Experimentation and prediction of machining characteristics in laser-assisted high speed milling of aluminium alloy using vegetable-based cutting fluids

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Presentation Outline

1. Literature Review
2. Problem Statement
3. Objective
4. Methodology
5. Expected Outcome

Literature Review

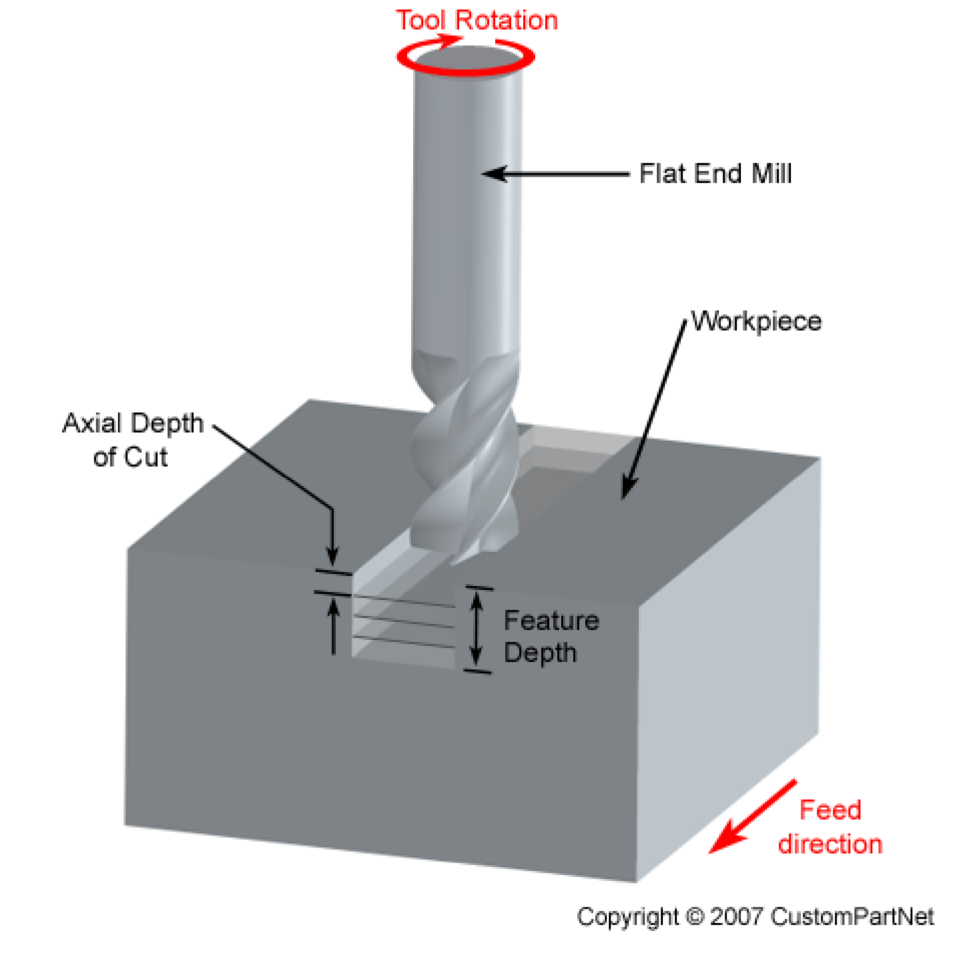
Milling operation

Need to be

Productivity

Production time and cost

High-speed milling



Literature Review

High-speed milling

Feature:

