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EXPERIMENTAL STUDY ON BEESWAX USING WATERJET DRILLING

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Abstract

Conventional rotary drilling has been the main technique used for drilling in the oil and gas industry. However, this method has showed its limitations regarding the depth of the wells drilled in addition to the use of toxic drilling fluids. This paper proposes an alternative method that is waterjet drilling. This drilling technique is environmentally friendly, fast, and feasible. Based on laboratory experiments, empirical models have been developed to describe the jet-rock interaction simulated by using beeswax samples. The resourceful and conclusive results show that the depth and rate of penetration increase with time, temperature, and thermal exposure.

Keywords: waterjet; drilling engineering; beeswax; penetration depth; penetration rate.

1. Introduction

Drilling is one of the oldest technologies in the world. At present, drilling technology has modernized well profiles and directions. High pressure waterjet (HPWJ) technique is now used for horizontal drilling. Horizontal wells are being drilled across the reservoir for exposing a relatively large reservoir area which is used as drainage or injection. Most of the new wells are completed without cementing or liner. Due to the long opening, acidization is used to remove mud cake. Since, this process is very costly, the HPWJ process is increasingly used. HPWJ is a cost effective and simple to handle process in drilling technology. This 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.

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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 rate of penetration in hard 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. (2010) have briefly described the contributions of different researchers on waterjet drilling and the importance of this technology. They have developed some empirical relations using waterjet drilling on rate of penetration, depth of penetration (DOP) based on paraffin wax as a sample. They also found out the variation of depth, rate of penetration (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. They did not study the effects of gap variation between drill bit tip and sample top surface. The present study investigated this effect.

To study the waterjet drilling system in more detail, beeswax sample has been used as a rock sample. The properties of beeswax samples are well described by Hossain et al. (2009a). Moreover, the factors that may affect the drilling activities are also explained by Hossain et al. (2009b). A series of laboratory tests were run to know the effect of water flow rate, the ROP, and pressure. This research examines the effect of jet time and temperature on the depth and ROP. In addition, the effect of change of waterjet pressure on the depth and rate of penetration is studied.

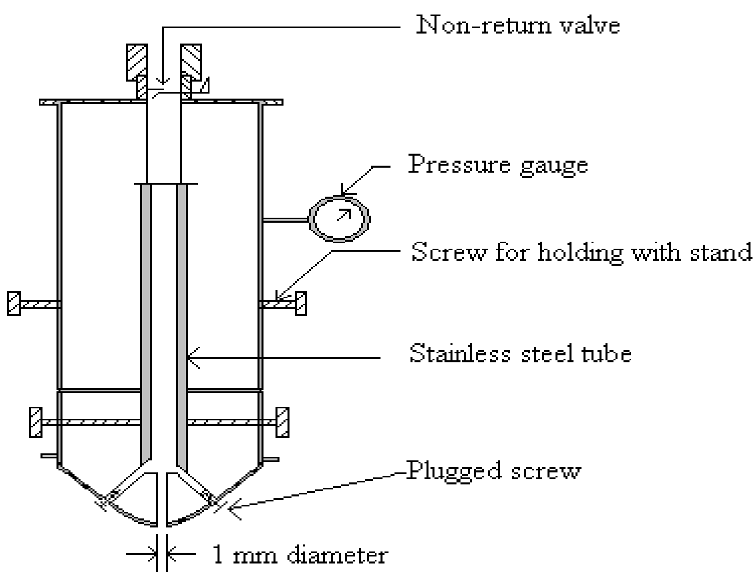

Figure 1. Stainless steel drill bit (redrawn from Hossain et al., 2006).

2. Experimental Setup

Figure 1 shows a laboratory experimental drill bit for waterjet drilling technique. Here normal tap water is used with a maximum of 72 psig pressure to create a waterjet 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 stand. A pressure gauge has been set with the bit for measuring the inside pressure of the bit.

Figure 2 shows a schematic view of the experimental setup used in the laboratory test. A garden hose was connected with the tape and drill bit top to get the continuous water flow. Figure 3 shows the beeswax that is used as a rock sample in the experiment.

Figure 2. Experimental setup at the laboratory.

