

MEASUREMENT OF LUBRICANT OIL FILM  
THICKNESS UNDER MINIMUM QUANTITY  
LUBRICATION MILLING PROCESS

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MASTER OF SCIENCE

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We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science



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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements  
for the award of the degree of  
Master of Science

Faculty of Manufacturing & Mechatronic Engineering Technology

UNIVERSITI MALAYSIA PAHANG

AUGUST 2022

## ACKNOWLEDGEMENTS

First and foremost, I would like to vent out my gratefulness towards Allah SWT for the rezq and opportunities for me to further study in Masters and finally complete this research although it is tough and quite challenging. I am truly grateful with His blessings Alhamdulillah.

Throughout my study to finish the research, I have received many motivations and supports for being parts in my journey. I would like to express my highest appreciation to my beloved supervisor, Dr. Nurrina Binti Rosli for being the best superior that I ever had. I am beyond my words to thank her for always guiding and assisting me to complete this research. She always continuously put the efforts to teach me even it is very fundamentals, voice out her opinions, recommendations and suggestions to put on this project and dissertation. I am truly thankful for the precious time sacrificed by her as well as the motivational words being expressed by her to keep me pushing forward and completing this challenging journey especially when the experiment is conducted during the outbreak pandemic Covid-19.

Other than that, my sincerely thanks goes to my co-supervisor, Dr. Amiril Sahab Bin Abdul Sani for supervise me to complete the research. I am very grateful for his time in assisting me doing the experimental work in the lab. His expertise in the machining knowledge has been very helpful to me. I am also thankful for the opinions and tips I gained from him in order to improve my work.

Furthermore, I would like to express my sincere appreciation to the staffs of Faculty of Manufacturing and Mechatronics Engineering Technology, Universiti Malaysia Pahang for allowing me to utilize the faculty labs and properties in order to carry out my research successfully. Not to be forgotten, my deepest thankful to my research colleague, Nur Izzati Khoirunnisa Binti Ismail for her greatness guidance, help and cooperations during this study.

Last but not least, I would like to express my highest appreciation to the biggest support system in my life which are my family. They have been very supportive and always understand with my commitment on this project. Besides, they always encouraged and keep me motivated whenever I feel lost or down while doing this study. Without these support systems, I am nowhere to complete my journey. This precious dissertation is a proof that all those pressure, tears, sweats and blood have been finally paid off. Alhamdulillah thank you to those people who took a part with me in completing this journey.

