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A COMPARATIVE STUDY OF PARAFFIN WAX AND BEESWAX WITH A VIEW TO SIMULATING WATERJET DRILLING OF ROCKS

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Abstract

Properties of rock samples vary depending on their origin and historical pathway. The effective drilling efficiency within a rock depends on rock properties. Because field experimentation is prohibitively expensive, laboratory testing is the most useful technique for testing a technique for drilling efficiency. It is generally acceptable to scale certain parameters in order to have a clear idea about the field applicability. This paper takes a novel approach in simulating drilling in the laboratory scale. The behavior of rock is simulated with beeswax, while the behavior of steel is simulated with paraffin wax. The rationale for this simulation is that beeswax is a natural material and, therefore, would simulate the characteristics of rock, while paraffin wax (a 'refined' product) would do the same for steel, another 'engineered' product. The efficiency of waterjet drilling is investigated using paraffin wax and beeswax samples as the simulated medium. Parameters such as depth of penetration (DOP), rate of penetration (ROP), flow rate, pressure, temperature, thermal exposure time, distance between jet-tip and sample top surface have been investigated. The results show that beeswax is closer to the real rock matrix of formation which can be used as a rock sample in any experimental drilling activity.

Keywords: waterjet; drilling; beeswax; paraffin wax; depth of penetration; rate of penetration.

1. Introduction

Existing rotary drilling systems are capable of drilling shallow directional holes. However, the equipment is heavy, drilling rates are low and costs are high. For any drilling system, the factors such as type of formation, depth of drilling and depth of desired screen setting should be considered when selecting an appropriate drilling method. Therefore, to overcome the limitations of conventional rotary drilling technique,

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waterjet drilling may be the best solution. Due to this reason, waterjet drilling is becoming a popular technique.

High pressure waterjet drilling (HPWD) need not require any torque or thrust during jet erosion. For this reason, HPWD supplies an exclusive capability for drilling a constant radius directional hole without any steering corrections. Moreover, pure waterjet drilling is less sensitive to formation changes than rotary drilling because cutting is controlled by the bit orientation. Chemical additives are used in rotary drilling system. HPWD present high rates of penetration because the power available at the bit is extremely high. Rotary drilling provides slightly higher drilling rates. However, this approach generates torque loads and these loads can cause the hole trajectory to spiral. HPWD is capable of rapidly drilling small-diameter holes in a wide range of erosion-resistant rock types. Finally, a HPWD system could be made very lightweight because the thrust and torque requirements are nominal. The HPWD systems have little loss of pressure or power throughout its drill pipes. The bit power is essentially equal to the power available at the surface.

Normally, high strength, high permeability rock types such as Berea sandstone has a low specific energy and threshold pressure. Medium strength, low permeability rocks such as limestones and sandstones have intermediate specific energy. Finally, High-strength, low permeability rocks such as granite, quartzite and basalt have high specific energy and threshold pressures. As a result, it is necessary to compare the characteristics of different laboratory samples for getting a real reservoir rock feature. This comparison is helpful to simulate or upscale the laboratory findings for a real formation rocks. Based on the batter benefits comparing with other rotary drilling system, waterjet technology has been the topic of many researchers due to its variety usages in the industry. As a result, recently, researchers are very interested on this tropic.

Buset et al. (2001) described the penetration effects on formation zone due to waterjet technology. Lia et al. (2001) pointed out that the combined cutting effect of waterjet and polycrystalline diamond compact (PDC) is very effective in very hard rocks. They did experiments on waterjet and PDC for ROP in hard rocks. However they did not compare the behavior of rocks. Arangath et al. (2002) discussed the high hydraulic horsepower jetting tool which is used for scale removal. They have also shown waterjetting in horizontal well drilling. Dunn-Norman et al. (2002) discussed processes for sustainable recovery of heavy oil from ultra-shallow reservoirs, using low cost, innovative horizontal drilling and completion methods. They have argued the use of waterjet drilling over 15,000 ft (5,000 m) which is more competitive with the conventional rotary drilling system. They also concluded that waterjet drilling methods appear most favorable for drilling horizontal wells in ultra-shallow reservoirs.