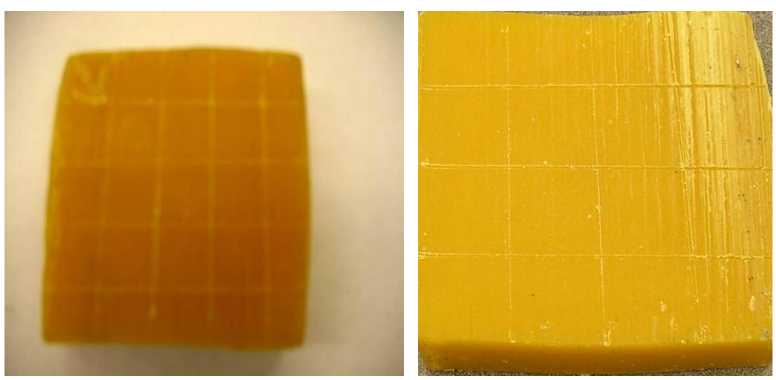

Figure 3. Beeswax sample for experiment.

3. Results and Discussion

Figure 4 shows the dependence of different influential parameters such as DOP, ROP, flow rate, pressure of the drilling fluid system and temperature with time. The graph shows that depth is increasing with time almost linearly. However, after 20 minute, it does not increase any more. Initially, the rate of penetration decreases rapidly and with time, it decreases gradually. The flow rate is almost same during the experiment; however there is a little variation due to the variation of pressure in the laboratory water tap. It was attempted to keep the pressure constant during the experiment. However, there was little variation on pressure which shows in the figure (Figure 4). This was due to the direct use of tap water in the system. There is no temperature variation during the experiment in this case. So the trend is constant with time. The polynomial trendline for DOP with time is shown in Figure 5. The empirical relationship between these two parameters has been derived by best fit regression analysis. The relationship is represented by equation 1;

$$D = -0.024\,t^2 + 1.0302\,t + 0.2084 \quad \text{and } R^2 = 0.9959 \qquad (1)$$

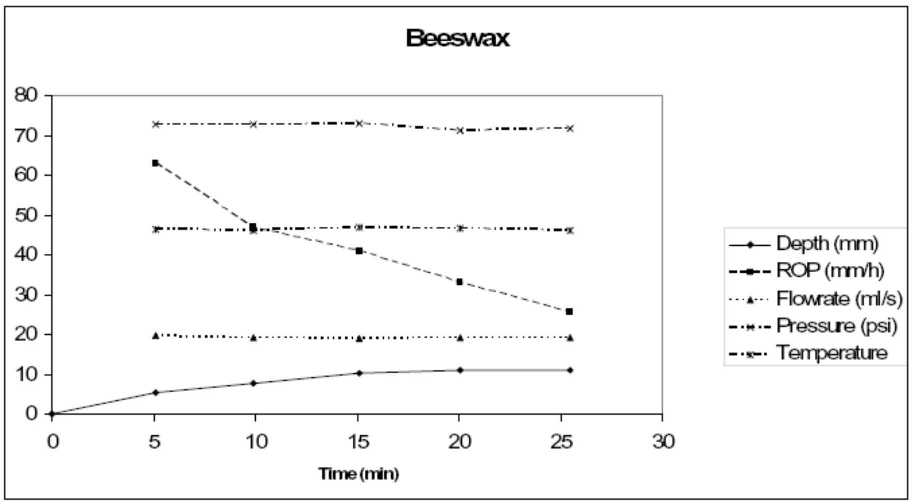

Figure 4. Dependence of different parameters on time.

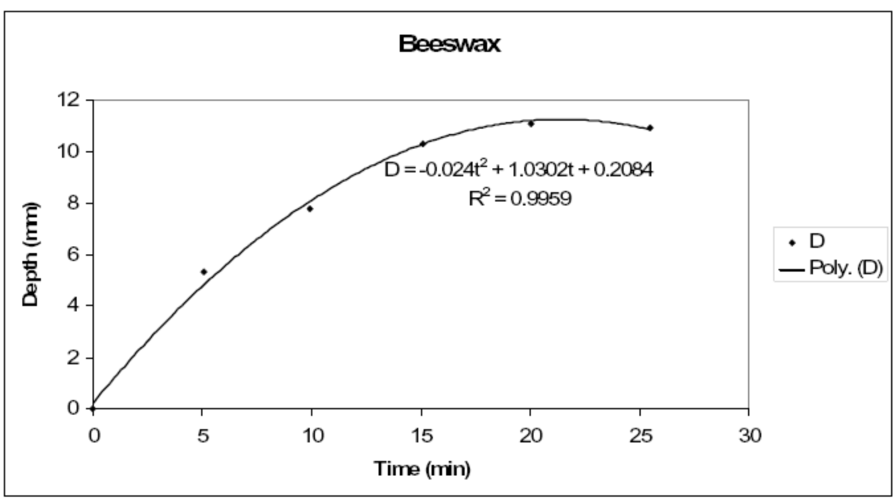

Figure 5. Dependence of depth on time for empirical relation.

