# REVIEW OF DEVELOPMENT TOWARDS MINIMUM QUANTITY LUBRICATION AND HIGH SPEED MACHINING OF ALUMINUM 7075-T6

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**Article History**: Received 12 August 2017; Revised 20 October 2017; Accepted 30 December 2017

**ABSTRACT:** Nowadays, the challenge in machining industries is focused on achieving high-quality product on component accuracy, and high production rate. It is necessary to enhance existing technology and develop the product with reasonable cost. Thus, researchers have developed advanced technology such as high-speed machining. High-speed machining plays a very important role in achieving cost and time savings together with better surface finish and dimensional accuracy. High-speed machining is being widely employed in the aerospace industry. Aluminum 7075-T6 is one of the popular materials with attractive properties such as high tensile strength, toughness and high corrosion resistance. Minimum quantity lubrication is known as a technique to provide the best cutting performances. This paper provides the recent studies in minimum quantity lubrication and high-speed machining of aluminum 7075-T6. The influence of high-speed machining process parameters in term the surface roughness and relevant cutting fluid technique have been discussed based on the findings of the recent studies.

**KEYWORDS**: *High Speed Machining; Aluminum 7075-T6; Minimum Quantity Lubrication; Cutting Fluid*

## 1.0 INTRODUCTION

Metal cutting industries faced great challenges because of stringent quality requirements. The reason of quality requirements becomes stringent is the increasing attention to the preserved energy resources and productivity. Metal cutting has the machining part shapes, different parts and components. In the machining processes a cutting tool removes material from a work piece. The removed material is also known as chip slides on the tool face and leaves the work piece material [1]. A popular material that widely used in metal cutting industries is aluminum alloys because of relatively low-cost.

Aluminum alloys are categorized as light metals and easy-to-machine materials [2]. A trending material of aluminum alloys for machining in the aerospace industry is a group of 7000 series. Aluminum 7075-T6 was selected from 7000 series because primarily used in the aerospace industry as structural components and are strengthened by age-hardening [3]. It also offers the attractive properties such as moderate hardness, moderate toughness, heat treatable, high tensile strength and high corrosion resistance [4]. It has been employed in aerospace industries to manufacture the complex parts by high-speed machining (HSM).

High-speed machining is extensively used in the aerospace industry where the surface quality is important to be achieved. It also has the potential to reduce the lead times and machining costs. HSM is different from conventional machining due to characterize by cutting alloys at high speeds and feeds [5-6]. An approximate range of high-speed machining is shown in Figure 1 [7]. Speed below 600 m/min, 600 to 1800 m/min, 1800 to 18000 m/min and 18000 m/min above are considered as conventional, high speed, very high speed and ultrahigh speed, respectively for the overall machining operation.

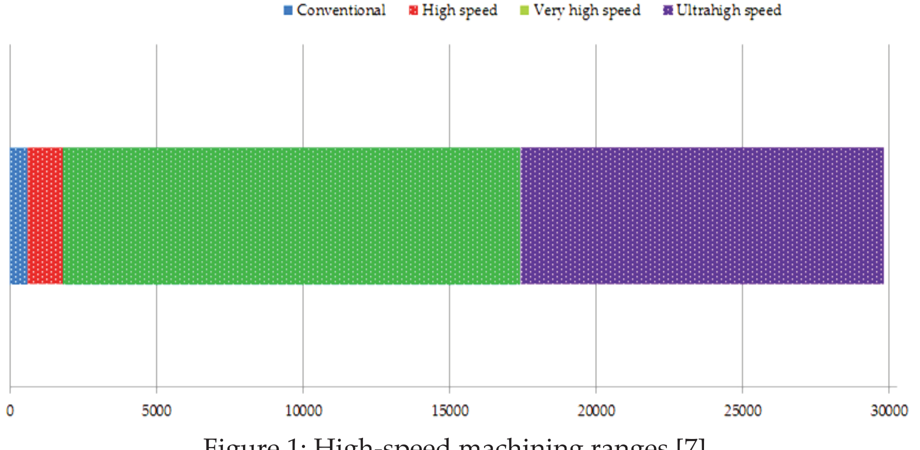


Figure 1: High-speed machining ranges [7]