## ABSTRAK

Keperluan cecair pelincir banyaj digunakan dalam bidang pembuatan terutama dalam bidang pemesinan disebabkan oleh hasil yang bermanfaat dengan kata lain, keupayaan untuk melincirkan proses pemotongan, bahan yang dapat mengurangkan suhu pemotongan dan juga untuk mengurangkan cip dari terkumpul di atas zon pemotongan. Tambahan pula, pendekatan pelinciran ini juga telah banyak digunakan untuk meningkatkan prestasi pemesinan seperti mengurangkan kekasaran permukaan kerja dan meningkatkan kadar hayat alat pemotong. Secara tradisional, minyak pelinci telah digunakan sebagai kaedah pelinciran semasa proses pemesinan. Bagaimanapun, oleh kerana kepeluan berlebihan yang dibekalkan oleh kaedah tersebut telah menyebabkan risiko bahaya kesihatan, kesan peningkatan kepada kos pembuatan dan kerosakan alam sekitar global. Untuk mengatasi permasalahan ini, satu improvisasi kaedah pelinciran yang dikenali sebagai Pelinciran Kuantiti Minimum (MQL) telah dilaksanakan. MQL ialah kaedah pelinciran alternatif untuk proses pemotongan yang menggunakan campuran udara termampat dengan pengurangan penggunaan minyak pelincir. Campuran tekanan udara dan minyak pelincir yang dilakukan oleh MQL dalam aplikasi pemesinan telah terbukti menjadi alternatif yang lebih baik untuk kaedah pelinciran telah terbukti dapat mengurangkan penggeseran yang berlaku di zon pemotong, dapat mengurangkan risiko bahaya pekerja serta dapat mengurangkan kos pembuatan. Walaubagaimanapun, oleh kerana penggunaan minyak adalah sangat sedikit, keberkesanan MQL dalam proses pelinciran adalah sangat bergantung kepada keupayaan minyak untuk menembusi zon pemotongan yang kecil. Ini boleh dicapai dengan mengkaji mekanisma minyak semasa proses pelinciran zon pemotongan, di mana kajian ini masih terhad kerana kebanyakan kajian terdahulu hanya menumpukan kepada keberkesanan pemesinan atau pelinciran tanpa menunjukkan secara terperinci bagaimana tingkah laku pelincir memberi kesan kepada keupayaan pemotongan. Kajian sifat asas minyak pelincir semasa operasi pemesinan adalah sangat penting tetapi kajian ini masih terhad disebabkan oleh kerumitan penyediaan penyelidikan semasa operasi dijalankan serta aliran minyak semulajadi yang tidak boleh diganggu mungkin menyebabkan kebatasan untuk melaksanakan kajian ini. Untuk mengatasi isu ini, satu kerja penyelidikan dengan tujuan untuk menganalisis tingkah laku minyak pelincir dalam aplikasi MQL menggunakan kaedah yang dikenali sebagai pendarfluor teraruh oleh laser (LIF) telah dijalankan. Kajian ini dilaksanakan untuk mengkaji ketebalan minyak semasa proses pemesinan MQL dengan perubahan kelikatan minyak pelincir dan kelajuan pemotongan mesin. Empat jenis minyak iaitu minyak campuran ester, bunga matahari, minyak zaitun dan minyak semulajadi penaga laut dengan nilai kelikatan,  $\eta$  dari 11.075, 35.260, 35.260 dan 63.223 mPa.s pada suhu 40°C yang telah dilarutkan pewarna neon pendafLOUR, Coumarin 153 untuk mendapatkan minyak pelincir. Dalam masa yang sama, kelajuan pemotongan mesin  $V_c$  dari 14.514, 19.514, 24.514 dan 29.514 m/minit telah diselaraskan untuk melihat purata ketebalan filem minyak pelincir sepanjang jalur pemotongan. Prosedur kalibrasi telah dijalankan sebelum menjalankan operasi pemesinan untuk mencapai hubungan linear antara cahaya dipancarkan dan ketebalan filem minyak pelincir. Dari kajian tersebut, didapati bahawa purata ketebalan filem minyak pelincir meningkat apabila kelikatan minyak menurun. Fenomena ini dijelaskan kerana partikel minyak berlikt rendah yang lebih kecil menjadikannya lebih mudah untuk menembusi dari muncung MQL dan meningkatkan

daya sebaran minyak pelincir ke jalur pemesinan. Sementara itu, diperhatikan dari pemenuan bahawa ketika kelajuan pemotongan meningkat, purata ketebalan minyak pelincir juga meningkat. Peningkatan kelajuan pemotongan telah meningkatkan penggeseran antara alat pemotong dan benda kerja yang akhirnya memberikan pelinciran yang baik. Untuk menjelaskan hubungan antara tingkah laku minyak pelincir MQL dan prestasi proses pemesinan, pengukuran kekasaran permukaan benda kerja telah dianalisis. Hasil menunjukkan nilai purata kekasaran permukaan adalah menurun dengan peningkatan kelajuan pemotongan dalam proses pemesinan. Ini dapat disokong dengan hasil yang mengesahkan ketebalan filem minyak pelincir di bawah keadaan yang sama, menunjukkan bahawa lebih banyak pelincir yang dibekalkan pada bahan kerja, menghasilkan kelicinan permukaan bahan kerja yang lebih baik. Walaubagaimanapun, purata kekasaran permukaan di analisis dan menunjukkan graf peningkatan dengan penurunan kelikatan minyak,  $\eta$ . Ini sebaliknya dengan apa yang dicapai pada ketebalan filem minyak pelincir. Walaupun zarah dalam minyak likat rendah lebih mudah untuk menembusi zon pemotongan dan memenuhi laluan pemotongan, minyak tersebut tidak dapat menghalang serpihan besi pemotongan dan dengan itu menyebabkan bahan kerja menjadi kasar.

