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Discussions

Interactive comment on "Performance Characteristics of a Small Hammer Head Pump" *by* Krishpersad Manohar et al.

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The introduction section of the paper was enhanced to address the constructive comments received from reviewer 2. More specific: Referee comments: "Experience with hydro-powered pumps is rather extensive already, and as such one can certainly argue that any new design needs to clarify why its newness brings added value - which could be financial, because it is cheap, or functional, because it delivers water in a specific way, or relate to maintenance, as the pump is easy to repair. None of these aspects are discussed."

Author's response:'The major hindrance in using this established technology in third world countries is the exorbitant cost of the commercially available units. For a UK

built pump the cost is US$ 1800 [10] and cheaper china made pumps range between US$500 to US$1300 [11]. One of the objectives of the Prude University project in Haiti was to develop a cheaper alternative, however, the cost was US$100 [9]. Therefore, there is the need to develop a low cost alternative that can be easily built from readily construction materials and requires minimal technical skills.'

Referee comments: "The design, the analysis and the numerical statements that are presented remain rather difficult to value when we do not find any information about user prospects, robustness in daily practices, etcetera. I do not want to suggest that the authors need to engage in full-scale field tests first before they can present their own designs. However, just dropping a design with some numbers without explaining why this particular design would be of interest for any target group, is not really appropriate."

Author's response:'In many rural farming areas, having a reliable source of water for crops and livestock can prove to be an expensive venture. In developing and under-developed countries, farmland are usually located close to a reliable water source to ensure viability [6, 7]. However, in many instances these locations are far from any reliable source of electricity and the cost can be prohibitive [6, 8]. In cases where the water source is situated below the level of the farmlands, getting the water to where it is needed can be challenging. Under these circumstances, a water pump operating on the water hammer effect and requires no external power source can serve as an effective means of pumping water to a higher altitude, once a reliable source is available. Also, in under developed countries, such as Haiti, the feasibility of using small hammer head pumps to provide clean water for citizens were explored by Prude University [9].'

Referee comments:"Are the different test settings in any way realistic, when we would consider farming practices? "

Authors response: 'The delivery output is a non-linear relationship with variables of input head and output head. Therefore, for a specific hydraulic ram pump, determining the delivery output at variable input and output head heights will be a critical factor in determining the applicability, suitability and effectiveness for use.'

Referee comments: "Is the discharge in any way useful? What type of use do the authors assume? What additional equipment would a farmer need to make the pump a viable asset on a farm?"

Authors response: 'Also, in under developed countries, such as Haiti, the feasibility of using small hammer head pumps to provide clean water for citizens were explored by Prude University [9]. The ram pump can operate 24/7 and hence a water storage facility, such as storage tanks, at the water delivery end will be needed. This will serve as the reservoir to supply the needs when required.'

Referee comments: "A final comment may relate to the number of references. In general, one cannot easily decide what six references mean, but in this case - given the rather high number of documents available on hydro-powered pumps - one would expect a few more references."

Authors response: 'The number of references were increased to sixteen as shown in the revised introduction section below.'

Introduction: The first type of pumps to use the water hammer effect is the hydraulic ram pump which was reported in 1775 and was built by John Whitehurst [1]. His design was not automatic and was controlled by manually opening and closing a stopcock which resulted in the device only being able to raise water to a height of 4.9 meters. This involved a significant amount of work and consumed a lot of time to operate. However, in 1797 the design was improved and the first reported automatic hydraulic ram was developed by Joseph and Etienne Montgolfier to raise water to a paper mill [2]. Although this was an improved design it still contained design flaws which caused the air in the pressure chamber to dissolve or drop. In 1816 this problem was eliminated when Pierre Montgolfier designed the sniffer valve that reintroduce air into the chamber. This valve was 15 cm in radius and it was reported that the pump was able to raise water to 48 meters in height [3]. The automatic hydraulic ram has been used for centuries to lift

