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Influence of Surface Roughness on the Performance of a Radial Pump Impeller

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SUMMARY This paper discusses the effect of improving the surface roughness of a radial flow pump impeller on the efficiency of the pump. A cost analysis comparing the additional manufacturing cost for improving the surface finish and the resultant saving in operating cost has been given.

1 INTRODUCTION

The surface roughness is the most important factor that controls the magnitude of the hydraulic losses and disc friction losses in the impeller of a radial flow pump. Varley (1961) has contributed much to the understanding of the influence of the surface roughness of the impeller flow surfaces on the performance of radial flow pumps. In his experiments, the impeller surfaces were sprayed with adhesive coated sand particles of different sizes to create different roughness values. This paper deals with the experimental results in which the impeller surfaces were artificially roughened by pasting emery sheets of different grades. These emery sheets, whose backing papers were peeled off before pasting on the impeller surfaces, provided a better uniformity on the size of the particles as well as how they were distributed on the entire surface. Surfaces with four different roughness values were selected for the experimental study. These four roughness values were taken as approximately equal to the roughness values of rough cast surface, good cast surface, machined surface and polished surface which normally exist in the impeller surfaces after definite manufacturing and machining operations.

2 NOMENCLATURE

C.L.A	Centre line average
D	Diameter
M	Hydraulic depth of flow at the outer diameter.
Q	Discharge
R.F	Roughness factor
U	Blade velocity
b	Width of a blade
t	Thickness of a blade
z	Number of blades
∅	Flow Coefficient = $\left[\frac{Q}{\pi D_2 - z.t.\text{cosec}\beta_2) b.U_2}\right]$
β	Blade angle with negative U
ν	Viscosity
η	Efficiency

Subscripts

1	Inlet of impeller
2	Outlet of impeller

3 TEST SET UP

Tests were conducted on a fabricated type impeller seen in figure 1. The front and rear shrouds were made separately. The blades were fabricated individually, each blade having two studs at two different radii. The front shroud, the blades and the rear shrouds were held together by having nuts at the two ends of the studs as seen in figure 1. The details of the impeller are given below

$D_1 = 105$ mm $z = 6$
$D_2 = 235$ mm
$b = 14$ mm
$t = 4$ mm
$\beta_1 = 21$ deg.
$\beta_2 = 25$ deg.

This impeller was assembled in a research spiral casing having vaneless diffuser. This pump assembly was fitted on to the radial pump research test bed of the Hydroturbomachines Laboratory, Indian Institute of Technology, Madras. The pump was tested at a constant speed of 1000 rpm. The experimental Reynolds number of the flow is

$$\left(\frac{U_2 D_2}{\nu}\right) = 5.8 \times 10^6$$

4 EXPERIMENTAL PROGRAMME

To start with, all the surfaces of the impeller were polished. The performance characteristics of this polished impeller was found out by experiments and peak efficiency with the polished impeller was taken as reference for later comparisons. To create definite roughness on the surfaces of this impeller, emery sheets of three different grades were selected in such a way that their centre line averages (C.L.A- average of peak and valley dimensions from the centre line over a certain length) were approximately equal to the centre line averages of rough cast, good cast, and machined surfaces. A non dimensional 'Roughness Factor' was defined to compare the performances of impellers with different rough surfaces. It was defined as the ratio of C.L.A. value to the hydraulic mean depth of flow at the outer diameter of the impeller.

$$\text{Roughness Factor(R.F)} = \frac{\text{C.L.A. value}}{M}$$

where

$$M = \frac{b\,[\pi D_2 - zt \operatorname{cosec} \beta_2]}{2[\,\pi D_2 - zt \operatorname{cosec} \beta_2 + zb\,]}$$

The selected emery sheets and the surfaces they represent are listed here along with their roughness factors.