## ABSTRACT

Cutting fluid has been extensively used in the manufacturing fields, especially in the machining areas due to its beneficial outcomes, i.e. the capability to lubricate the cutting process, reduce the cutting temperature as well as to slide away the chips from agglomerated onto the cutting zone. Furthermore, this lubrication approach also has been widely utilised to improve the machining performance such as to minimise the surface roughness of workpiece and enhance the rate of tool life. Traditionally, flood coolant has been used as the lubrication method during the machining process. However, excessive amount of oil being supplied through flood cooling method has caused occupational health hazards, manufacturing cost rising and global environmental damage. To overcome these drawbacks, an improvisation lubrication method known as Minimum Quantity Lubrication (MQL) has been implemented. MQL is an alternative lubrication method for near-dry cutting process using a mixture of compressed air and less amount of lubricant oil. MQL in the machining application proven to minimize friction at the cutting zone, reduce the occupational health hazards as well as lower the manufacturing cost. However, since the usage of oil is very little, the goodness of MQL in the lubrication process highly depends on the ability of the oil to penetrate the narrow cutting. This can be obtained by examining the mechanism of oil while lubricating the cutting zone, where this study is still scarce because most of the past studies were merely focus on the effects of machining or lubrication parameter without showing how the lubricant behaviour related to the cutting performance. The study of fundamental nature of lubricant oil during machining operation is highly important to be observed but nevertheless it is still deficient due to the complexity of experimental setup during the ongoing operation as well as the natural flow of oil cannot be disrupted have caused the limitations to accomplish the study. To cater this issue, an experimental work with the objective to analyse the lubricant oil behaviour in MQL milling process by using a non-intrusive method known as laser induced fluorescence (LIF) was carried out. The study was conducted to investigate the thickness of oil during the MQL milling process under various oil viscosity and cutting speed effects. Four different types of oil, i.e. mixed esters oil, sunflower oil, olive oil, and calophyllum inophyllum oil with dynamic viscosity values at 40°C of 11.075, 35.260, 35.260 and 63.223 mPa.s , respectively were dissolved into a fluorescent dye, i.e. Coumarin 153 as the working fluid. Concurrently, machining cutting speed of 14.514, 19.514, 24.514, and 29.514 m/min were set to observe the average lubricant oil film thickness along the milling path. Calibration procedure was carried out before conducting the milling operation to achieve a linear relation between emitted light intensity and the lubricant oil film thickness. From the study, it was found out that the average lubricant oil film thickness increased as the oil viscosity decreased. This phenomenon is explained due to the smaller particles of low viscous oil that made it easier to penetrate from MQL nozzle which increased the spreadability of lubricant oil onto the milled path. Meanwhile, it was observed that as the cutting speed increased, the average lubricant oil film thickness also increased. The increment in cutting speed has raised the friction between cutting tool and workpiece which eventually led to providing a good lubrication effects. To clarify the relation between MQL lubricant oil behaviour and the performance of milling process, the measurement of surface roughness of workpiece was analysed. The results showed that the average surface roughness decreases with the increasing of machining cutting speed. This is supported by the findings that confirmed the results of lubricant oil film thickness under the same conditions, indicating that more lubricant supplied on the workpiece gives better surface finishing of workpiece.



However, it was found that the average surface roughness increased with the decreasing of dynamic viscosity,  $\eta$ . This is contradict with what was found in lubricant oil film thickness. Although the small particles of low viscous oil was easier to penetrate the cutting zone and spread along the milled path, the oil unable to repel the flying chips and thus made the workpiece rough. Finally, the findings from this research study was able to fill the gap of knowledge in clarifying the oil film thickness behaviour on the machining performance.

