Advanced Materials Research *Online: 2012-05-14*
ISSN: 1662-8985, Vols. 518-523, pp 3432-3435
doi:10.4028/www.scientific.net/AMR.518-523.3432

Pumping Characteristics of Calcium Carbide Waste Paste

Xuedi Hao[1, a], Changyong Gong[2] , Jichang Guo[1] , Huaxu Yang[1] , Miao Wu[1,b]

[1] School of Mechanical Electronic & Information, China University of Mining & Technology (Beijing), Beijing 100083, China

[2] China Center for Industrial Economic Security Research in Beijing Jiaotong University, Beijing 100044, China

[a]hxd2003@126.com, [b]wum@cumtb.edu.cn

Keywords: calcium carbide waste, pastes, pipeline transportation, solid pump

Abstract. Calcium carbide waste paste is highly concentrated and viscous, rich in calcium, and has a great comprehensive utilization potential. Comprehensive utilization process based on high-pressure pipeline transportation is the best choice for use of calcium carbide waste. But the theory of pipeline transportation of the paste has rarely been reported. Industrial-scale transportation experiments with diameter of 75mm, 100mm, and 125mm were conducted, respectively. The results show that the pipe pressure is linearly distributed along the pipeline, but it is piecewise linear. The pipe pressure in the front end drops faster than that in the back end of the pipeline. The pipe pressure is proportional to the flow rate of calcium carbide paste. The delivery resistance increases greatly as the pipe diameter decreases at the same flow rate.

Introduction

Calcium carbide waste (CCW) is the by-product generated in the hydrolysis of calcium carbide during the processes of industrial production of polyvinyl chloride, polyvinyl alcohol and acetylene gas. The output of CCW is great, approximate 12 million tons every year. The main component is calcium hydroxide and water, which is strongly alkaline; also contain sulfides, phosphides, and other toxic and hazardous substances. Land stack is the usual disposal mode which caused serious erosion and pollution of land and water resources.

Calcium carbide waste is calcium-rich and highly alkaline, and has great potential for resource utilization. At present, the main utilization ways of CCW are production of building materials, using as chemical raw materials, mineral processing ingredients and materials for waste treatment [1-3]. To use CCW large-scale transportation from its generation area to procession area should be conducted, with the moisture content is generally 45%~50% to meet the requirements of the follow-up treatment process. The CCW with moisture content at this range is highly viscous, does not have liquidity at normal temperature and pressure, and is thick-paste like. Traditional transportation methods by scraper conveyor and belt conveyor can easily result in adhesion and leaking of material, and the throughput cannot be controlled precisely. The delivery methods are difficult to integrate with the subsequent treatment processes. It is the bottleneck for large-scale industrial utilization of CCW.

Practice has proved that delivery by pipeline is the most effective transportation method for resource utilization and harmless treatment of CCW. However, little theory of pipeline transportation of thick-paste like materials can be referred. Material characteristics of pumping concrete and mineral backfilling materials are different from that of CCW. Consequently, the results of research cannot be copied to use [4-6]. Research on pipeline transportation of coal slime [7], red mud [8] and sewage sludge [9] were conducted in the pipeline transportation lab of high concentration and viscous materials [7]. But research on pipeline transportation of CCW has not been reported. This paper presented experimental research on the pipeline transportation characteristics of CCW, which provides the basis of theoretical research and engineering application.

Experiments of pipeline transportation

Transportation tests were conducted to study transportation characteristics of CCW with three diameter sizes, 75mm, 100mm, and 125mm, respectively. The CCW conveyed by the pipe of 100mm is from Cangzhou Chemical Group with the moisture content of 43.7%, w/w. The CCW conveyed by the pipes of 75mm and 125mm is from Yibin Tianyuan Goup of Sichuan Province with the moisture content of 45.25% and 43.64% respectively. Eight pressure transducers were arranged along the pipeline of diameter 100mm, fourteen and ten for the pipeline of diameter 75mm and 125mm, respectively.

The flow rate of pumping can be alternated by changing the switch number of the two pistons in unit time. In engineering, it is believed that the control signal amplitude corresponds to the flow rate of the pump. The flow rate is denoted by the percent of the maximum amplitude of the control signal, named the nominal flow rate.

