cutting speed (m/min)**	**calculated Spindle speed (rpm)**	**Micro section Pictures Lance 5×0.13HD**	**Micro section Pictures Lance 20×0.4HD**	**Micro section Pictures Lance 50×0.7HD**
1	0.1	1	60	477.47			
2	0.1	1	80	636.63			
3	0.1	1	100	795.79			
4	0.1	1	120	954.95			
5	0.1	1	140	1114.11			
6	0.1	1	160	1273.27			
7	0.1	1	180	1432.43			
8	0.1	1	200	1591.59			
9	0.1	1	220	1750.75			

10	0.1	1	240	1909.91			

18. CHIP HARDNESS TEST RESULTS AND CALCULATIONS

This test is conducted in the machine name called Rockwell and Brinell Hardness Tester Verzus 710 Series by Innovatest.

Figure 18.1 Chip hardness test machine (710 Series by Innovatest) [20]

In the test of the chip hardness, the main force is applied to the chip is starts from 0.0kgf to 10.0kgf in this experimentation.

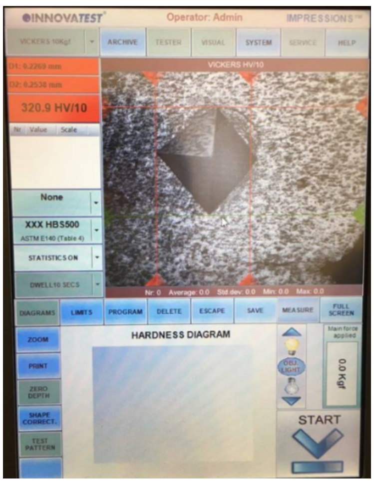


Figure 18.2 Measuring method of the chip hardness test

The measurement of the chip thickness is measured as shown in the figure 18.2. The mark on the chip is seen as pyramid in shape. That shows the test point on the chip. The chip hardness test is tested in 5 different places on the chip, to calculate the average chip hardness value.

Table 18.1 Chip hardness test results with heating the workpiece

EXP No	Feed rate (mm/ rev)	Depth of cut (mm)	Cutting speed (m/ min)	Spindle speed calculation (rpm)	Chip hard ness Test 1	Chip Hard Ness Test 2	Chip hard Ness Test 3	Chip Hard Ness Test 4	Chip Hard Ness Test5	Chip hardness test average value HV/10
1	0.1	1	60	477.47	262.2	280.6	313.4	189.8	350.4	279.3
2	0.1	1	80	636.63	298.8	373.7	305.3	345.7	325.3	329.8
3	0.1	1	100	795.79	242.7	286.1	234.4	219.7	308.7	258.3
4	0.1	1	120	954.95	304.5	286.4	304.9	279.0	286.3	292.2
5	0.1	1	140	1114.11	317.4	364.3	371.6	368.7	361.0	356.6
6	0.1	1	160	1273.27	307.8	342.1	346.7	314.1	329.7	328.1
7	0.1	1	180	1432.43	345.6	355.7	347.2	344.0	323.8	343.2
8	0.1	1	200	1591.59	309.5	324.5	333.3	333.9	353.1	330.9
9	0.1	1	220	1750.75	267.1	266.0	342.6	329.0	350.9	311.1
10	0.1	1	240	1909.91	157.5	198.5	194.6	174.2	179.3	180.8