At high cutting speeds, it is well known that the lubrication or cutting fluid used in the cutting zone is less effective [8]. A cutting fluid refers to any liquid that is applied directly to the tool and work piece interface to cool and lubricate interface. It also acts to reduce tool wear and increasing tool life [9-10]. Cutting fluids are applied to machining operations in various techniques [6]. Currently, environmentally suitable tool cooling technique is sought because cutting fluid contributes to ecological and health damages. The health and safety aspects of using cutting fluids add to the cost of metal cutting as suitable disposal of the cutting fluid are required. The need to improve the cost and environmental-friendly is required. An alternative technique is called Minimum Quantity Lubrication (MQL). The advantages of MQL are less polluted, reduces labour costs and disposal as well as improving cycle time [11]. MQL is also known as micro-lubrication or near dry machining [12]. It is a latest technology that enables delivering fluid to the tool and work piece interface in mist form or small particles assisted by air [13]. A substantial difference in how effective a tool performs can be made when using this technique by applying a small amount of fluid [14]. Besides that, the application of MQL is cost-effective, wherein the flow rate of MQL is about 50 to 500 ml/h compared with the 120,000 ml/h in conventional lubrication for economic view [15-16]. Puvanesan et al. [17] noted that MQL technique is becoming increasingly more important and popular due to environmental friendly. That is why minimum quantity lubrication and high speed machining are often associated. The main objective of this paper is to highlight the overview on machining of aluminum 7075-T6 under MQL and HSM.

## 2.0 MQL and HSM OVERVIEW

Input parameters in machining process such as cutting speed, feed rate and depth of cut are affecting the production cost and product quality. The following sections present the overviews of numerous studies involving these parameters with reference to high-speed machining. There are limits to these cutting parameters since they also have an effect on surface roughness. The technique of cutting fluids also affects the process of production.

### 2.1 Studies on Minimum Quantity Lubrication

Minimum quantity lubrication (MQL) is a promising technique to reduce the usage of cutting fluids in metal cutting. Several recent studies were conducted to investigate the potential of the MQL technique in the metal cutting.

Tosun and Huseyinoglu [18] studied the impact of minimum quantity lubrication (MQL) in term of surface roughness in milling of Aluminum 7075-T6. MQL and flood were also utilized as the lubrication techniques in the experiments. The flow rates of 5 and 1000 ml/min were kept in MQL and flood, respectively. The result showed that the ratio of MQL of 1:10 technique led to lower roughness values due to effective lubrication at the work-tool interface. They concluded that the surface roughness in the cutting under MQL decrease as spindle speed was increased.

Kouam et al. [19] analyses the impact of lubrication of minimum quantity lubrication (MQL) at flow rate of 1.75 and 3 ml/min and dry when turning of the aluminum alloy 7075-T6. The roughness and chip formation was chosen as the response variables. They observed that the MQL flow rate of 1.75 ml/min gives a lowest surface roughness than the MQL flow rate of 3 ml/min and the dry. In terms of chip formation, the flow rate of 3 ml/min at cutting speed of 657 m/min shows more long chips compared to flow rate of 1.75 ml/min and dry as shown in Figure 2. It concluded that the best lubrication was 1.75 ml/min.

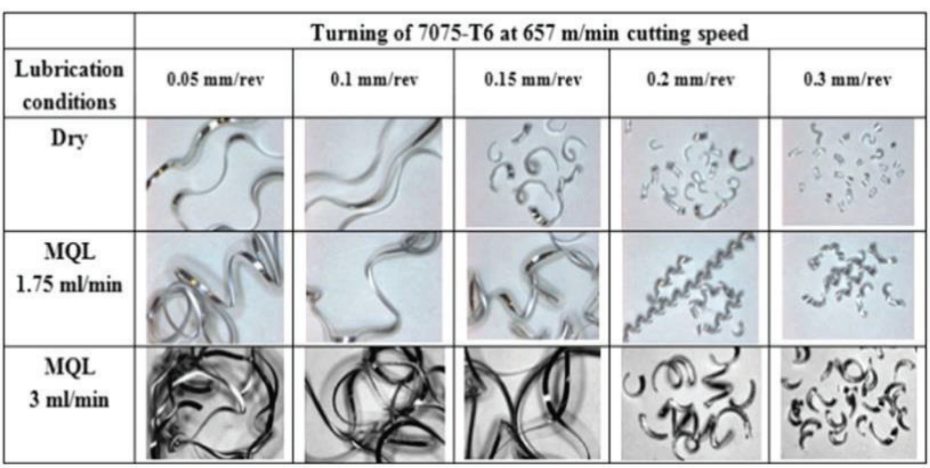


Figure 2: Chip morphology image at 657 m/min [19]

