Alternate Materials and Design Methodology for efficiency improvement of centrifugal Pump.

Overview:

Efficiency improvements in Pump and pumping systems have become the need of the hour. There are wide varieties of pumps being used both in Domestic Industrial and Agricultural sector. There are many types of pumps used in domestic sector. But it has become customary to use Regenerative self priming Pumps. The centrifugal pumps has been used for centuries in Agricultural application as they can handle high flow rates, provide smooth non pulsating flow, and can regulate the flow rate over a wide range without damaging the pump. The centrifugal pump have very low moving parts compared to any other pump and has low wear when operated within its normal range. The Monoset pumps in particular are compact and are easy to dismantle and assemble for maintenance.

Energy Conservation has become an important aspect both in Domestic Industrial sector and Agricultural Sector. Optimum utilisation of resources and reduction of Wasteful Energy have become areas of growing concern. The design of both efficient pump and efficient pumping system are discussed here so as to save energy and make this Universe Green.

Efficiency of Pumps:

The efficiency of Pumps depend upon specific speed. The specific speed is a non dimentional number used to classify the pumpsas to their types and proportions. In SI units it is defined as speed in revolutions per minute at whgich a geometrical similar pump Impeller would operate at a head of 1m while delivering one cubic meter of water.

The formula for specific speed has been

$$N_s = \frac{n\sqrt{Q}}{(gH)^{3/4}}$$

where:

N_s is specific speed (unitless)

n is pump rotational speed (revolutions per minute)

Q is flowrate (Cu m Per sec)

H is total head per stage (m)

g is acceleration due to gravity (m per second per second)

In many texts the constant g is dropped. Fig 1 shows the attainable efficiency of Pumps. The specific speed values shown are with g value dropped.