Surfaces	Emery Grade (BSS)	Roughness Factor
Rough cast	80	0.01107
Good cast	150	0.003915
Machined	280	0.001404
Polished	-	0.0000962

After the polished impeller was tested, the positive surface of all the blades were pasted with the emery sheet of grade 280 representing the machined surface and reassembled. The performance of this pump was found out. The same emery sheet was pasted on the negative surface also and the experiments were repeated. Then the same emery sheet was pasted on to the inner surfaces of both the shrouds and finally on to the outer surfaces of the shrouds also after finding the performance every time. All the above experiments were repeated with emery sheet of Grades 150 and 80 representing good cast and rough cast surfaces respectively.

5 RESULTS AND DISCUSSIONS

A comparative study of the experimental results with individual surfaces of the impeller roughened with different grades of emery sheets has been made. The general shape of the efficiency versus discharge characteristics as seen in figure2 are almost same for all roughness factors. Only the values of peak efficiencies reduced with increasing value of roughness factors. There was not much change in the value of the discharge at the peak efficiency point. This is in contrast with the findings of Varley who has stated that the discharge and head at peak efficiency increased with the roughness factor of the impeller surface. The reason may be due to the fact that Varley has used sand particles which provided a larger roughness factors compared to the studies discussed here.

Figure 3a shows the drop in peak efficiency of the pump when the different impeller surfaces were roughened to have a roughnessfactor of 0.001404 representing the machined surface. Figure 3b and 3c show the similar graphs when the impeller surfaces were roughened to roughness values 0.003915 and 0.1107 representing good cast and rough cast surfaces.

These figures indicate that the roughening of the positive surface of the blade alone caused a major drop in peak efficiency by over 5 percent when compared to the roughening of all the remaining surfaces. This may be due to the fact that the positive surface of the blade is relatively a more active surface since the flow is mainly guided by the positive surface and the flow is not always guided along the entire length of the blades on the negative side due to the possibilities of separation. These results agree well with the Varley's findings. It can be noted from these results that when the outer surfaces of both the shrouds were also roughened, further drop in peak efficiency was not significant. This may be due to the fact that the emery sheets could be pasted only on a limited area due to the presence of the rim, the nuts of the studs and the curvature near the hub. Further the presence of the rim at the outer diameter of the impeller might have reduced the radial flow along the external sides of the rear shroud and front shroud, thus limiting the disc friction loss.

Figure 4 shows the drop in peak efficiency when all the impeller surfaces were roughened to different grades of roughness. This graph gives quantitatively the values of drop in peak efficiency if the roughness of the impeller surfaces is increased. In other words, one could quantitatively find out the possible increase in the efficiency of the pump by increasing the surface finish of the impeller by using different finishing processes. An increase in efficiency reduces the power consumption leading to reduction in operating cost. Figures 5a,b, and c show graphs similar to figure 4 for individual impeller surfaces.

6 COST ANALYSIS

A simple example is discussed here to stress the importance of improving the surface finish of the impellers.

A rough cast impeller approximately equal to the tested impeller with outer surfaces alone machined will cost around Rupees 40 (5 US Dollars). Its peak efficiency is around 48 percent (Point A in figure 5c). If both the surfaces of the blades and inner surfaces of this impeller shouds could also be machined with suitable fabrication cum machining operations, then its efficiency could be improved to a value of 54.5 percent(Point B in figure 5c). Improving the efficiency by about 6 percent on a pump consuming about 2.5 kiloWatts and having a life of about 5000 hours will result in anenergy saving of 750 kiloWatt-hours. Considering a present charge of 0.4 Rupee per unit, the saving in the energy cost for the customer is around Rupees 300, whereas the fabricated impeller with all inner surfaces also machined will cost only around Rupees 120.

In an agricultural country like India, such a saving in energy would be enormous considering a huge number of irrigation pumps. The Tamilnadu State with about 60 Million population has presently about 0.6 Million pumps in operation. Assuming 2 hours of daily operation for these pumps the daily energy consumption is about 1.2 Million kiloWatthours. The subsidised rate for agricultural use is 0.2 Rupee per kiloWatthour and 6 percent improvement in the efficiency of these pumps would result in a energy saving of 7200 kiloWatt hours and a cost saving of Rupees 1440 per day. These 7200 units could be profitably used elsewhere to increase the production level.