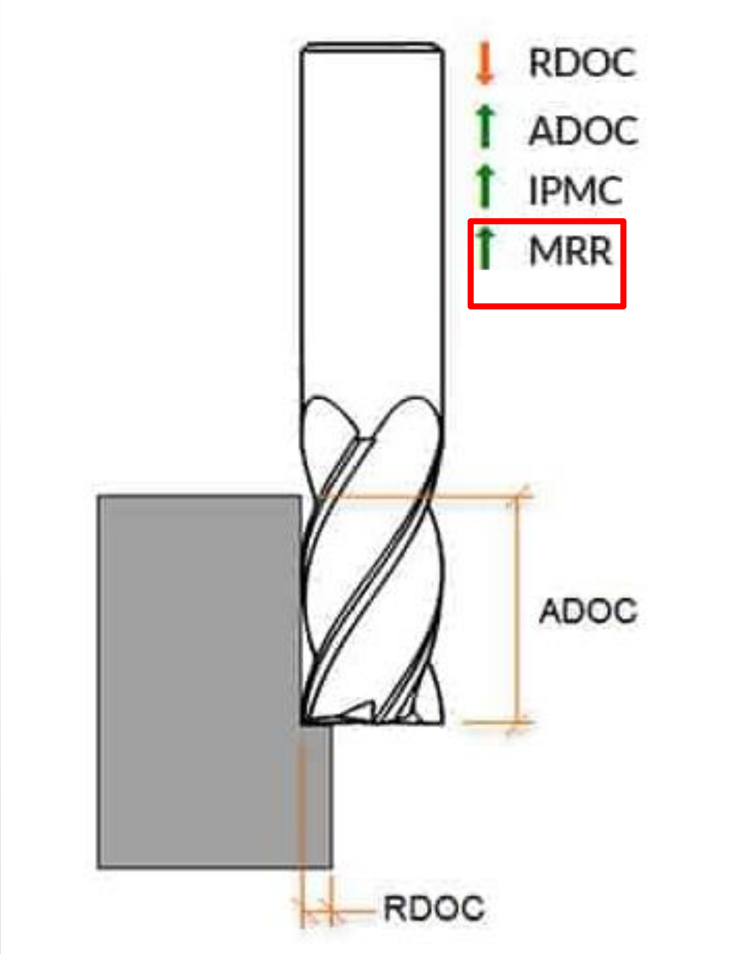
- Feed rate increment
- Rise of cutting speed

Applications:

- Aluminum alloy [Khorasani et.al. 2016]
- Titanium alloy [A. Li et.al. 2012]
- Inconel [A. Çelik et al. 2017]

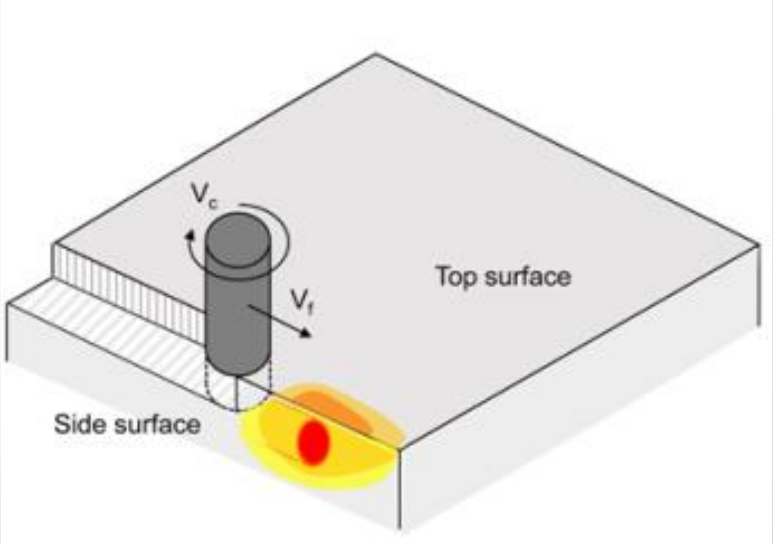
Benefits:

- Increase in surface finish with high cutting speed (i.e. 4500 m/min) [Zhong et al. 2015]
- Increase in quality of surface with high feed rate (i.e. 0.41-0.45 m/min) [Khorasani et al. 2016]



Literature Review

Laser-assisted high-speed milling



- Able to lower the material strength by thermally soften the material surface in the cutting area for easy machining.

Advantages:

- Improvement of surface finish (i.e, 25% at cutting speed of 500 m/min with the feed rate of 0.5 mm/rev) [Attia et al. 2010]

However,

Shorter tool life at high laser power [Ito et al. 2017]

Literature Review

Cutting fluid

Mineral oil-based cutting fluids

- Non-biodegradable
- Unhealthy and dangerous to operator
- Containing toxic
- Costly

Vegetable oil-based cutting fluid

- Low cost
- Excellent lubrication performance
- Biodegradability
- Renewability

Advantages of the use of vegetable-based cutting fluid:

