The effects of cavitation on pump efficiency

During the design and assessment of pumping systems, one of the factors that must be taken into account is the effect of cavitation on pump efficiency. Cavitation is a phenomenon where, under certain conditions, vacuum bubbles are created within the pump, leading to increased pump damage and decreased efficiency.

To better appreciate cavitation, an understanding of the physics of how a pump works is necessary. In a pump, the rapid spinning of the impellor creates an area of low pressure in the centre of the impellor. The outside air pressure then pushes water up the suction line and into the pump to fill the low pressure area created. The centrifugal force of the spinning impellor then imparts pressure on the water, before delivering it from the pump outlet.

As it is air pressure which pushes the water along the suction line into the pump, the higher the pump is above the water surface the less water can be delivered to the impellor. Atmospheric pressure at sea level is approximately 10.33m (100kPa), and this means the theoretical maximum height the water can be pushed above the water surface is 10m. Friction in the suction line; which is a function of the flow rate, pipe material, pipe condition and pipe diameter; height above sea level, restrictions in the suction line (e.g. foot valves), and pump characteristics reduce this height to a practical maximum of approximately 6m above the water surface. It should be noted, that at this height, the performance of the pump would be significantly reduced, and in practice, the height could be much less than 6m. There are some complex calculations used to determine the situations a particular pump will cavitate under, but the effects of not getting this right can range from a decrease in efficiency, to the destruction of the pump.

In a situation where the limits of suction are exceeded, tiny vacuum bubbles are created in the water. When these vacuum bubbles contact a surface within the pump, they explode, and start to erode the inner surfaces of the pump, which can lead to premature pump failure. The more apparent effect of cavitation is the decrease in the performance of the pump compared to its pump curve i.e. the pump not pumping as much water as it should.

Cavitation can occur if the flow rate exceeds the capacity of the pump. When the vacuum bubbles form, the amount of water being pumped decreases, because the bubbles are taking up space that would otherwise be occupied by water. At low flow rates, the water circulates within the pump causing recirculation cavitation, where the rapid spinning of the impellor creates vacuum pockets because the water isn’t moving through the pump quickly enough. Another scenario is, if the height of the pump above the water surface is too high, not enough water can be pushed into the pump by atmospheric pressure and cavitation occurs.

The best description of cavitation is the pump sounding like it is pumping gravel. This sound is the explosions of the vacuum bubbles collapsing. Air within a pump may
produce similar symptoms, but air is much less damaging than a vacuum, but will still affect pump efficiency.

During the RWUE-IF project, a pump was assessed which was being used to fill a tank. There was no flow restriction in the system, so the pump was pumping at the upper limit of its capacity. This set up conditions suitable for pump cavitation, and it was assumed by the grower the bubbles that could be heard were air bubbles. As part of the assessment, the pump was first run under the usual operating conditions. The outlet pressure measured was 330 kPa, and the flow rate 5040 L/hr. It was found that these measured points didn’t match the pump curve, due to the effects of cavitation. A second test was carried out with the delivery tap adjusted until the pump started to run more quietly, and then a second test was conducted. During this test, the outlet pressure measured was 420 kPa and the flow rate 6480 L/hr. When the pressure and flow rate was compared to the pump curve they matched exactly, showing a significant improvement in performance and reduction in the energy costs of pumping.

Lex McMullin - RWUE-IF Irrigation Technical Contractor