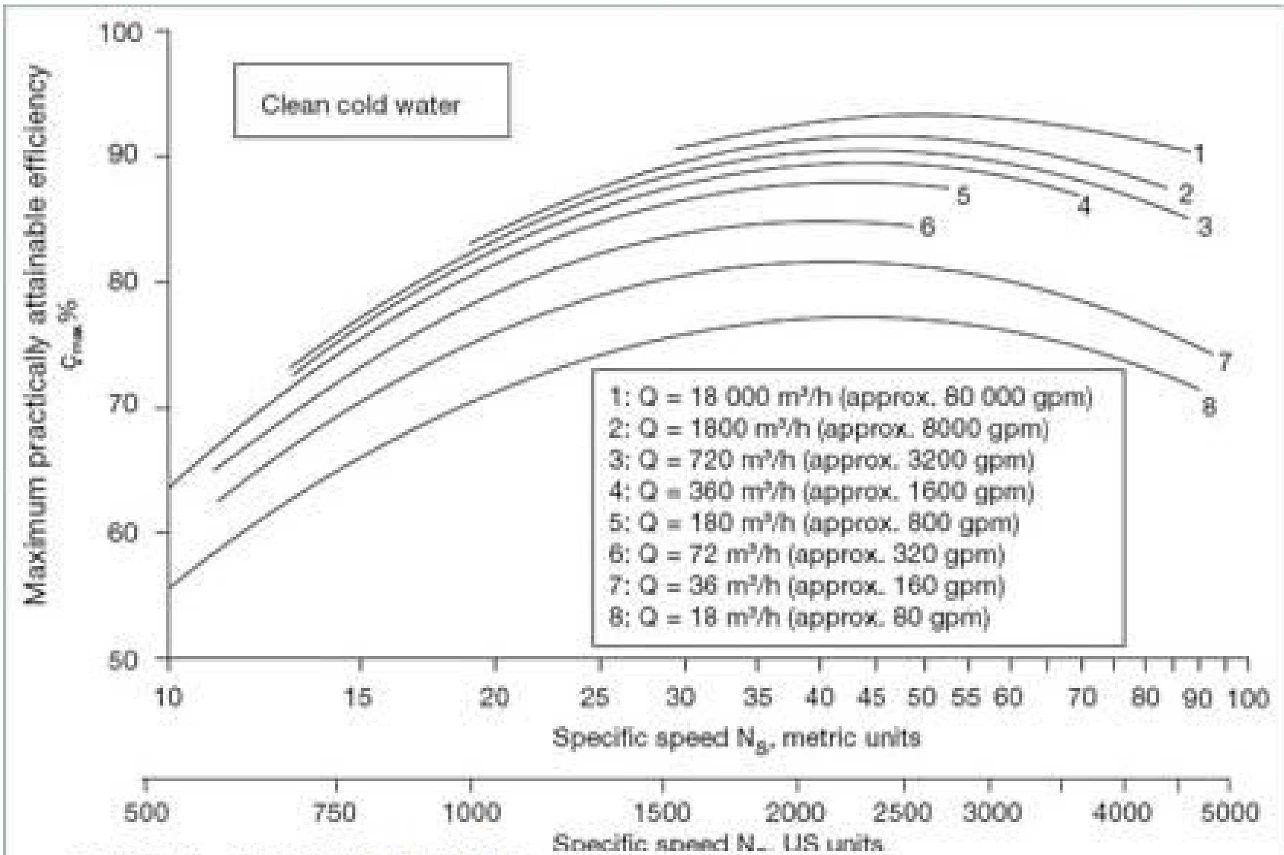

FIG 1 ATTAINABLE EFFICIENCY

It is evident from above that the higher the head and lower the flow rate value pump the specific speed of the pump will be lower and thus the efficiency of the pump.

DOMESTIC PUMPS:

There are 2 types of domestic pumps

- Regenerative self priming monoset pumps. Fig 2
- Multistage Monoset Pumps. Fig 3

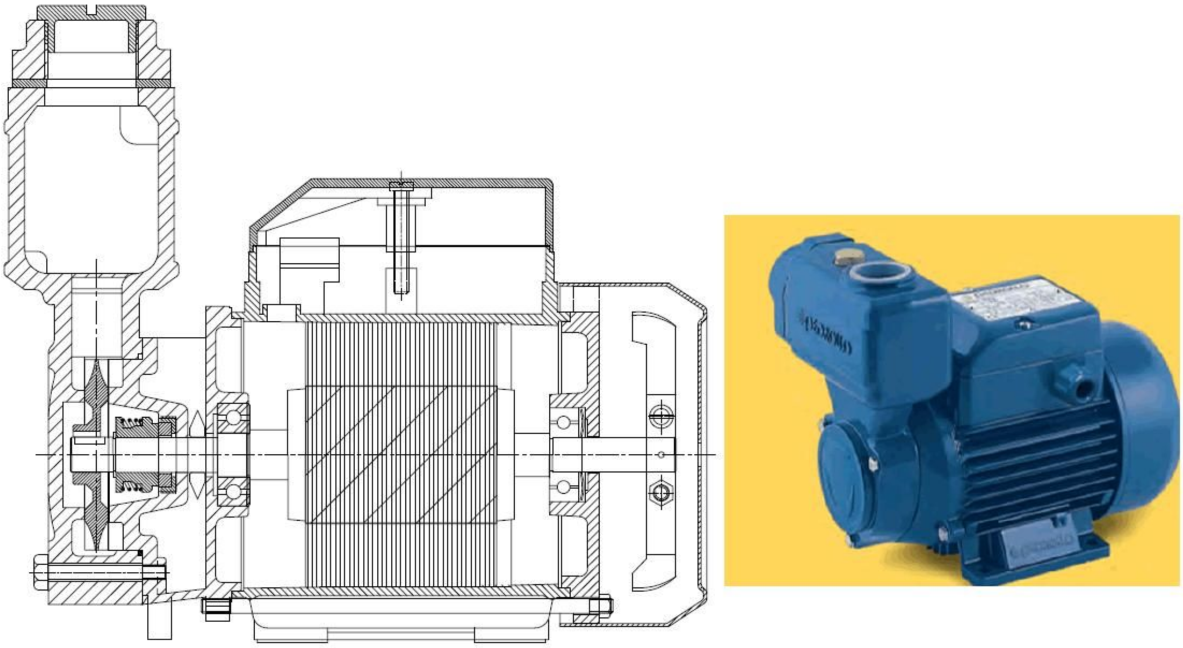

Fig 2 Typical regenerative self priming Domestic Pump.