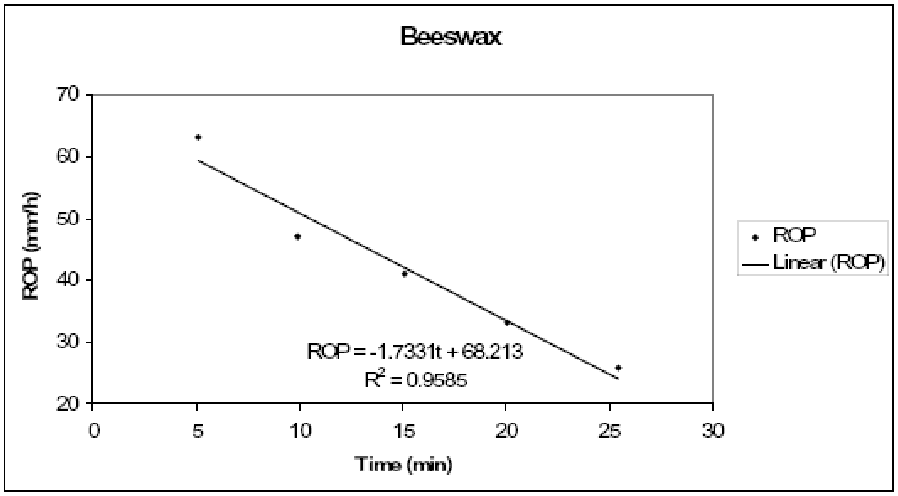

Figure 6. Dependence of rate of penetration on time for empirical relation.

The linear trendline for ROP with time is shown in Figure 6. The empirical relationship between these two parameters has been derived by best fit regression analysis which shows in equation 2.

$$D_t = -1.7331\, t + 68.213 \quad \text{and } R^2 = 0.9585 \qquad (2)$$

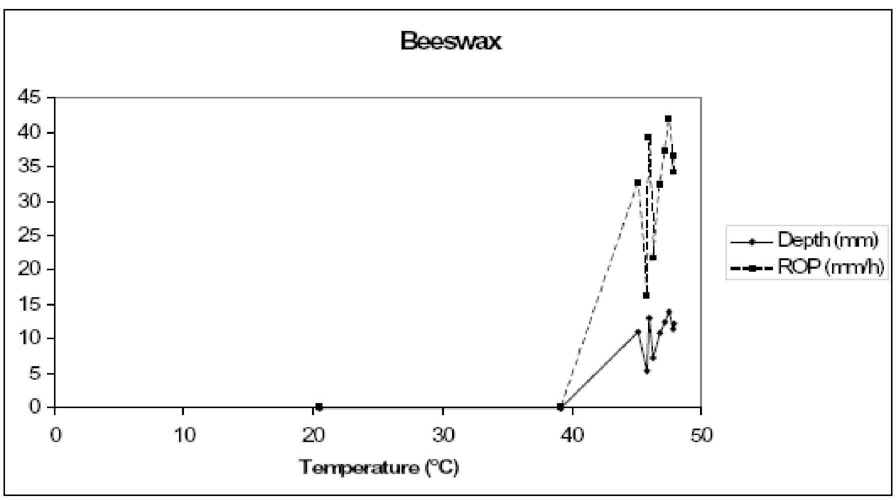

Figure 7. Effects of temperature on depth and rate of penetration.

Figure 7 shows the affects the temperature of the drilling fluid on the DOP and ROP. There is no temperature affects up to 39.2^{0}C however after this temperature, the DOP and ROP increase with the increase of temperature. For both cases, the trend of variation is chaotic; there is no definite trend of variation for these two parameters. In addition, the depth and ROP are affected by other parameters such as side effect (Figure 8), thermal exposure, waterjet pressure and wax composition. To investigate the side effect, sets of experiment have been completed marking the sample in 2.3 cm interval from each other and each side (Figure 8). The figures show the orientation and DOP at different places within the sample. Each of holes has an interval of 2.3 cm between each others and side.

