Technical paper:

Applying feed pump systems without boosters in NPPs

The main feed water pump during assembly for the Kalinin NPP.

In order to overcome the technical challenge of achieving super low Net Positive Suction Head in feed pumps, Russian engineers have developed a system which does not require a booster pump. This has the advantage of requiring fewer pumps, thereby lowering costs and producing significant space savings. Adding an inducer in the first stage means it is no longer necessary to have two pumps, plus the pump can operate without a booster.

Keywords: *Pumps, Feed pumps, Boosters, Inducer, Cavitation*

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The 1960s were notable for the rapid development of nuclear and thermal power generation capacities. Units capable of producing 200 MW, 300 MW and 500 MW were engineered and manufactured at an accelerated pace. The main systems and pumps for thermal power plants were also developed in this period.

The VNIIAEN Sumy pump facility, (now called HMS Group) was founded in 1956, mainly to develop condensate and circulation pump engineering. One of the major technical challenges was to achieve super low Net Positive Suction Head (NPSH - see box) in the engineered pumps. Analysis of all possible solutions conducted at that time predetermined ways in which to handle the challenge.

Achieving the required NPSH for condensate pumps by placing them below the foundation level was found to be an expensive, material-consuming and ineffective option. This led to the decision by our engineers to install an inducer in the first stage. While these inducer stages had been applied mostly in rocket and space technology and a number of papers on research and modeling had been published, there had not been any research or experimental studies in relation to industrial pumps. Therefore thorough theoretical and experimental studies preceded the engineering of these to identify problems and solutions. These first experiences of inducer engineering for condensate pumps, and eventually feed pumps, was also valuable from the point of view of overcoming the psychological barrier of whether it was possible. It is necessary to point out that quite a number of engineers have not yet overcome this.

Combating cavitation

At present, various types of cavitation have been thoroughly studied and prediction methods for the expected operational life of impellers have been developed. The key factors for the impact on cavitation have been extensively described, namely:

- Circumferential velocity at the leading edge of impeller blade;
- Pump design, primarily impeller geometric features and then suction chamber features.
- $NPSH_i$ / $NPSH_R$ ratio
- Liquid density
- Impeller material resistance to cavitation erosion
- Liquid temperature
- Modes of operation
- Suction specific speed.

These factors are often not taken into consideration in relation to inducer stages, and the probable cause of that may be that same psychological barrier. Meanwhile, our research of the impact of these cavitation factors suggests that impeller research results published by numerous foreign authors are also valid with regard to inducer stages.

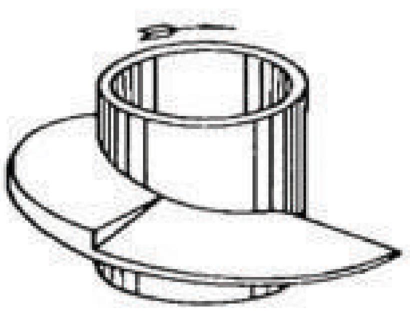

Figure 1. Blade of inducer with a cuneate ledge.

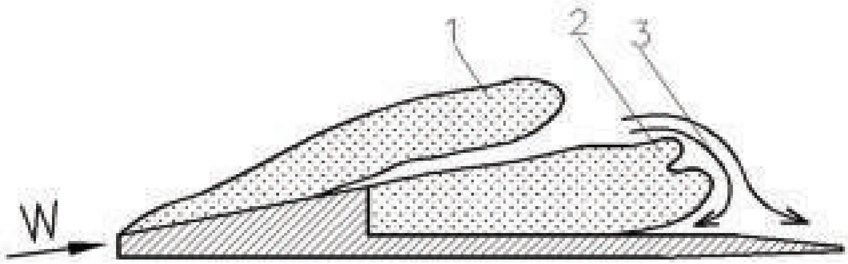

Figure 2. Flow diagram on suction surface of the blade with a cuneate ledge 1 – main bubble; 2 – bubble behind the cuneate ledge; 3 – returned flow.

Therefore, in this paper we will focus on our patented solution, which provides conditions for separate cavitation flow formation, which is known to reduce damaging effects of cavitation. To ensure this, the suction surface of the inducer was given a cuneate ledge (Figure 1). Visual observations showed the formation of two bubbles in the cavitation flow on the surface of the blade (Figure 2). The second bubble, located behind the cuneate ledge, represents minimal damage from cavitation due to periodic separation from the surface by returned flow. At the same time it acts as a damper and protects the surface from the damaging effects of the main bubble.

Figure 3 shows the comparison of cavitation erosion resistance with a traditional inducer design vs. design with cuneate ledge.

was empirically defined by taking into account the circumferential velocity, liquid temperature, material selection, suction specific speed, etc. Data shows that the coefficient of erosion (coming from known CE = $U_{inducer} \times D_{inducer}$1/2 relation) is below the threshold value for inducers with a cuneate ledge.

- In world practice operators expect to achieve between 40,000 and 60,000 hours of operation while the cumulative damage should not reach 75% blade thickness. As seen from data, the cuneate ledge ensures pumps comply with that requirement.
- Cuneate ledge also ensures erosion-free operation of the inducer stage.

At present, pumps with an inducer stage make up a significant portion in many product lines for our company. Altogether there are about 60 types including:

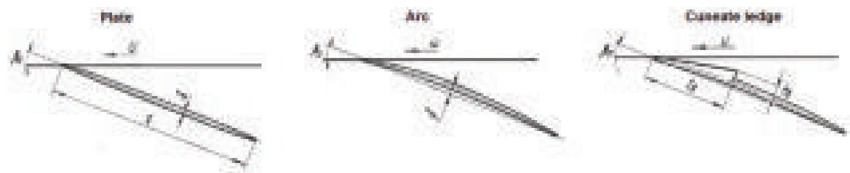

Figure 3. Comparison of cavitation erosion resistance – traditional inducer design (profile – arc, plate) vs. design with cuneate ledge.

