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CAVITATION DUE TO THE RECIRCULATION - IMPORTANT CRITERIA FOR DESIGN OF HEAVY DUTY PROCESS PUMPS

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ABSTRACT

Design of heavy duty process pumps usually based on different design criteria depends of pumps application. Cavitation due to the recirculation is not often mentioned as design criteria although many problems in pump operation appear because of cavitation due to the recirculation. In this article cavitaton due to the recirculation will be analyzed as design criteria.
This paper gives an analysis of operating condition of pumps in pumping systems cause damage by cavitation due to the recirculation on impeller of split casing pump operate at partial flow.
New hydraulic design for pump is developed to improve the operating range and avoid the range of recirculation on partial flow.

1. INTRODUCTION

Design of heavy duty process pumps usually bases on end user requirements. Operating condition of pumps in the system dictate technical solution to reach high performance pump design.

Pumps for nuclear power plants and pumps for special application should reach very high design criteria. API 610, ISO 13709 international standards specifies requirements for pumps for petroleum, petrochemical and natural gas industry.

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Basic requirements

Optimum flow rate, optimum head
Efficiency level on the highest values between world competitors
NPSH very low at very high efficiency
Material requirements

Other requirements

Q – H stability
Life time / operation cycles
Critical speed
Reliability characteristics - critical reliability – probability of failure
Seismic requirements
Flow – vibration limit
Noise criteria
Axial / radial forces

Thermal analysis
Structural analysis
Fatigue analysis

Thermal barrier
Control and protection system
Instrumentation / alarms

Recirculation range

Design criteria could be selected according to the application

- Nuclear power plant
- Petroleum, petrochemical and natural gas industry.
- Other application

Requirements for pumps for nuclear power plants are very high and very specific. Design criteria should provide high reliability and high performance pumps.

API 610, ISO 13709 international standards specifies requirements for pumps for petroleum, petrochemical and natural gas industry.

Requirements for pumps for other application usually consider basic design requirements with some additional other requirements.
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2. NPSH AND RECIRCULATION REQUIREMENT

Cavitation in a centrifugal pump has a significant effect on pump performance.
NPSH characteristic of the pump directly influence reliability of the pump and strong limits the operating range.

Cavitation can occur under certain conditions and cause damages of impellers or other pump parts.

NPSH available of the system is very important and this should be analyzed even for every pump sales.

Cavitation appear when the energy of the system $NPSH_a$ is not enough higher than NPSH characteristic of the pump in operating range. NPSHreq is basic requirement for any pumps design. Recirculation range is not very often a design requirement or even more, many model pumps tests do not contain testing of recirculation range.

Hydraulic design of pump should prevent many negative effects of cavitation in pumps.

Criteria for NPSHreq is suction specified speed SS

$SS = nQ^{0.5} / NPSH^{0.75}$

SS is determinate for BEP and 3% NPSHreq.
Normal values of SS
SS = 160-220 for axial inlet impellers
SS = 220-280 for suction impeller with axial inlet.

Design criteria for SS usually is as much as higher for high level of efficiency.

Some important parameters for NPSHreq

Circumferential velocity at the impeller inlet
Impeller inlet diameter D_1
Inlet angle of impeller blade
Number of blades

Some important parameters for Recirculation range

Impeller inlet diameter D_1
Impeller hub diameter D_o
Suction specific number SS

In general, parameters improving NPSHreq and higher SS cause to increase the recirculation range and limit pump safety operating range.

3. CAVITATION DAMAGE OF PUMP IMPELLER DUE TO THE RECIRCULATION

Cavitation damage due to the recirculation happens very often in the pump operation. The suction vortex is occurring at the inlet of the impeller between the vanes. Such vortex can cavitate at its core and attack the metal surface of the pressure side of the impeller blades. One example is water cooling pump with wide operation range and very often operating point reach recirculation range.

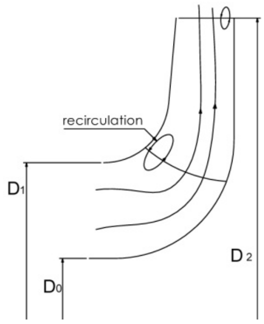

Fig. 1 Suction recirculation at the inlet

Water cooling split casing pump nq = 40
Medium: Water 62 °C
SS = 206 (for half flow rate)

