Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 17 Issue 2 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN:2249-4596 Print ISSN:0975-5861

Effect of Particle Concentration and Sliding Velocity in Magnetic Abrasive Finishing of Brass Pipe

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GJRE-A Classification: *FOR Code: 290501*

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Strictly as per the compliance and regulations of:

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Abstract- The present study investigates the influence of magnetic field on the internal surface finish of Brass UNS C26800 pipe. The input parameters such as sliding velocity of electromagnets, concentration ratio (castor oil and magnetic abrasive particles) and number of cycles were varied in the selected range and their effect was comprehended in terms of percentage change in surface finish (%ΔRa). The remaining process parameters were kept constant throughout the experimentation. According to the results, %ΔRa initially increases and afterwards decreases with an increase in sliding velocity of electromagnets in case of concentration ratio 7:3 and 8:2. But, in case of concentration ratio 9:1, there is uniform increase in %ΔRa with an increase in sliding velocity. Also, at low sliding velocities (0.62 mm/sec and 1.23 mm/sec), the %ΔRa decreases with an increase in concentration ratio but at 2.46 mm/sec, the %ΔRa increases with increase in amount of oil added.

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I. Introduction

The surface finish has a vital influence on the surface properties such as wear and friction on most of the engineering applications (Boparai et al., 2017). Magnetic abrasive finishing (MAF) is a super finishing process which uses a resilient multi point cutting tool to finish the work pieces (Kala and Pandey, 2014). A mixture of abrasive powder and ferromagnetic powder form the polishing tool called flexible magnetic abrasive brush (Givi et al., 2012). An internal magnetic abrasive finishing process was proposed for producing highly finished inner surfaces of tubes used in critical applications including clean gas or liquid piping systems (Yamaguchi and Shinmura, 1999). By varying various process factors, the finishing force and torque acting on the workpiece can be varied and thus, surface finish can be improved.

The various analytical parameters such as spindle speed, type of abrasives, electromagnet - workpiece gap, percentage weight of abrasives, magnetic flux density, no. of cycles, processing time etc. were studied by many researchers for optimization. Most of the researchers have concentrated on surface finishing at single location in the pipe. But, for practical applications, it is required to finish the whole internal surface of pipe. The present research work has explored the effect of varying sliding velocity of electromagnets on surface finish and material removal rate.

Magnetorheological Finishing uses the Magnetorheological (MR) polishing fluid for the precise finishing of components (Bedi and Singh, 2015). The magnetic abrasives particles mixed oil provides better and controlled internal finishing of pipes (Jha and Jain, 2004). But, hitherto no study has been performed to evaluate the impact of variable concentration ratio of oil and abrasives. Thus, castor oil is mixed with Magnetic Abrasive Particles (MAP) to gain better control over the nano finishing for the present work.

Also, as cited by many researches, number of cycles plays a crucial role in MAF process (Kala and Pandey, 2014; Givi et al., 2012). Hence, number of cycles has been varied in order to achieve controlled and efficient surface finish. The full factorial experimental design has been considered to study the influence of analytical parameters such as sliding velocity of electromagnet, concentration ratio (castor oil to abrasive mixture) and number of cycles of electromagnet on the surface finish. The remaining parameters were kept constant throughout the experimentation.

II. Experimentation

The workpiece material Brass UNS C26800 was taken and two types of abrasive materials i.e. Iron (Fe) and Iron Oxide (Fe_3O_4) were used throughout the experimentation. The average particle size of nano abrasives was 30-40 nm whereas for micro abrasives it was 350-450μm. The specialized designed experimental apparatus (Figure 1) has been used which facilitates the variation in sliding velocity of electromagnets along the horizontal axis of brass pipe.

