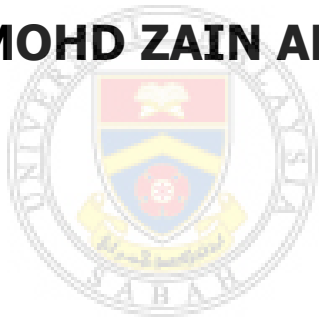


**A BLADE CUTTER DESIGN FOR AN EFFECTIVE
OIL PALM FRONDS CUTTING PROCESS**

MOHD ZAIN ABDULLAH@JOIN BIN GOROB



UMS
UNIVERSITI MALAYSIA SABAH

**FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2023**

**A BLADE CUTTER DESIGN FOR AN EFFECTIVE
OIL PALM FROND CUTTING PROCESS**

MOHD ZAIN ABDULLAH@JOIN BIN GOROB



UMS

**THESIS SUBMITTED IN FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ENGINEERING**

**FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2023**

PERPUSTAKAAN UNIVERSITI MALAYSIA SABAH



**BORANG PENGESAHAN STATUS
TESIS**

JUDUL: _____

IJAZAH: _____

SAYA: _____ **SESI PENGAJIAN:** _____
 (NAMA PENULIS DALAM HURUF BESAR)

Mengaku membenarkan tesis *(LPSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hakmilik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian, pembelajaran, penyelidikan dan pemeliharaan sahaja.
3. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat pendigitasian
5. Sila tandakan (/)

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana Penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

 TANDATANGAN PENULIS

 (TANDATANGAN PUSTAKAWAN)

Alamat tetap:

 (NAMA PENYELIA)

Tarikh: _____

Tarikh: _____

Catatan :- *Potong yang tidak berkenaan.
 *Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
 *Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM)

DECLARATION

I, Mohd Zain Abdullah@Join Bin Gorob, hereby declare that the thesis presented here is submitted to the Postgraduate Academic Council of the University Malaysia Sabah as a partial fulfillment of the requirements for the Master's Degree in Mechanical Engineering. I confirm that this thesis has not been submitted to any other university for any master's degree. I further declare that the work described in this thesis is solely my own, except for citations and summaries from duly recognise sources.

This thesis may be made available in the university library and can be photocopied, loaned, or accessed from other libraries for reference purposes.

15 December 2022

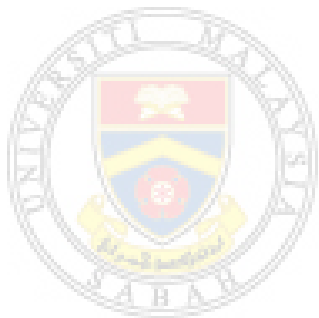
Mohd Zain Abdullah@Join Bin Gorob
MK1621035T



UMS
UNIVERSITI MALAYSIA SABAH

CERTIFICATION

NAME : **MOHD. ZAIN ABDULLAH@JOIN BIN GOROB**
MATRIC. NUM. : **MK 1621035T**
TITLE : **A BLADE CUTTER DESIGN FOR AN EFFECTIVE
OIL PALM FROND CUTTING PROCESS**
DEGREE : **MASTER OF ENGINEERING**
FIELD : **MECHANICAL ENGINEERING**
VIVA DATE : **15 DECEMBER 2022**



Certified By:

UMS
Signatures
UNIVERSITI MALAYSIA SABAH

1. **MAIN SUPERVISOR**
Dr. Kamel Bin Wan Ibrahim _____
2. **CO-SUPERVISOR**
Dr. Azlan Bin Ismail _____

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to Allah S.W.T for His blessings and guidance throughout the completion of this research. I am truly thankful for His support in enabling me to successfully accomplish this work. I am deeply grateful to my First Supervisor, Dr. Kamel Bin Wan Ibrahim, and my secondary supervisor, Dr. Azlan Bin Ismail, for their valuable supervision, guidance, and sharing their extensive knowledge in machine design. Their expertise and encouragement were instrumental in the successful completion of this research, and I am truly grateful for their support both intellectually and financially.

I would also like to extend my sincere appreciation to my beloved family, including my late father Gorob Bin Bangkong and my mother Kilong Binti Dapit, my 1st wife Misilia Binti Tobias, and 2nd wife Norazrina Lily Chen, as well as my children and in-laws. Their unwavering support, understanding, and encouragement have been vital throughout this journey.