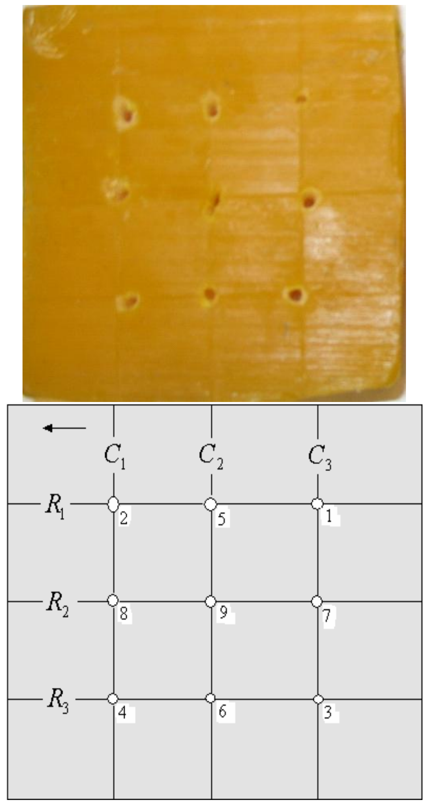

Figure 8. Systematic drilling to investigate side effects.

Figure 9 shows the column wise side effects on depth of penetration where distance from the centre of the wax sample has been considered as benchmark. Side effect is more effective in column 1 especially in reference point 2 and 8 (Figure 8). This is due to thermal effect on sample. Reference point 9 of column 2 is more affected than reference point 5 and 6. It seems that reference 9 should be less affected than point 5, 6 or 8 and 7 of column 1 and 3 respectively. This indicates that thermal effect is more sensitive than side effect. Reference point 7 shows more affected than reference point 1 in column 3. It is true that for beeswax, temperature is more influential parameters than side effects.

Figure 10 shows the row-wise side effect on DOP. Distance from the centre of the wax sample has been considered as the reference. Side effect is more effective in row 2 (Figure 8) due to thermal exposure effect. The behavior of row 3 is quite interesting where the trend of the line exhibits the side affect. Reference point 8 is the most affected point by side effect in the system.

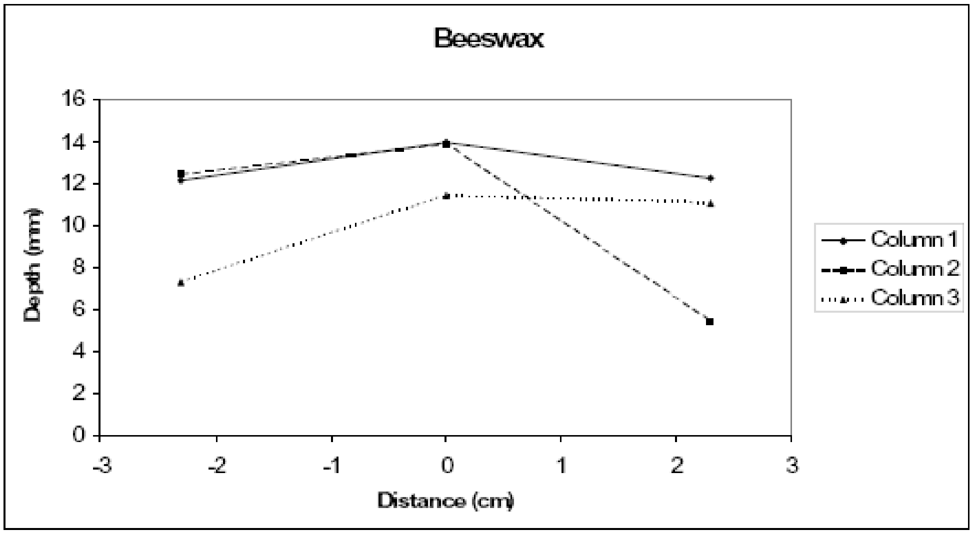

Figure 9. Side effects on depth of penetration (column-wise).

