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# Tests on the wear in handpump cylinders

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## 1. Introduction

Most traditional handpump piston designs employ a reciprocating piston fitted with cup seals made from leather or rubber (ref.1). For a leather cup seal to operate efficiently, it is essential to maintain good quality control over its manufacture. The experience on rubber cups is that they are not very durable and they require regular and frequent replacement. A study of a new plastic IDRC-UM handpump in which the pumping element consists of a plastic PVC cylinder through which slides a PVC piston equipped with two polyethylene (HDPE) ring seals was reported in an earlier work (ref.2). The piston is made slightly smaller than the cylinder and the sealing action is achieved by the piston rings which expand or contract to fit the dimensional variations of the cylinder. It has been shown that differences in diameter between the piston and cylinder of up to 0.4 cm. did not significantly affect the mechanical performance of the pump as characterised by the volumetric and mechanical efficiencies. This is a major advantage because the components of the pumping element do not have to be made with very precise tolerances. This is particularly relevant for local manufacture in a developing country where quality control may be difficult to maintain. The ring seal design also enables the handpump to be operated at a higher piston speed without a corresponding increase in friction. In fact, it may be shown that the sealing efficiency of the ring seals increases with piston speed (ref.3). Acceptibility surveys of village users give the frequent comment that the handpump is "light and easy to operate" (ref.4).

A major problem of the present design is excessive wear of the PVC cylinder when fine sand particles are present in the water. The intention of the present design is for the softer polyethylene ring to wear in preference to the harder PVC cylinder. This was found to be true if the rings were rubbed against the PVC cylinder in clean water. However when fine sand particles are present in the water, wear on the PVC cylinder was very pronounced while no significant wear was observed on the piston rings (ref.1).

## 2. The present study

Much of our recent effort has been directed to finding a solution to the PVC cylinder wear problem. A simple solution is to switch the materials of the rings and the cylinder. The PVC rings rubbing against the polyethylene cylinder will wear off much faster and they may be readily replaced. Unfortunately such an arrangement has other disadvantages as polyethylene cannot be solvent welded together and the pump cylinder has to be designed with special threaded couplings. The VLOM (Village Level Operation and Maintenance) handpump concept (ref.5) requires the handpump to be designed for easy maintenance and repairs by villagers themselves. It is also important to encourage local fabrication of the handpump as it guarentees technology transfer as well as ensuring the availability of spare parts. PVC pipes, which are relatively cheap and commonly available in most developing countries, are the obvious choice for use as handpump cylinders at the moment.

## 3. Some field results

All of the 17 prototype handpumps installed for field tests in two rural areas in Malaysia are still in operation after approximately three and a half years. The PVC cylinders of five of these handpumps were removed and cut into halves along the longitudinal axis so that the wear on the cylinder section can be measured in the laboratory. Figure 1 shows a plot of the wear (which is represented here as the total volume of material removed due to wear) against total accumulated sliding distance. As field monitoring was carried out only for a eight and a half month period, the total accumulated sliding distance at any time is obtained by extrapolation using the average accumulated sliding distance computed from counter readings over the monitored period. It may be observed that the cylinder wear is higher initially but stabilises to a lower but constant rate. The piston ring seal is not perfectly circular as it is formed after cutting off a small segment from a circular ring which is of a slightly bigger diameter than the pump cylinder. "Bedding-in" of the piston ring seals may have contributed to the initial higher rate of wear as observed in the field data. The cylinders of handpumps No. NS008PL and No. PK004L have worn through causing water to leak through the cylinders. It was also observed that the cylinder wall has worn so thin that it has become flexible. This may account for the scatter in the readings of wear for these two handpumps.