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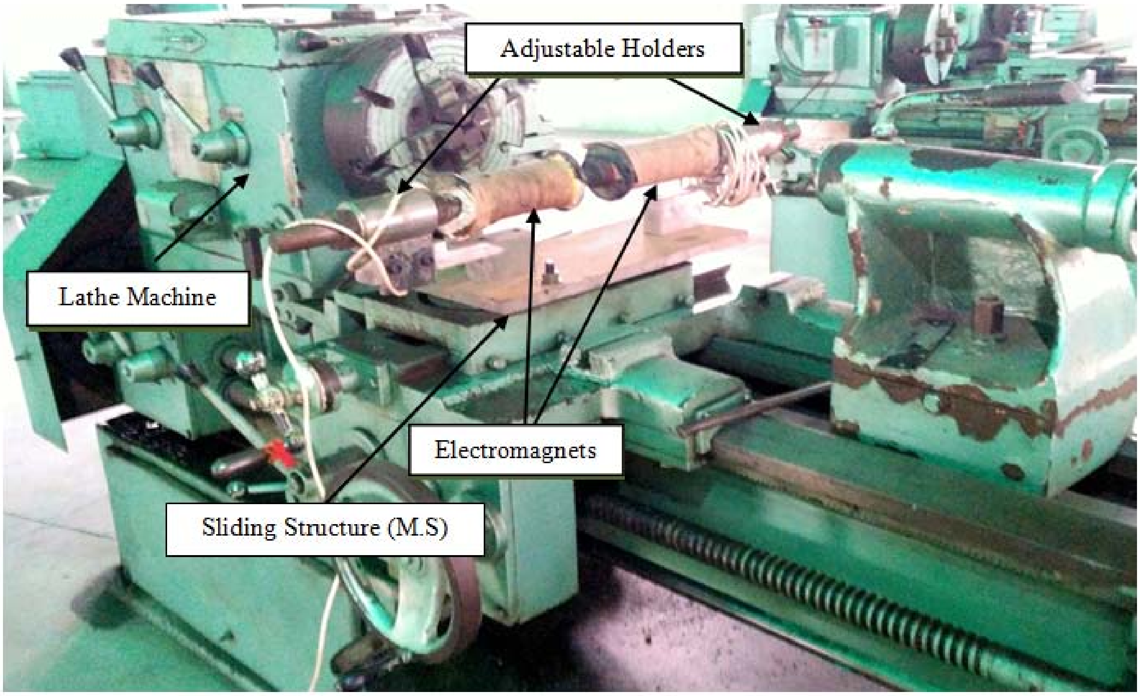


Figure 1: Schematic of experimental setup

The variable and fixed input parameters have been shown in Table 1 and 2 respectively. The range of variable input parameters has been worked out based on pilot experiments and previous studies carried out in case of conventional lathe machines (Boparai et al., 2017).

Table 1: Variable input parameters

S.No.	Input Parameters	Range
1.	Sliding velocity of electromagnets (mm/s)	0.62, 1.23, 2.46
2.	Concentration Ratio (castor oil to MAP) (vol.)	7:3, 8:2, 9:1
3.	No. of cycles	1, 2

The Magnetic abrasive particle (MAP) ratio has been fixed as 3:1 against magnetic flux density of 0.2 Tesla. The effect of selected process parameters was studied on the surface finish and material removal rate (MRR) of magnetic abrasive finishing.

Table 2: Fixed input parameters

	Input Parameters	Range
1.	Workpiece material	Brass UNS C26800
2.	Type of Abrasive	Fe_3O_4
3.	Magnetic flux density	0.2 Tesla
4.	Voltage	220 – 230 V
5.	Current	4 A
6.	Rotational speed	600 rpm
7.	Workpiece gap	2 mm
8.	MAP ratio	3:1

The surface roughness was measured at eight different locations at both ends of brass pipe workpiece with the digital “Surftest SJ 210” roughness tester having stylus tip radius 2µm and tip angle 60°C with measuring force 0.75mN. The measurements were taken employing Gaussian filter, cut-off length 0.25 mm and 2.5 mm exploratory length as per ISO-4287 regulations. Surface roughness (Ra) average values was calculated from mean of eight measurements and percentage improvement in roughness was estimated as:

$$\%\Delta Ra = \frac{(\text{Initial Roughness} - \text{Final Roughness})}{\text{Initial Roughness}} \times 100$$