Recently, Hossain et al. (2007a) have briefly described the contributions of different researchers on waterjet drilling and the importance of this technology. They have developed some empirical relationships using waterjet drilling on ROP, DOP based on paraffin wax as a sample. They determined through laboratory experiments the variation of depth, ROP, temperature, flow rate and pressure with time. The variations of depth and ROP with temperature, side effect and thermal exposure time have also been studied. Hossain et al. (2007b) developed some empirical relationships using waterjet drilling on

ROP, DOP based on beeswax as a sample. They reported the variation of depth, ROP, temperature, flow rate and pressure with time. They also reported depth and ROP with temperature, side effect and thermal exposure time. Moreover, they studied the effects of gap variation between drill bit tip and sample top surface. However, both papers did not study the variation of the sample effects in waterjet drilling and the comparison of laboratory samples.

In this paper, some of the questions, as related to scaling of rock with a different medium during waterjet drilling operations are answered. A series of experimental work have been conducted to investigate and compare the effects of different influential parameters such as DOP, ROP, flow rate, pressure and temperature on laboratory samples.

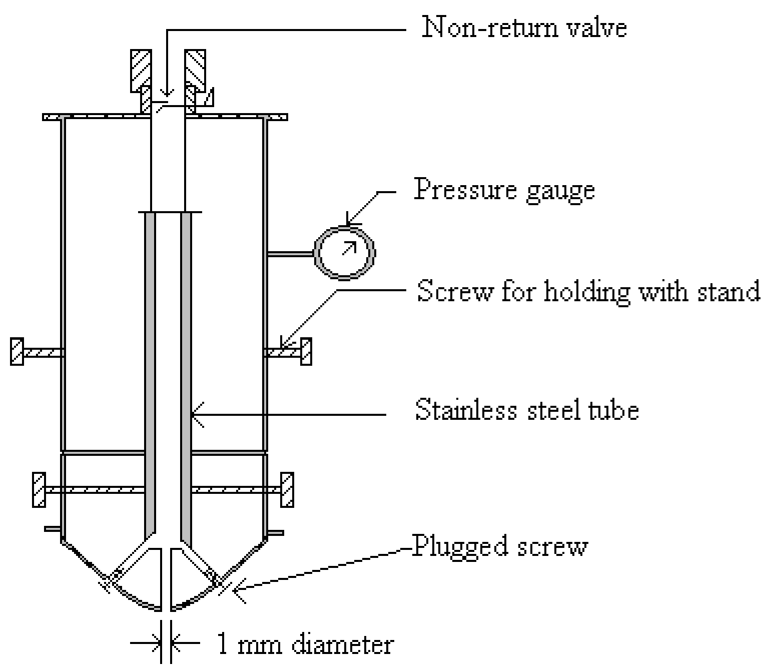

Figure 1. Stainless steel drill bit (redrawn from Hossain et al., 2007a).

2. Experimental Setup

A stainless steel drill bit is designed for the experiment (Figure 1). Water from laboratory supply line is used with a maximum of 72 psig pressure to create jet energy through a 1 mm diameter hole at the tip of drill bit. A non-return valve has been used for protecting back flow and pressure. Two grooved screws are attached with the drill bit for holding it with a supporting stand. A pressure gauge is used to measure the inside pressure of drill bit.

Figure 2 shows the paraffin wax and beeswax samples that is used as a rock sample during the experiment. Figure 3 shows a schematic view of the experimental setup for both paraffin wax and beeswax respectively. A garden hose was connected with supply line and drill bit top to get the continuous water flow.

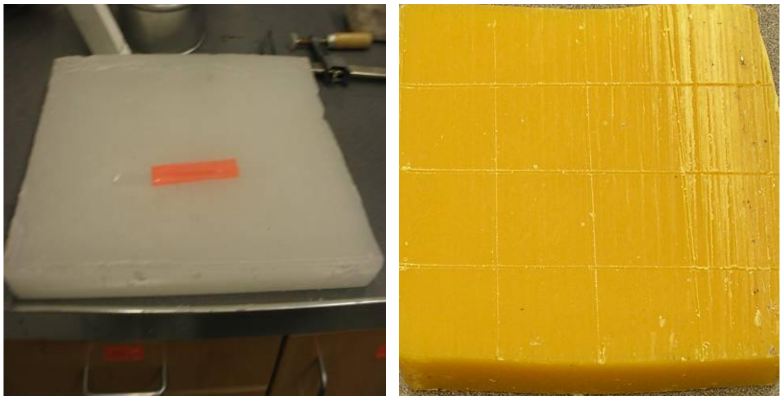

Figure 2. Paraffin and beeswax samples for experimental work (presented from Hossain et al., 2007a and b).