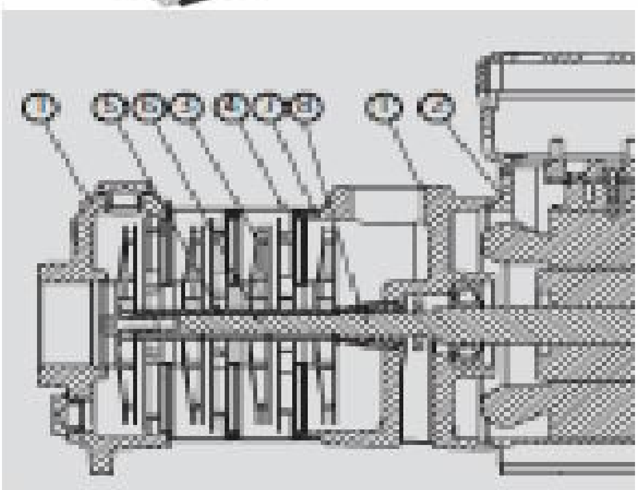

Fig 3 Multistage centrifugal domestic Pump.

Regenerative self priming pumps

The typical values of specific speed for Domestic REGENRATIVE pumps works out to 5-7 with flow rate as low as 2.5m^3/h. and the values are beyond the scope of curve shown in Fig 1. The values of efficiency of these pumps are recorded to just 25-35% and their overall efficiency with pump set are recorded to values of 15-22%. India produces nearly 30 lacs of these pumps and out of which nearly 40% of production is done in Coimbatore alone. The amount of Energy required to energise and run these pumps is nearly 50000 MWH per annum assuming they run for just 300days in a year with 0ne hour of operation.

The regenerative self priming as well as non self priming pumps uses extremely low clearances and these clearances increase as passage of time. In clear cold potable water the clearances almost double after a working of 500 hours making these pumps as superb inefficient.

A study was undertaken in Goa region to find behaviour pattern and power consumption of self priming regenerative pumps in actual field of operation. A site was selected pumping clean clear Well water from Open well to overhead tank and study was conducted for a period of 2 years.

Typical Power Consumption of 0.5 HP Regenerative pump under Installation							
Date	Static suction Head (m)	Static Delivery Head (m)	Time for 2000 liters hrs	Power Input watts	Energy consumed in filling kW	Yearly consumption kWh	% Increase
15-06-2006	4	10	1.190476	470	0.55952381	167.8571	0
15-09-2006	3.5	10	1.333333	450	0.6	180	7.234043
15-03-2007	5.2	10	1.449275	430	0.62318841	186.9565	4.144311
15-10-2007	3.7	10	1.666667	420	0.7	210	13.72803
15-06-2008	3.8	10	1.960784	420	0.82352941	247.0588	22.0776

Table 1 Deteriotion of performance with time of Regenerative Pumps.

The drop in efficiency and relevant increase in consumption is attributed to corrosion of cast Iron resulting in increase of clearances. This can be brought down by using alternate materials.

Pedrello of Italy has intelligently combined the aluminium with Brass to overcome the galling corrosion and holds a patent right on the same.. The same can also be done by using non metallic materials such as PEEK Poly-Ether-Ether-Ketone (PEEK)with carbon fibers.. These thermoplastics give excellent corrosion and wear resistance to the pump and we can save nearly 80 units of power per pump see Table 1. No doubt the Pump efficiency also improves by 1.5-2 points and this can result in considerable saving to nation.