III. Results and Discussions

The impact of sliding velocity on percentage improvement in surface finish varied due to blunting of abrasive particles in case of concentration ratio 7:3. As shown in Figure 2, initially the %ΔRa increases but upto a certain limit and then starts decreasing at high velocity of particles. Mishra et al., 2013 stated that rubbing action of magnetic abrasive particles with the work surface resulted in the generation of high frictional forces between them and causes wear of abrasives. With the increase in linear velocity of electromagnets, frictional force increases followed by the high spindle speed which causes blunting of abrasives. Due to blunting of abrasives, the cutting ability of abrasives is reduced which further decreases %ΔRa. Djavanroodi (2013) also found that the blunting of abrasive particles resulted in the slow improvement in surface finish.

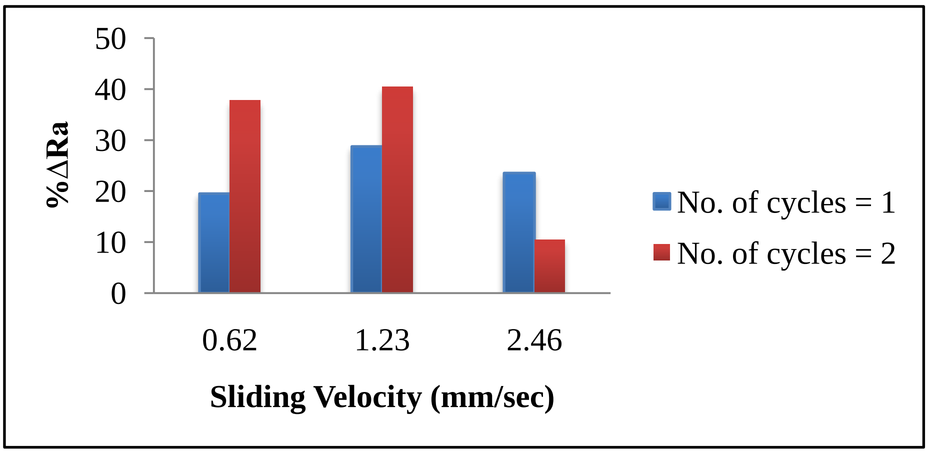


Figure 2: Effect of sliding velocity on surface finish with concentration ratio 7:3

The impact of sliding velocity in case of concentration ratio 8:2 has been plotted in Figure 3 which shows similar results as discussed earlier., As the sliding velocity increases, the surface finish increases but upto a certain limit and then starts decreasing. As rubbing action increases, more amount of lubricant (8:3) could not recompense the blunting of abrasives at very high sliding velocity.

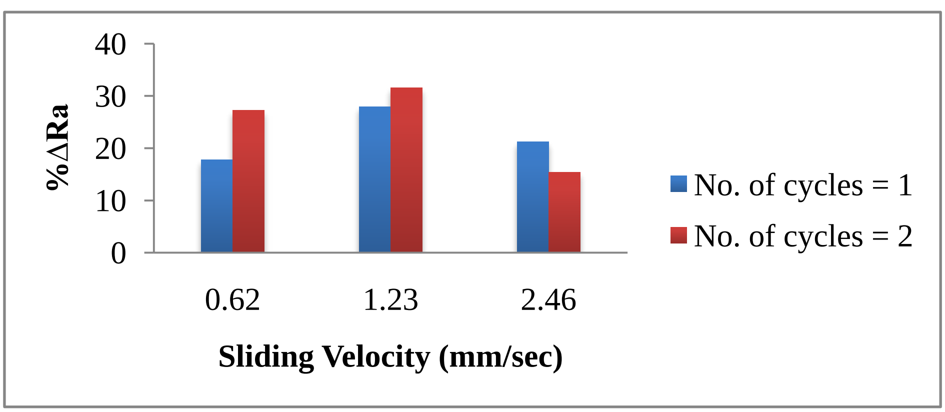


Figure 3: Effect of sliding velocity on surface finish with concentration ratio 8:2