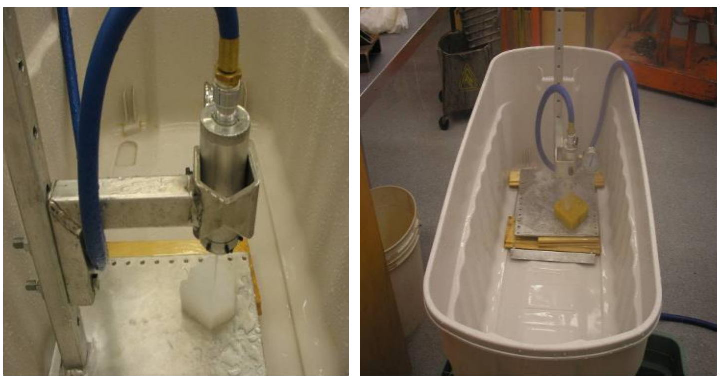

Figure 3. Experimental setup at the laboratory (presented from Hossain et al., 2007a and b).

3. Results and Discussion

Figures 4 and 5 show the dependence of different influential parameters such as DOP, ROP, flow rate, pressure of the drilling fluid, and temperature with time for paraffin wax and beeswax samples. The specific energy on waterjet (i.e., pressure), temperature and flow rate are almost same for both samples. Depth vs. time curve is almost linearly increasing for the case of paraffin wax (Figure 4) because paraffin wax is a processed refined material. ROP is more complex to describe because it fluctuate with time. There is no regular increasing or decreasing trend for ROP plotting.

However, in the case of beeswax, the penetration depth increases with time nonlinearly because it is a natural unrefined product. This trend continues and after 20 minute, it does not increase any more (Figure 5). In the same graph, initially ROP decreases very fast with time and gradually it decreases. Natural wax absorbs more energy when penetration starts and continues to decrease up to a certain level of depth based on applied pressure on the tip of drill bit.

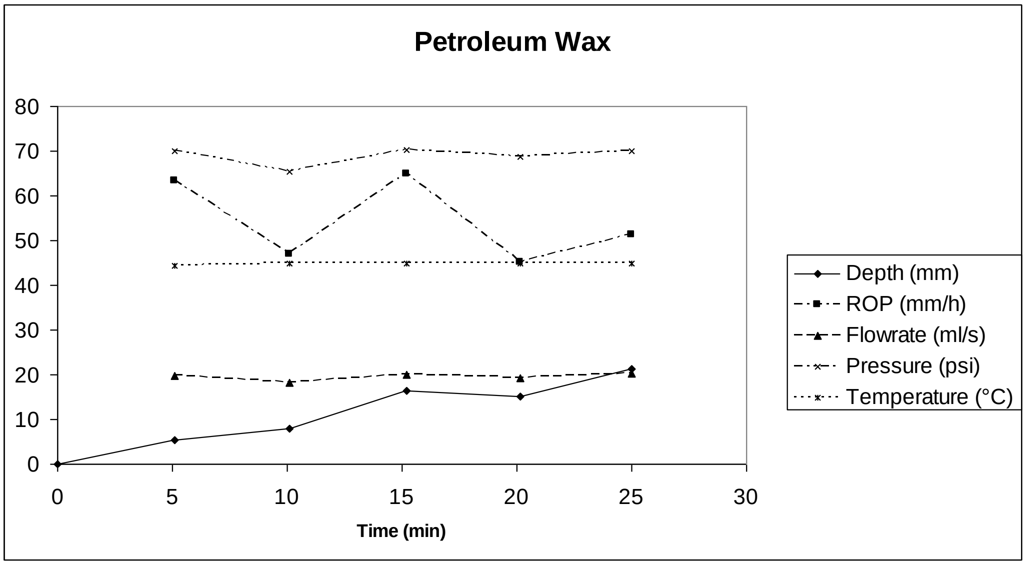

Figure 4. Dependence of different parameters on time for paraffin wax.