I would like to acknowledge the invaluable assistance and support provided by the UMS Mechanical Laboratory staff. Their contributions in fabricating the prototype and conducting associated research have been indispensable. Lastly, I would like to express my gratitude to all those who have directly or indirectly contributed to the successful completion of this research. Your support and encouragement have been invaluable.

Thank you.

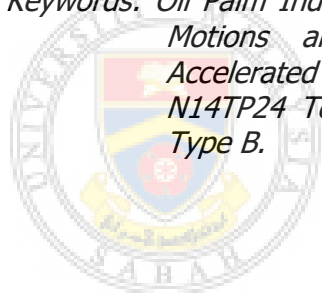
Mohd Zain Abdullah@Join Bin Gorob

15 December 2022

ABSTRACT

This study aimed to design an improved crosscut blade for fronds cutting in the oil palm industry, considering the cutting vector X - Y - Z axis and testing different blade designs based on various Kerf-Sets tooth trigonometrical patterns. The research consisted of two stages; the development of a statistical laboratory test rig platform to analyze the cutting timeline in the Straight-Tooth sections, and a High Accelerated Life Test (HALT) conducted in real field conditions to assess reliability and tooth fracture-wear. The results showed that blade type "F" met the technical design requirements, achieving a Hardness Rockwell of 127HRC per 1mm². The N14TP14 Kerf-Sets tooth size provided the fastest fronds cutting, powered by 100V, with a recorded timeline of 00:15.7 seconds per 6.5 kg pressing drag mass cutting against 29 cm² fresh fronds specimens. These findings contribute to the development of an improved crosscut blade design, with blade type "F" N14TP14 tooth configuration being the most effective, exhibiting high Hardness Rockwell and no fractured tooth blades. The large Kerf-Set tooth sizing facilitated strong cutting force, and the correct Pitch Pressure Angle design Type B at Cosine 10⁰ to 15⁰ contributed to prolonged sharpness quality.

Keywords: Oil Palm Industry, X-Y-Z Axis Cutting Vectors, Technical Reliability, Motions and Inertia, Statistical Static-State, (HALT) High Accelerated Life Test, Hardness Rockwell, Kerf-Sets Sizing, N14TP24 Teeth Trigonometry Dimensions, Pitch Pressure Angle Type B.



UMS
UNIVERSITI MALAYSIA SABAH

ABSTRAK

REKABENTUK PEMOTONG BILAH UNTUK PROSES PEMOTONG PELEPAH KELAPA SAWIT YANG BERKESAN

Kajian ini bertujuan untuk mereka bentuk bilah potong silang yang lebih baik untuk pemotongan pelepah dalam industri kelapa sawit, dengan mengambil kira paksi vektor pemotongan paksi X-Y-Z dan menguji reka bentuk bilah yang berbeza berdasarkan pelbagai corak trigonometri gigi Kerf-Sets. Penyelidikan terdiri daripada dua peringkat; pembangunan platform pelantar ujian makmal statistik untuk menganalisis garis masa pemotongan dalam bahagian Gigi Lurus, dan Ujian Hayat Dipercepatkan Tinggi (UHDT) yang dijalankan dalam keadaan lapangan sebenar untuk menilai kebolehpercayaan dan kehausan patah gigi. Keputusan menunjukkan bahawa jenis bilah "F" memenuhi keperluan reka bentuk teknikal, mencapai Kekerasan Rockwell 127HRC setiap 1mm². Saiz gigi N14TP14 Kerf-Sets memberikan pemotongan pelepah terpantas, dikuasakan oleh 100V, dengan garis masa yang direkodkan 00:15.7 saat setiap 6.5 kg pemotongan jisim seretan menekan terhadap spesimen pelepah segar 29cm². Penemuan ini menyumbang kepada pembangunan reka bentuk bilah potong silang yang lebih baik, dengan konfigurasi gigi jenis bilah "F" N14TP14 adalah yang paling berkesan, mempamerkan Kekerasan Rockwell yang tinggi dan tiada bilah gigi yang patah. Saiz gigi Set Kerf yang besar memudahkan daya pemotongan yang kuat, dan reka bentuk Sudut Tekanan Pitch yang betul jenis B pada Cosine 10^o hingga 15^o menyumbang kepada kualiti ketajaman yang berpanjangan.