Cakir et al. [20] study the optimum conditions on the cutting speed and feed rates using MQL technology when turning aluminum 7075-T6. Four different flow rates which are 0.25, 0.45, 0.90 and 3.25 ml/min were applied along with cutting speed and feed rates. They concluded that the surface roughness value is increased when increasing feed rate and the surface roughness values will be decreased when increasing flow rate. However, the surface quality not has severe effect though the cutting speed was increase.

It has been observed that the impact of the flow rate on the surface quality was influenced at a high feed rate. It can be seen that there are different result in termination of the flow rate amount of MQL between Kouam et al. [19] and Cakir et al. [20].

## 2.2 Studies on Surface Roughness

Surface roughness has a significant role in the performance of finished components. Surface roughness have an impact on the mechanical properties like fatigue behaviour and corrosion resistance. In general, parameters that affect surface roughness include process parameters, cutting tool properties and work pieces properties.

Alagarsamy [21] analysed the effect of turning process parameters on surface roughness of aluminum 7075-T6 using Taguchi's method. The Taguchi method was employed to obtain a lower surface roughness value for turning process of aluminum 7075-T6 considering three influencing input parameters, which were the cutting speed, feed rate and depth of cut. The results showed that feed rate influencing the surface roughness the most. Best parameters found for surface roughness were cutting speed of 500 m/min, feed rate of 0.10 mm/rev and depth of cut of 0.3 mm.

Khodke [22] investigated the impact of process parameters on surface roughness when end milling aluminum 7075-T6. Signal to noise (S/N) ratio and analysis of variance (ANOVA) were employed in determining the influence of different cutting parameters on the response. According to S/N ratio graphs, the optimal setting of machining parameters for minimum surface roughness was at cutting speed of 2500 rpm, feed rate of 240 mm/min and depth of cut of 2.0 mm. Feed rate has a contribution of 46.36%, spindle speed has moderate contribution 34.78% and depth of cut has the least based on ANOVA.

Vakondios et al. [3] investigated the surface roughness in end milling of the aluminum 7075-T6. A number of experiments testing with different cutting conditions, including cutting speed, axial and radial depth of cut and feed rate were performed and further analysed using regression analysis and analysis of variance. The outcome was to develop a series of mathematical models for the surface roughness. They concluded that the cutting speed was the important parameter affecting the surface roughness.

Varvatte [23] analysed optimization of machining parameters when turning aluminium 7075-T6. Taguchi method was employed and was determined suitable to optimize the surface roughness in turning of 7075-T6. An experiment was conducted with the optimal parameter settings by taking three trials. Optimal parameters setting for surface roughness in turning of aluminium 7075-T6 are 6.376, 6.379 and 6.377 μm and obtained the mean of 6.377 μm. The result showed that the depth of cut is significant parameter that influencing the surface roughness compared to speed and feed rate.

Durakba et al. [24] investigated a relationship between the work piece surface roughness and a cutting tool edge radius when end milling of aluminum 7075-T6. The Taguchi method was used for the experimental design. They found tool edge radius wear as crucial parameter to give the minimum surface roughness.

Rawangwong et al. [25] carried out experimental of optimum surface roughness in face milling of aluminum 7075-T6 using design of experiment (DOE). They employed factorial designs and the result showed that the factors affecting the surface roughness were the feed ratio and the speed, while the depth did not significantly affect the surface roughness. The lower values of surface roughness were obtained at a speed of 2930 rpm and feed of 808 mm/min as shown in Figure 3. It concluded that increased speed and decreased feed tend to lower values of surface roughness.