However, the results are different at concentration ratio 9:1where uniform increase in %ΔRa is noted with an increase in the sliding velocity (Figure 4). At higher concentration ratio, the findings are relatively different than 7:3 and 8:2. The higher concentration of castor oil ensures the smooth cutting action and thus blunting of abrasives is prevented as castor oil also acts as lubricating agent. However, in this case the phenomenon of material embrittlement dominates the blunting of abrasives. As the sliding velocity increases, the surface undergo work hardening and thus surface profiles become brittle which can be fragmented easily by the sharp abrasives. Singh et al. (2008) suggested that the amount of material removal and %ΔRa for a particular setting of the process parameters depends upon the ability of the work surface to undergo work hardening and subsequent embrittlement. In present case (concentration ratio 9:1), the phenomenon of which improves cutting action at high velocity.

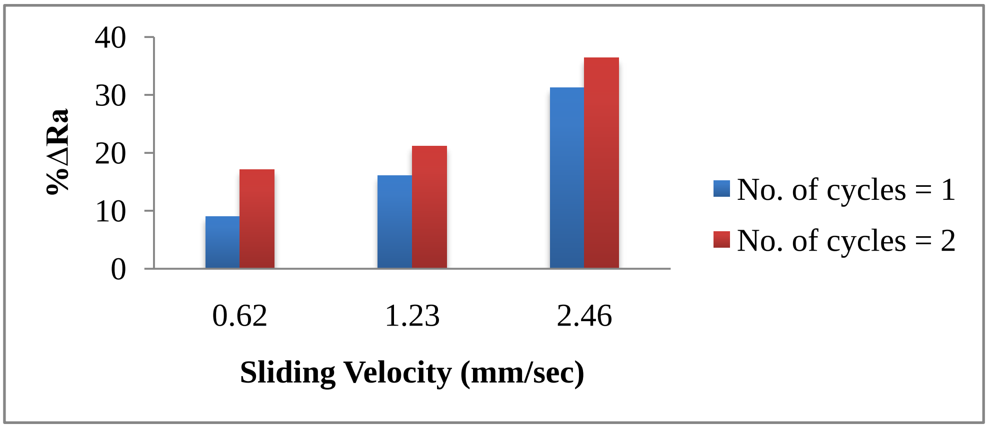


Figure 4: Effect of sliding velocity on surface finish with concentration ratio 9:1

The percentage improvement in surface finish (Figure 5) decreases with the increase in amount of castor oil added in magnetic abrasive particles at sliding velocity 0.62 mm/sec. This might be due to the reasons that with higher concentration of oil, the abrasive mixture become thick. Patil et al. (2012) explained that the oversupply of lubricant could either cause fluid lubrication between the abrasives and the workpiece or wash away the abrasives from the finishing area. This reduces the number of cutting edges acting on the surface, thereby disturbing the finishing action (Sharma and Singh, 2013).

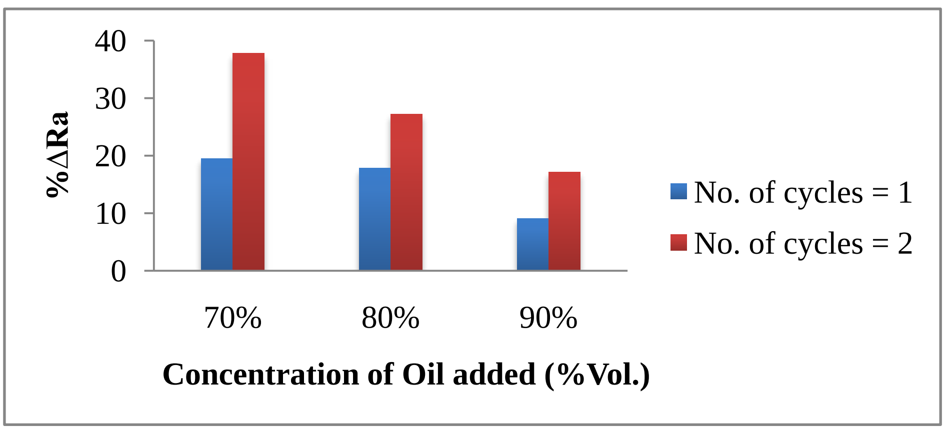


Figure 5: Effect of concentration ratio on surface finish at sliding velocity 0.62 mm/sec