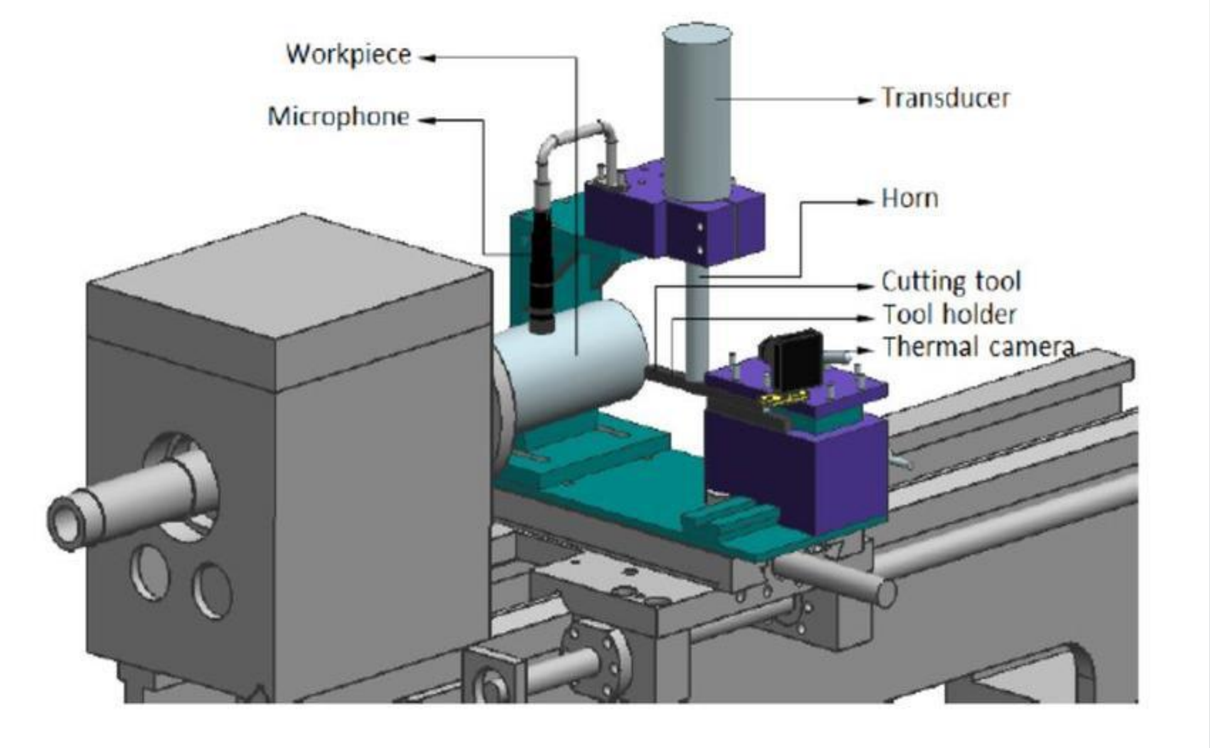
- Improvement of tool life (i.e, five times compared to conventional laser-assisted milling (dry machining)) [Bermingham et al. 2015]
- Reduction in surface roughness, cutting forces and cutting temperatures compared to dry and conventional cutting fluid [Padmini et al. 2016]

Literature Review

Ultrasonic-assisted milling

Advantages:

- Good surface topography [Razfar et al. 2011]
- High surface finish [Shen et al. 2012]
- Reduced cutting force [Verma et al. 2019.]



Limitation:

- Low cutting speed [Razfar et al. 2011]
- Low feed rate

Problem Statement

1. Ultrasonic-assisted milling is favorable to obtain improved surface finish but high-frequency vibration (generally greater than 20 kHz) usually applied to a tool or a workpiece, making it not viable for the application in high speed machining.

2. No previous study on the application of ultrasonic-induced vegetable-based cutting fluids (palm oil and sago starch) on machining characteristics of aluminium alloy.

Objectives

- To investigate the effects of ultrasonic-induced vegetable-based cutting fluids (palm oil and sago starch) on machining characteristics of aluminium alloy.
- To determine optimum machining parameters by response surface methodology (RSM).
- To predict the machining characteristics by extreme learning machine (ELM), and compare with the experiment.