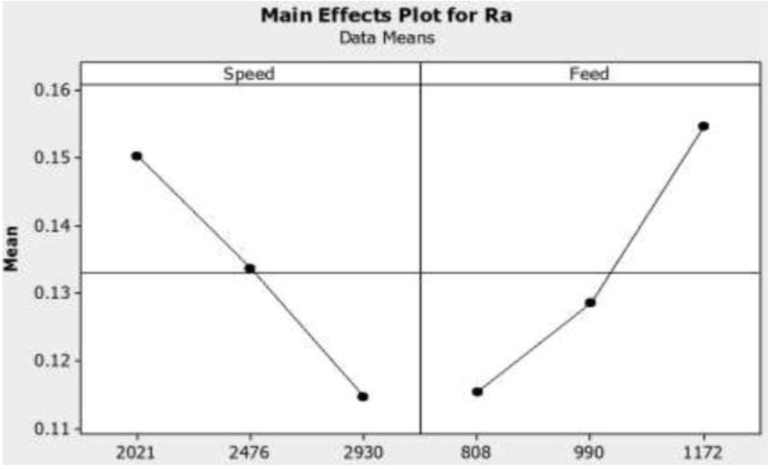


Figure 3: Average surface roughness Ra affected by cutting speed [25]

Cai et al. [26] analyses the experiments on the surface roughness when milling of aluminum 7075 with different cutting conditions. The values of surface roughness were measured in two directions which are perpendicular and parallel to feed. Average surface roughness, Ra was determined by take measurements at three different locations on machined surfaces. Based upon result, the lower Ra values were obtained in the direction along feed than in the perpendicular direction as shown in Figure 4. It concluded that the cutting speed (Vc) was 800 m/min, feed rate (fz) was 0.16 mm/tooth, axial depth of cut (ap) was 10 mm and radial depth of cut (ae) was 2 mm are vital parameters in effect of surface roughness.

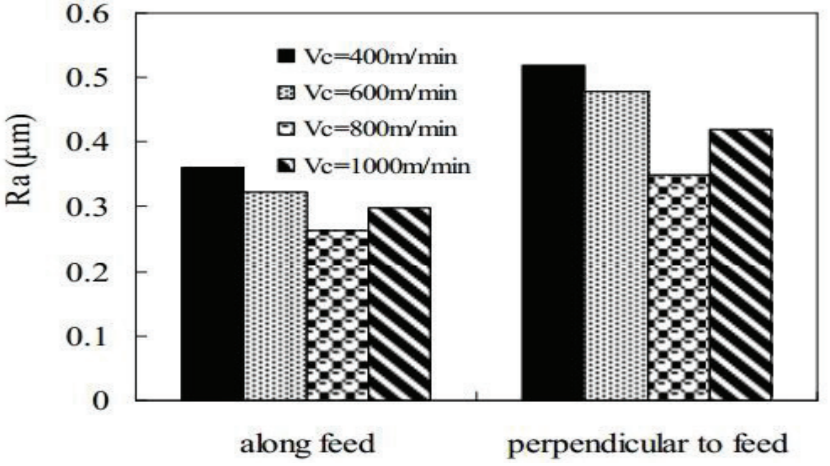


Figure 4: Average surface roughness Ra affected by cutting speed [26]

Anwar et al. [27] analysed optimization of surface roughness for aluminum 7075-T6 in milling process. Response surface methodology (RSM) with central composite design (CCD) technique has been used to carry out the analysis of experimented results. They make the comparison between the actual and predicted as shown in Figure 5 to validate the model generated and obtain an error of 3.29%. The results showed that the model generated is valid and at high cutting speed and low feed rate, lower values of surface roughness have been achieved with the additional depth of cut. They concluded that the minimum value of surface roughness has been obtained at a depth of cut equal to 0.25 mm and cutting speed of 5000 rpm at a feed rate of 900 mm/min. According to observation, the minimum value of surface roughness can be obtained at the lowest cutting speed and feed rate.