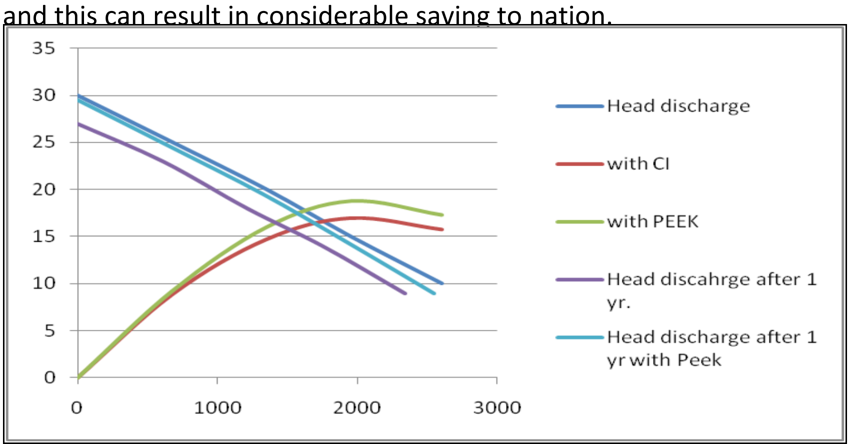

Fig 4 Improvement in efficiency with PEEK.

Though the quality of life of society has been improved by Domestic Regenerative pumps yet due their inherent poor efficiency it has become a drain on national resources and is contributing to Green House effect and therefore it is the duty of us to ensure that they should be produced in most efficient ways. Using Thermoplastic like PEEK or other Carbon filled materials also gives another distinct advantage to designers like shaping of channels with ease. This is depicted in fig 5. Shaping the channel in this manner helps to improve the efficiency as well as improve suction lift.

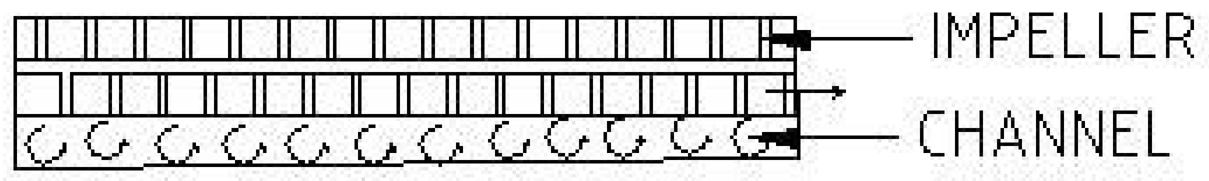

Fig 5 Tapered channel to improve efficiency of Regen pump

Multi stage Centrifugal Pumps.

A typical Multistage centrifugal Pump is shown fig3. Since these pumps can be designed for specific speed 15 and above these pumps have better efficiency. The efficiency of Multi stage centrifugal pumps is as high as 45% but due to cost these pumps are hardly manufactured in the country. Most of these pumps are High Head and low discharge pump and by multistaging they can be made to give almost same head discharge curves of Regen self Priming Pumps. Table 2 just compares performances of a typical multistage centrifugal pumps and Self priming pumps.

Rated Power	Model	No of stages	Head m	Q lpm	P1 W	Effy %	Weight
0.5	Centrifugal	2	20	37	570	25.2	10.9
0.5	Regenerative	1	20	27	470	18.8	8.5
1	Centrifugal	4	24	80	960	34.7	14
1	Regenerative	2	24	65	980	22.0	11

P1 Input power watts

Table 2 Efficiencies of Regen and multi stage Pumps

These pumps however cannot be manufactured by normal cast Iron diffuser or Impeller. These pumps require either engineering Plastics or Stainless steel.

Engineering Plastics for Multi stage Pumps.

There are many engineering Plastics available to make Impeller and Volute. The best among them are PPO Poly phenolic oxide commonly known as Noryl. Other materials like Delrin have been successfully tried which gives better wear resistance and lower frictional resistance. There are few manufacturers offering Multistage pumps shown in Fig 2 in Engineering Plastics and have been found to give very good efficiencies. There are manufacturers who have tried to make these pumps self Priming by allowing recirculation of flow in initial stage of priming and than auto closing of recirculation of flow moment the pump develops the pressure. These pumps are observed to run consistently over years without any drop in efficiency.