## TABLE OF CONTENT

<b>DECLARATION</b>	
<b>TITLE PAGE</b>	
<b>ACKNOWLEDGEMENTS</b>	<b>ii</b>
<b>ABSTRAK</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>v</b>
<b>TABLE OF CONTENT</b>	<b>vii</b>
<b>LIST OF TABLES</b>	<b>xi</b>
<b>LIST OF FIGURES</b>	<b>xii</b>
<b>LIST OF SYMBOLS</b>	<b>xvii</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xviii</b>
<b>CHAPTER 1 INTRODUCTION</b>	<b>1</b>
1.1 General Background	1
1.2 Problem Statement	3
1.3 Research Objectives	4
1.4 Research Scope	4
1.5 Thesis Layout	5
<b>CHAPTER 2 LITERATURE REVIEW</b>	<b>6</b>
2.1 Introduction	6
2.2 Minimum Quantity Lubrication	6
2.2.1 Minimum Quantity Lubrication in Milling	9
2.3 Effects of Oil Viscosity	14

2.4	Effects of Cutting Speed	21
2.5	Laser-Induced Fluorescence	27
2.6	Summary	35
<b>CHAPTER 3 METHODOLOGY</b>		<b>37</b>
3.1	Introduction	37
3.2	Apparatus and Material	37
	3.2.1 MQL Milling Operation	38
	3.2.1.1 Milling machine	38
	3.2.1.2 MQL generator	39
	3.2.1.3. Aluminium alloy workpiece	40
	3.2.1.4 Milling cutter	41
	3.2.1.5 Working oil	42
	3.2.2 Measurement of Lubricant Oil Film Thickness	44
	3.2.2.2 Diode laser	45
	3.2.2.3 Green filter	46
	3.2.2.4 Optical flat lens	47
	3.2.2.5 Neutral density (NDX) filter	47
	3.2.2.6 Video camera	48
	3.2.3 Measurement of Surface Roughness	49
	3.2.3.1 Surface roughness tester	49
3.3	Calibration Procedure	50
	3.3.1 Measurement Lubricant Oil Film Thickness for Calibration by Image Analysis Processing	53

3.4	Experimental Conditions and Parameters	56
3.5	Experimental Methodology	58
3.5.1	Research Flowchart	58
3.5.2	Methodology of MQL Milling Process	59
3.5.3	Procedure of Measuring Surface Roughness After MQL Milling Process	62
3.6	Summary	63
<b>CHAPTER 4 RESULTS AND DISCUSSION</b>		<b>64</b>
4.1	Introduction	64
4.2	Effects of Cutting Speed on Lubricant Oil Film Thickness Fluctuation Under Different Lubricant Oil Viscosity After Milling Process Completed	64
4.3	Effects of Cutting Speed on Lubricant Oil Film Thickness Fluctuation Under Different Lubricant Oil Viscosity During Milling Process	71
4.4	Frequency Data of Average Lubricant Oil Film Thickness for Different Lubricant Oil Viscosity	79
4.4.1	Frequency data of average lubricant oil film thickness, $\delta$ on 30 – 44 mm from machining starting point, $x$	79
4.4.2	Frequency data of average lubricant oil film thickness, $\delta$ on 45 – 55 mm from machining starting point, $x$	86
4.4.3	Frequency data of average lubricant oil film thickness, $\delta$ on 50 – 70 mm from machining starting point, $x$	92
4.5	Average Surface Roughness of Workpiece After MQL Process	97
<b>CHAPTER 5 CONCLUSION</b>		<b>105</b>
5.1	Introduction	105
5.2	Conclusion	105
<b>REFERENCES</b>		<b>108</b>

## LIST OF TABLES

Table 3.1	Specifications of MAKINO KE55 CNC Vertical milling machine	39
Table 3.2	Specifications of Kuroda Ecosaver KEP-WR MQL generator	40
Table 3.3	Chemical composition of Aluminium Alloy 6061	40
Table 3.4	Physical and mechanical properties of Al6061	41
Table 3.5	Properties of uncoated carbide end mill	42
Table 3.6	Properties of working oil	43
Table 3.7	Properties of Coumarin 153	44
Table 3.8	Properties of diode laser	45
Table 3.9	Specifications of green filter	46
Table 3.10	Specifications of optical flat lens	47
Table 3.11	Properties of NDX filter	48
Table 3.12	Specifications of Canon EOS 90D	49
Table 3.13	Specifications of SURFCOM TOUCH 50 surface roughness machine	50
Table 3.14	Linear equation of calibration	55
Table 3.15	Experimental conditions and parameters	56

