

## Effect of Workpiece Orientation, Lubrication and Media Geometry on the Effectiveness of Vibratory Finishing of Al6061

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**Abstract.** Vibratory Finishing is a commonly used process for deburring and polishing. The process effectiveness is difficult to quantify due to a nexus of variables relating to workpiece, media, compound and machine. In this paper, effect of orientation of rectangular Al6061 workpieces is considered with respect to the motion of ceramic media using water as lubricant. It is found that parallel orientation of workpiece to media motion and higher lubrication level lead to higher degree of sliding, thereby leading to smoother finish. Experiments with different ceramic media showed smoother finish with the geometry more susceptible to rounding. The aforesaid findings can be employed in applications requiring superpolished surfaces.

### 1 Introduction

Vibratory Finishing is a secondary manufacturing process employed for surface modification of components. Vibratory finishing can perform different roles of polishing, deburring, cleaning etc. and is extensively used for wide range of products [1]. Vibratory Finishing cannot remove heavy burrs and process internal features of components. Vibratory or Media Finishing works by abrasive action of pellets called Media against the workpiece. This is primarily done by means of a vibrating bowl/ trough to impart energy to the contents therein. Media refers to the abrasive grit used for finishing. Media is a composite comprising of abrasive particles embedded in a binder matrix. Mass Finishing media is generally made from ceramic, plastic or metal.

Compound is usually added to a Mass Finishing operation to act as a lubricant and cleaning agent. Some compounds can be chemically reactive and aid in the material removal process. Higher degree of lubrication increases the tendency for media to slide than create normal impacts. Reduced ratio of normal to tangential impulse decreases the extent of plastic deformation per impact, thereby leading to lower hardness. Better lubrication also results in lower friction coefficient, thus reducing the amount of pitting damage per impact on the surface, leading to finer polishing [2]. Presence of lubrication also reduces the amount of embedded ceramic wear debris in the workpiece, leading to

smaller Ra [3]. It is realized that presence of too much compound is likely to reduce the degree of vibratory action due to dampening of media motion [1].

It has been observed that under unlubricated (“dry”) conditions impacts tend to be more of normal type while tangential sliding is more frequent in the lubricated (“wet”) conditions. Higher values of impact forces and frequency of impact rate occur in the “dry” conditions as compared to “wet” conditions. The higher probability of normal impact signifies that vibratory finishing in the “dry” condition results in a “peening” effect as compared to a polishing effect in the “wet” condition. It was also found that a larger proportion of the specimen surface tends to be covered by media debris or lodged in the after “dry” finishing as compared to “wet” finishing [3]. This may be due to the washing effect of the lubricant cleaning away the debris in the “wet” condition.

It has been found that the direction of media motion is critical to determine the principal type of wear. Adhesion wear is caused due to media slippage against workpiece surface while abrasive wear occurs due to media impacting normally to the workpiece [4].

Media geometry is also known to affect polishing results. Experimental studies show that Material Removal Rate (MRR) is maximum for media with the highest roughness [5]. Presence of grooves on media surface and increased number of edges increases the MRR. Higher MRR results in a rougher surface [4].

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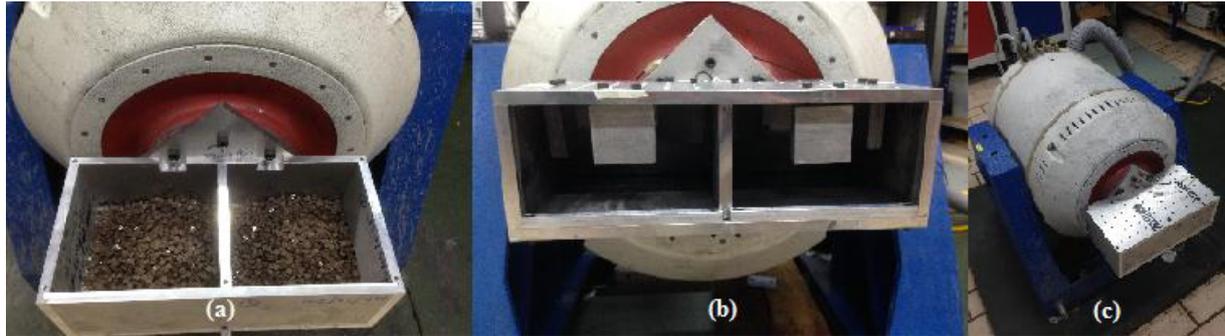
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## 2 Experimental Setup and Procedure