Stainless Steel for Multistage Pumps.

One of the most important criteria in Centrifugal Impeller design is the assumption of near zero thickness of Blades and shrouds which is possible only with stainless steel fabricated Impeller. Stainless steel fabricated Impellers have great advantage. The impellers as well as diffusers can be easily fabricated using Electic projection welding machines which are of capacitive discharge type or can also be fabricated by using Laser Welding.

1. Easy to fabricate.
2. Consistency in dimensions.
3. No machining
4. Consistent performance due to control of dimensions.

The cons against these stainless steel Pumps are high initial cost of development but if a company year marks its annual budget towards development than one can easily take development of the same. Though these pumps are expensive they have great advantages over both Plastic and cast Impellers. The wear being the fundamental criteria. A stainless steel Multistage Pump was installed and monitored for almost 2 years and showed very impressive results in its working over 2 years, The results are shown in Table 3

Typical Power Consumption of 0.5 HP Multi Stage Stainless steel Centrifugal pump under observation at a typical Installation							
Date	Static suction Head (m)	Static Delivery Head (m)	Time for 2000 liters hrs	Power Input watts	Energy consumed in filling	Yearly consumption	% Increase
20-06-2006	4	10	0.900901	470	0.42342342	127.027	0
16-09-2006	3.5	10	0.854701	450	0.38461538	115.3846	-6.9359
15-03-2007	5.2	10	0.854701	430	0.36752137	110.2564	-3.0551
16-10-2007	3.7	10	0.913242	420	0.38356164	115.0685	2.866773
16-06-2008	3.8	10	0.888889	420	0.37333333	112	-1.82804

Table 3 Power consumption of Multi stage Pump over a period of 2 years

Impeller Neck Rings

The impeller Neck clearance plays important part in improving efficiency of pump. The lower the clearances the lower are recirculation losses and as result better the efficiency. Lower clearance can lead to jamming especially where dissimilar materials are used and there is a temperature gradient and unequal expansions. For small pumps of capacity ranging up to 20 HP wear rings are hardly used from economic angle. This results in loss of efficiency due to corrosion and subsequent increase of clearances. Depending upon head discharge characteristics the efficiency of these pumps comes down by 3 -7 % (points) after a year of operation and the prime cause of this drop in efficiency is increase of neck clearances.

The Polymer wearing rings can be used in these pumps with a marginal increase in the cost; this improves the efficiency as well as reduces noise in the pump besides reducing NPSH requirements of the pump. Reduction of noise is due to dampening of vibration of impeller.

Various polymers are used which gives low friction, excellent dimensional stability (when in contact with water) and low wear. Chief among these are modified Nylons such as Delrin. Other Polymers like Vespel and Zytel have also been tried for wear rings. Other best materials for neck rings once again lead to Carbon filled Thermoplastics.

The leakage past the rings depends upon diametrical clearance length of leakage path. For a leakage path length of 12 mm and for a neck diameter of impeller of 30 mm Table 1 & Graph 1 gives the leakages past the wearing rings in lpm for various Heads of operations.

Table 4 Leakage past Wearing Rings Q Lpm

Head (m)	**Leakage past (lpm)**	**DIAMETRICAL CLEARANCES IN MM**				
		0.80	0.70	0.50	0.30	0.20
32		42	36	26	16	10.2
25		37	32	23	14.2	9
20		32.5	29	20.5	12.5	8
15		28	25	18	10.5	7
10		23	20	15	8	6

