EFFECT OF DELIVERY HEAD VARIATION AND INLET GUIDE VANE FAILURE ON THE OPERATING POINT AND BLADE WEAR OF LARGE VERTICAL CENTRIFUGAL PUMPS

Sayliyev Odiljon Ixtiyor o'g'li
https://orcid.org/0009-0008-5091-9804
saylievodiljon@gmail.com
tayanch doktorant
Jovliyev Uktam Temirovich
jovlievuktam1985@gmail.com
ORCID iD: 0000-0003-4490-9518
Meliorativ texnika va mexanizmlar laboratoriya mudiri
Scientific Research Institute of Irrigation and Water Problems, 100187 Tashkent, Uzbekistan.
Irrigatsiya va suv muammolari ilmiy-tadqiqod instituti

Pumping station No. 7 of the Karshi Main Canal lifts Amu Darya water into the Talimarjon reservoir. Seven of its nine units are 2400VR-25/25 vertical centrifugal pumps with a rated flow of 25 m^3/s and a rated head of 25 m, driven by 8000 kW synchronous motors at 187.5 rpm [1]. According to the technical inspection act of 2022, the geometric lift of the station varies from 7.6 to 26.1 m and the manometric head from 16.0 to 32.8 m, mainly because of the changing water level in the reservoir. The same act states that the inlet guide vanes of the pumps are out of service and their drives are faulty [1]. Without guide vane control the operating point of a pump is fixed only by the head required by the system. Because the hydro-abrasive wear rate of impeller blades depends strongly on the relative flow rate [2, 3], the aim of this work is to estimate how the head variation shifts the operating point and changes the blade wear.

The head curve of the pump was represented by a schematic parabola

$$H(q) = H_{\text{opt}}(a_H - b_H q^2), \qquad q = Q/Q_{\text{opt}} \quad (1)$$

with H_{opt} = 25 m, a_H = 1.35 and b_H = 0.35. The coefficient a_H was chosen so that the shut-off head (33.75 m) exceeds the maximum manometric head of 32.8 m. The operating point for a given manometric head H_m follows from (1):

$$q = \sqrt{\frac{a_H - H_m/H_{\text{opt}}}{b_H}} \quad (2)$$

The relative blade wear was estimated from the power law $E/E_0 = (C_m/C_{m0})\, q^{2.61}$, which the authors obtained earlier from Lagrangian particle tracking in the impeller of this pump; C_m is the sediment concentration and C_{m0} = 3 kg/m³. The minimum-wear zone A, $0.75 \le q \le 1.15$, was taken from field studies of irrigation pumps on the Amu Darya [4].

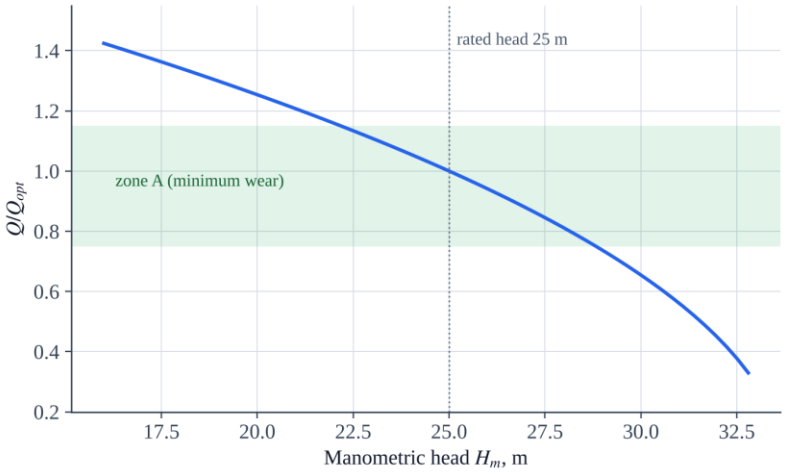


Fig. 1. Operating point of the 2400VR-25/25 pump versus manometric head (schematic head curve); the shaded band is the minimum-wear zone A

Table 1. Operating points and relative blade wear at different manometric heads ($\boldsymbol{C_m}$ = 3 kg/m³)

H_m, m	16.0	20.0	25.0	28.0	30.0	32.8
$q = Q/Q_{\text{opt}}$	1.42	1.25	1.00	0.81	0.66	0.33
Zone	C	C	A	A	B	B

H_m, m	16.0	20.0	25.0	28.0	30.0	32.8
E/E_0	2.50	1.80	1.00	0.58	-	-

Figure 1 and Table 1 show that within the recorded head range the relative flow rate changes from 0.33 to 1.42. The pump stays in zone A only when the manometric head is between about 22.2 and 28.8 m. At low heads (low reservoir level) the pump runs at large flow rates (zone C), and the blade wear is 1.8-2.5 times higher than at the best efficiency point. At high heads the pump runs at part load (zone B), where inlet recirculation, incidence and vibration increase; here the power law is not applicable, and wear is controlled by recirculation [2].

The combined effect of head and sediment concentration is shown in Fig. 2. The most severe condition occurs when a low head coincides with high turbidity: at H_m = 16 m and C_m = 7 kg/m³ the blade wear is about 5.8 times higher than at the reference condition. In the Amu Darya basin the highest turbidity occurs in summer [4], so the seasonal change of the reservoir level and of the turbidity must be considered together when planning repairs.

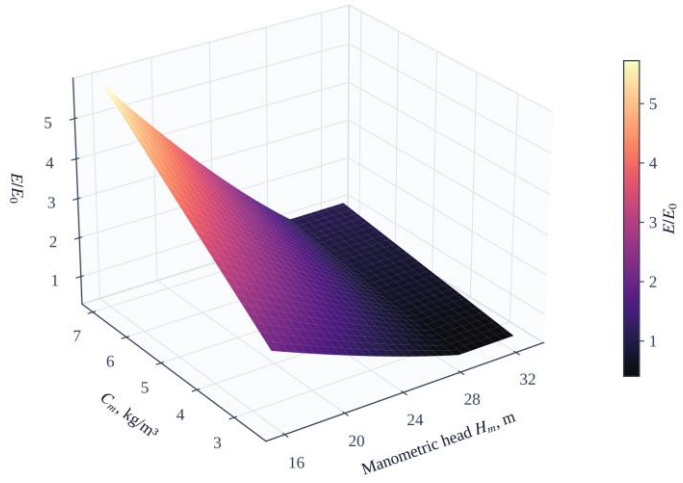


Fig. 2. Relative blade wear versus manometric head and sediment concentration (for $q < 0.75$ the wear is limited to the value at $q = 0.75$)

Conclusions. Loss of inlet guide vane control at pumping station No. 7 forces the pumps to operate in a wide range of relative flow rates (0.33-1.42) dictated by the reservoir level. At low heads blade wear increases up to 2.5 times, and up to 5.8 times when low heads coincide with high turbidity. Restoring the inlet guide vanes is therefore an important hydraulic measure for reducing wear, because it keeps the operating point in the minimum-wear zone. Until they are restored, the manometric head of each unit should be recorded continuously and the operating hours at low heads should be counted with a higher weight in the service-life calculation. The schematic head curve used here should be replaced by the measured pump characteristic, for example according to [5].

References

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