The percentage improvement in surface finish (Figure 6) decreases with the increase in concentration ratio at sliding velocity 1.23 mm/sec. Similar results are found at sliding velocity 0.62 mm/sec.

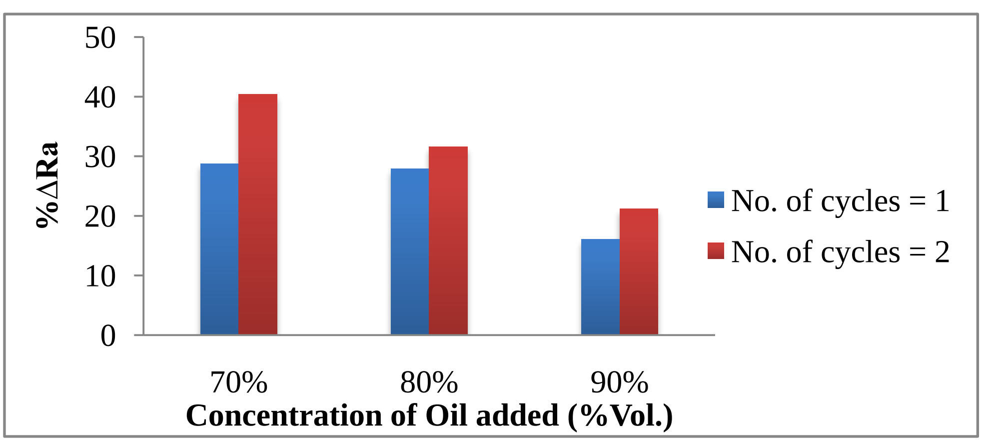


Figure 6: Effect of concentration ratio on surface finish at sliding velocity 1.23 mm/sec

Figure 7 depicts the impact of concentration ratio on percentage improvement in surface finish at sliding velocity 2.46 mm/sec. Results are quite different from sliding velocities 0.62 mm/sec and 1.23 mm/sec. At high sliding velocity of electromagnets, particles move with very high linear speed followed by high spindle speed carrying workpiece (Jain et al., 2001). Thus, the proper lubrication at high velocities provides better and smooth control over the surface.