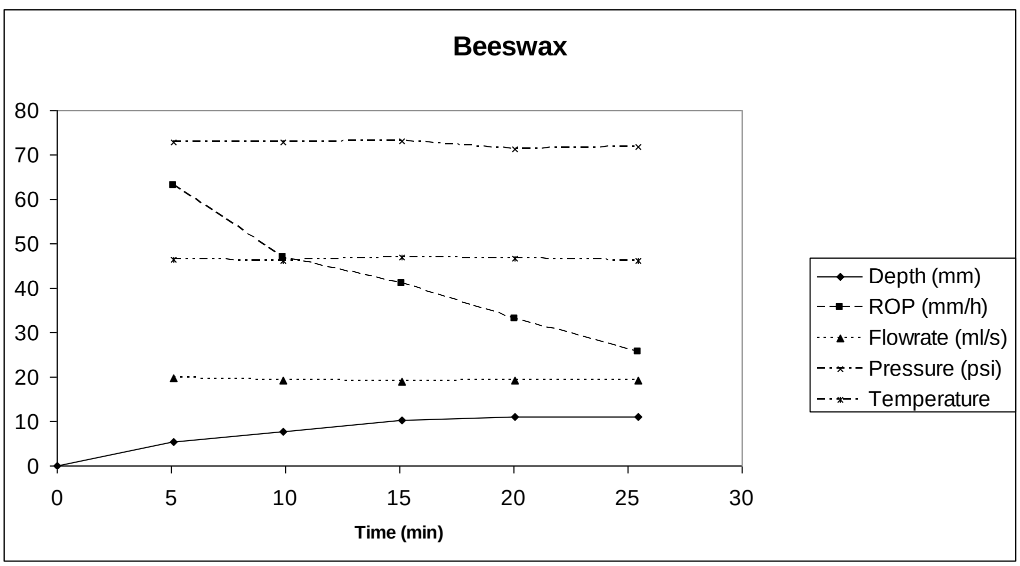

Figure 5. Dependence of different parameters on time for beeswax.

The dependence of different parameters on distance between drill bit tip and wax samples surface are shown in Figure 6 and 7. DOP, ROP, flow rate, pressure of the drilling fluid and temperature with distance have been studied for both samples. Flow rate is almost same during the experiment; however there is a small variation due to the variation of pressure water line. It was attempted to keep the pressure constant during the experiment. However, there was slight variation on pressure (Figures 6 and 7). This variation is due to the direct use of tap water in the system. There is no temperature variation during the experiment in this case. DOP increases with gap distance of paraffin wax sample (Figure 6). This trend continues up to 18 mm for the distance of 18 cm (7.1”).

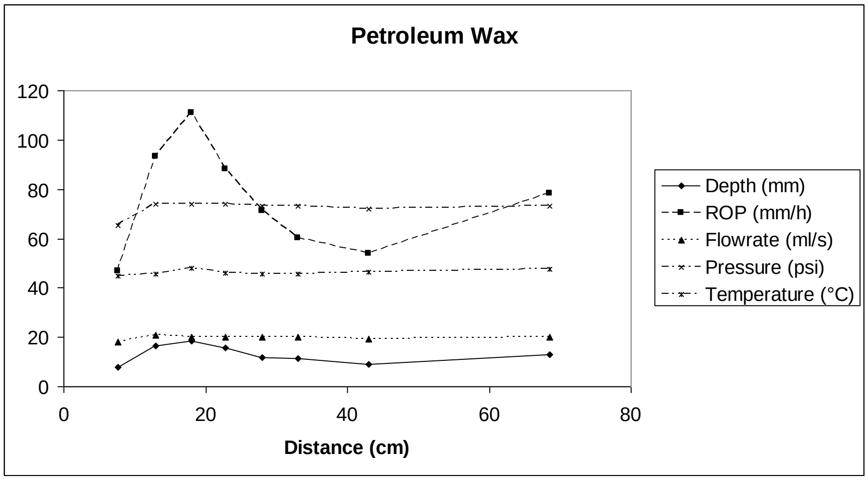

Figure 6. Dependence of different parameters on distance between jet nozzle and paraffin wax sample surface.