## 4. Comparison of field data with laboratory tests

An experimental rig for testing handpumps in the laboratory, which has been described in an earlier paper (Ref.1), was used to investigate wear of the PVC cylinder when sand particles are present in the water. Initially 1.27 cm. thick HDPE piston ring seals similar to those used in the field tests were fitted to the pistons. It may be observed from figure 1 that the measured wear after 400,000 strokes fall on the wear curve of the field results. A further test using 0.635 cm. thick HDPE piston rings showed a reduction in wear after the same number of strokes. This is to be expected as the effective accumulated sliding distance is half that for the 1.27 cm. thick piston rings. To overcome the inevitable reduction in spring tension in the thinner ring, a stainless steel wire spring is inserted in a groove on the inside of the ring. Figure 2 shows a comparison of the measured mechanical efficiency of the handpump when 1.27 cm. and 0.635 cm. thick ring seals were used at 2 different stroke lengths of operation. The results show that the mechanical efficiency of the handpump fitted with 0.635 cm. thick piston seals is not significantly different from that of the handpump fitted with 1.27 cm. thick piston ring seals.

## 5. Variation of wear of PVC cylinder with different ring materials

A laboratory investigation was also carried out to determine the PVC cylinder wear rate when ring seals made from different materials are used. In this experiment, ring specimens were rubbed against flat PVC pieces in horizontal motion in water containing fine sand particles.

Figure 3 shows the results of cylinder wear when ring specimens made from Polycarbonate, PVC, Acetal, Nylon, HDPE, a combination HDPE/copper oxide and lastly plasticised PVC were rubbed against PVC plates. It may be observed that with the exception of the last two materials, all the rest cause more wear than if HDPE were used as the ring material.

A plausible explanation of the behaviour of polymer-sand-polymer wear is that the sand particles, when trapped between two polymer surfaces in sliding contact, becomes embedded in the softer of the two polymer surfaces forming an abrasive surface which wear off the harder polymer surface. When a combination of HDPE and copper oxide is rubbed against PVC, the copper oxide is shed and acts as a solid lubricant which prevents the formation of the abrasive surface. Plasticised PVC , on the other hand, behaves differently. Because of its "rubber-like" property, it is difficult for the sand particles to get embedded in the plasticised PVC surface - hence no abrasive surface is formed. It also reduces the abrasive action by "giving-way" when pressure is applied and by expelling the sand particles from its surface when the pressure is released.

## 6. Conclusions

The results showed that wear in the handpump PVC cylinder may be reduced by decreasing the piston ring thickness and by the selective choice of ring seal materials such as a combination of HDPE and copper oxide or a plasticised rubber. Depending on the chosen ring seal material, it may be neccessary to modify the ring seal design to maintain the high mechanical efficiency of the handpump.

## References:

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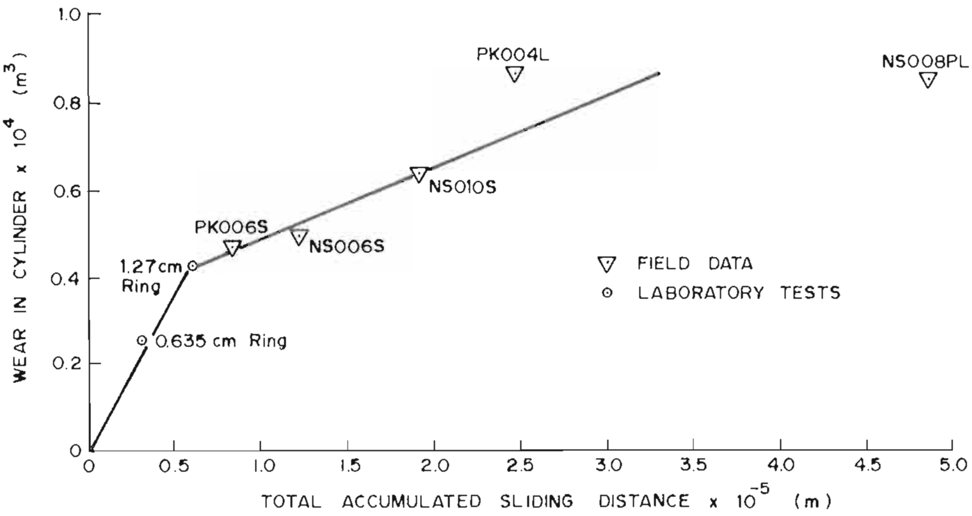