In order to create controlled vibratory conditions, a purpose-built setup was arranged. TIRA Vibration Test System (TV 55240/LS-180) Electrodynamic Shaker was used to generate one-dimensional vibrations. Sinusoidal pattern with 3mm amplitude running at 50 Hz was created for all the experiments. A two-chambered Aluminium box was constructed and attached to the TIRA Shaker, as shown in Fig. 1. As a result of the one-dimensional vibration of the box, the contained media exhibits planar motion along the direction of vibration. Two different

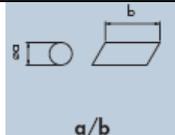
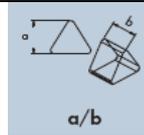
experimental conditions could be created in the individual chambers independently while keeping the same vibration profile. The workpieces used were 50mm x 50mm x 10mm flat Aluminium plates in pre-machining condition. The workpieces were screwed through the perforated lid of the box as shown in Fig 1. Ceramic media of two different geometries – Angle Cut Cylinder (ACC) and Triangular (TRI) were used for testing, as shown in Table 1. Water was used as lubricant for the experiments. No recirculation system was employed unlike most commercial vibratory polishing setups.



**Figure 1.** (a) Two-chambered Aluminium container attached to the TIRA Shaker. (b) Al 6061 workpieces attached through the perforated lid. (c) The complete experimental assembly.

Prior to polishing, Roughness Average (Ra) values of the workpiece surfaces were measured at three evenly spaced locations. Form Talysurf Profilometer from Taylor-HobsonTM was used for Ra measurements. Arithmetic mean of Ra values from 3 evenly spaced tracks was used in each case. The aluminium work-pieces were then attached at their assigned locations and orientations on the container lid using screws. 3 different orientations: planar, perpendicular and 45o diagonal with respect to media motion were created. Media was then transferred into the shaker container and the appropriate amount of lubricant for each trial was added. Lubrication level was determined by water-to-media weight ratio. Thereafter the lid supporting the work-pieces was secured to the container using screws and the TIRA vibration shaker was run for a time period of two hours. At the end of two hours, the used media was removed and a new set of experiments was started. Media mass was measured by taking 100 random media samples, dried to remove the absorbed moisture.

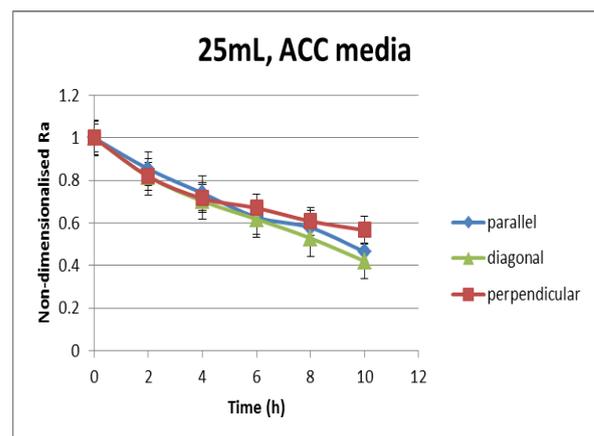
**Table 1.** Specifications of Media used for experiments.

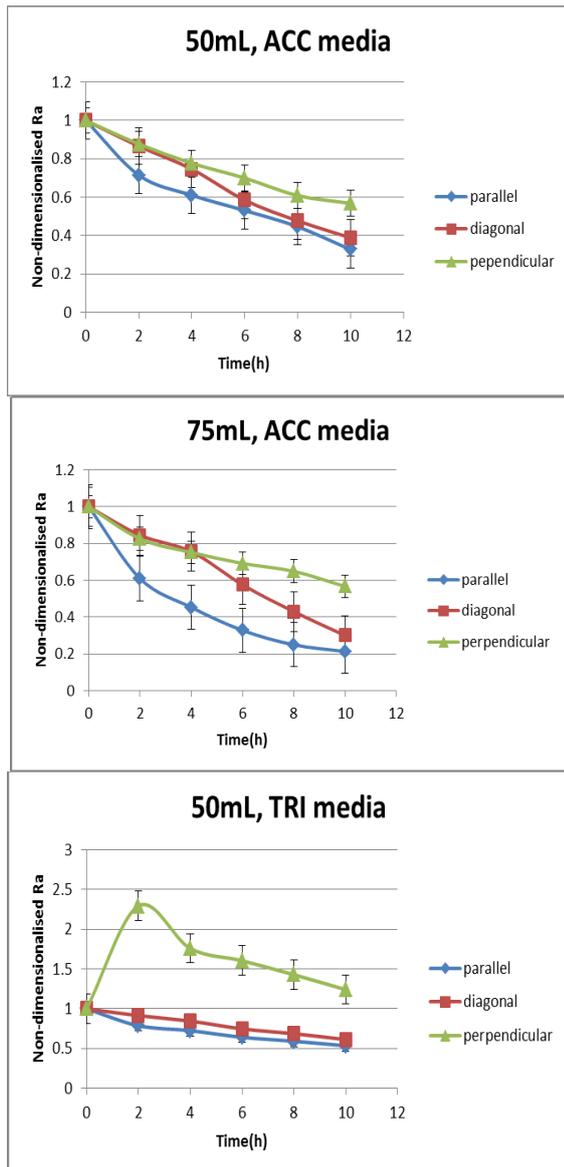
Shape	Angle Cut Cylinder (ACC)	Triangle (TRI)
Material	Ceramic	Ceramic
Dimensions	 a/b 04/05 mm	 a/b 06/06 mm