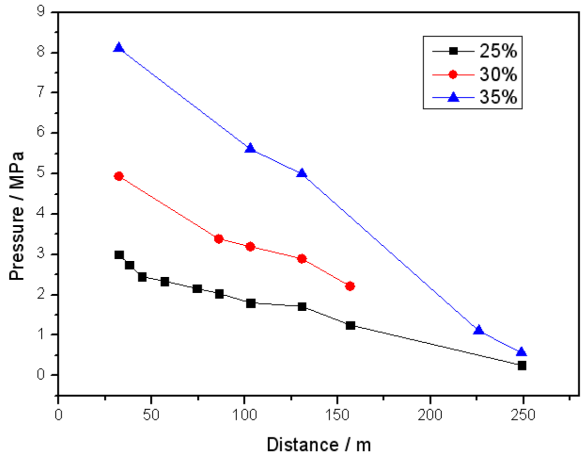

Fig. 1 Pipe pressure vs. distance from pump outlet (DN75)

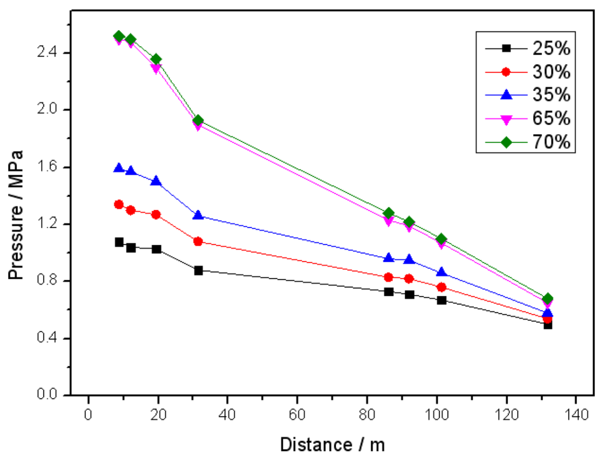

Fig. 2 Pipe pressure vs. dvestance from pump outlet (DN100)

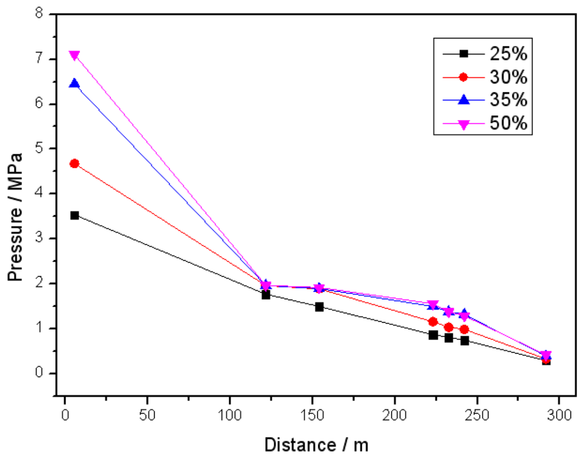

Fig. 3 Pipe pressure vs. Distance from pump outlet (DN125)

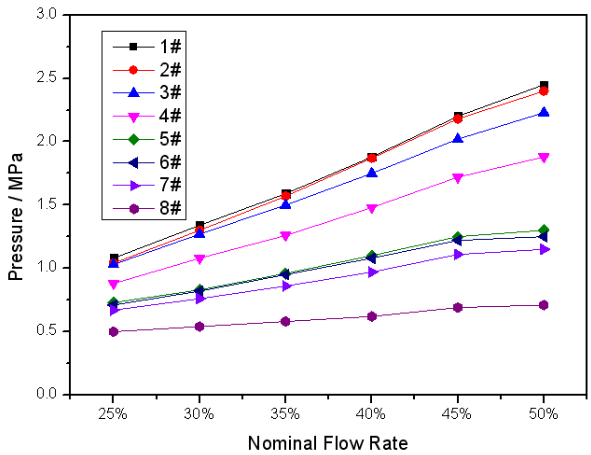

Fig. 4 Pipe pressure vs. nominal flow rate (DN100)

Experimental results and analyses

Fig. 1 is the curves of pipe pressure versus distance from the outlet of the pump of 75mm pipeline diameter. Fig. 2 is that of 100mm, and Fig.3 is that of 125 mm pipeline respectively. Fig. 4 is curves of pipe pressure versus nominal flow rate by 100mm diameter of pipeline. Fig. 5 is the curves of pipe delivery resistance versus the nominal flow rate.

Pressure distribution along the pipeline. Fig. 1 to Fig. 3 shows a basic linear pressure distribution along the pipeline, but it is piecewise linear, whose the slope in the front end is greater than that of the back end of the pipeline. The reason is that four right angle bends were arranged closely in the front part of the pipeline, and the other right angle bends were arranged far apart each other in the back part. The flow behavior of CCW paste in bend and straight pipe is different. In straight pipe, the paste flows as lamina, there is no material exchanging between flow layers. However, material exchanging between layers occurs in bend flow, and the flow resistance increases greatly accordingly. In addition, continuous bends make calcium carbide paste cannot be restored to the steady laminar flow, the resistance will also increase. Therefore, the actual piping should try to avoid arrangement of continuous bends.

The linear pressure distribution along the pipeline is very useful for designing the pipeline transport system. If the pressure at the pump outlet and the delivery resistance in a unit pipe length are known, the distance to pump can be calculated, and the parameters of the power system can also be achieved.