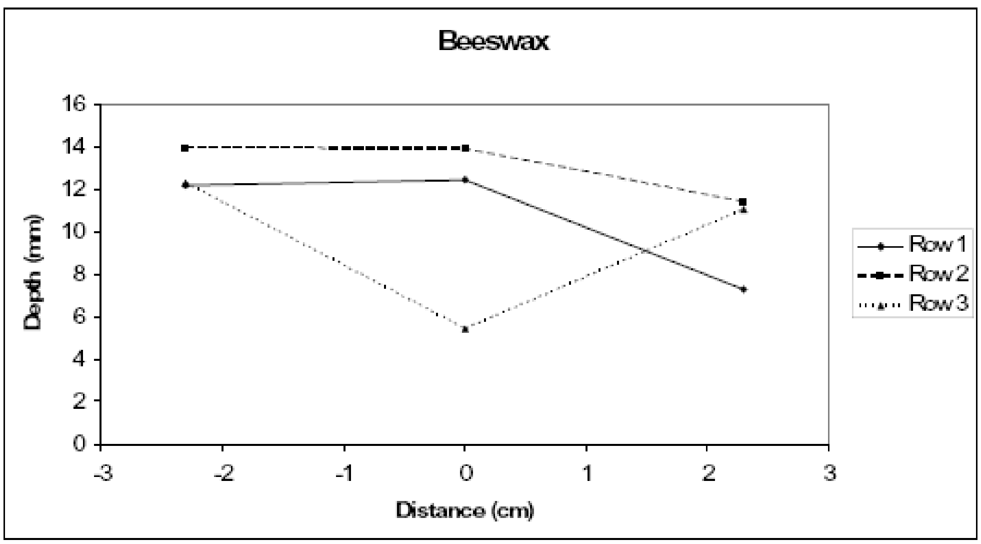

Figure 10. Side effects on depth of penetration (row-wise).

Figure 11 shows the column-wise side effects on ROP. Distance from the centre of the wax sample has been considered as the reference. The trend of all the columns is same as explained for Figure 9. The row wise influence of side effects on ROP is represented by Figure 12. The behavior of the curves is almost same as DOP described for Figure 10.

Figure 13 explains more clearly the effects of side on the beeswax sample. First point has been generated by averaging all the reference points of columns 1, 2, and 3 excluding the centre point 9 (Figure 8). The second point is the central point reference point 9. The same procedure is used to calculate both depth and ROP. The data trends depend on the drilling time, the water temperature, and the sample thermal exposure time. Figure 13 indicates the side effect for the sample experiments with varying depths and rates of penetration. To eliminate the sampling errors that affect these variables, every experiment should be conducted by an individual sample keeping sufficient distance from the edges i.e. at the center point.

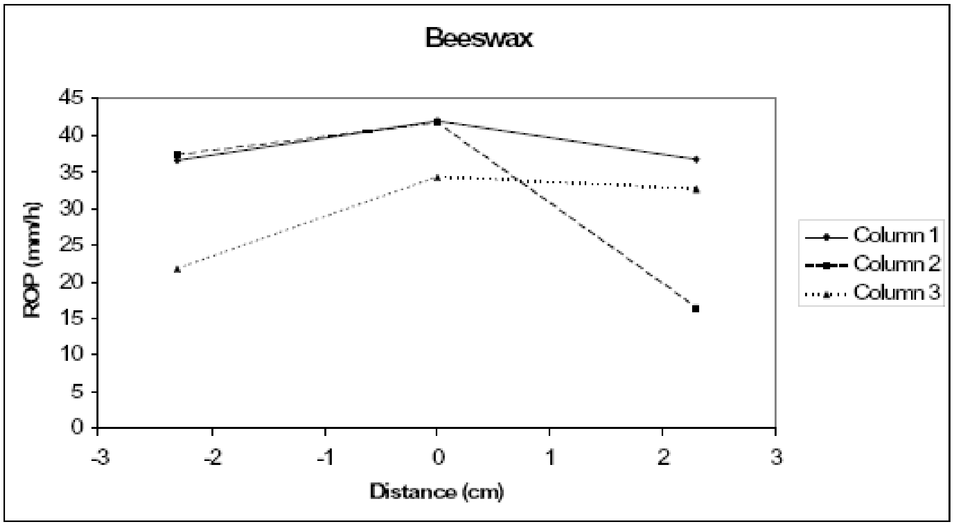

Figure 11. Side effects on rate of penetration (column-wise).