Kata kunci: Industri Kelapa Sawit, Vektor Pemotong paksi X-Y-Z, Kebolehpercayaan Teknikal, Pergerakan dan Inersia, Keadaan Statik Statistik, Ujian Hayat Dipercepatkan Tinggi (UHDT), Kekerasan Rockwell, Saiz Set Kerf, Dimensi Trigonometri Gigi N14TP24, Sudut Tekanan Pitch Jenis B.

LIST OF CONTENTS

	Page
TITLE	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
<i>ABSTRAK</i>	vi
LIST OF CONTENTS	vii
LIST OF TABLES	xi
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xx
LIST OF SYMBOLS	xxii
LIST OF APPENDICES	xxiii



UMS
UNIVERSITI MALAYSIA SABAH

CHAPTER 1: INTRODUCTION

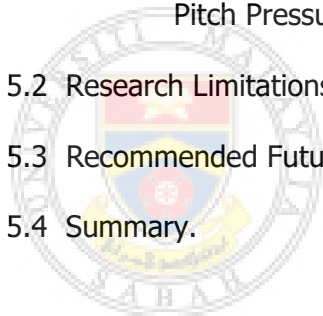
1.1 Overview.	1
1.2 Problem Statement.	3
1.3 Importance of Research.	4
1.4 Objectives of the Research.	7
1.5 Scopes of Work.	7
1.6 Thesis Organization.	8
1.7 Summary.	8

CHAPTER 2: LITERATURE REVIEW

2.1 Overview.	10
2.2 Challenges of Expensive Manual Labour.	10
2.3 Frond Cutting Technologies and Blade Design Considerations.	18
2.4 Design Considerations for Effective Cutting.	22
2.5 Environmental and Sustainability Considerations in Frond-Cutting.	23
2.5.1 The Outline Consideration in Fronds-Cutting.	26
2.6 The Development and Potential of Cross-Cut Saws.	27
2.7 The Straight-Tooth and Circular Sectional Tooth's Weakest Points.	34
2.8 The Technical Design Foundations of the Cross-Cut Blade Cutter.	39
2.8.1 The Role of Motion and Inertia in Oil Palm Cross-Cutter Tools.	40
2.8.2 The Curved Shape Facilitate High-Velocity Impact Cut.	44
2.8.3 Centrifugal Impulse and Impact Force.	56
2.9 The Blade Wear Life-Cycle.	59

2.9.1 Traditional Wear Control .	64
2.10 Data Management Guidelines (DMG) and Quality Control Measures (QCM).	65
2.11 Summary.	68
CHAPTER 3: METHODOLOGY	
3.1 Overview.	70
3.2 Research Framework.	70
3.3 Research Approach.	73
3.4 The Blade Type Development Process.	74
3.4.1 Tooth-Blade Fabrication Process.	78
3.4.2 Kerf-Sets Fabrication Process.	82
3.5 Tooth Blade Hardening Process.	90
3.6 The Static-Test Rig Construction and Blade Selection.	96
3.7 Data Sampling.	100
3.8 Technical Design of Static-State Test Rig.	111
3.9 Data Collection Approach.	120
3.10 Data Analysis.	124
3.11 The Mechanical Features of the Blade Cutter.	126
3.12 Summary.	138
CHAPTER 4: RESULTS AND DISCUSSIONS	
4.1 Overview.	139
4.2 Results and Discussions.	139
4.2.1 The Steel Blade Hardness Rockwell Class C (HRC) Designed Requirements Sustaining Tooth Fracture.	140

4.2.2	The Appropriate Sizing of Blade Type "F" N14TP14 Kerf-Sets Tooth Dimension Provide to Supplement the Largest Combine Shear-Stroke Cutting Force.	171
4.2.3	The Destructive Shearing Sharpness Depends on the Correct Designed of Pitch Pressure Angular Value.	196
4.3	Summary.	213
CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS		
5.1	Conclusions.	214
5.1.1	Requirements of Highest Hardnes Rockwell Class C (HRC).	213
5.1.2	Efficient Kerf-Setss Tooth and Trigonometrical Geometric Sizing Formation.	215
5.1.3	Prolonged Sharapness with Maintainable Pitch Pressure Angle.	200
5.2	Research Limitations.	216
5.3	Recommended Future Studies.	217
5.4	Summary.	218
	References.	220
	List of publications.	229