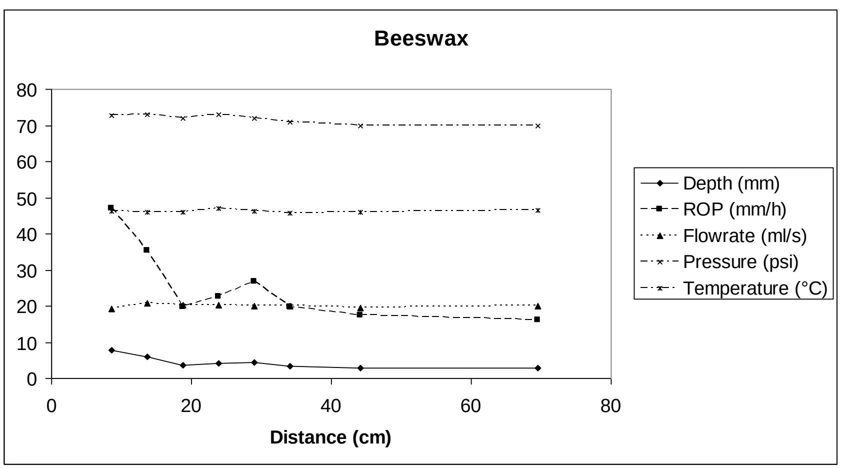

Figure 7. Dependence of different parameters on distance between jet nozzle and beeswax sample surface.

After this, the trend is decreasing with the distance which goes up little bit beyond the gap distance 43.0 cm. From this analysis, it can be concluded that the effective gap distance is 18 cm. DOP decreases with gap distance for beeswax sample (Figure 7). It continues up to 3.6 mm for the distance of 18.8 cm and then it increases with the distance which goes up to 4.5 mm for the gap distance of 29 cm. After this point, the trend is decreasing. From this analysis, it can be concluded that the effective gap distance should be as low as possible and should be 29 cm.

Figure 8 shows a comparison of DOP with time for paraffin wax and beeswax. The depth increases in the same trend up to 7.8 mm for 10 minute in both cases. After this, paraffin wax depth increases very fast with time comparing with beeswax. However, there is a decrease of depth with the time interval of 15 to 20 minute. The trend is again increasing after this. The depth for beeswax increases continuously with time up to 20 minutes where the depth is 11 mm. After this point, there is no further penetration with time. So the maximum depth for beeswax in the specified experimental pressure, flow rate and temperature is 11 mm for 20 minute.

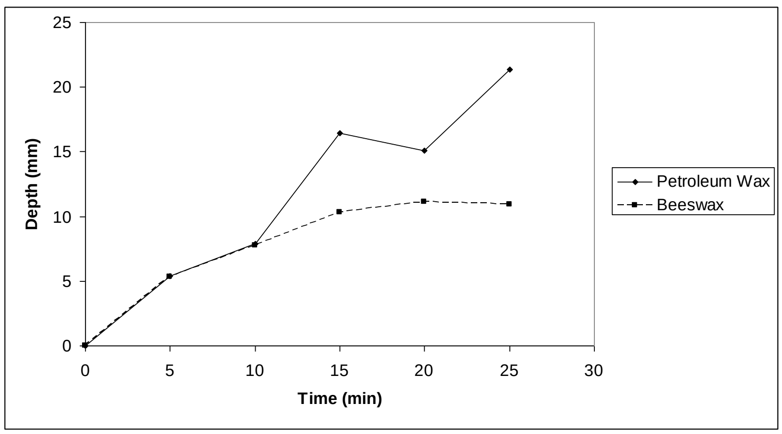

Figure 8. Dependence of DOP on time.

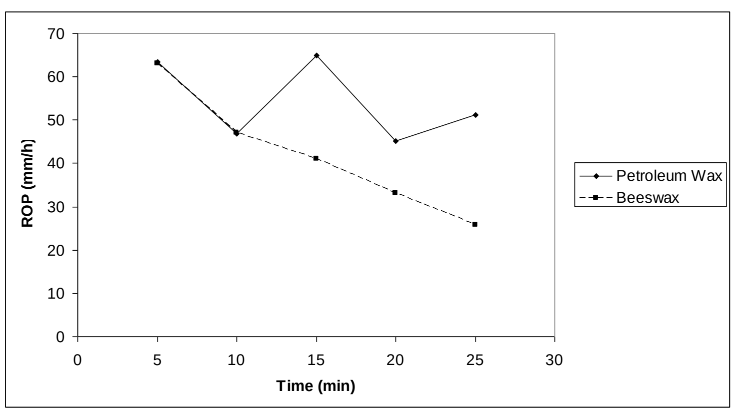

Figure 9. Dependence of ROP on time.

