Inducer Designs

Axial flow inducers are intended to improve the cavitation performance of centrifugal or mixed flow pumps

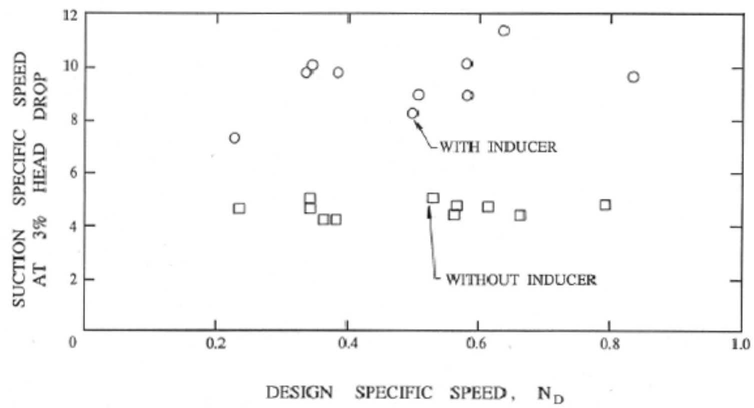


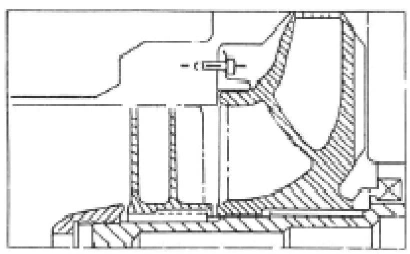
Figure 1: Comparison of the suction specific speed at 3% head drop for process pumps with and without inducer (from Janigro and Ferrini 1973).

by increasing the inlet pressure to the pump to a level at which it can operate without excessive loss of performance due to cavitation. Typically they consist of an axial flow stage placed just upstream of the inlet to the main impeller. They are designed to operate at small incidence angles and to have thin blades so that the perturbation to the flow is small in order to minimize the production of cavitation and its deleterious effect upon the flow. The objective is to raise the pressure very gradually to the desired level. The typical advantage gained by the addition of an inducer is illustrated in figure 1 taken from Janigro and Ferrini (1973). This compares the cavitation performance of a class of process pumps with and without an inducer.

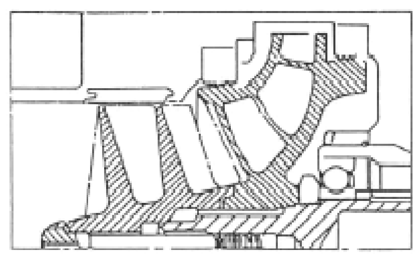
Various types of inducer design are documented in figure 2 and in table 1, both taken from Jakobsen (1971). Data on the low pressure LOX pump in the Space Shuttle Main Engine (SSME) has been added to table 1. Most inducers of recent design seem to be of types (a) or (b). They are unshrouded, with a swept leading edge and often with a forward cant to the blades as in the case of the low pressure LOX pump in the SSME (figure (Mbbi)). This blade cant has the effect of causing the leading edge to be located at a single axial plane counteracting the effect of the sweep given to the leading edge. They are also designed to function at an incidence angle of a few degrees. The reason that the design incidence angle is not zero is that under these conditions cavitation could form on either the pressure or suction surfaces or it could oscillate between the two. It is preferable to use a few degrees of incidence to eliminate this uncertainity and ensure suction surface cavitation.

Table 1: Typical rocket engine inducer geometry and performance (from Jakobsen 1971 and other sources). Key: (a) Main + Partial or Main/Tandem (b) Radial (RAD), Swept Backwards (SWB) or Swept Forward (SWF)

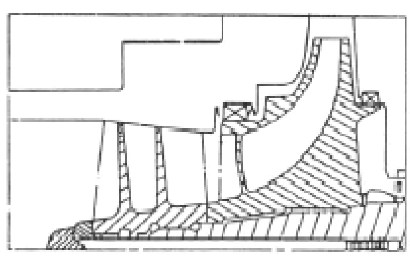
Rocket:	THOR	J-2	X-8	X-8	J-2	J-2	SSME
Fluid:	LOX	LOX	LOX	LOX	LH2	LH2	LOX
No. of Blades (a)	4	3	3	2	4+4	4+4	4/12
R_{H1}/R_{T1}	0.31	0.20	0.23	$\sim$0.19	0.42	0.38	0.29
R_{T2}/R_{T1}	1.0	1.0	$\sim$0.9	$\sim$0.8	1.0	$\sim$0.9	1.0
R_{H2}/R_{H1}	1.0	$\sim$2	$\sim$1.5	1.5	$\sim$2	$\sim$2	2.6
Leading Edge (b)	RAD	SWB	SWB	SWF	SWB	SWB	SWB
β_{bT1} (deg.)	14.15	9.75	9.8	5.0	7.9	7.35	7.3
ϕ_{1D}	0.116	0.109	0.106	0.05	0.094	0.074	0.076
ψ_{1D}	0.075	0.11	0.10	0.063	0.21	0.20	0.366
N_{1D}	4.21	3.06	3.25	3.15	1.75	1.61	0.68
α_{T1} (deg.)	7.5	3.5	3.7	2.1	2.5	3.1	4.3
σ_D	0.028	0.021	0.025	0.007	0.011	0.011	
S_D	10.4	12.5	11.4	21.2	15.8	16.2	



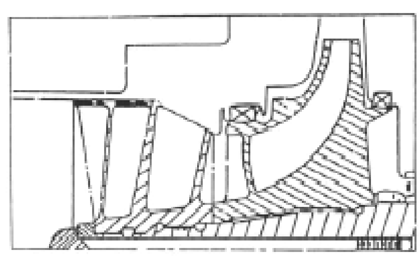
[a] Low-head inducer with cylindrical tip and hub.



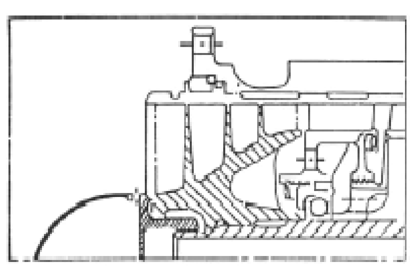
[b] Low-head inducer with cylindrical tip, tapered hub.



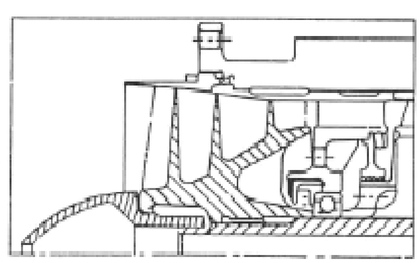
[c] Low-head inducer with tapered tip and hub.



[d] Low-head inducer, shrouded.



[e] High-head inducer with cylindrical tip, tapered hub.



[f] High-head inducer with tapered tip and hub.

Figure 2: Various geometries of cavitating inducers (from Jakobsen 1971).