Analyzing the data

Analysis of the data in Table 1 shows the following.

- Suction specific speed n_{ss}= f($NPSH_3$) does not exceed 400, while the maximum achievable for inducer stages amounts to 700 according to our experience and confirmed by international peers. On-site this coefficient is even lower due to the fact that the pump operates at $NPSH_A$ > $NPSH_3$. The difference is selected by the pump supplier.
- During research and experimental studies we introduced a threshold value of coefficient of erosion, which

- KsV and KsVA condensate pumps, 30-2200 m^3/h flow-rate range.
- PE and PEA feed pumps with up to 2000 m^3/h flow-rate.

Based on experience around the world and our own practice we can unequivocally justify the use of inducer stages in some pumps. Therefore we now offer new feed pumping systems without a booster for new nuclear power generating units with 3000 rpm drive:

- multistage barrel insert pumps with double suction first stage with inducer and without booster;

Table 1. Similar pumps.

Q, m^3/h	n, rpm	*Suction specific speed, $n_{ss} = f(NPSH_3)$	Liquid temperature, °C	Circumferential velocity, m/s	Blade type	Coefficient of erosion (CE)	CE, threshold value	Operating time, h	Presence of destruction on blades
500	1500	400	50	24	Plate, arc	13,4	9	2000	Damage (through-holes in some places)
					cuneate ledge		20	18000	without damage
625	3000	326	50	25,6	Plate, arc	14,7	9	87	Damage (through-holes in some places)
					cuneate ledge		20	8000	without damage
850	3000	337	165	41,4	cuneate ledge	21,3	50	180000	without damage
1000	1500	316	50	27,9	Plate, arc	16,6	12	1173	Damage (through-holes in some places)
					cuneate ledge		20	12949	without damage
1650	3000	372	165	51,5	cuneate ledge	29,6	50	55000	without damage

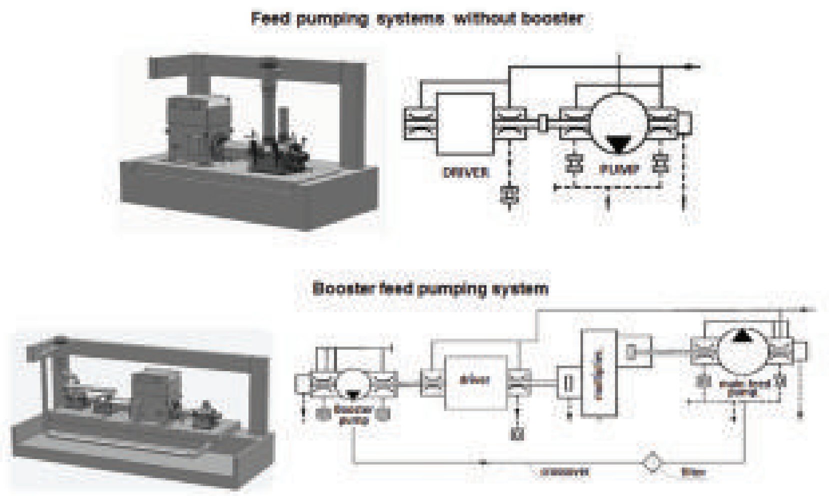

Figure 4. Comparison of booster systems and systems without booster.

- multistage barrel insert pumps with back-to-back impeller design and first stage with inducer and without booster.

It is possible to regulate these pumps with a hydro coupling or frequency converters.

Taking into account the special requirements for pumps operating in nuclear plants, the NPSHA value must be more than (1,25 + 0,025 × U1) x $NPSHR_3$. In the world of pump engineering practice this rule is recommended to minimize damage from erosion for the whole operating range of pump.

Booster systems

Booster systems are used for similar applications around the world, consisting of a main high-speed pump with 1500 rpm drive through a multiplier and booster pump with the same rotation speed (Figure 4). The advantages of feed pumping systems without a booster compared to booster systems include:

- No booster pump, crossover (pipe), multiplier, filter
- Significantly reduced system dimensions. So are the overall space ~ by 26 m^2 and foundation – less capital costs. Fewer dampers, foots, etc.
- Performance (efficiency) is higher
- Lower cost of maintenance
- Oil system, mechanical seal support, control system and other support systems are simpler.
- More reliable operation of pumps in the system because of lower rotation speed
- Significantly reduced weight of the system
- Cost of the system is cut by 20-25%.

Conclusion

The practice of applying feed pumping systems without a booster and hence with low NPSH because of inducers has been developed in Russia since the 1960s. The practice has proven its worth and suitability for possible application in the new nuclear and thermal power generating units.

What is Net Positive Suction Head (NPSH)?

The NPSH parameter shows the difference between the actual pressure of a liquid in a pipeline and the liquid's vapor pressure at a given temperature. NPSH is an important parameter to take into account when designing a circuit: whenever the liquid pressure drops below the vapor pressure, liquid boiling occurs, and the final effect will be cavitation: vapor bubbles may reduce or stop the liquid flow, as well as damage the system.

NPSHA = NPSH available amount to the pump intake after pipe friction losses and head pressures have been taken into account.

NPSHr = NPSH required is the amount of liquid pressure required at the intake port of a pre-designed and manufactured pump.

Source: http://en.wikipedia.org/wiki/NPSH