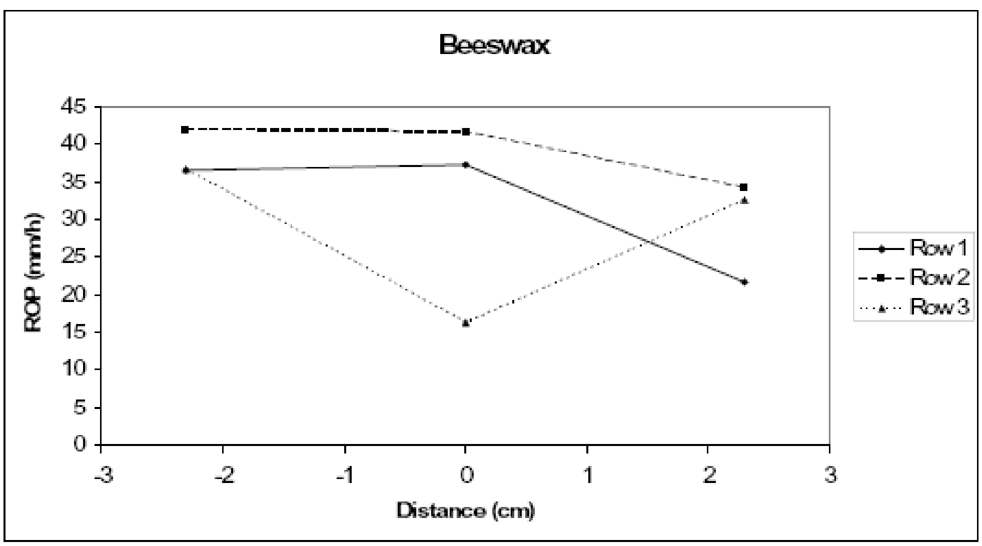

Figure 12. Side effects on rate of penetration (row-wise).

Thermal exposure time of the wax sample is investigated since the same wax sample was drilled at high temperatures and for many holes consecutively (Figure 14). As thermal exposure time increases, depth and ROP increases with time. It is obvious that there is a thermal effect during any hot water action. However, initially the influence is much more. The temperature is more sensitive in both depth and ROP. When the beeswax sample temperature reaches the drilling fluid temperature, it becomes steady. This indicates that thermal effects on the sample are limited by its drilling fluid temperature. If the temperature of the drilling fluid increases, thermal exposure time increases. The longer the thermal exposures time the more depth and ROP. Therefore, to soften the rock matrix, thermal action is helpful during waterjet drilling. As long as time progresses, thermal action plays a role in the rock matrix system shown in this figure.

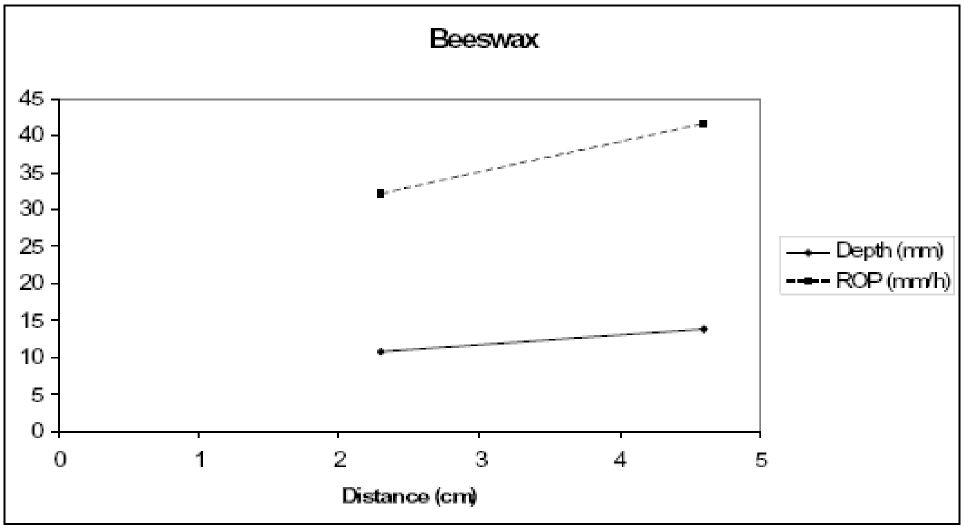

Figure 13. Side effects on depth and rate of penetration (towards centre from edge of the wax sample).