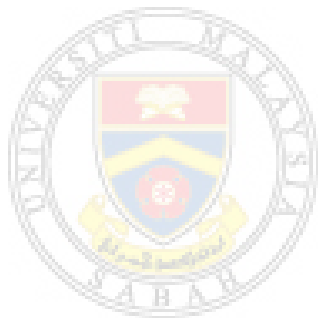


UMS
UNIVERSITI MALAYSIA SABAH

LIST OF TABLE

	Page
Table 2.1: The Correct Guidelines for Fronds Pruning.	17
Table 3.1: The Fabrication of Kerf-Set Tooth Trigonometry.	79
Table 3.2: The Kerf-Sets Formations at 850 ⁰ C– 1300 ⁰ C.	92
Table 3.3: The Wrong Quenching Colour Above 850 ⁰ C– 1300 ⁰ C.	93
Table 3.4: The Correct Metal Heat Colour Suitable for Hardness Rockwell Class C (HRC) of 127 HRC per 1mm ² .	94
Table 3.5: The Reciprocating Jig-Saw Specification.	98
Table 3.6 (a.): Variable Autotransformers Specification.	105
Table 3.6 (b.): Contact Type Tachometer Specification.	105
Table 3.6 (c.): DC Quartz Digital Stopwatch Specification.	106
Table 3.7: Hardness Rockwell Tester Specification.	108
Table 3.8: Microscopic Imaging System Specification.	110
Table 3.9: The K Type Thermocouple Temperatures Detector.	119
Table 3.10: The Technical Static-State Experimental Equipment.	112
Table 3.11: Blade Cutter Type "A" N18TP14 Mechanical Feature.	127
Table 3.12: Blade Cutter Type "B" Mechanical Feature.	129
Table 3.13: Blade Cutter Type "C" N18TP14 Mechanical Feature.	131
Table 3.14: Blade Cutter Type "D" Mechanical Feature.	133
Table 3.15: Blade Cutter Type "E" Mechanical Feature.	135
Table 3.16: Blade Cutter Type "F" N14TP14 Mechanical Feature.	137
Table 4.1: Blade Type "A".	156
Table 4.2: Blade Type Palm King.	157
Table 4.3: Blade Type "B".	159
Table 4.4: Blade Type C.	161

Table 4.5: Blade Type "D".	163
Table 4.6: Blade Type "E".	165
Table 4.7: Blade Type "F".	167
Table 4.8: The 1-Minute Straight-Tooth Tabulated Cutting Timeframe.	175



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF FIGURES

	Page
Figure 1.1: Malaysian Oil Palm Major Estate locations.	2
Figure 1.2: Focus Study Area.	5
Figure 1.3: Tooth Blade Structure.	6
Figure 2.1 Over-Pruning of Fronds Cutting.	14
Figure 2.2: Non-Pruned Oil Palm Trees.	15
Figure 2.3: The Correct Fronds Pruning.	16
Figure 2.4: The Correct Fronds Stacking Methods.	18
Figure 2.5: Pole Deflection at Hi-Reach Cutting.	20
Figure 2.6: Thick Parasitic Plants Hindering Cutting Sight.	21
Figure 2.7: One-Man Cross-Cut Saw.	29
Figure 2.8: The Terminology of Cross-Cut Blade Cutter	30
Figure 2.9: Tooth Blade Radius of Infinity.	31
Figure 2.10: Enlarge Tooth Blade Weakest Point.	30
Figure 2.11: Enlarge <i>GCG</i> at Side View.	36
Figure 2.12: Straight Tooth Section Motion and Inertia.	41
Figure 2.13: "C" Semi-Circle Section Motion and Inertia.	42
Figure 2.14: Curved Section Motion and Inertia.	43
Figure 2.15: Blade Tooth X-Y-Z Axis Cutting Vector Displacements.	44
Figure 2.16: Kerf-Sets Acceleration at ST9.	46
Figure 2.17: Acceleration of Set Tips Pitches at Blade Tooth Sectional.	48
Figure 2.18: Blade Angular Velocity.	49
Figure 2.19: Angular Accelerations for ST9.	50
Figure 2.20: Centripetal Force.	52