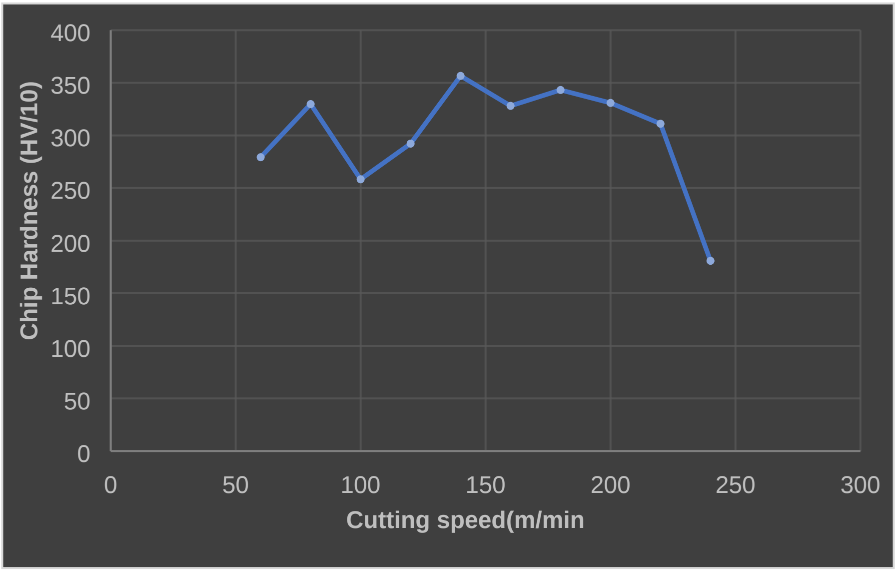


Figure 18.3 Chip hardness graph (with heating the workpiece)

Table 18. 2 Chip hardness test results without heating the workpiece

EXP No	Feed rate (mm/ rev)	Depth of cut (mm)	Cutting speed (m/ min)	Spindle speed calculation (rpm)	Chip hard ness Test 1	Chip Hard Ness Test 2	Chip hard Ness Test 3	Chip Hard Ness Test 4	Chip Hard Ness Test 5	Chip hardness test average value HV/10
1	0.1	1	60	477.47	218.9	265.3	189.6	232.2	165.7	214.3
2	0.1	1	80	636.63	223.9	287.9	249.1	183.9	302.5	249.4
3	0.1	1	100	795.79	323.3	359.8	340.9	334.5	335.8	338.9
4	0.1	1	120	954.95	326.3	399.4	375.0	360.2	391.5	370.5
5	0.1	1	140	1114.11	314.9	325.1	331.9	332.4	351.7	331.2
6	0.1	1	160	1273.27	234.7	325.8	332.9	301.0	269.4	292.7
7	0.1	1	180	1432.43	350.4	322.3	347.9	377.9	340.5	347.8
8	0.1	1	200	1591.59	348.4	285.1	266.0	338.6	303.8	308.4
9	0.1	1	220	1750.75	232.9	294.1	291.7	294.7	295.8	281.8
10	0.1	1	240	1909.91	217.7	353.5	328.4	348.3	423.6	334.3

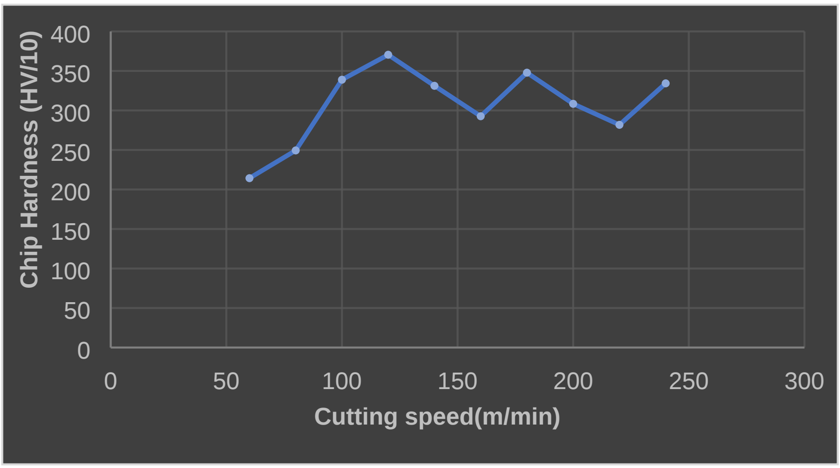


Figure 18.4 Chip hardness graph (without heating the workpiece)