## 3 Results and Discussion

### 3.1 Effect of workpiece orientation:

The 3 orientations created (planar, perpendicular and diagonal) were then tested with different lubrication levels. The non-dimensionalised Ra value of the workpiece surfaces was plotted for different test cases, as shown in Fig. 2. The Ra values were non-dimensionalised by dividing the absolute values with the initial roughness value of the unpolished surface.



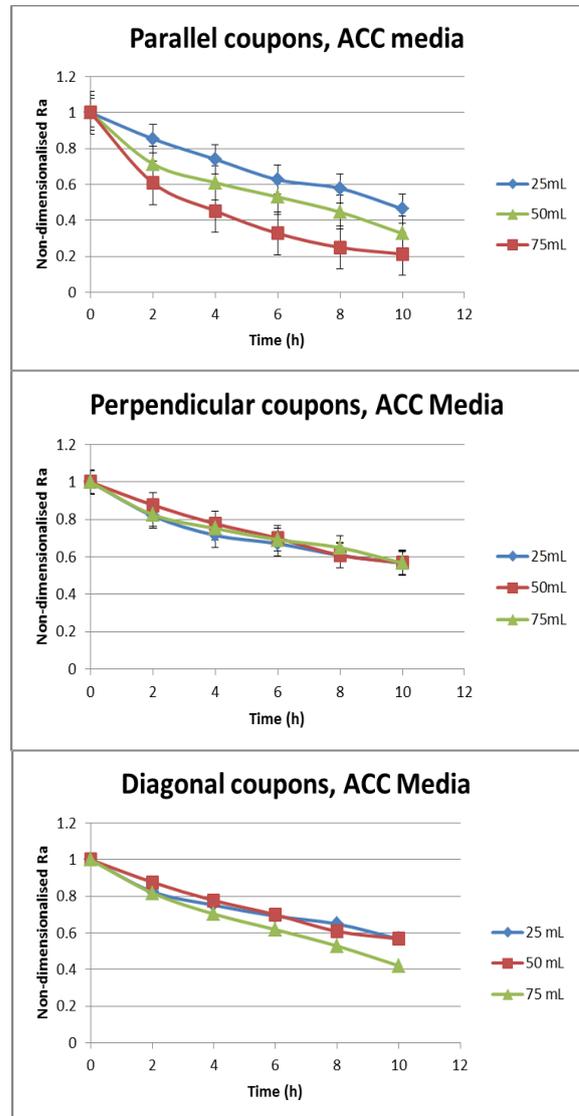


**Figure. 2.** Effect of variation of workpiece orientation on workpiece Ra. Results for different lubrication levels and media types are shown.

Comparing the graphs plotted in Fig. 2, it can be seen that the roughness average values (Ra) achieved are clearly affected by the difference in workpiece orientation. At the end of 10 hours, parallel orientations generally achieve a lower value of Ra, followed by diagonal orientation and then perpendicular orientation. This means that parallel orientation results in a smoother surface or has the best rate of polishing, while perpendicular orientation generally has the worst polishing effect. This holds true for both angle-cut cylinder and triangle shaped media. However, there was an anomalous trend in 50mL, TRI media case where Ra values for the perpendicular orientation spiked sharply after the first 2 hours of testing and steadily decreased thereafter. This can be attributed to the relatively sharp edges of the triangle media impacting against the specimen, creating a pitted surface and increasing the Ra value. After the initial few hours, the media edges generally get blunted hence pitting effect was

reduced and polishing effect became dominant, resulting in gradual decrease in Ra values.