7 CONCLUSIONS

From the results discussed above, it could be concluded that the additional manufacturing cost in improving the surface finish is really worth spending and results in the reduction of operating cost and saves energy. For a power starved country this energy saving would be an additional boon to the economy.

8 REFERENCES

VARLEY,F.A (1961) Effects of Impeller design and surface roughness on the performance of centrifugal pumps. Proc. Instn.Mech.Engrs.Vol.175,n21,pp 955-989.

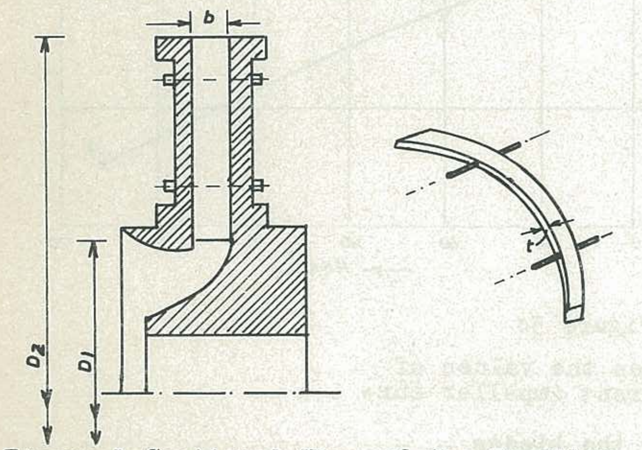

Figure 1 Sectional View of the Impeller

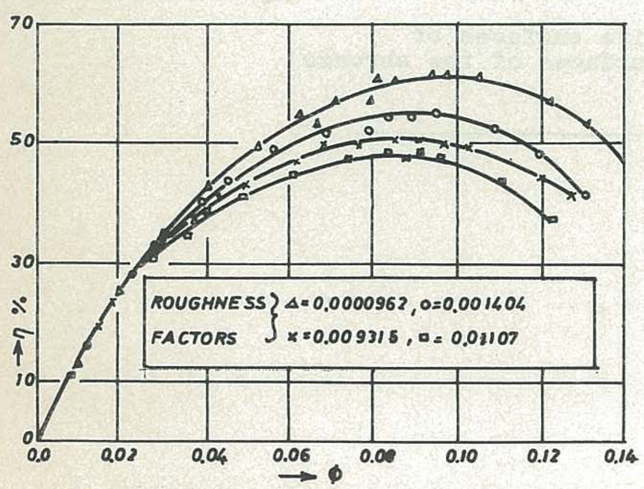

Figure 2 Efficiency of the Impeller for different roughness values.

