CHAPTER 8
CONCLUSIONS AND SCOPE FOR FURTHER WORK

Experimental and numerical investigations have been carried out to evaluate the performance of a Cross Flow Turbine (CFT) specifically for low head and low discharge conditions. From the literature review it was observed that the design of nozzle walls of CFT had not been attempted with proper theoretical background. Hence, based on ideal fluid theory a spiral vortex profile has been used for the design. Nozzles having combinations of proposed spiral vortex profile and circular arc profile were numerically anslysed using Finite Element Analysis. Using nozzle exit conditions as input parameters, the flow through first stage runner has been modeled and analysed with runners having 18, 24 and 30 blades.

From insights derived from these numerical analysis an experimental facility with precise instrumentation has been created. Performances of CFT with S-S and C-S nozzle were attempted. Effect of angle of attack and number of blades have been investigated experimentally. A concept of installing a second nozzle has been introduced to utilize the unused part of the runner periphery. The experimental investigations with CFT with two nozzles were carried out and the impact of flow fraction on CFT performance was tested. The major conclusions drawn from these wider ranges of study are listed hereunder.

8.1 CONCLUSIONS FROM FEA OF NOZZLES

1. Spiral vortex profile could be selected to define the nozzle walls shapes for which accurate mathematical predictions are established. The theory of spiral vortex profile has enabled to obtain the required spiral rear wall for the nozzle with a minimum flow deviation from design values.
2. For low head, low discharge applications nozzle with front wall shape circular and rear wall shape spiral vortex found to be the best combination than spiral-spiral, circular-circular and spiral-circular combinations.
3. Nozzles with front wall circular, rear wall spiral vortex, angle of attack 16^0 and nozzle entry arc 60^0 are proved to be the best combination nozzle for the low head and low discharge applications.

4. For the above nozzle 3m-supply head and 45 lps proved to the ideal condition to operate. There would be different nozzle entry arc and flow angle (angle of attack) combinations for different supply heads and corresponding flow rate.

8.2 CONCLUSIONS FROM FEA OF FIRST STAGE FLOW THROUGH RUNNER

1. Apart from the magnitude of relative velocity at the exit of the first stage, the angle of relative velocity vector is found to be more important to analyse the first stage work done.
2. In order to derive higher work output, the angle of relative velocity β_2' vector with respect to the tangent measured counter clockwise have to be greater than or equal to 90^0. (i.e. $\beta_2' \geq 90^0$)
3. To achieve $\beta_2' \geq 90^0$, issuing jet from the nozzle plays a vital role. The best combination nozzle emerged from nozzle analysis has found to meet these requirements.
4. Among the runners analysed runner efficiency with 24 blades meets $\beta_2' \geq 90^0$ condition more satisfactorily than 18 and 30-blade runners.
5. The highest efficiency of 84% is obtained for CFT with $\alpha = 16^0$, $\delta = 60^0$, $N_b = 24$, H = 3 m, Q = 35 lps using C-S nozzle experimentally. Under similar a maximum efficiency of 78% is obtained using S-S nozzle.

8.3 CONCLUSIONS FROM EXPERIMENTAL INVESTIGATIONS WITH SINGLE NOZZLE

1. With increase in discharge the speed Vs η curves get shifted towards higher speed ratios and higher efficiencies up to the optimum discharge for the given head.
2. For given angle of attack and head the speed of the turbine at maximum efficiency is almost constant.
3. The efficiency variation is minimized for wider range of speeds at optimal discharge for the given load i.e., a flat η Vs N_r curve.

4. The increase in the design flow angle from optimum value will result in larger drop in efficiencies at higher discharges. For the present CFT under investigation the optimum design flow angle is found to be 16^0.
5. The study on the effect number of blades indicate that there should exist an optimum value for number of blades which yields a better performance than other values for any given discharge. For the current CFT under investigation the optimum number of blades is found to be $N_b = 24$.

8.4 CONCLUSIONS FROM EXPERIMENTAL INVESTIGATIONS WITH TWO NOZZLE

1. In the present study, the nozzle orientation of $\theta = 0^\circ$ performed better when compared to that with $\theta = 90^0$.
2. It appears that for optimum performance there would be an optimum angle of attack-nozzle entry combination.
3. It is possible to derive higher power outputs by accommodating either more discharge or for the given discharge with the use of two nozzles for the adapted CFT. This permits better utilization of available runner periphery and more uniform loading.
4. The flow fraction is an important parameter when two nozzles employed.
5. A flow fraction of 15% is found to be an optimum for the turbine under study.
6. Interaction between the two streams is deterrent to the performance in other flow fractions than the optimum.

With the operating experience gained from the present investigation, use of CFT with two nozzles would be an ideal choice for Micro Hydel power plants in isolated hilly regions especially for low head and low discharge streams.

8.5 SCOPE FOR FURTHER WORK

1. On the numerical analysis side the nozzle and first stage flow were analyzed. The flow through runner interior and the second stage need to be analyzed.
2. In the nozzle analysis, the nozzle exit pressure was assumed as atmosphere. However, in a practical CFT due to the presence of runner may introduce a

backpressure and hence the pressure at the nozzle exit may be slightly higher than atmospheric. This could be analyzed by modeling the entire system as a single unit, which may be attempted.

3. The nozzle estimation appears to have significant effect on CFT performance, which may be studied further.
4. It appears from the present investigation that the angle of attack and nozzle entry arc are inter-linked. An attempt may be done to establish the relationship between these two parameters.
5. The performances obtained with CFT using two nozzles are higher than due to any one of the nozzles individually under certain optimum flow fraction. By using a flow separator placed at the runner interior, the flow from one of the nozzles may be taken out axially after first sage. A preliminary study conducted had revealed that by using such separators higher output could be derived from the given CFT over wider range of flow fraction. A detailed study may be carried out to have quantitative substantiation.