FIG. 1 VARIATION OF WEAR OF PVC CYLINDER WITH TOTAL ACCUMULATED SLIDING DISTANCE

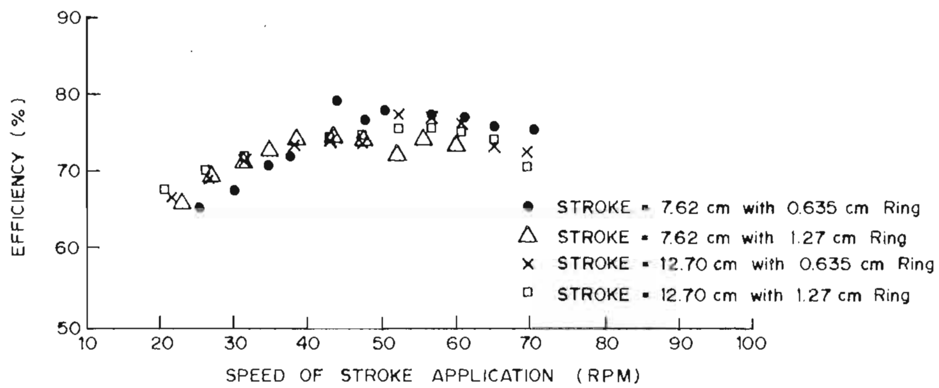


FIG. 2 VARIATION OF MECHANICAL EFFICIENCY WITH SPEED OF STROKE APPLICATION AT 612 cm WATER HEAD

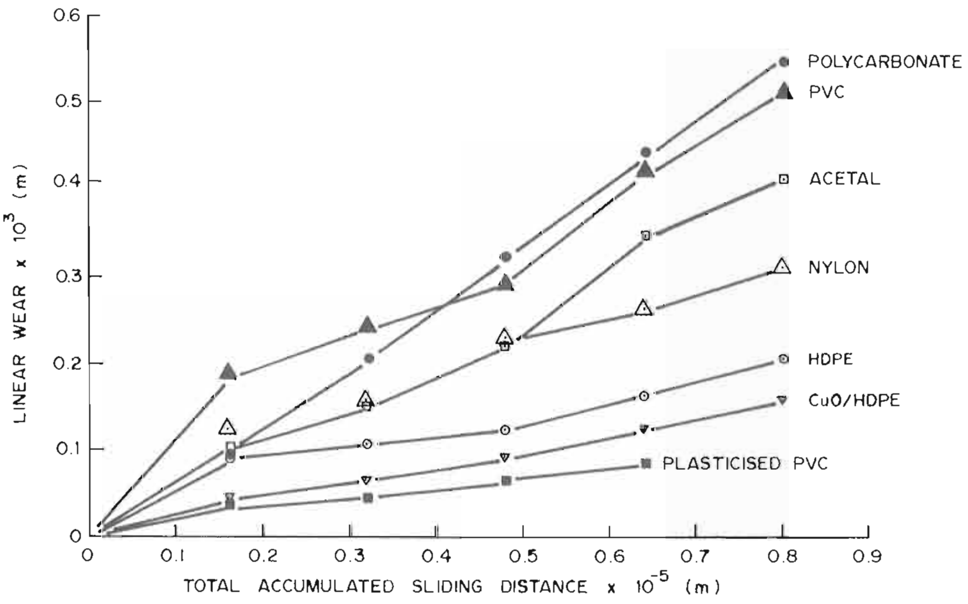


FIG. 3 VARIATION OF WEAR OF PVC CYLINDER WITH TOTAL ACCUMULATED SLIDING DISTANCE FOR DIFFERENT RING MATERIALS