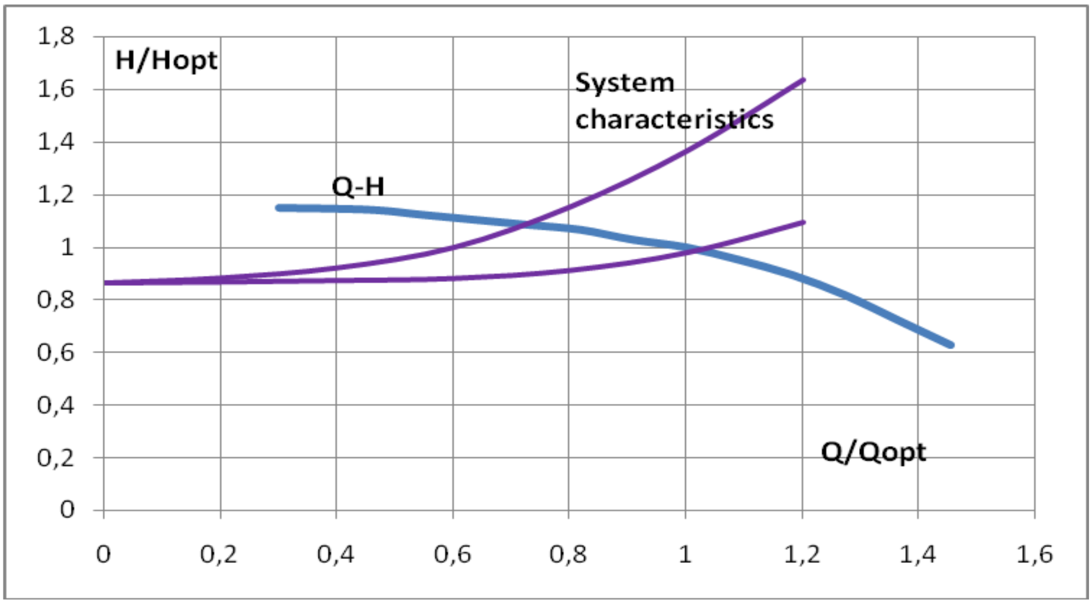

Fig.2 Dimensionless characteristic curve of existing pump and system characteristic

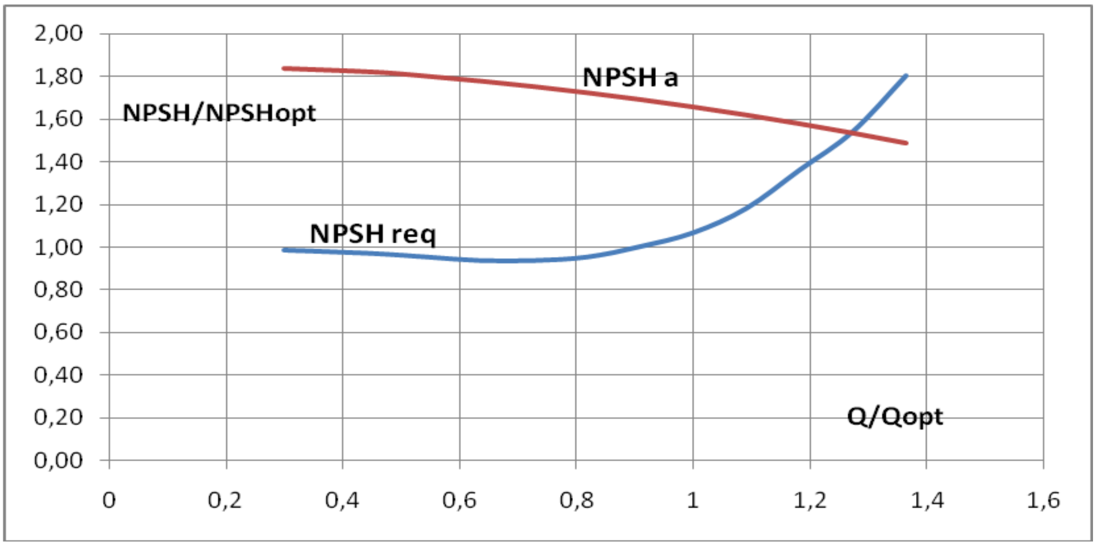

Fig.3 Dimensionless characteristic of NPSH req and NPSH a

Pump operates in the range 0,7-1,0 of Q opt (Fig.3) Although available NPSHa in the system is enough higher than NPSHreq of the pump cavitation due recirculation damaged impeller (Fig.4)

Fig.4 Cavitation damage due to the recirculation

4. SOLUTION OF THE PROBLEM WITH NEW HYDRAULIC

New hydraulic was developed to provide wider operating range without recirculation and reach operating range around BEP.