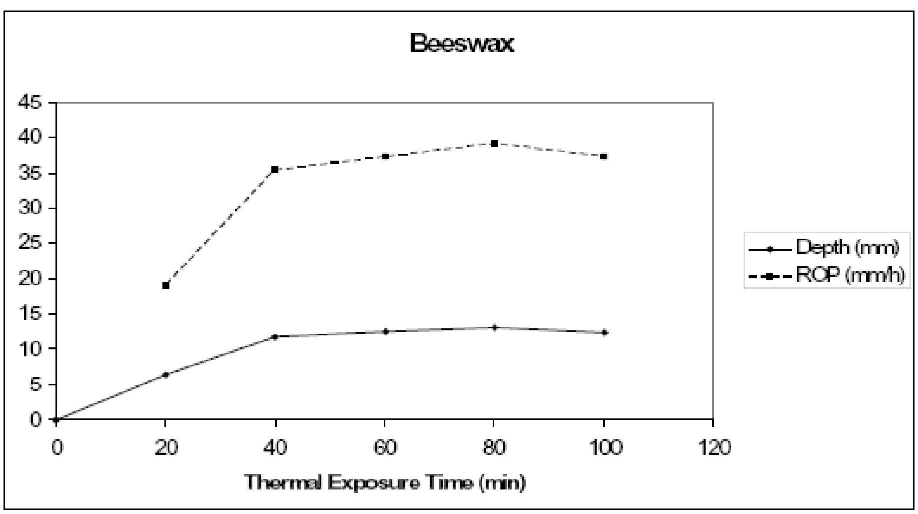

Figure 14. Variation of depth and rate of penetration with thermal exposure time.

Figure 15 shows the affects of different influential parameters such as DOP, ROP, flow rate, pressure of the drilling fluid system and temperature with distance between jet nozzle and beeswax surface. The graph shows that depth is decreasing with distance between jet nozzle and beeswax surface. However, after 44 cm, it is almost linear. Initially, the rate of penetration decreases rapidly with distance between jet nozzle and beeswax surface up to 18.8 cm and then there is a fluctuation with distance up to 34.0 cm. After this distance, it decreases gradually. The flow rate is almost same during the experiment; however there is a little variation due to the variation of pressure in the laboratory water tap. It was attempted to keep the pressure constant during the experiment. However, there was little variation on pressure which shows in the figure (Figure 15). This was due to the direct use of tap water in the system. There is also some variation of temperature during the experiment which is shown in the figure.

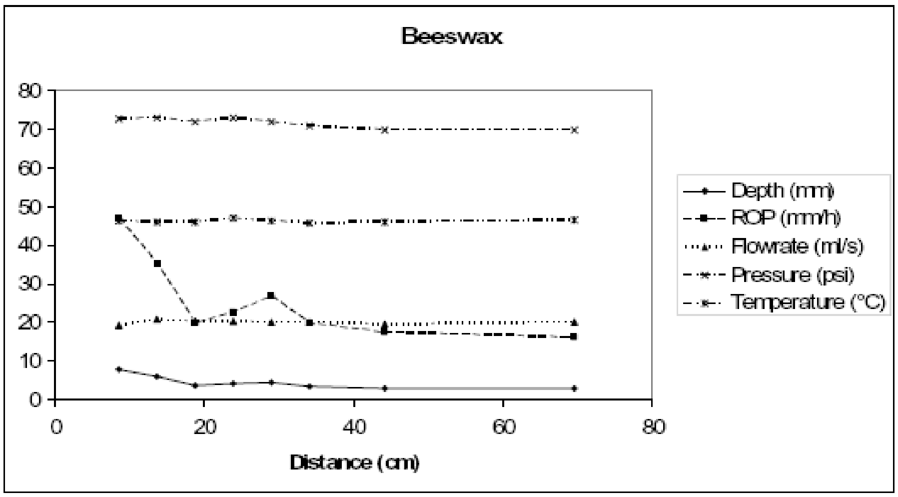

Figure 15. Dependence of different parameters on distance between jet nozzle and beeswax surface.