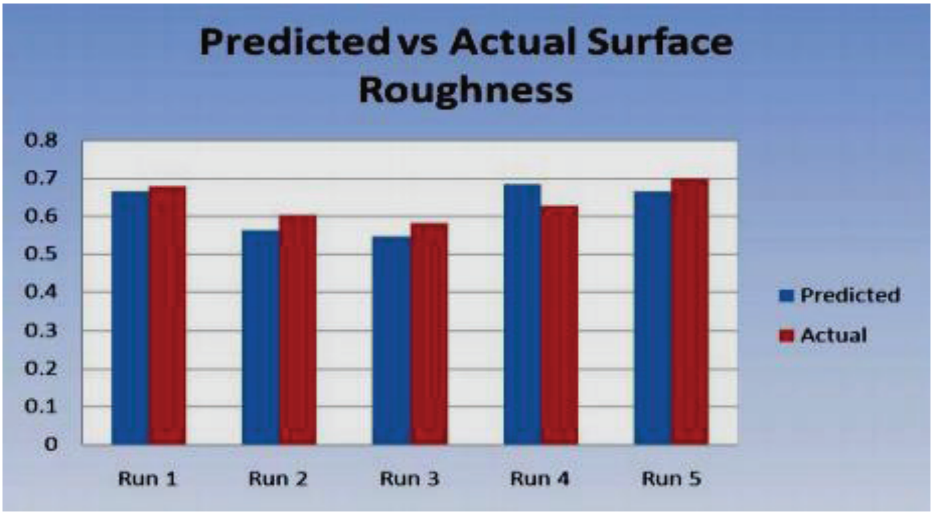


Figure 5: Predicted versus Actual values of Surface Roughness [27]

It was observed that the parameter of tool edge radius wear and depth of cut is less effective into the contribution of surface roughness. Obviously two process parameters, namely cutting speed and feed rate were becoming the superior factor in order to generate the lower value of surface roughness.

## 3.0 SUMMARY

Several studies related to the machining of aluminium 7075-T6 have been carried out over the recent years. Table 1 shows a summary of recent studies on machining of aluminum 7075-T6 in accordance to ascending year. It was observed that more attention is focusing on the milling over turning processes. Aluminum 7075-T6 was seen mostly used in the milling process because possessing the unique properties and commonly used for manufacturing complicated parts in the aerospace industry [3]. Most of the application of milling process was employed cutting under the dry condition as presented in Figure 6 that summarized based upon Table 1.

Table 1: Summary of recent studies on machining of Aluminum 7075-T6

| Author | Cutting process | Cutting tools type | Cutting fluid technique | Cutting parameter | | |
|---|---|---|---|---|---|---|
| | | | | vc (m/min); n(rpm) | fn(mm/rev); fz(mm/tooth); vf(mm/min); f(mm/sec) | ae(mm); ap(mm) |
| [18] | End milling | WC-Co alloy with 6% cobalt, HSS, TiCN-coated HSS tools | Flood 1000 mL/min,MQL 5 ml/min | n: 260, 780, 1330 vc: 8, 25, 42 | vf: 20, 40, 80 | ae:6; ap:1 |
| [3] | Ball end milling | Coated carbide (ACZ350) | Dry | vc: 60 | fn: 0.3, 0.6 | ae: 0.3, 0.6; ap: 0.3, 0.6 |
| [26] | End milling | Cemented carbide insert R390-170416E-KMH13A | Dry | vc: 400, 600, 800, 1000 | fz: 0.1 - 0.2 | ae: 2; ap: 10 |
| [25] | Face milling | Carbide tool model Kennametal type KEGT25L512 PEERLDJ | Dry | n: 2930, 2476, 2021 vc: 580, 490, 400 | vf: 1172, 990, 808 | ap: 0.5 |
| [21] | Turning | TNMG115100 tungsten carbide insert | Dry | vc: 500, 1000, 1500 | fn: 0.1, 0.15, 0.2 | ap: 0.3, 0.5, 0.8 |
| [24] | End milling | Carbide cutting tools (coating) AlTiN/AlTiCN/ZrN | Dry | vc: 50, 75, 100, 150, 200 | fz: 0.05, 0.10, 0.15, 0.20, 0.30 | ap: 0.50, 0.75, 1.00 |
| [19] | Turning | Carbide (DNGP-432 KC5410 Kennametal) | Dry, MQL 1.75, 3 ml/min | vc: 64, 169, 365, 657 | fn: 0.05, 0.1, 0.15, 0.2, 0.3 | ap: 1 |
| [20] | Turning | Kennametal K313 quality CCGT 12 04 04 HP | MQL 0.25, 0.45, 0.90, 3.25 ml/min | vc: 150, 187.5, 240, 300 | fn: 0.1, 0.2 | ap: 2.5 |
| [22] | End milling | End mill 10mm tungsten carbide, four flute | Dry | n: 2000, 2500 vc: 63, 79 | vf: 240, 320 | ap: 2, 2.5 |
| [23] | Turning | TNMG tungsten coated carbide tool insert | Dry | vc: 500, 1000, 1500 | f: 0.1, 0.15, 0.2 | ap: 0.4, 0.6, 0.8 |
| [27] | End milling | End Mill | Dry | n: 4200, 4600, 5000 vc: 335, 367, 399 | vf: 900, 950, 1000 | ap: 0.1, 0.15, 0.25 |