Figure 2.21: Blade-Fronds Cut-Mating Interactions Couple.	53
Figure 2.22: Centrifugal Force.	54
Figure 2.23: Centrifugal Impulse and Impact Force.	58
Figure 2.24: The Cutting Mechanics Energy.	61
Figure 3.1: Research Framework.	72
Figure 3.2: The Heating-Cooling Curve for Pure Steel Blades.	75
Figure 3.3: Local Black Smith Charcoal Furnace.	77
Figure 3.4: The Set Flanks Formation.	86
Figure 3.5: The Cosine Angle.	87
Figure 3.6: The Type of Pitch Pressure Angle.	88
Figure 3.7: Thinner Kerf-Sets Formation.	89
Figure 3.8: The Thicker Kerf-Set Formation.	90
Figure 3.9: Blade Thermal Heating.	92
Figure 3.10: Kerf-Sets Formations.	92
Figure 3.11: Wrong Heat Colour Temperatures.	93
Figure 3.12: Kerf-Sets Quenching.	93
Figure 3.13: Correct Heat Colour.	94
Figure 3.14: Colour of Tooth Blade After Quenching.	94
Figure 3.15: The Final Kerf-Set Straight-Tooth Fabrications.	95
Figure 3.16: Static-State Test Rig and Equipment's.	97
Figure 3.17: The Final Selected Experimental Blades.	99
Figure 3.18: Unprocessed Fronds Sample.	100
Figure 3.19: Processed Equal 29 Cm ² Size Fronds Work-Piece Specimens.	101
Figure 3.20: Fronds Cut-Size Developed at 29 cm ² .	102

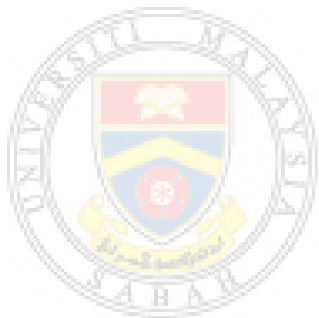
Figure 3.21: Fronds Perpendicular Grains and Softs Fibrous Content.	103
Figure 3.22: Voltage Control, Tachometry (RPM) and Stop Watch.	104
Figure 3.23: Digital Rockwell Hardness (HRC) Tester.	107
Figure 3.24: Microscopic Imaging System.	109
Figure 3.25: Thermocouple Temperatures Detector.	110
Figure 3.26: Static-State Test Rig Actual Dimension.	113
Figure 3.27: Footing Bolted and Nut.	114
Figure 3.28: Fronds Holders Mounting.	115
Figure 3.29: Fronds Holders Set-Up.	116
Figure 3.30: Static-State Viewed at B-B.	117
Figure 3.31: Frond Holders Viewed at A - A.	118
Figure 3.32: Static-State Rear View.	119
Figure 3.33: Relationship of Data, Information and Intelligence.	126
Figure 3.34: Non-Thermal Treated Blade Image Type "A" N18TP14.	128
Figure 3.35: Non-Thermal Treated Blade Image Type "B" N18TP14.	130
Figure 3.36: Non-Thermal Treated Blade Image Type "C" N18TP14.	132
Figure 3.37: Non-Thermal Treated Blade Images Type "D" N18TP14.	134
Figure 3.38: Non-Thermal Treated Blade Images Type "E" N18TP14.	136
Figure 3.39: Thermal Treated Blade Images Type "F" N14TP14.	138
Figure 4.1: Blade Mass Moment of Inertia at Tall Palm Trees Cutting.	141
Figure 4.2: Blade Mass Moment of Inertia at Chest Level Cutting.	142
Figure 4.3: Blade Mass Moment of Inertia at Low Level Cutting.	143
Figure 4.4: Straight-Tooth Sections.	145
Figure 4.5: Semi-Circular Sections.	146