Methodology (Objective 1)

Cutting fluid delivery system

- **Ultrasonic-induced droplet cutting fluid**

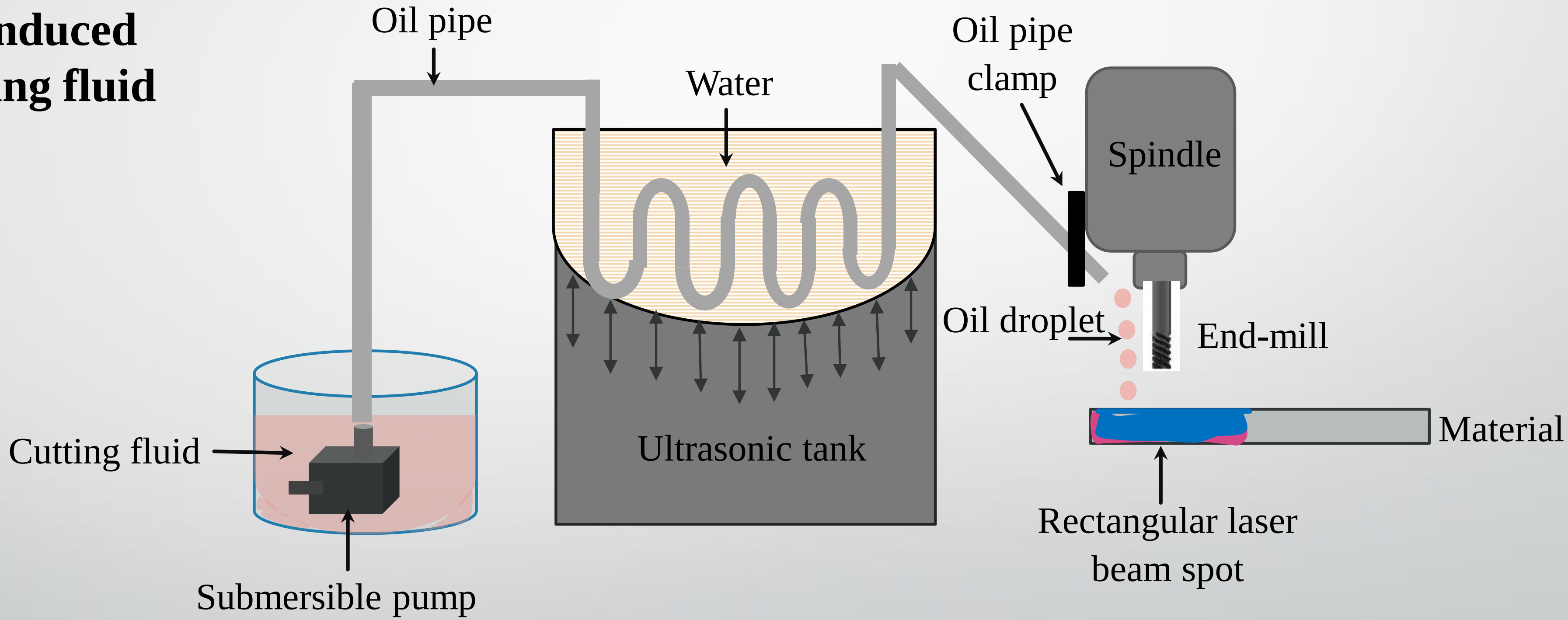


Fig. 1. Schematic diagram of experimental setup

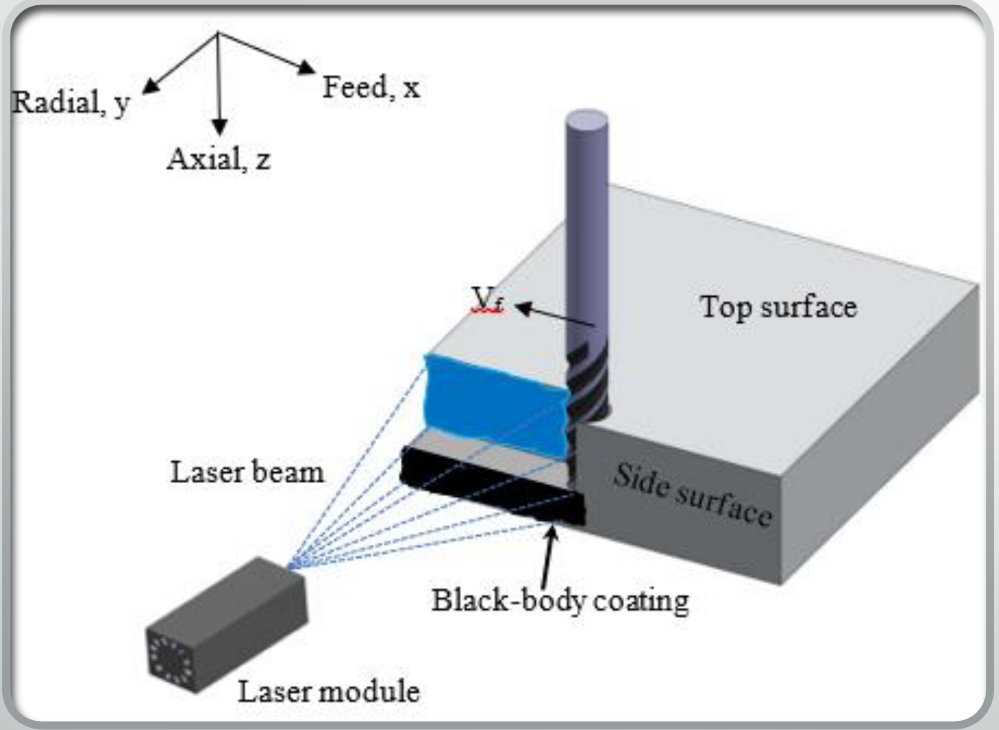
Methodology (Objective 1)