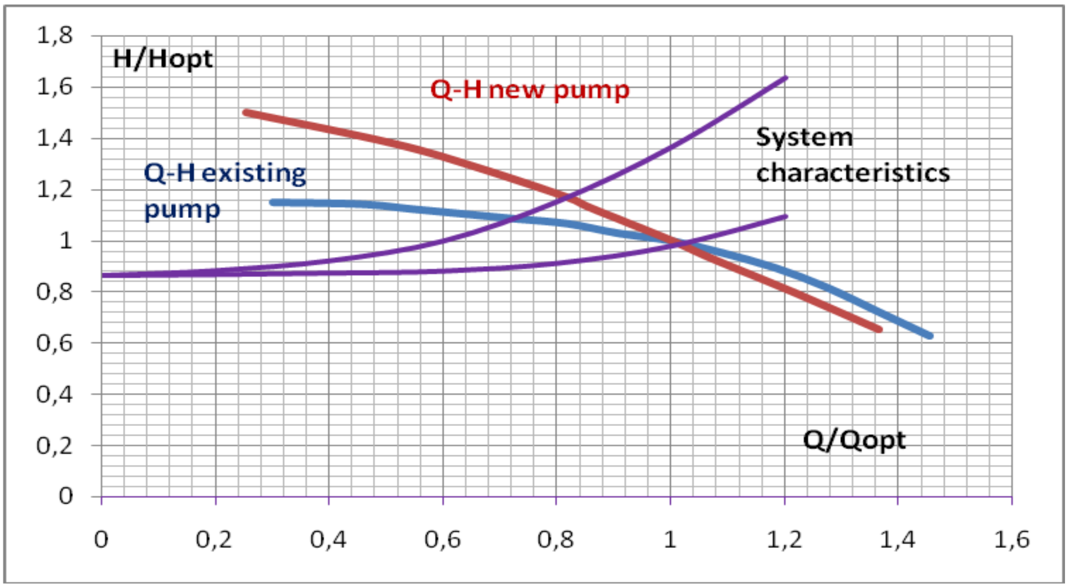

Fig.5 Dimensionless Q-H Characteristic of the new pump compare with existing one

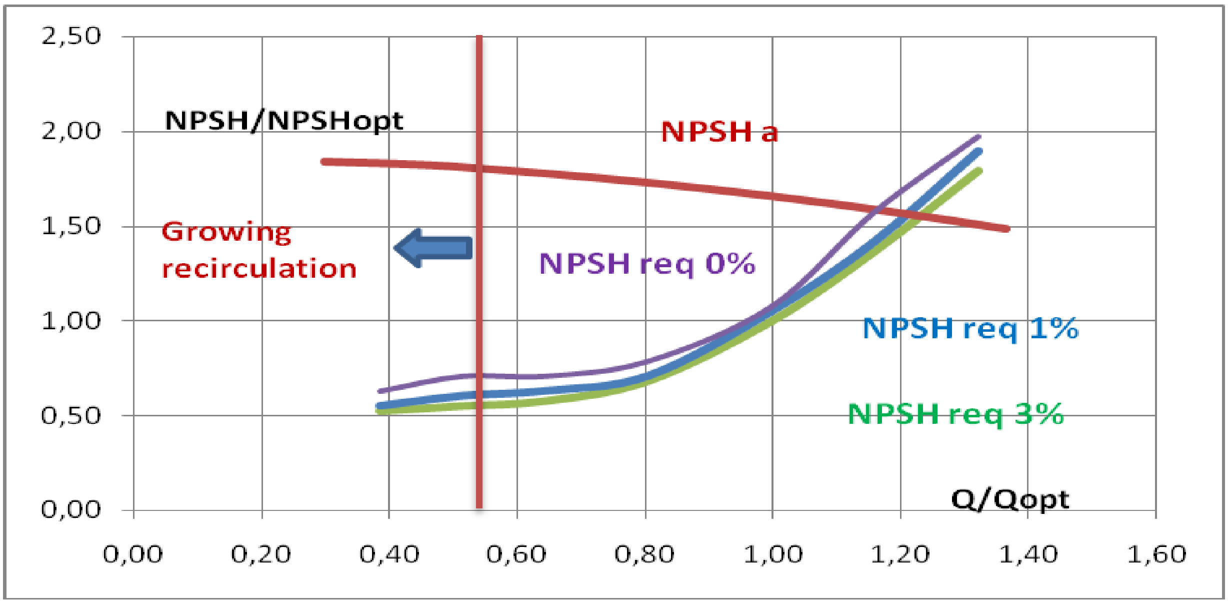

Fig.6 Dimensionless Q-NPSH Characteristic of the new pump

Hydraulic of hte new pump enable operating range between 0,82-1 Qopt which is good improvement compare with existing pump.

NPSH characteristics in fig. 6 shows that expecting range of recirculation could be for partial flow rate Q<0,6 Q opt.

In table 1 is shown comparison for important NPSH and recirculation criteria.

	nq	SS	Do/D1
Existing pump	40	206	0,51
New pump	41	191	0,56

Tab.1. Comparison of NPSH and recirculation criteria

Better recirculation range is obtained with reduction the suction specific speed and increase the ratio of impeller Hub diameter D_o and Impeller eye diameter D_1.

Numerical analysis (Fig. 7) is done for calculation the NPSH characteristics of the new pump.