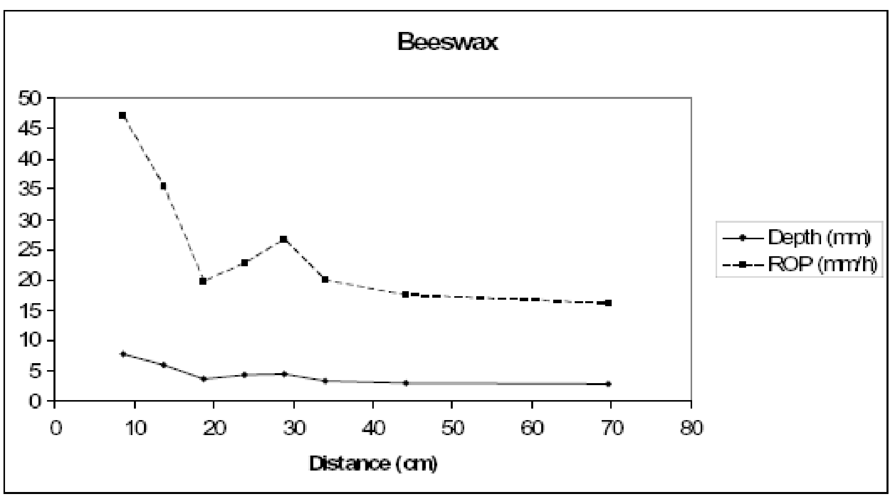

Figure 16. Dependence of depth and ROP on distance between jet nozzle and beeswax surface.

Figure 16 shows the affects of important parameters – depth of penetration, and ROP with distance between jet nozzle and beeswax surface. The trend is more clearly visible in this figure.

4. Conclusion

The conventional practice in the oil industry is to use different drilling techniques where huge capital is involved. The technology is also more complicated to handle. In this regard, waterjet drilling is simpler and needs less capital involvement. Experiments show that DOP and ROP depend on pressure, temperature and flow rate of the waterjet. The ROP decreases with time, however DOP increases with time. The variation of depth and ROP is established with thermal exposure time. There is a negligible side effect during the experiment. It decreases from the edge towards the centre of the sample. The variation of depth and ROP on distance between jet nozzle and beeswax surface are also studied and shown. Empirical models are developed to describe the depth and rate of penetration with time.

Nomenclature

A	=	cross sectional area of drill bit tip, mm^2, $[L^2]$
D	=	depth of penetration, mm, $[L]$
D_t	=	rate of penetration (ROP), mm/hr, $[L/t]$
p	=	pressure of the system, psi, $[M/Lt^2]$
Q	$= A \times u$ =	flow rate, cc/sec, $[L^3/t]$
T	=	temperature, $[T]$,℃
t	=	time, minute, $[t]$
t_T	=	thermal exposure time, minute, $[t]$
u	=	waterjet velocity at the tip of the drill bit, cm/sec, $[L/t]$

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References

Arangath, R., Ogoke, V. C. & Onwusiri, H. N. (2002) 'A Cost-Effective Approach to Improve Performance of Horizontal Wells Drilled in High Permeability Formations', SPE 73786, presented at the *SPE International Symposium and Exhibition on Formation Damage Control* held in Lafayette, Louisiana, 20–21 February.

Dunn-Norman, S., Gupta, A., Summers, D. A., Koederitz, L. F. & Numbere, D. T. (2002) 'Recovery Methods for Heavy Oil in Ultra-Shallow Reservoirs', SPE 76710, presented at the *SPE Western Regional/AAPG Pacific Section Joint Meeting* held in Anchorage, Alaska, U.S.A., 20–22 May.

Hossain, M. E., Ketata, C. & Islam, M. R. (2010). 'Scaled model experiments of waterjet drilling', *Advances in Sustainable Petroleum Engineering Science*, 2(1), in press.

Hossain, M. E., Rahman, M. S., Ketata, C. & Islam, M. R. (2009d). 'SEM-based structural and chemical analysis of paraffin wax and beeswax for petroleum applications', *Journal of Characterization and Development of Novel Materials*, 1(1), 21 – 38

Hossain, M. E., Ketata, C. & Islam, M. R. (2009b). 'A scaled model study of waterjet drilling", *Petroleum Science and Technology*, 27, 1261 – 1273.

Lia, X. B., Summersb, D. A., Rupertb, G. & Santib, P. (2001) 'Experimental investigation on the breakage of hard rock by the PDC cutters with combined action modes', *Tunneling and Underground Space Technology*, Vol. 16, pp. 107-114.