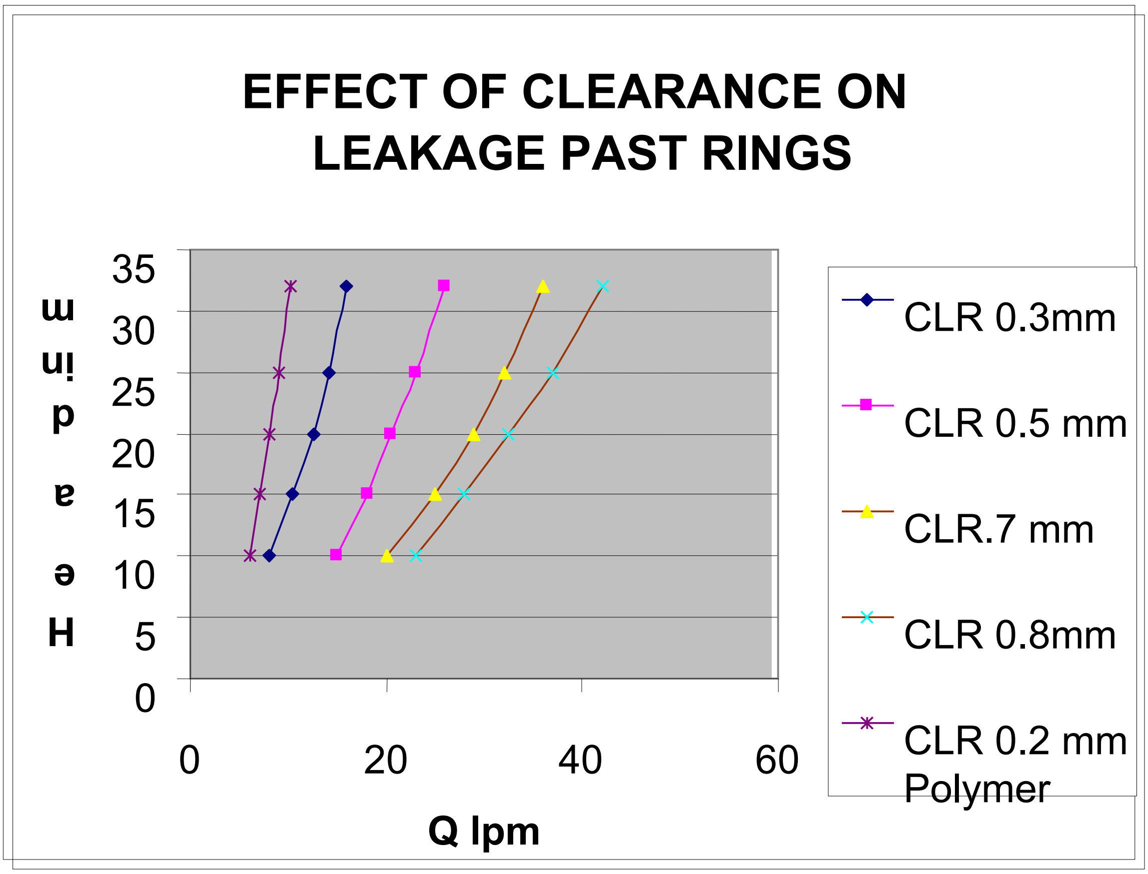

Fig6 Effect of Clearances on Leakage Past Wear Ring

Fig 7 shows effect of clearances on efficiencies for various heads for a given duty of 80 lpm.