Table 1: The chemical requirements to prepare the water-soluble sago starch

Chemical Properties	Quantity
Distilled water	11 L
Sago Starch	5 g
Sodium Carbonate	50 g
Sodium Hydrogencarbonate	30 g
Sodium Bromide	1 g
Sodium Fluoride	5 g
Ethanol	2 cc
Dehydroacetic acid	0.5 g
m-Cresol	25 g
Sodium dodecyl-benzene sulfonate	25 g
Rust Preventive Agent (Linoleic acid)	10 cc

Methodology (Objective 1)

- Preliminary experiments by changing parameters: **feed rate, laser power, fluid flow rate**.



Affect

Surface roughness and flank wear

Observation

SEM (scanning electron microscope) and optical microscope

Methodology (Objective 2)

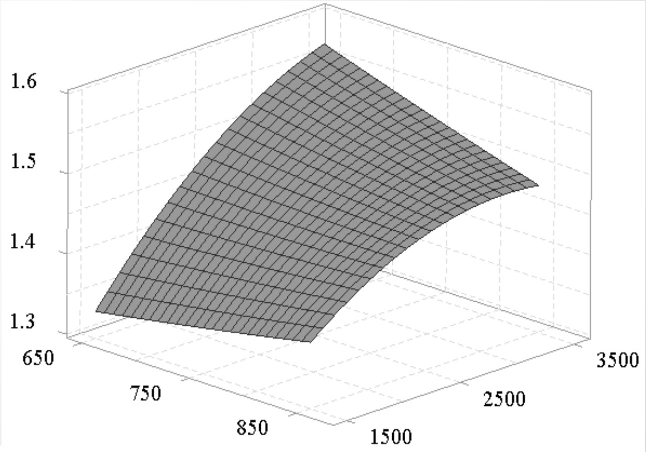
Optimization of machining parameters by response surface methodology (RSM)

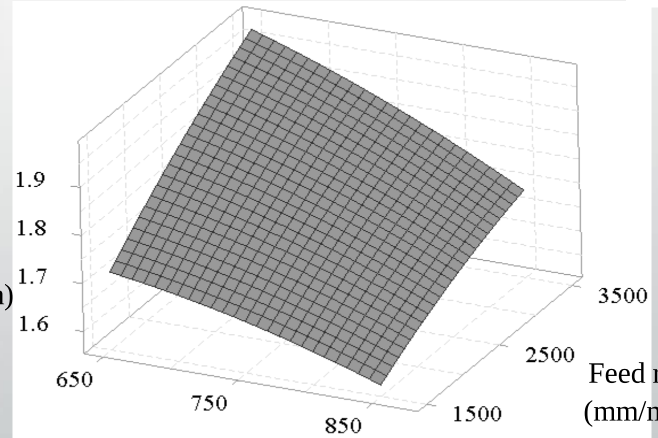
Regression model for the optimization:

1. Least-squares method
2. A second order polynomial equation

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j}^{k} \beta_{ij} x_i x_j + \varepsilon$$