It is well known in general that dry condition could help to minimize the cutting fluid cost and to protect the environment though there are drawbacks on tool interface. In addition, there are a few recent studies apply the cutting speeds in the range of 600 to 1800 m/min that considered as high speed. However, the range of cutting speeds about 500 to 700 m/min was selected as high speeds in this study, even the definition of high-speed is 600 m/min above as shown in Figure 1. Cutting speeds of 500 to 700 m/min is classified as high speed machining after considering the cutting process, the size of the cutting tool and the machine tool's ability to achieve desired cutting speed. MQL becomes a vital technique in this study because it offers favourable solutions.

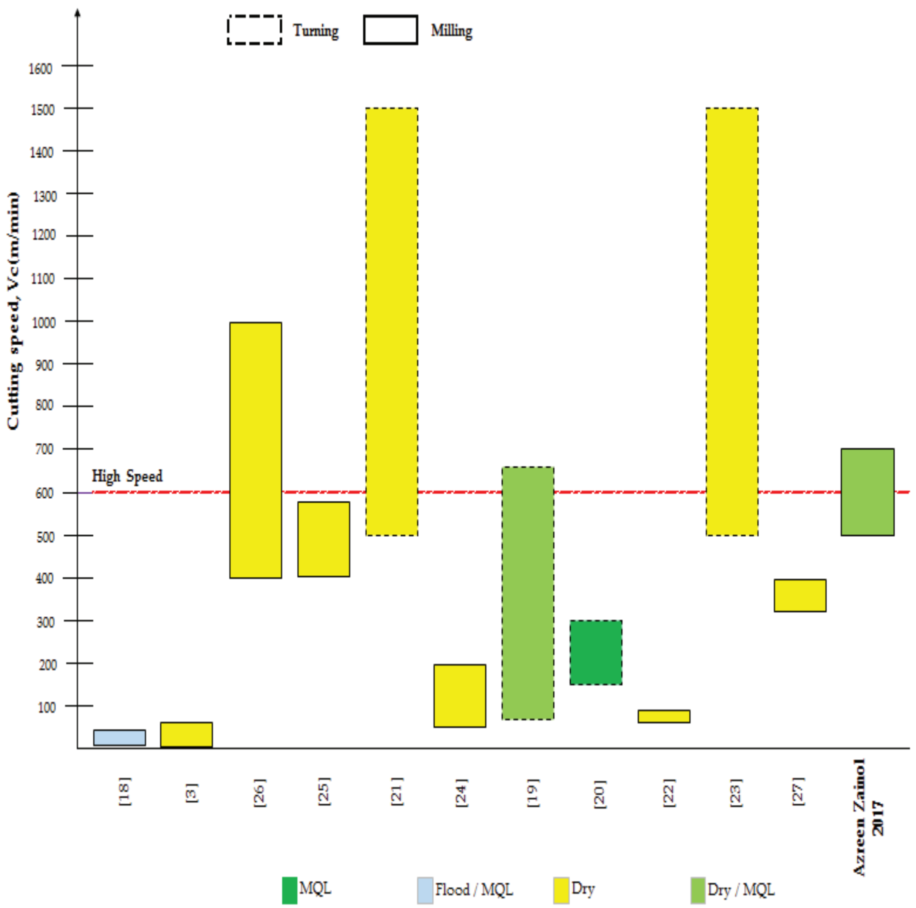


Figure 6: Recent studies chart on machining of Aluminum 7075-T6

## 4.0 CONCLUSION

On the basis of the recent studies findings reported in the overview of MQL and HSM, the major observations are drawn as follows:

- MQL, cutting speed and feed rate are the significant factors on the surface roughness.
- Speed of 657 m/min and 3 ml/min of flow rate under MQL is the promising parameter on the chip formation when machining aluminium 7075-T6.
- Most of the milling process applied the cutting speeds below 600 m/min.

## ACKNOWLEDGMENTS

The authors would like to thank Universiti Kuala Lumpur Short Term Research Grant (STR 15051) for financial support to carry out this study.

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