## LIST OF FIGURES

Figure 2.1	The concept of ejector nozzle and conventional nozzle for external mechanism of MQL	7
Figure 2.2	The principle of single channel and dual channel of internal MQL mechanism	8
Figure 2.3	Surface roughness of Inconel 718 alloy between MQL machining condition and traditional flood machining condition	10
Figure 2.4	Surface roughness of mild steel between MQL and flood cooling environment at cutting speed of 225 rpm	11
Figure 2.5	Surface roughness of AISI 420 martensitic stainless steel in different cutting condition	12
Figure 2.6	Average surface roughness of Inconel 718 alloy in MWCNTs and Al <sub>2</sub> O <sub>3</sub> nano-MQL condition	13
Figure 2.7	Surface finish of AISI 304 stainless steel with different cutting condition	14
Figure 2.8	Surface roughness of X100CrMoVs steel alloy in different cutting environments	17
Figure 2.9	Cutting force of machining 1045 mild steel disk against different oil conditions with variation cutting speed	18
Figure 2.10	Surface roughness of AISI 1045 under various vegetable oils	19
Figure 2.11	Average surface roughness of AISI 4340 steel under different fluid conditions	21
Figure 2.12	Surface roughness of Aluminium 6061 T6 under different cutting speed with various machining conditions	22
Figure 2.13	Machining outcomes of milling Inconel 718 under various cutting speed	23
Figure 2.14	The results of (a) cutting force and (b) surface roughness in different machining conditions	25
Figure 2.15	The mean surface roughness of workpiece in different machining conditions	26
Figure 2.16	Schematic diagram of experimental setup for LIF technology	28
Figure 2.17	The emitted light of Rhodamine-B solution which excited by 532 nm laser beam pointer	28
Figure 2.18	Sample processed image of the liquid film thickness in gas-liquid Taylor flow	29
Figure 2.19	Schematic diagram of (a) experimental setup for LIF application and (b) visualization box for liquid film measurement	30
Figure 2.20	The arrangement set up in test area of PLIF for liquid film thickness measurement	31

Figure 2.21	The diagram of (a) illustration acute PLIF application and (b) experimental setup for measurement of liquid film thickness in circular tubes with small curvatures	32
Figure 2.22	Experimental setup of LIF application and Raman imaging process for water film thickness	33
Figure 2.23	Experimental setup of LIF application for holography imaging fluorescent	34
Figure 2.24	Schematic diagram to measure the thickness of spray coating film	35
Figure 3.1	MAKINO KE55 CNC Vertical milling machine	38
Figure 3.2	Kuroda Ecosaver KEP-WR MQL generator	39
Figure 3.3	Aluminium Alloy workpiece	41
Figure 3.4	Uncoated carbide end mill	42
Figure 3.5	Mixed esters oil, sunflower oil, olive oil, calophyllum inophyllum oil <sup>43</sup>	
Figure 3.6	(a) Physical appearance of Coumarin 153 and (b) Absorption spectrum of Coumarin 153 (S. Li, Yu, & Lu, 2016)	44
Figure 3.7	(a) Diode laser module 405 nm and (b) Blue violet module crosshair	45
Figure 3.8	Green filter	46
Figure 3.9	Optical flat lens	47
Figure 3.10	NDX filter (ND 400)	48
Figure 3.11	Canon EOS 90D	49
Figure 3.12	SURFCOM TOUCH 50 surface roughness machine	50
Figure 3.13	Schematic view of calibration procedure	51
Figure 3.14	Image of calibration (a) without test liquid injected and (b) with test liquid injected to fill the spaces	52
Figure 3.15	Sample image of calibration when test liquid is injected in a dark environment	52
Figure 3.16	Video to jpg converter software	53
Figure 3.17	Sample grey scaled image to obtain the intensity plot graph	54
Figure 3.18	ImageJ software application	54
Figure 3.19	(a) Graph obtained from ImageJ and (b) Lists of values from the graph	54
Figure 3.20	Relationship between emitted light intensity and lubricant oil film thickness of (a) mixed esters oil (b) sunflower oil (c) olive oil and (d) calophyllum inophyllum oil	55
Figure 3.21	Research methodology flowchart	58
Figure 3.22	Illustration view of experimental setup for MQL milling process and LIF operation	59