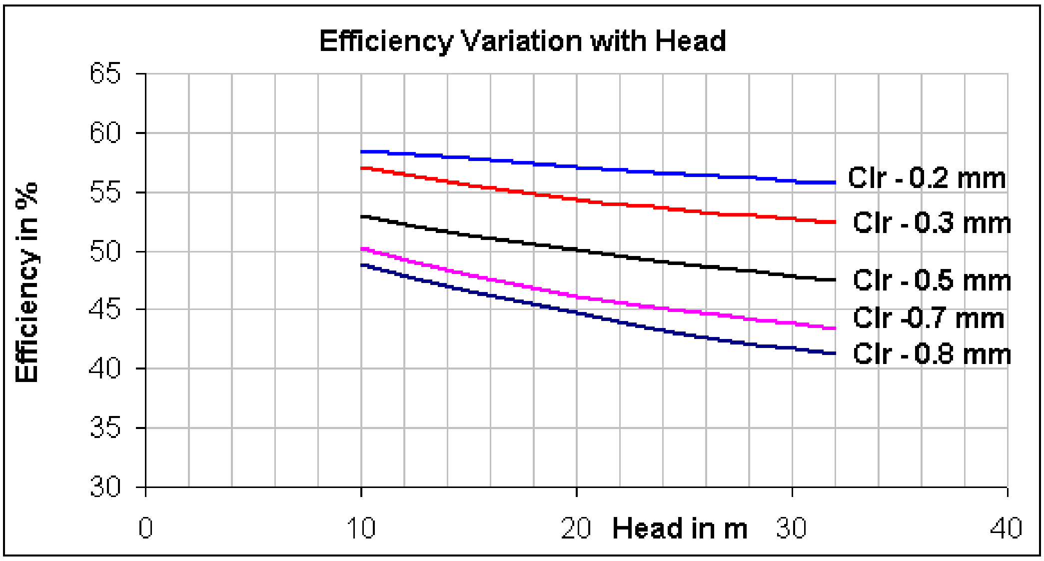

Fig 7 Efficiency variations for a duty point discharge of 80 lpm for various clearances

Metal wearing rings cannot be used as the close diametrical clearances cannot be maintained and they are susceptible to corrosion wear. Polymer rings in contrast are ideally suited for the task as they exhibit low coefficient of friction which translates into low wear rates of the rings. Hence use of polymer wearing rings is warranted for efficient use of pumps. The various type of Polymer wearing rings are discussed below.

Wearing Ring Designs:

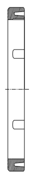

Fig 8

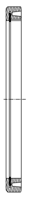

Fig 9

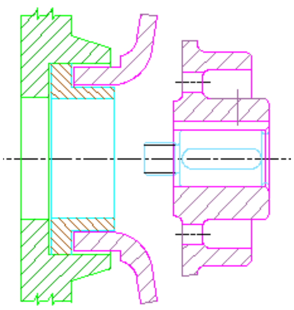

Fig10

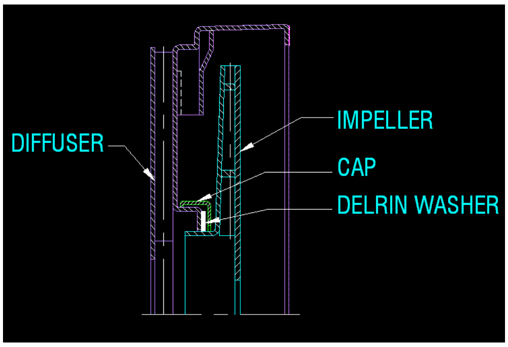

Fig 11

Fig 8,9,10,11 shows four types of wear rings molded from Delrin.

Fig 8 has an annular space making the lip of the ring to contract as delivery head increases there by decreasing the neck ring clearance and thus reducing the leakage. Grooves in axial direction can be cut on the ring to form sectors and allowing for boundary layer lubrication and damping effect to occur.

Fig 9 has an elastomeric ring included in the groove. The elastomer should have low abrasive properties. This design helps to reduce leakage to nearly zero but cannot be used with Impellers moulded with Engineering Plastic as it forms a groove on the neck ring. The design however is good for multi staged impeller like submersible pump using either stainless steel or brass impeller.

Fig 10 shows a molded ring used in the eye of impeller. This gives a double path and low leakage but is unsuitable for pumps handling turbid water, as sediments settle in the neck and tends to jam the pump.

Fig 11 shows a wear ring in the form of a flat ring held by a still canopy as retainer. This design is helpful where axial length are constaints., such as multistage pumps. This design can bring neck ring length reduced to just 2.5-3 mm and also controlling leakages past rings to nearly 1-2 % of full flow.

Conclusion:

Prudent manufacturers have to realise the importance of their duty towards the nation and towards the environment and make the pumps that they are manufacturing more efficient. This can be done by substituting materials wherever there is likely to be corrosion and resulting in loss of efficiency. Innovative and cost effective solutions are to be applied so that the pumps sold by them give a good life over its life span of minimum 5 years. This can be done by innovative approach to the design and substituting materials of construction.