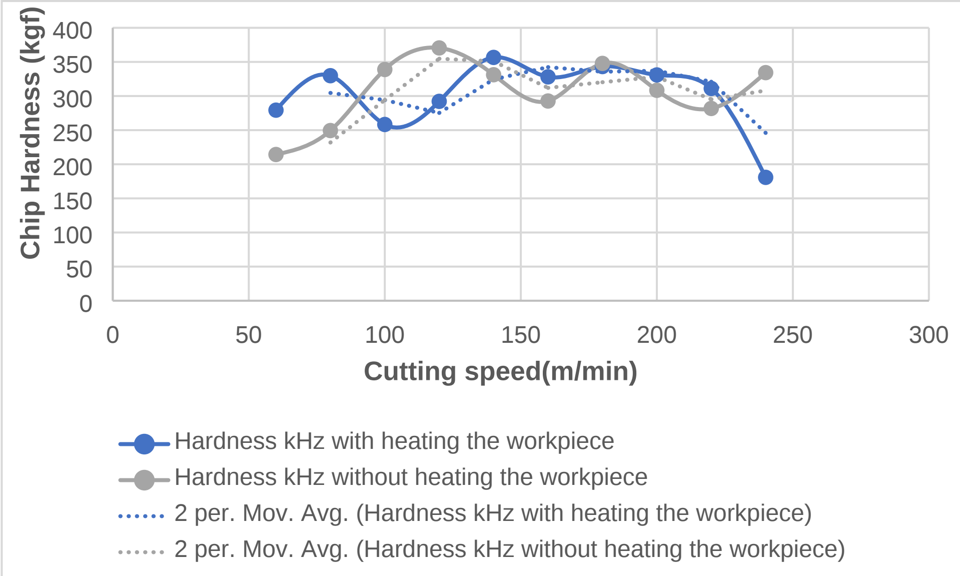


Figure 18.5 Chip hardness comparison (kgf) between the workpiece with heating and without heating

19. CHIP SEGMENTATION RESULTS

In this chapter, we are calculating the chip segmentation and their results. The measurements are taken as shown in the below figure 19.1. The measurements are taken in three different places on the chip to get average value of hip segmentation.

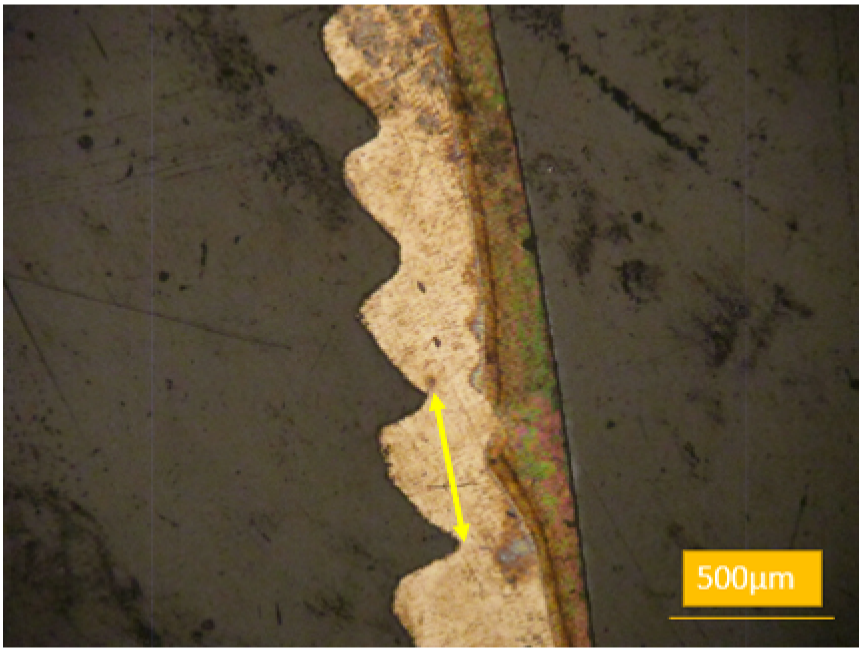


Figure 19.1 Chip segmentation measurement picture

Table 19.1 Chip segmentation measurements (Lance 5/0.13HD) with heating the workpiece*

EXP No	Feed rate (mm/rev)	Depth of cut (mm)	Cutting speed(m/min)	Cutting speed (m/sec)	Spindle speed calculation (rpm)	Measurement of chip segment 1 (number of scale bars)	Measurement of chip segment 2 (number of scale bars)	Measurement of chip segment 3 (number of scale bars)	Measurement of chip segment average (number of scale bars)	Calculated the width of chip segment (µm)
1	0.1	1	60	1	477.47	11	12	12	11.66	110.6
2	0.1	1	80	1.33	636.63	10	11	10	10.33	100.3
3	0.1	1	100	1.66	795.79	11	11	12	11.33	110.3
4	0.1	1	120	2	954.95	13	14	13	13.33	130.3
5	0.1	1	140	2.33	1114.11	15	16	15	15.33	150.3
6	0.1	1	160	2.66	1273.27	15	14	15	14.66	140.6
7	0.1	1	180	3	1432.43	10	11	11	10.66	100.6
8	0.1	1	200	3.33	1591.59	10	12	13	11.66	110.6
9	0.1	1	220	3.66	1750.75	12	11	10	11	110
10	0.1	1	240	4	1909.91	10	11	9	10	100