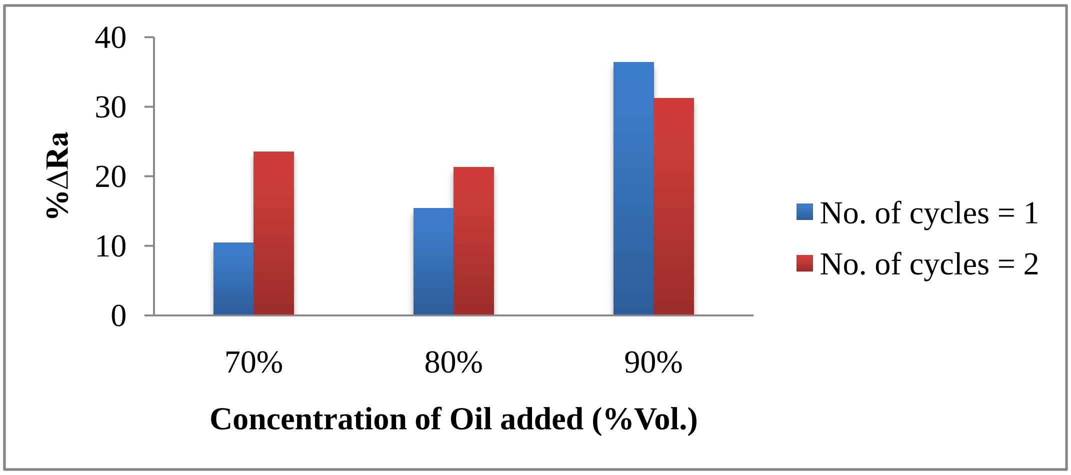
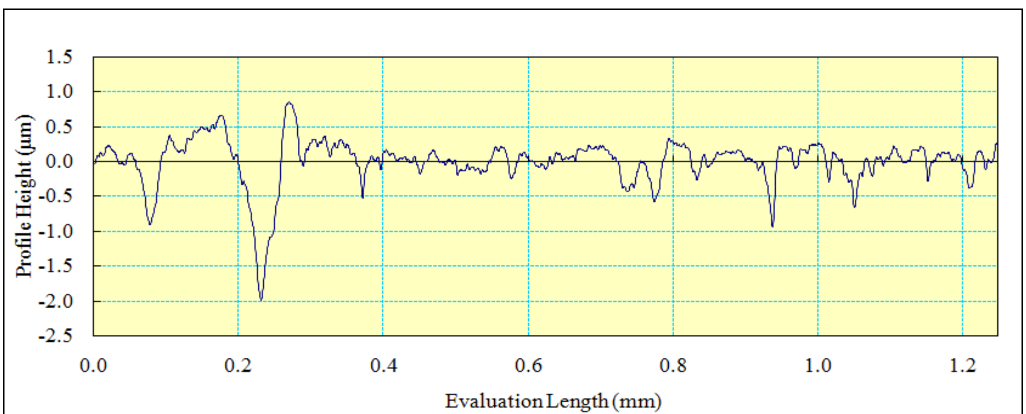


Figure 7: Effect of concentration ratio on surface finish at sliding velocity 2.46 mm/sec

The surface profiles were generated using the surface roughness tester (Mitutoyo Surftest SJ-210) with the help of communication tool during internal surface testing of pipes taken before and after experimentation. The experiments are selected randomly with comparatively different process parameters that offered best results out of the entire practice.

The roughness profiles have been arranged in Figure 8 for experiment performed at 1.23 mm/s, concentration ratio 8:2 and one cycle. The maximum height of profile before finishing is around 2.75 μm and after finishing is around 0.9 μm. This means that magnetic abrasive finishing assisted magnetorheological finishing diminishes the grooves or plows of the surface and smoothen the surface which results in the change in average height of the roughness profile (Verma et al., 2016).



(a)

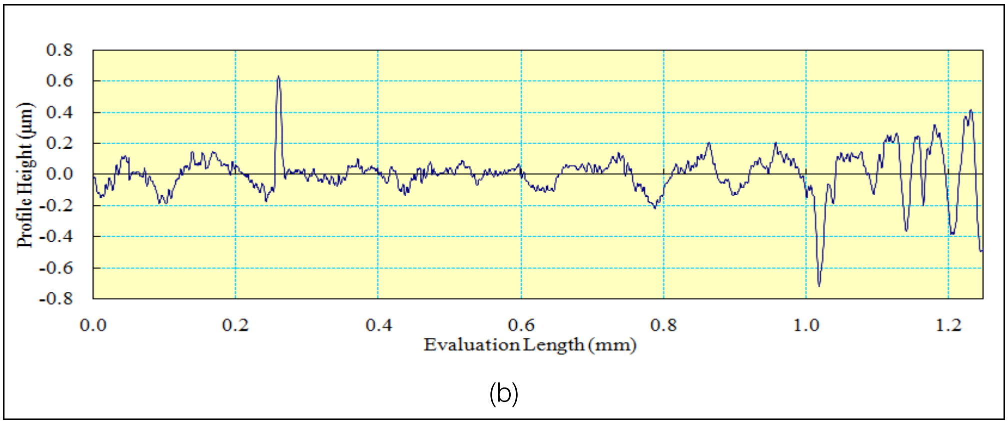


Figure 8: Roughness profiles (a) Before Finishing (b) After Finishing

The Figure 9 plots the roughness profiles acquired during experimentation at sliding velocity 1.23 mm/s, concentration ratio 7:3 and two cycles. The maximum profile height before finishing is around 2.0 μm and after finishing is around 1.6 μm. So, there is reduction in maximum profile height and also the graph is stable towards the centre line after the finishing process which results in the impressive reduction of average roughness (Ra) throughout the process.