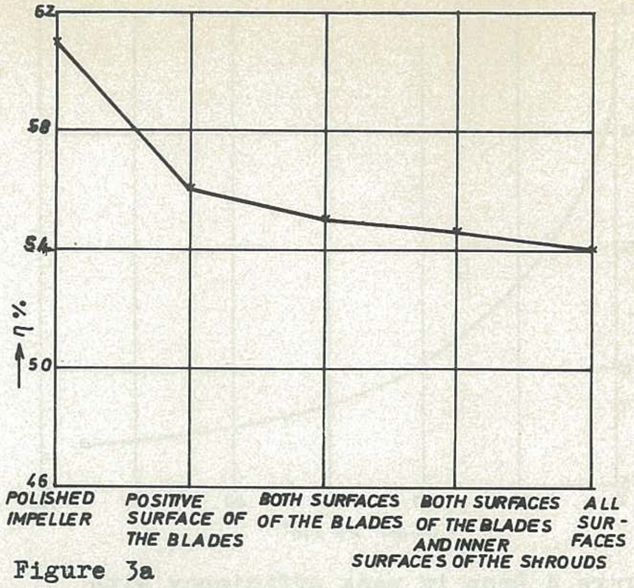

Figure 3a

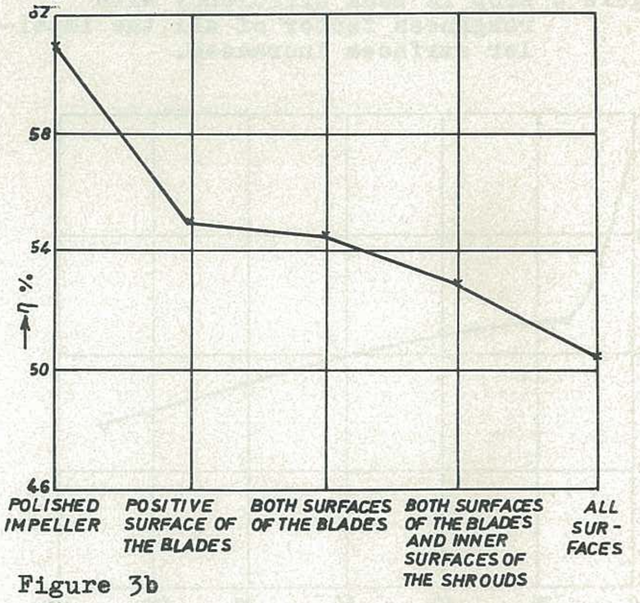

Figure 3b

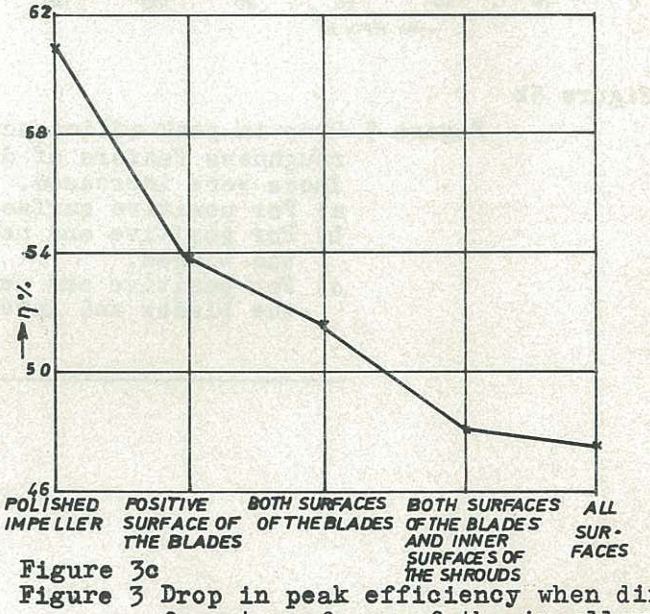

Figure 3c

Figure 3 Drop in peak efficiency when different surfaces of the impeller were roughened to have different roughness factors.
a) R.F. = 0.001404
b) R.F. = 0.003915
c) R.F. = 0.01107

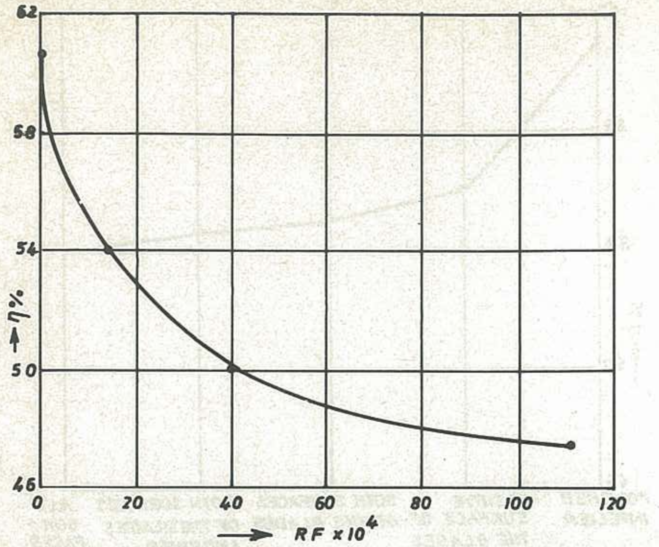

Figure 4 Drop in peak efficiency with roughness factor of all the impeller surfaces increased.