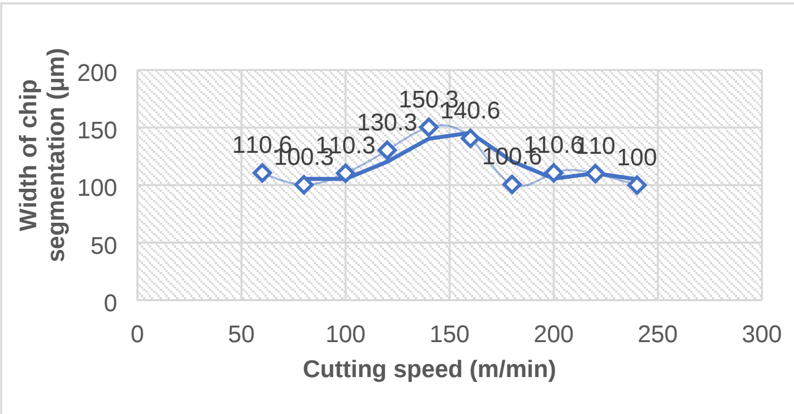


Figure 19.2 Calculated chip segmentation µm graph (with heating the workpiece)

Figure 19.2 graph shows the chip segmentation width is between 160µm to 100 µm. The width of the chip segment is constant between the 160μm to 100 μm.

Table 19.2 Chip segmentation measurements (Lance 5/0.13HD) without heating the workpiece*

EXP No	Feed rate (mm/rev)	Depth of cut (mm)	Cutting speed (m/min)	Cutting speed (m/sec)	Spindle speed calculation (rpm)	Measurement of chip segment 1 (number of scale bars)	Measurement of chip segment 2 (number of scale bars)	Measurement of chip segment 3 (number of scale bars)	Measurement of chip segment average (number of scale bars)	Calculate the width of chip segment (μm)
1	0.1	1	60	1	477.47	6	5	5	5.33	50.3
2	0.1	1	80	1.33	636.63	6	7	6	6.33	60.3
3	0.1	1	100	1.66	795.79	12	13	13	12.66	120.6
4	0.1	1	120	2	954.95	14	15	15	14.66	140.6
5	0.1	1	140	2.33	1114.11	9	8	8	8.33	80.3
6	0.1	1	160	2.66	1273.27	15	16	14	15	150
7	0.1	1	180	3	1432.43	16	17	17	16.66	160.6
8	0.1	1	200	3.33	1591.59	17	16	16	16.33	160.3
9	0.1	1	220	3.66	1750.75	13	12	14	13	130
10	0.1	1	240	4	1909.91	10	11	11	10.66	100.6

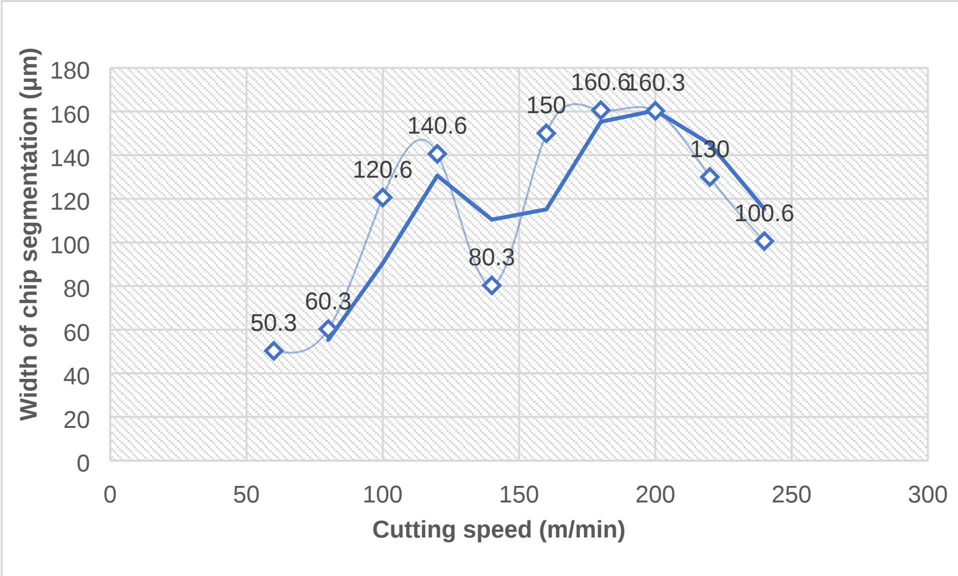


Figure 19.3 Calculated chip segmentation (µm) graph (without heating the workpiece)