CFD analysis still not reach satisfactory results for NPSH calculation as calculation the Q-H-eta characteristics, but this calculation can show the expecting range of NPSH and range of recirculation.

In many industrial applications [3], [4] a CFD analysis is important for determination of velocity distribution on impeller inlet (Fig. 8) which enable to reach optimal design of impeller and casing geometry.

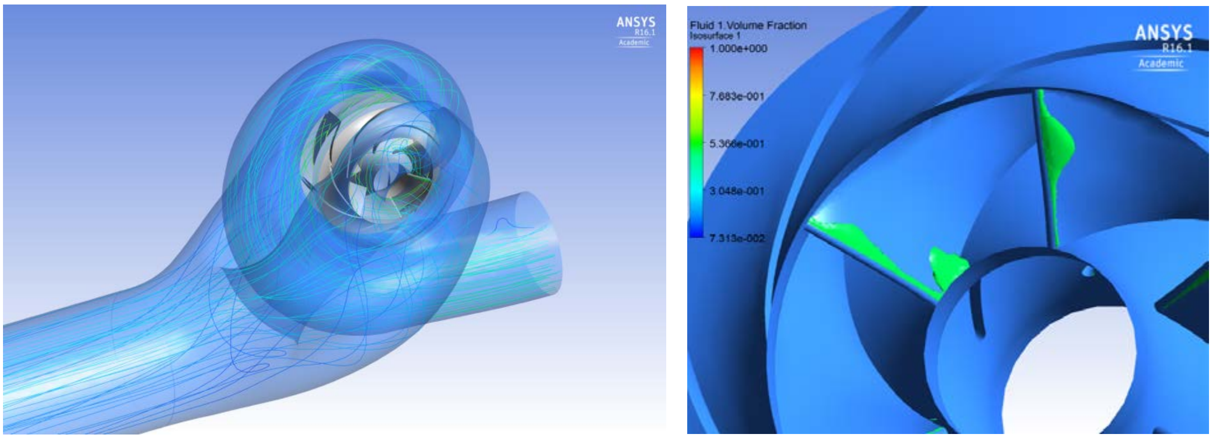

Fig. 7 CFD calculation of bubble formation

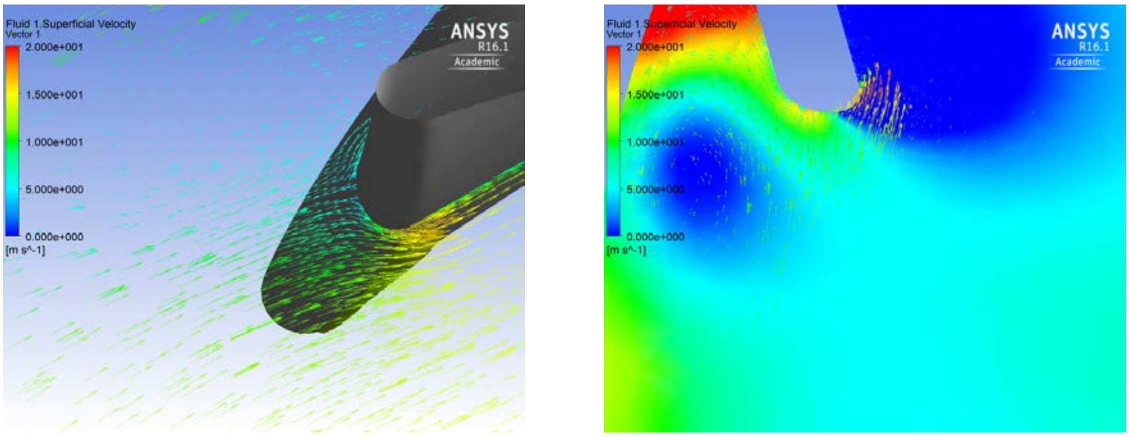

Fig. 8 CFD calculation of inlet recirculation

5. CONCLUSION

Recirculation design criteria is important to reach reliable pump design for all types of application. Testing of model pumps characteristics should contain high precision measurement of NPSHo%, NPSH 1%, NPSH 3% and cavitation noise measurement.

6. REFERENCES

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7. NOMENCLATURE

SS	[-]	suction specify speed
n	[rpm]	revolution per minute
Q	[m^3/s]	flow rate
Qopt	[m^3/s]	optimum flow rate
NPSH	[m]	net positive suction head
NPSHa	[m]	available net positive suction head
NPSHreq	[m]	required net positive suction head
NPSH o%	[m]	net positive suction head at 0% head drop
NPSH 1%	[m]	net positive suction head at 1% head drop
NPSH 3%	[m]	net positive suction head at 3% head drop
Hopt	[m]	optimum head
H	[m]	head
D_o	[m]	impeller hub diameter
D_1	[m]	impeller eye diameter