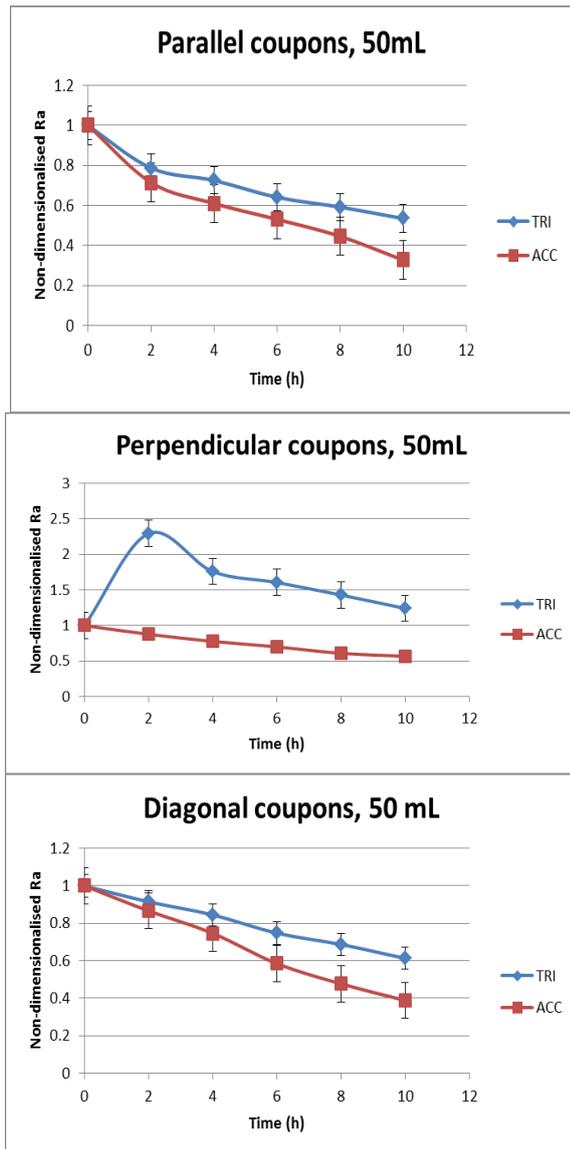
**3.2 Effect of lubrication:**



**Figure.3.** Effect of varying lubrication level (water quantity) with ACC media for Parallel, Perpendicular and Diagonal workpiece orientations.

Comparison of Ra values achieved by angle-cut cylinder media (ACC) at different levels of lubrication and at different orientations is shown in Fig. 3. For the parallel and diagonal orientations, there is a distinct improvement in the polishing characteristics as lubrication (water- to-media weight) ratio increases, in agreement with [2] and [3]. It is to be noted that the effect of lubrication is the most pronounced in parallel orientation, followed by diagonal and perpendicular. For the perpendicular orientation, increasing lubrication does not have any visible effect on the Ra values. The peening effect due to perpendicularity of workpiece is observed to be dominant even in the presence of lubrication.

**3.3 Effect of Media Geometry:**



**Figure.4.** Effect of varying Media type for Perpendicular and Diagonal workpiece orientations. Lubrication level is kept constant at 50mL of water for each case.

Fig. 4 compares the results for the two different media at a constant level of lubrication (water-to-media weight ratio of 50:1000) in the 3 different orientations. From the plots, it can be seen that for all three orientations, the angle-cut cylindrical media is able to achieve significantly better Ra values as compared to the triangular media. Triangular media has more number of edges than the angle-cut cylindrical media. Owing to geometry, the former has sustained edges while the latter gets rounded faster. Higher

sharpness level of triangular media can explain the rougher finish thus obtained, for all the 3 orientations.

## Conclusion

The one-dimensional vibratory finishing experiments performed on Al 6061 coupons using ceramic media show that a parallel workpiece orientation leads to smoother finish due to greater degree of sliding as mentioned in [4]. Variation of water-to-media ratio, i.e. lubrication level shows that higher degree of lubrication results in smoother surface finish, as explained in [2] and [3]. Moreover, no lubrication recirculation was employed for these experiments which resulted in debris suspended within the experimental chamber. In industrial practice, lubrication mechanism for vibratory finishing is almost exclusively circulatory which is expected to remove debris and provide a better finish. Finally, experiments with different media geometry suggested that higher geometrical sharpness results in a rougher surface finish, as observed in [4] and [5].

## Acknowledgements

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