Figure 3.23	Actual view of experimental setup for MQL milling process and LIF	59
Figure 3.24	Illustration view of MQL nozzle position during the milling process	60
Figure 3.25	Actual view of MQL nozzle position during the milling process	61
Figure 3.26	Black tent used to conduct experiment in dark environment	61
Figure 3.27	Milled workpiece for surface roughness measurement	62
Figure 3.28	Actual method of measuring surface roughness of the workpiece	62
Figure 3.29	Overview of the location for surface roughness measurement after milling process	63
Figure 4.1	Average lubricant oil film thickness fluctuation, $\delta$ against distance from milling starting point, $x$ for oil viscosity of (a) 11.075 mPa.s (b) 30.224 mPa.s (c) 35.260 mPa.s and (d) 63.223 mPa.s after MQL milling process completed	65
Figure 4.2	Average lubricant oil film thickness fluctuation, $\delta$ against distance from milling starting point, $x$ for oil viscosity of (a) 11.075 mPa.s (b) 30.224 mPa.s (c) 35.260 mPa.s and (d) 63.223 mPa.s after MQL milling process completed	75
Figure 4.3	The variation in boundary lubrication regime of machining cutting speed, $V_c$ against the lubrication oil film thickness fluctuation, $\delta$ under different lubricating oil viscosity	77
Figure 4.4	The variation in boundary lubrication regime of dynamic viscosity, $\eta$ against lubricant oil film thickness fluctuation, $\delta$ under different cutting speed	78
Figure 4.5	Histogram graph of average lubricant oil film thickness, $\delta$ on distance of 30-44 mm from machining starting point, $x$ against frequency for oil viscosity, $\eta$ 11.075 mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min	80
Figure 4.6	Histogram graph of average lubricant oil film thickness, $\delta$ on distance of 30-44 mm from machining starting point, $x$ against frequency for oil viscosity, $\eta = 30.224$ mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min	82
Figure 4.7	Histogram graph of average lubricant oil film thickness, $\delta$ on distance of 30-44 mm from machining starting point, $x$ against frequency for oil viscosity, $\eta = 35.260$ mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min	84
Figure 4.8	Histogram graph of average lubricant oil film thickness, $\delta$ on distance of 30-44 mm from machining starting point, $x$ against frequency for oil viscosity, $\eta = 63.223$ mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min	85



- Figure 4.9 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 45-55 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 11.075$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 87
- Figure 4.10 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 45-55 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 30.224$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 88
- Figure 4.11 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 45-55 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 35.260$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 90
- Figure 4.12 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 45-55 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 63.223$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 91
- Figure 4.13 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 50-70 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 11.075$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 92
- Figure 4.14 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 50-70 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 30.224$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 93
- Figure 4.15 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 50-70 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 35.260$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 95
- Figure 4.16 Histogram graph of average lubricant oil film thickness,  $\delta$  on distance of 50-70 mm from machining starting point,  $x$  against frequency for oil viscosity,  $\eta = 63.223$  mPa.s under machining cutting speed (a) 14.514 m/min (b) 19.514 m/min (c) 24.514 m/min and (d) 29.514 m/min 96
- Figure 4.17 Results of average surface roughness against distance from machining milling point,  $x$  after MQL milling process for oil viscosity (a) 11.075 mPa.s (b) 30.224 mPa.s (c) 35.260 mPa.s and (d) 63.223 mPa.s 98

Figure 4.18 The variation in boundary lubrication regime of dynamic viscosity,  $\eta$  against average surface roughness,  $Ra$  under different cutting speed

103

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