Figure 4.6: Curve Sections.	147
Figure 4.7: The Cross-Cut Blade Cutting Force.	149
Figure 4.8: After HALT Test Broken Straight-Tooth Blade Type A, B, C, D, E and Non-Broken Blade Type F.	150
Figure 4.9: After HALT Test Broken Semi-Curve Tooth Blade Type A, B, C, D, E and Non-Broken Blade Type F.	151
Figure 4.10: After HALT Test Broken Curve Tooth Blade Type A, B, C, D, E and Non-Broken Blade Type F.	152
Figure 4.11: Durable Tooth-Blade Type "F" N14TP14 After HALT Test.	153
Figure 4.12: The Quenching Time -Temperature Relationship.	154
Figure 4.13: Recommended Temperature for Blade Heat Treating.	155
Figure 4.14: Blade Type "A" Hardness Rockwell Class C (HRC).	156
Figure 4.15: Blade "A" Rockwell Hardness HRC at Tooth Point 1, 4, 6, 8, 11, 13 and 14.	157
Figure 4.16: Blade Type Palm King Rockwell Hardness HRC.	158
Figure 4.17: Palm-King Blade Rockwell Hardness HRC at Tooth Point 1, 4, 6 and 8.	159
Figure 4.18: Blade Type "B" Hardness Rockwell Class C (HRC).	160
Figure 4.19: Blade "B" Rockwell Hardness HRC at Tooth Point 1, 4, 6, 8, 11, 13 and 14.	161
Figure 4.20: Blade Type "C" Hardness Rockwell Class C (HRC).	162
Figure 4.21: Blade "C" Hardness Rockwell HRC at Tooth Point 1, 4, 6, 8, 11, 13 and 14.	163
Figure 4.22: Blade Type "D" Hardness Rockwell Class C (HRC).	164
Figure 4.23: Blade "D" Rockwell Hardness HRC at Tooth Point 1, 4, 6, 8, 11, 13 and 14.	165
Figure 4.24: Blade Type "E" Hardness Rockwell Class (HRC).	166
Figure 4.25: Blade "E" Rockwell Hardness HRC at Tooth Point 1, 4, 6, 8, 11, 13 and 14.	167

Figure 4.26: Blade Type "F" Hardness Rockwell Class C (HRC).	168
Figure 4.27: Blade "F" Rockwell Hardness HRC at Tooth Point 1, 4, 6, 8, 11, 13 and 14.	169
Figure 4.28: Blade Hardness Rockwell Class C HRC/1 mm ² .	170
Figure 4.29: The Cutting Performance Straight-Tooth Sections at 80 Voltages for Blade Type A, B, C, D, E and Non-Broken Blade Type F with 2kg, 4.5kg and 6.5kg.	176
Figure 4.30: The Cutting Performance Straight-Tooth Sections at 90 Voltages for Blade Type A, B, C, D, E and Non-Broken Blade Type F with 2kg, 4.5kg and 6.5kg.	177
Figure 4.31: The Cutting Performance Straight-Tooth Sections at 100 Voltages for Blade Type A, B, C, D, E and Non-Broken Blade Type F with 2kg, 4.5kg and 6.5kg.	178
Figure 4.32: Transient-State of Field Cutting.	180
Figure 4.33: Rapid Transient-State of Cutting Force.	181
Figure 4.34: Kerf-Sets C.O.G Tooth Structure.	183
Figure 4.35: Straight-Tooth Dimension for Blade Type "A".	185
Figure 4.36: Straight-Tooth Dimension for Blade Type "B".	186
Figure 4.37: Straight-Tooth Dimension for Blade Type "C".	187
Figure 4.38 Straight-Tooth Dimension for Blade Type "D".	188
Figure 4.39: Straight-Tooth Dimension for Blade Type "E".	189
Figure 4.40: Blade Type "F" N14TP14 Straight Tooth Sections.	190
Figure 4.41: Blade Type "F" N14TP14 Kerf-Sets Front View.	191
Figure 4.42: Larger Tooth Blade Type "F" N14TP14.	192
Figure 4.43: Kerf-Sets Z-Axis Cutting Force.	193
Figure 4.44: Blade Type "F" Tooth Sharpening.	194
Figure 4.45: Verification and Validations Limits.	196
Figure 4.46: Kerf-Set Rough Cut Surfaces and Actual Dimension Blade Type "F".	198

Figure 4.47: Blade Type "F" N14TP14 Fabricated Straight-Tooth Sections.	199
Figure 4.48: Set Tips Pitch Pressure Angle.	200
Figure 4.49: Pitch Pressure Angle Type A and B.	201
Figure 4.50: Blade "F" Type B Pitch Pressure Angle.	202
Figure 4.51: Blade Type "F" Kerf-Sets Actual Dimensions.	203
Figure 4.52 - Blade Type "A" Lesser 10^0 Pitch Pressure Angle.	204
Figure 4.53: Blade Type "B" Lesser 10^0 Pitch Pressure Angle.	205
Figure 4.54: Blade Type "C" Lesser 10^0 Pitch Pressure Angle.	206
Figure 4.55: Blade Type "D" Lesser 10^0 Pitch Pressure Angle.	207
Figure 4.56: Blade Type "E" Lesser 10^0 Pitch Pressure Angle.	208
Figure 4.57: Blade Type "F" 10^0 to 15^0 Pitch Pressure Angle.	209
Figure 4.58: Blade Type "F" Tooth No. 8 at 5x Larger.	210
Figure 4.59: Blade Type "F" Tooth No. 25 at 10x Larger.	211
Figure 4.60: Blade Type "F" Tooth No. 8 Viewed 10x and 20x Larger.	212
Figure H1.1: The Force of Set Tips Body Motions Along Arc of a Circle.	252
Figure H1.2: The Pull-Push Cutting Force Weight of Single Set-Tips Pitches at ST9.	254
Figure H1.3: The Cutting Efficiency of Single Set Tips Pitches.	257
Figure H1.4: The Cutting Speed of a Straight Tooth.	260
Figure H1.5: The Tension at Tooth Set Flank Surfaces.	263
Figure H1.6: To Determine the Set Tip Cutting Pressure Value in Newton's.	267
Figure H1.7: The Angular Velocity and Resultant Impulsive Reaction at O_1 .	270
Figure H1.8: The Force at Set Flank During Angular Acceleration.	274
Figure I1.1: The Set-Flanks Pressure Angle.	278