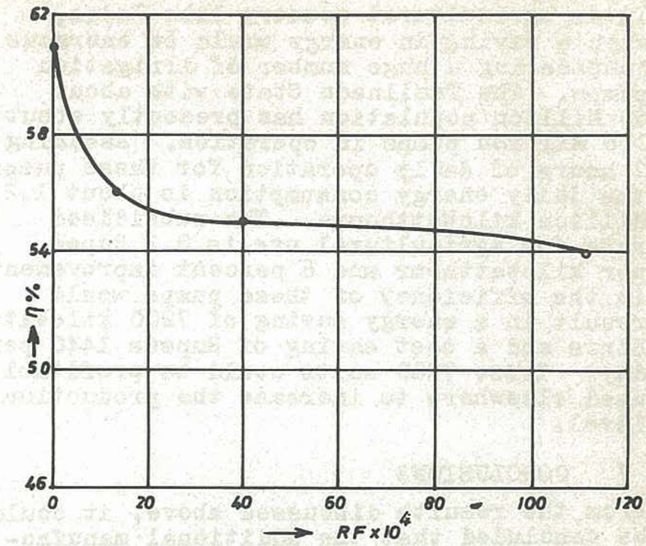

Figure 5a

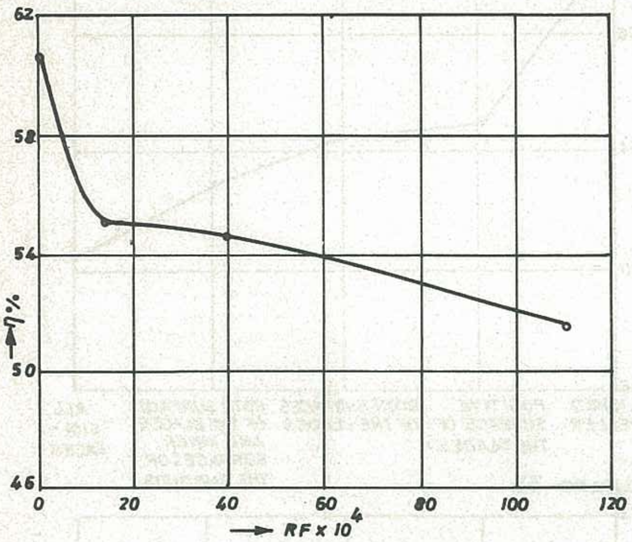

Figure 5b

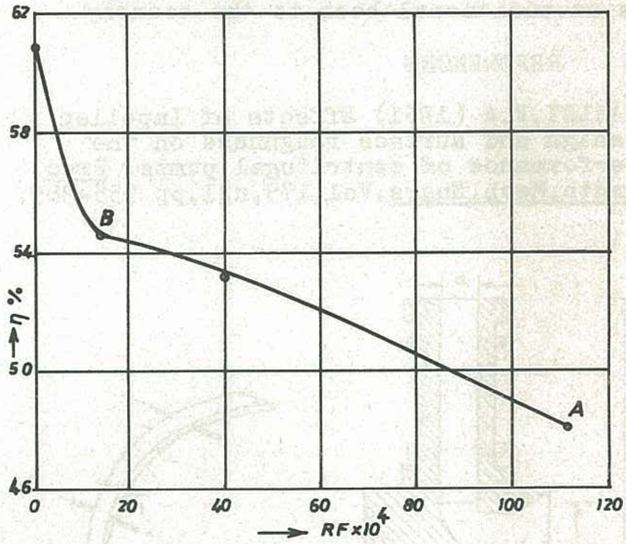

Figure 5c

Figure 5 Drop in peak efficiency when the values of roughness factors of different impeller surfaces were increased.
a) For positive surface of the blades
b) For positive and negative surfaces of the blades.
c) For positive and negative surfaces of the blades and inner surfaces of the shrouds