brought to you by **CORE** provided by Universiti Teknologi Malaysia Institutional Repository

vii

TABLE OF CONTENTS

CHAPTER	TITLE DECLARATION		PAGE	
			ii	
	DED	DICATION	iii	
	ACK	iv		
	ABS	v		
	ABS	vi		
	TAB	BLE OF CONTENTS	vii	
	LIST	Х		
	LIST	Γ OF FIGURES	xi	
	LIST	LIST OF SYMBOLS		
	LIST	Γ OF APPENDICES	xiv	
1	INT	1		
	1.1	Elastohydrodynamic Lubrication	1	
	1.2	Bio – based Lubrication	4	
	1.3	Objective	5	
	1.4	Scope of Study	5	
2	LIT	6		
	2.1	Theory of Elastohydrodynamic Lubrication	6	
	2.2	Film thickness	7	
	2.3	Previous Study of elastohydrodynamic		
		(EHL) In Elliptic Contacts	8	
		2.3.1 Result for Steady State	9	

2.4	Previous study of bio-based lubricants		12
	2.4.1	Biodegradable ester vs. mineral oil	12
		2.4.1.1 Results	13
	2.4.2	Lubricants properties of Moringa Oil	14
		2.4.2.1 Results	15
	2.4.3	Palm Olein as Lubrication Oil	16
		2.4.3.1 Results	17
2.5	Summ	nary	18
MA	ГНЕМА	TICAL OF FORMULATION	21
3.1	Reyn	olds Equation	21
	3.1.1	Newtonian Fluids	23
	3.1.2	Non-Newtonian Fluids	24
3.2	Balan	ce of Forces	24
3.3	Flow,	26	
	3.3.1	Mass flow rate per unit width	26
	3.3.2	Tangential load components	27
	3.3.3	Shear forces	28
	3.3.4	Center of pressure	29
3.4	Introdu	30	
	3.4.1	Governing Equation for CFD	30
		3.4.1.1 Continuity Equation	31
		3.4.1.2 Momentum Equation	33
3.5	The S	tandard RNG and Realizable	
	k-epsi	lon Model	35
	3.5.1	Standard k-epsilon Model	36
	3.5.2	RNG k-epsilon Model	37
MET	THODO	LOGY	38
4.1	Pre-Processing CFD		38
4.2	Building Geometry		
4.3	Meshi	40	

	4.4	Proces	ssing CFD	41
5	RESULT AND DISCUSSION		42	
	5.1	Result	Results	
		5.1.1	Dynamic pressure between two	
			surfaces for mineral oil	44
		5.1.2	Static pressure between two	
			surfaces for mineral oil	47
		5.1.3	Dynamic pressure between two	
			surfaces for bio-based lubricants	
			(biodegradable ester)	48
		5.1.4	Static pressure between two	
			surfaces for bio-based lubricants	
			(biodegradable ester)	51
		5.1.5	Comparison between mineral oil and	
			bio-based lubricants (biodegradable ester)	
			at two surfaces.	52
6	CON	CLUSI	ON	56
	6.1	Concl	usion	56
	6.2	Recor	nmendation for future research	57
REI	FEREN	CES		58
APF	PENDIC	ES		60
	-			

ix

LIST OF TABLE

TABLE NO.	TITLE	PAGE
2.1	Viscosity and other physicochemical	
	properties of oils	15
2.2	Oxidation and thermal stability of oils	
	measured using PDSC, Rancimat and TG	15
2.3	Low temperature properties of vegetable oils	16
2.4	HFRR lubricity data on vegetable oils	16
2.5	Measured Properties and their values	17
2.6	Physical properties for cams and different	
	bio-based lubricant	20
4.1	Zone name and type for each boundary condition	41

LIST OF FIGURES

FIGURES N	O. TITLE	PAGE	
2.1	Lubricant film thickness and pressure distribution	8	
2.2	Steady-state pressure and film thickness	10	
2.3	Distributions of pressures and film thicknesses		
	on the y axis for various central distance	11	
2.4	Distributions of pressures on the x axis for		
	various central distances	11	
2.5	Stabilized oil sump temperature vs. input		
	speed and torque for ester and mineral industrial		
	gear oils	13	
2.6	Predicted friction coefficient between gear teeth		
	for ester and mineral oils at predicted stabilization		
	temperatures, depending on the wheel applied torque		
	and speed	14	
2.7	Example of cams system	20	
3.1	Fluid film between two solid surfaces	22	
3.2	Flow Characteristics as a Function of Shear		
	Strain Rate	23	
3.3	A small elements of fluid	24	
3.4	Load components and shear forces	28	
3.5	Element used to come out continuity equation	31	
3.6	Models to come out momentum equation	33	

4.1	Model and tunnel was done in the Gambit for this			
	project respectively	39		
4.2	The meshing was done in Gambit before export			
	to Fluent	40		
5.1	Variation of pressure between P. Yang and J. Cui			
	and this study	43		
5.2	Dynamic pressure distribution for x-axis	44		
5.3	Variation of dynamic pressure distribution for X-axis	45		
5.4	Variation of dynamic pressure distribution for Y-axis	46		
5.5	Dynamic pressure distribution for Y-axis	46		
5.6	Static pressure between two surfaces	47		
5.7	Dynamics pressure distribution for X-axis	48		
5.8	Variation of dynamics pressure distribution for X-axis	49		
5.9	Variation of dynamic pressure distribution for Y-axis	50		
5.10	Dynamics Pressure distributions for Y-axis	50		
5.11	Static pressure between two surfaces	51		
5.12	Dynamic pressure distribution for X-axis	52		
5.13	Dynamic Pressure distribution for Y-axis	53		
5.14	Static pressure between two surfaces	54		
5.15	Dynamic pressure distribution for X-axis at the			
	surfaces	55		

LIST OF SYMBOLS

Shear strain rate γ Absolute viscosity η -Normal stress σ_{x} -Fluid pressure р -Coefficient of viscosity μ -Flow velocity и -Mass flow rate q_m -Center of pressure x_{cp} f'_a Shear force per unit length -F Force _ Changes of deformation dl -Е Modulus Young -

Tangential load

Shear stress

τ

 $\overline{\gamma}$

-

-

LIST OF APPENDICES

APPENDIX	TITLE	PAGE	
A	Result for Mineral Oil	60	
В	Result for Bio-Based Lubricant	61	