As compared to the wave of the chip segmentation of the workpiece with heating the workpiece and without heating the workpiece the constant of the wave motion is not similar, this shows the benefits and differences between the steel S355 is showing better results as compared to the material without heating.

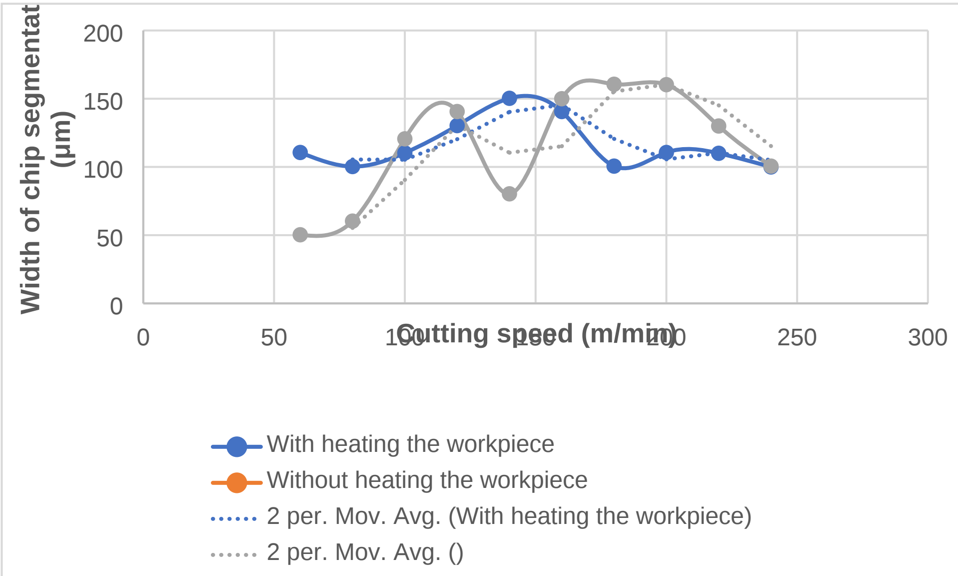


Figure 19.4 Comparison graph of chip segmentation µm average values between heated workpiece and without heating the workpiece

20. CONCLUSION ABOUT THE EXPERIMENTATION

- As per the main goal line is performing the longitudinal orthogonal turning process for the metal (STEEL S355JRG3) to cut the workpiece with ten different speeds and in the cutting process the result we can know that the chips are properly formed from the cut of 120m/min.
- After heating the material at 840 degrees in heating temperature, the stress is removed from the workpiece and after removing the stress we found a lot of variations in the result comparison of vibration frequency is better than workpiece without heating.
- From the carried experiment, heating process of the sample chip metals is performed and the materials which are not heated are taken in to account from Rohan Erava in batch 2017 June master thesis in industrial engineering and management for the comparison of results, where the chip segmentation, microsection, diamant polishing are carried out separately.
- After comparing the chip hardness material steel S355 with heated and without heating, we conclude that the material is strong as compared to the material without heating. The results of average value chip hardness is better for the workpiece with heating.
- There are total 10 cuts performed on the workpiece and the space between the tool and the surface is left to avoid the damage of the workpiece. Horizontal and vertical bump tests are performed in the experimental work and the comparisons are documented in graph and included in the report. The final generated results are useful for the automatic cutting software and used for investigating the results.

Hence, the experiment is conducted mainly to the improvements for the future experimentations for the scientists. And also, the results will be considered to the automatic monitoring software's (CAD, FEM…). In that orthogonal turning process is the one of the key role of it. During the experimentation myself have gain true practical experience working with the professor Virginija Gyliene. This experience will be helpful for my future goals.

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