Predicted response value



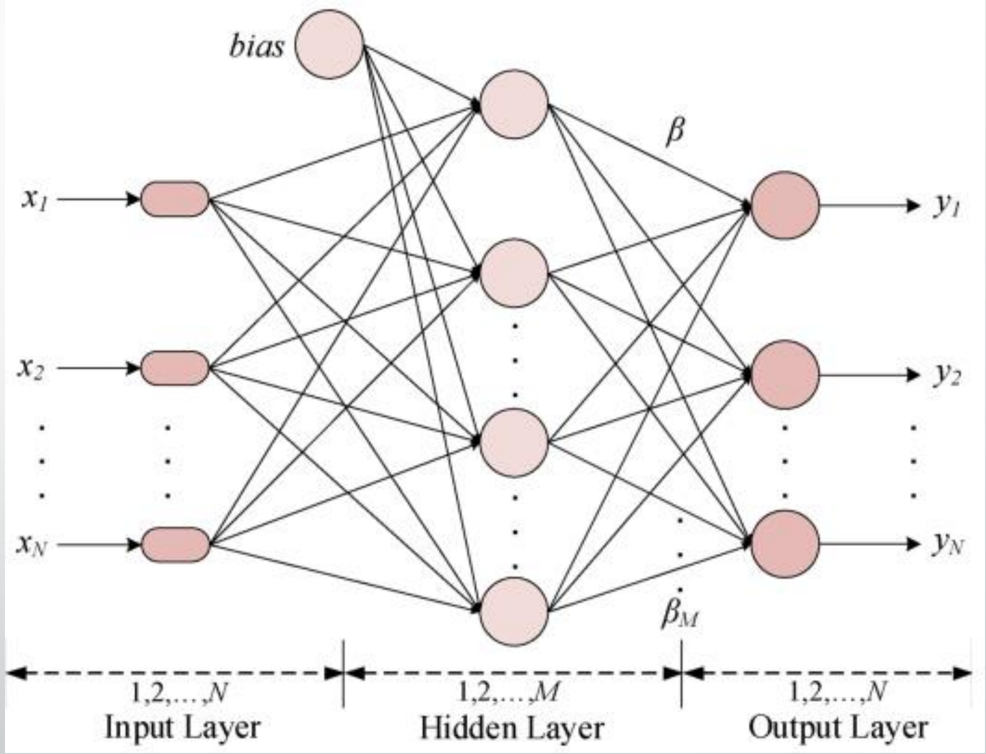


3D response surface plots

Methodology (Objective 3)

Prediction of the machining characteristics by Extreme Learning Machine (ELM)

- **Single hidden-layered feed-forward neural networks**



Why extreme learning machine (ELM)?

- Faster learning speed
- The smallest training error and norm of weights

Methodology (Objective 3)

Prediction of the machining characteristics by Extreme Learning Machine (ELM)

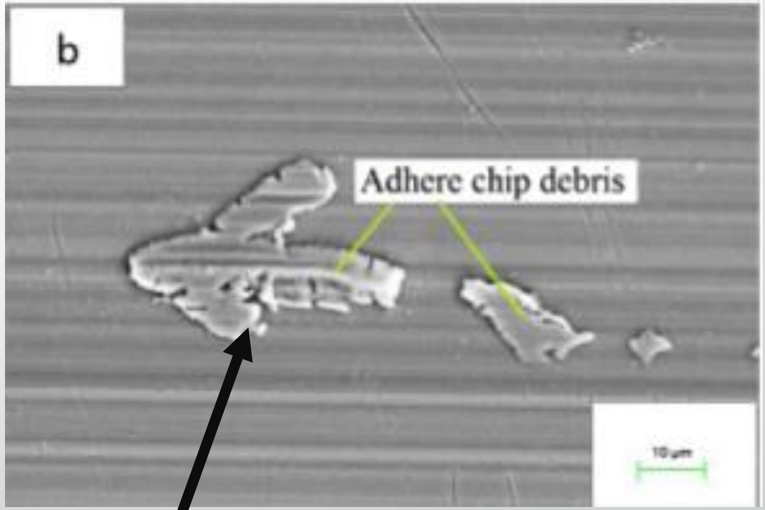
Run	Surface roughness (Ra) / flank wear (VB)					
	Palm oil			Sago starch		
	Experimentation (µm)	Prediction (µm)	Error %	Experimentation (µm)	Prediction (µm)	Error %
1						
2						
3						