Relationship of flow rate and pipe pressure. Fig. 4 shows the pipe pressure varies linearly with the nominal flow rate, indicating that the delivery resistance is proportional to the flow rate. But, pipe pressure in the front part increases more rapidly as increasing flow rate than that in the back part of the pipeline, as shown in Fig. 4, which curve slope for the front pressure transducer is larger than that for the back pressure transducer. In other words, the pipe pressure in the front part of the pipeline is more sensitive to the flow rate. In addition to the arrangement of piping results in the larger delivery resistance in the front end of the pipeline, the flow characteristics of calcium carbide paste is a main factor for it. However, the corresponding theory needs further study.

Relationship of pipe size and resistance. Fig. 5 shows that the delivery resistance increase rapidly with the decreasing of pipe diameter, which is different from the theory of slurry pipe transportation. Thick paste like calcium carbide waste behaves as plug flow in pipe, and there is a thin lubricating layer between the pipe wall and the flow core. The lubricating layer is effective to reduce the flow resistance. The inner of the lubricating layer is a laminar area, and then is the column as the flow core with no shear rate. If the shear yield stress of CCW is large, the laminar layer is very thin. The thickness of the lubricating layer is determined by the concentration of CCW and the pipe diameter. Consequently, the flow behavior or rheological characteristics of CCW changes as different solid concentration and pipe size, and the exact relationship of the resistance and the pipe size and solid concentration need further study.

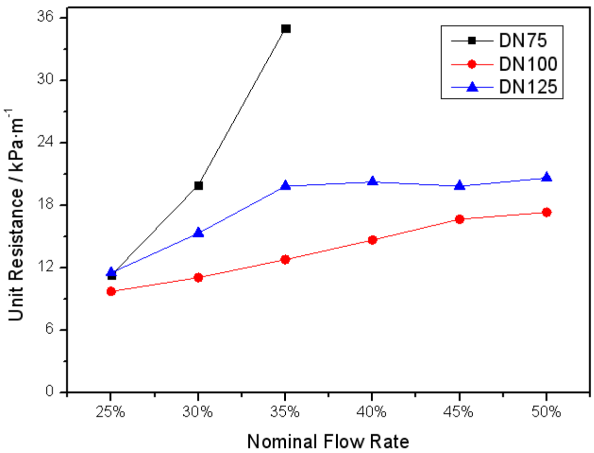

Fig. 5 Unit delivery resistance of pipeline vs. nominal flow rate

Conclusions

The paste of calcium carbide waste is highly concentrated and viscous and does not have liquidity under normal temperature and pressure. It is difficult to delivery by traditional slurry pump. Large-diameter twin cylinder piston pump under high pressure is suitable to delivery CCW paste.

However, the research of flow behaviors of CCW cannot fully meet the need of engineering applications. This paper presents pipeline transportation tests of CCW in industrial scale, pipe pressure distribution along the pipeline, the relationship of pressure and flow rate, delivery resistance and pipe diameter were all discussed. The main conclusions are following as:

(1) The pressure distribution along the pipeline is piecewise linear, the delivery resistance in the front end is larger than that in the back end.
(2) The delivery resistance is proportional to flow rate, the more the flow rate, the more the resistance.
(3) Pipe diameter affects the delivery resistance greatly, when the diameter decreases, the resistance increases rapidly.

Acknowledgements

It is a project supported by National Natural Science Foundation of China (51075389), China Postdoctoral Science Foundation (20080440043), Research Fund for the Doctoral Program of Higher Education of China (20100023110006), and Special Fund for the Base Scientific Business of Central Universities (2010QJ01).

References

[1] H.Q. Wang, J.H. Tong, L.P. Shen. Chemical Production and Technology, No. 14 (2007), p. 47-51, In Chinese.

[2] K. Yan, K.G. Zhou. Environmental Science Survey, S1 (2008), p. 103-106, In Chinese.

[3] X.J. Wu, Y.X. Zhao. Jiangsu Environmental Science and Technology, S1 (2007), p. 65-66, In Chinese.

[4] W.Q. Wu, W.X. Mo. Guangdong Architecture Civil Engineering, No. 3 (2001), p. 17-19, In Chinese.

[5] B. Yu, S.C. Zhang, Z. Li, et al. Hebei Metallurgy, Vol. 135 (2003), p7-10, In Chinese.

[6] Z.X. He, D.S. Gu. Nonferrous Metals, Vol. 60(2008), p. 116-120, In Chinese.

[7] M. Wu, X.Y. Zhao, Y. Jin, et al. Development & Innovation of Machinery & Electrical Products, Vol. 17 (2004), p. 25-27, In Chinese.

[8] X.Y. Zhao, J.Z. Fu, Y.J. Cui. Journal of China University of Mining & Technology, Vol. 35 (2006), p. 75-78, In Chinese.

[9] J. Chen. Study on rheological properties and frictional resistance of pipeline transport high concentration and viscous materials [D]. University of Science & Technology (Beijing), Beijing, 2007, In Chinese.

[10] M. Wu, X.Y. Zhao, Y. Pan, et al. Chinese Journal of Environmental Engineering, No. 2 (2008), p. 260-265, In Chinese.