water to heights over 100 meters and is considered an effective machine for pumping water once certain conditions are satisfied. The pump construction was simple and consisted of a pump chamber fitted with two moving parts, an impulse valve through which the driving water was wasted and a delivery valve through which the water was delivered [4]. It works solely on the power supplied from the water head in the source. This source could be a spring, streams, river, ponds, dam, lakes and even some wells, once the conditions exist for these water sources to create a hydraulic flow head, either by forming a dam or a naturally existing head. Basically, once a hydraulic head can be created, the pump can operate, however, the source must provide a steady and reliable supply of water [5]. The ram pump must be installed at a location lower than the water source which is used to create the flow giving the fluid (water) some velocity. In many rural farming areas, having a reliable source of water for crops and livestock can prove to be an expensive venture. In developing and under-developed countries, farmland are usually located close to a reliable water source to ensure viability [6, 7]. However, in many instances these locations are far from any reliable source of electricity and the cost can be prohibitive [6, 8]. In cases where the water source is situated below the level of the farmlands, getting the water to where it is needed can be challenging. Under these circumstances, a water pump operating on the water hammer effect and requires no external power source can serve as an effective means of pumping water to a higher altitude, once a reliable source is available. Also, in under developed countries, such as Haiti, the feasibility of using small hammer head pumps to provide clean water for citizens were explored by Prude University [9]. The ram pump can operate 24/7 and hence a water storage facility, such as storage tanks, at the water delivery end will be needed. This will serve as the reservoir to supply the needs when required. The major hindrance in using this established technology in third world countries is the exorbitant cost of the commercially available units. For a UK built pump the cost is US$ 1800 [10] and cheaper china made pumps range between US$500 to US$1300 [11]. One of the objectives of the Prude University project in Haiti was to develop a cheaper alternative, however, the cost was US$100 [9]. Therefore, there is the need to develop a low cost alternative that can be easily built from readily construction materials and requires minimal technical skills. Given the long history of the hydraulic ram pump, the design and manufacture has improved considerably with time and efficiency of operation increased. For commercial ram pumps the typical energy efficiency is about 60%, but can reach up to 80% [12].This is different from the volumetric efficiency, which relates the volume of water delivered to total water taken from the source. The amount of water delivered will be reduced by the ratio of the output head to the supply head. For example, if the source is 2 meters above the ram pump and the water is lifted to 10 meters above, only 20% of the supplied water will be available and the other 80% being spilled via the waste valve [13]. These ratios assumed 100% energy efficiency. The actual water delivered will be reduced further by the energy efficiency. Hence, for an energy efficiency is 70%, the water delivered will be 70% of 20%, which yields14% [13, 14]. Suppliers of rams often provide tables giving expected volume ratios based on actual tests. The amount of water delivered to the end for use will depend on source flow, height of supply reservoir above pump, height of delivery site above pump, length and size of delivery pipe and drive line, pump efficiency, and size of pump [15]. Considering the many combinations of these variables, the amount of water that can be delivered vary significantly. For example, delivery output from a single 2” ram pump system can range from a low of 17 gallons per day to 4,000 gallons per day or more [15]. Apart from the delivery output of the hydraulic ram pump depending on many variables the design itself is complicated by the three pipe flow system and the hydraulic ram effect [16]. The delivery output is a non-linear relationship with variables of input head and output head. Therefore, for a specific hydraulic ram pump, determining the delivery output at variable input and output head heights will be a critical factor in determining the applicability, suitability and effectiveness for use. This study investigates the performance characteristics of a low cost hydraulic ram pump with input and delivery head height variation and quantify the change in efficiency of delivered water. References [1] Whitehurst, J.: Account of a Machine for Raising Water, Executed at Oulton, in Cheshire, in 1772, Philosophical Transactions, 65, 277–279, doi:10.1098/rstl.1775.0026. JSTOR

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machine_60572542323.html?spm=a2700.7724857.normalList.2.20173dbdfO4fjp
[12] Advances in Civil Engineering Volume 2019, Article ID 9702183, https://doi.org/10.1155/2019/9702183 Determination of Hydraulic Ram Pump Performance: Experimental Results Wanchai Asvapoositkul, Jedsada Juruta, Nattapong Tabtimhin, and Yosawat Limpongsa [13] B. W. Young, "Simplified analysis and design of the hydraulic ram pump," in Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, vol. 210, no. 4, pp. 295–303, 2016. [14] W. M. Lansford and W. G. Dugan, "An analytical and experimental study of the hydraulic ram," University of Illinois Bulletin, vol. 38, no. 22, pp. 1–70, 1941. [15] TECHNICAL NOTES: U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE PORTLAND, OREGON, SEPTEMBER 2007, RANGE TECHNICAL NOTE NO. 26 Hydraulic Ram Pumps (available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_041913.pdf) [16] Tijsselingc, A. S., and Berganta, A.: Exact computation of water hammer in a three reservoir system, Eindhoven University of Technology, CASA-Report 12-41:1-10, 2012.

This cost list was included The materials/components required for the pump construction were obtained from the local hardware store. The cost of the components for the pump construction are shown in table 1. The total cost of the pump components is TT$178, which is equivalent to US$ 26.

Component TT$ (Trinidad and Tobago dollars) 2 One way swing valve (brass) 70 1 25.4mm PVC ball valve 15 50cm PVC pipe (32mm diameter) 5 1 13mm PVC ball valve 10 50cm PVC pipe (75mm diameter) 10 2 PVC end caps (75mm diameter) 12 1 PVC reducer 75mm to 32mm 8 1 PVC reducer 25.4mm to 13mm 3 3 male adapters 32mm 9 1 PVC elbow 32mm 4 2 PVC 'T' 25.4mm/32mm 20 1 PVC male adapter 13mm 2 1 PVC glue 50 ml 10

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