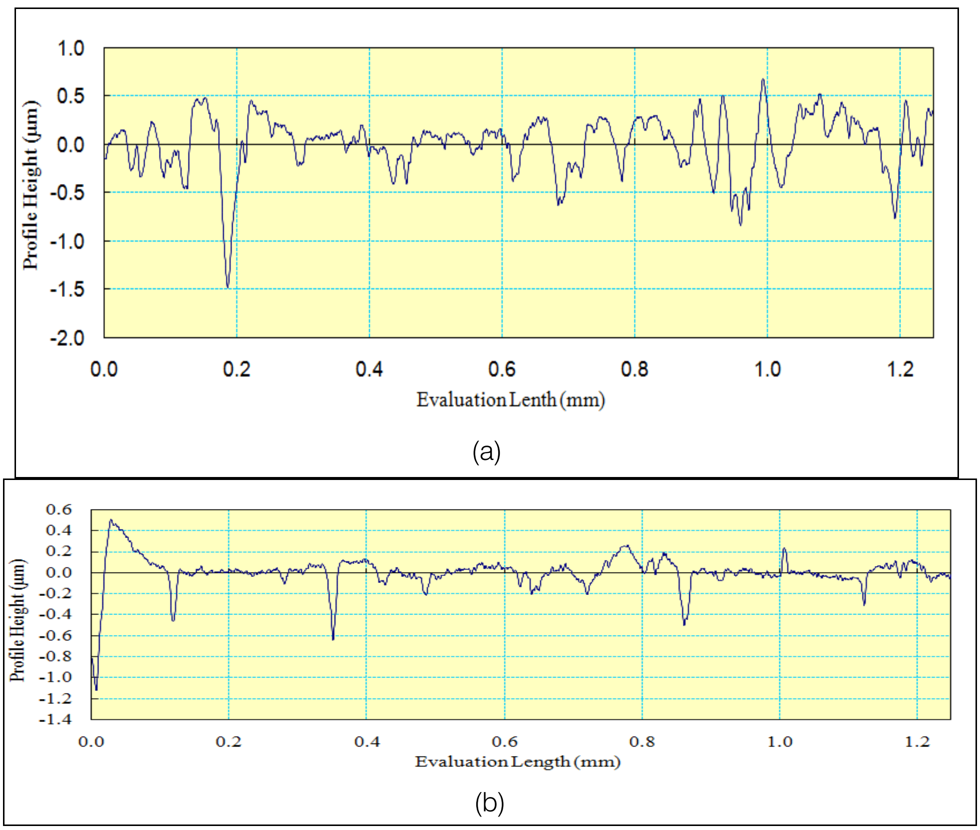


Figure 9: Roughness profiles (a) Before Finishing (b) After Finishing

IV. Conclusions

The investigative parameters such as sliding velocity, concentration ratio and number of cycles have been analyzed in the present research work using Brass UNS C26800 pipe. The surface finish improves with an increase in number of cycles of electromagnets. The amount of castor oil added in the abrasive mixture has significant effect on the percentage improvement in surface finish (%ΔRa). The surface finish improves with an increase in sliding velocity of electromagnets in case of concentration ratio 9:1 as brass undergoes embrittlement which ensures efficient micro-cutting. However, in ratio 7:3 and 8:3, the surface finish initially increase and afterwards decreases with an increase in sliding velocity which has been attributed to blunting of abrasives. The findings could be beneficial for brass pipe manufacturing industry as the internal finish of thin pipes has significant impact on fluid velocity, losses and turbulence in fluid.

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