Expected outcome

Ultrasonic-induced droplet cutting fluid

- **Acoustic cavitation mechanism**

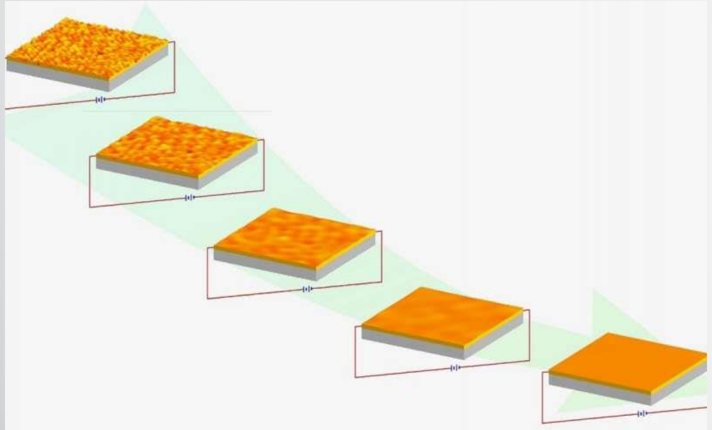
Lubricity of oil



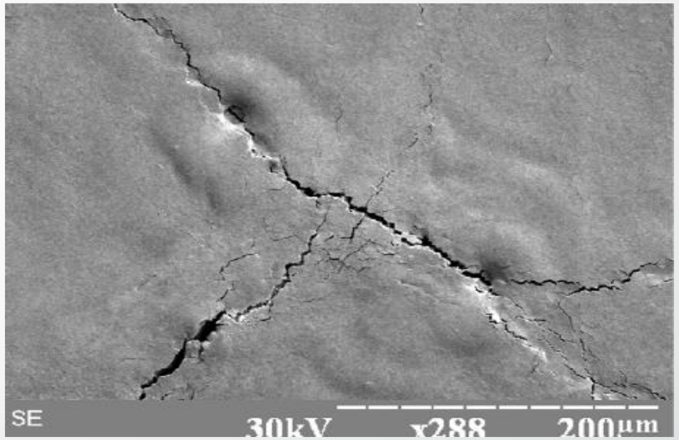
Remove micro-chips

Expected outcome

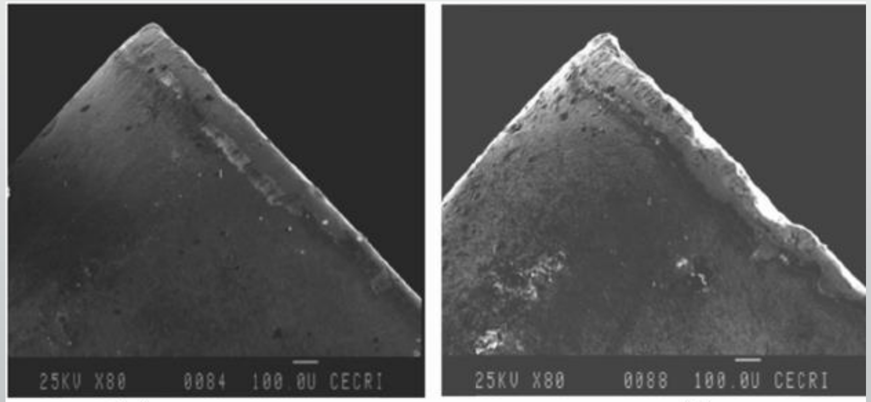
Vegetable-based cutting fluids (palm oil and sago starch)



Surface roughness



Surface crack



(a) (b)

Tool life

Gantt Chart / Milestones

Month / Task	2019									2020										
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Chapter 2- Literature review	■	■	■	■	■															
Assembling the experimental setup			■	■	■															
Chapter 3- Methodology						■	■	■	■											
Chapter 1- Introduction						■	■	■	■											
Proposal Defense										■										
Review paper											■	■								
Performing experiments and prediction						■	■	■	■	■	■	■	■	■						
Data analysis and result comparison															■	■				
Chapter 4- Results and discussion																■	■	■		
Chapter 5- Conclusion																■	■	■		
Paper																			■	■
VIVA																				■

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Research paper

1. F. Yasmin, K. F. Tamrin, and N.A. Sheikh, *Laser-assisted high speed machining of aluminium alloy: the effect of ultrasonic-induced droplet vegetable-based cutting fluid on surface roughness and tool wear.* Lasers in Engineering, 2020. **(Accepted)**

2. F. Yasmin, K. F. Tamrin, N. A. Sheikh, and S. S. Zakariyah, *Extreme Learning Machine in Laser-assisted High Speed Milling using Ultrasonic-induced Cutting Fluid.* Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. **(Under review)**

Thank You