Figure I1.2: The Effect of Set-Flanks Pressure Angle.	279
Figure J1.1 - The Effect of Pitch Pressure Angle.	283
Figure K1.1: More Fronds Least Ripe Fruit.	289
Figure K1.2: Flooded Oil Palm at Block A.	290
Figure K1.3: Slippery River Banks.	290
Figure K1.4: Thick Parasitic Plants.	291
Figure L1.1: Long Pole Handle Traverse Vibrations.	295
Figure M1.1: Portable Motorised Cutter.	302
Figure M1.2: Piston, Piston Ring, Gudgeoned Pin, and Connecting Rod.	302



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF ABBREVIATIONS.

mm	-	Millimeter
Cm	-	Centre meter
m	-	Meters
(ha) m²	-	Hectare
2.47 Acre	-	1 Ha
kg	-	Kilogram
MT	-	Metric Ton
Hp	-	Horse power
kWh	-	Kilowatt hour
V	-	Voltage
m/s²	-	Speed velocity
Newton N	-	Force
N/m²	-	Stress
Nm	-	Energy
hr	-	Hour
°	-	Degree
'	-	Minute
''	-	Seconds
HRC	-	Hardness Rockwell Class "C"
BUE	-	Built-Up-Edge
RPM	-	Revolution Per Minute.
RPS	-	Revolution Per Seconds.
Oil Palm	-	Oil Palm.
MPOB	-	Malaysian Oil Palm Board.
S	-	Straight-Tooth.
SC	-	Semi-Circular.
C	-	Curve.
M & I	-	Motion and Inertia.
HAV	-	Health Associated Vibrations.
YAP	-	Year After Planting.
M/T/H/M	-	Man/Tan/Hectares/Months.
SSSTR	-	Statistical Static-State Test Rig.
HRC	-	Hardness Rockwell Class "C".

HALT	-	High Accelerated Life Test.
UHDT	-	Ujian Hayat Dipercepatkan Tinggi.
STBICP	-	Statistical Tooth Blade Identified Cutting Performance.
DMG	-	Designed Management Guidelines.
DSP	-	Demand Side Platform.
SSP	-	Supply Side Platform.



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF SYMBOLS.

F	-	Force
<i>m</i>	-	Mass of the body
<i>v</i>	-	Velocity of the moving body.
<i>f</i>	-	Acceleration
<i>k</i>	-	Dimensionless constant.
<i>r</i>	-	Radius of curvature
<i>w</i>	-	Angular velocity vector.
<i>w</i>	-	Width of Tooth Blade
<i>t</i>	-	Thickness of tooth blade
<i>g</i>	-	The acceleration due to gravity,
<i>h</i>	-	Height of the tooth body above a reference point of the gullet depth.
<i>B</i>	-	Beta
<i>N-m</i>	-	Newton metre
<i>Cos</i>	-	Cosine
<i>PE (Nm)</i>	-	Potential Energy.
<i>K.E. (Nm)</i>	-	Kinetic Energy.
<i>S</i>	-	Distance traveled in meters
<i>V_o</i>	-	Initial velocity in meters/sec
<i>T</i>	-	Time interval in seconds
<i>F_t</i>	-	Acceleration in meters/sec ²
<i>p</i>	-	pressure in N/m ²
<i>d</i>	-	diameter of the piston in m ²
<i>n</i>	-	ratio of connecting rod to crank radius