Figure 9 shows the variation of ROP with time for both paraffin wax and beeswax respectively. ROP decreases in the same trend up to 47 mm/h for 10 minute in both cases. After this, paraffin wax ROP increases and then decrease. This oscillation continues with time. However, the trend is decreasing with time for paraffin wax. ROP for beeswax decreases further with time. The decreasing trend is almost linear with time.

To compare both samples further, DOP with thermal exposure time Variation is depicted in Figure 10. There is a great influence of temperature with time on both samples. DOP increases with thermal exposure time almost in the same trend up to 60 minute where the depth is 13 mm and 12.5 mm respectively for both cases. After this point, depth increases faster in the case of paraffin wax with a slight increase of thermal exposure time. However, beeswax depth increases little bit up to 80 minute and then turns to decrease. This behavior indicates that temperature has an affect on beeswax up to certain level.

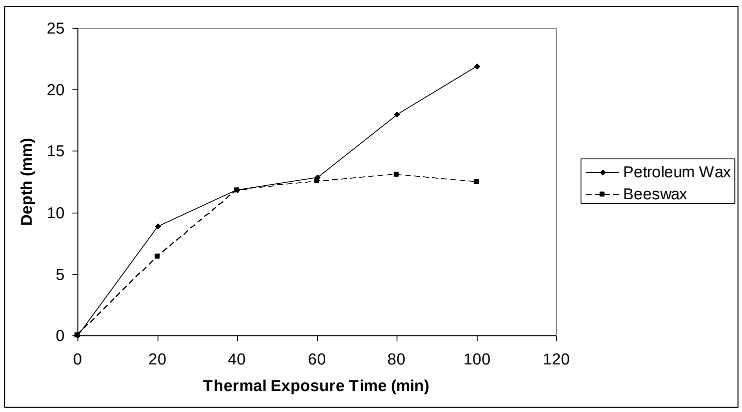

Figure 10. Dependence of DOP on thermal exposure time.

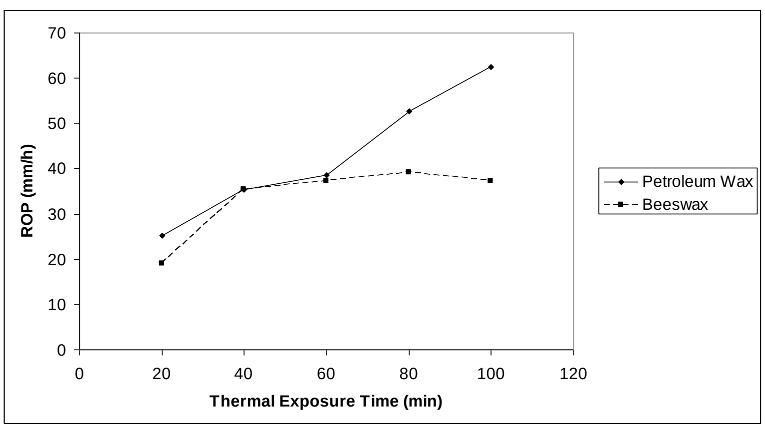

Figure 11. Dependence of ROP on thermal exposure time.

ROP variation with thermal exposure time is explained in Figure 11. The behavior is almost same as explained in Figure 10 except ROP magnitude. ROP increases with thermal exposure time almost in the same trend up to 60 minute where ROP is 39 mm/h and 37 mm/h respectively for both cases. After this point, ROP increases faster in the case of paraffin wax with a slight increase of thermal exposure time. On the other hand, beeswax ROP increases little bit up to 80 minute and then turns to decrease. This behavior indicates that temperature also has an impact on beeswax ROP up to certain level.

DOP with gap distance between drill bit tip and top surface of samples are depicted in Figure 12. The figure shows that paraffin wax is more sensitive to gap distance where the decreasing trend of depth is faster than beeswax. When the gap is maintained at around 18 cm, waterjet can penetrate maximum depth of 18.5 mm with the existing laboratory facilities. On the other hand, beeswax depth decreases with the increase of gap distance. The existing experimental setup gives a maximum depth of 8 mm, when the gap distance is maintained at around 8.6 cm.

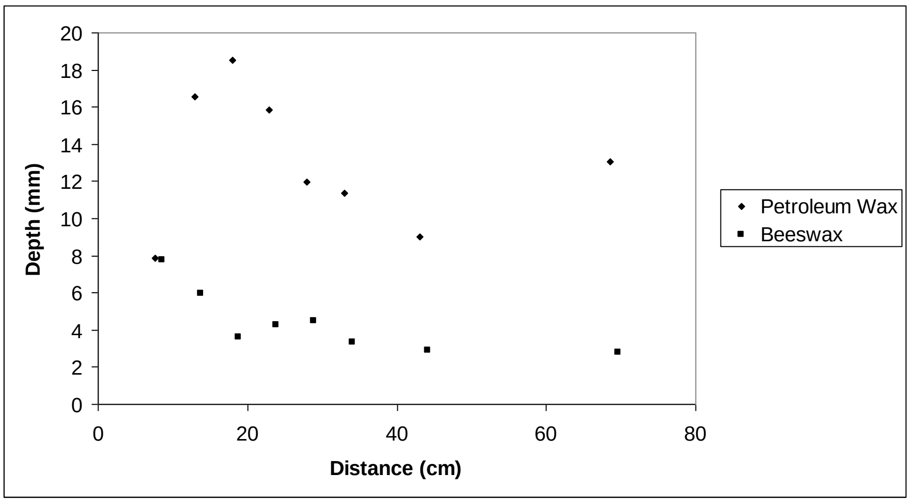

Figure 12. Dependence of DOP on gap distance between drill bit tip and top surface of sample.

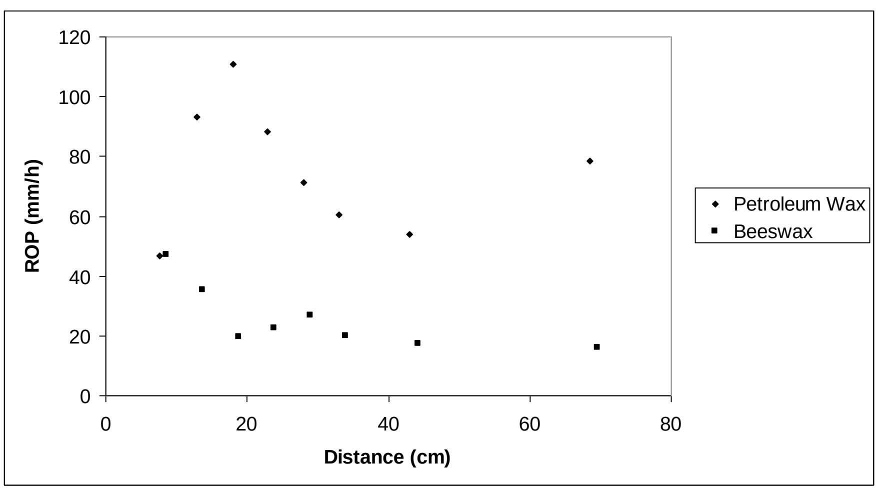

Figure 13. Dependence of ROP on gap distance between drill bit tip and top surface.

Figure 13 explains the variation of ROP with gap distance between drill bit tip and top surface of sample for both paraffin wax and beeswax. The behavior is almost same as explained in Figure 12. However, ROP increases with gap distance almost in the same trend up to 18 cm where the ROP is 111 mm/h for paraffin wax. After this point, ROP decreases with the increase of gap distance. ROP increases again with the increase of gap distance when the gap distance is 43.0 cm. On the other hand, beeswax ROP decreases with the increase of gap distance up to 19 cm and then turns to increase little bit up to 29 cm where ROP is 27 mm/h. The decreasing trend continues after this gap distance again. The existing experimental setup gives the maximum ROP of 47 mm/h, when the gap distance is maintained at a distance of 8.6 cm for beeswax.

4. Conclusions

Experiments show that DOP and ROP depend on pressure, temperature, time and flow rate for both paraffin wax and beeswax. The ROP decreases with time for both cases. However, DOP increases with time and become stable for beeswax. From this analysis, it can be concluded that the effective gap distance is 18 cm for paraffin wax and the effective gap distance should be low for beeswax. A maximum depth of 7.8 mm can be reached when the gap distance is maintained at a distance of 8.6 cm for beeswax. The maximum DOP for beeswax is 11.1 mm for 20 minute. Maximum ROP (111 mm/h) can be attained with gap distance of 18 cm for paraffin wax where as maximum ROP of 47 mm/h can get when the gap distance is maintained at a distance of 8.6 cm for beeswax.

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