CHAPTER 7

EXPERIMENTAL INVESTIGATIONS ON CFT WITH TWO NOZZLES

In the conventional CFT with a single nozzle, a second nozzle has been added. The necessity for such a second nozzle and the performance of the CFT with two nozzles are presented here.

7.1 NEED FOR A SECOND NOZZLE

It has reported by the earlier investigators that the power output at the first stage of CFT is of the order 60 to 75% of total power output and the rest by the second stage. Moreover, only a portion of the runner periphery is used by the fluid when CFT with single nozzle. (Refer Fig.2.2). The remaining portion of the runner is free. This results in uneven loading of runner. Hence an attempt is made A typical CFT with already existing primary nozzle (called Nozzle-1) and a secondary nozzle (called Nozzle-2) are shown in Fig.5.2. The details of the nozzle parameters are listed in table 7.1. The orientation of Nozzle-1 (θ_1) is kept as it is (i.e., θ_1= 90° from the vertical) whereas the Nozzle-2 is placed such that its centre is aligned along the vertical axis (i.e., θ_2= 0°)

7.2 RANGE OF EXPERIMENTS

All the physical dimensions of Nozzle-1 and Nozzle-2 and runner were kept constant as mentioned in Table 7.1. A supply head of 3.0 m was used in all the experiments. Flow rates of 20, 30 and 35 lps were used. The flow through the nozzle-1 is referred as Q_1 and that through nozzle-2 as Q_2 and the total flow rate is $Q = Q_1 + Q_2$. The flow fraction (Q_f) is defined as flow through nozzle-1 (Q_1) divided by the total flow ($Q_1 + Q_2$). Readings were taken by varying flow fraction from 0 to 100%, keeping the total flow rate constant. It will result in identification of the optimum flow fraction at which efficiency will be a maximum for a given total flow rate.

The primary S-S nozzle with $\propto_1$ = 24°, δ_1 = 60° was kept as it is. The another S-S nozzle with $\propto_1$ = 24°, δ_2 = 36° was fabricated and added. From chapter-6, Though the performance of CFTs with S-S nozzle were relatively lower than the CFTs with C-S nozzle in case of single nozzle study, S-S Nozzle profile was chosen for two nozzles system in order to study the effect of introducing the second nozzle in a magnified way.

Table – 7.1 Details of the CFT with two nozzles

RUNNER	NOZZLE – 1	NOZZLE -2
$B/D_1 = 0.5$ $D_1 = 300$ mm $D_2/D_1 = 0.667$ $N_b = 24$ $\beta_1 = \beta_4 = 30^0$ $\beta_2 = \beta_4 = 90^0$ $t_b = 3$ mm $r_b = 0.054$ m	$B/W_1 = 1.25$ $\delta_1 = 60^0$ $\theta_1 = 90^0$ $\alpha_1 = 24^0$ Rear wall shape: spiral vortex Front wall : spiral vortex	$B/W_2 = 1.25$ $\delta_2 = 36^0$ $\theta_2 = 0^0$ $\alpha_2 = 24^0$ Rear wall shape: spiral vortex Front wall : spiral vortex

7.3 THE EXPERIMENTAL PROCEDURE

The experiments were carried out as outlined in section 5.3. For each total flow rate, the flow is first admitted through the nozzle-1 (Q_f=1.0) and the readings were taken. Then a part of the flow is admitted through nozzle-2 and the corresponding quantity of flow is reduced in the nozzle-1 such that the sum of the flow through both the nozzles remains constant. This procedure is continued for different flow fractions for the given total flow rate till the flow through the nozzle-1 is completely cut-off and thereby all the flow is through nozzle-2 only (Q_f =0).

Experimental results for the CFT with two nozzles under discussion is furnished below. The presented results are from the repeated experiments for concurrent values. All the experiments are carried out at a constant head of 3-m.

7.4 PERFORMANCE OF CFT WITH EACH NOZZLE SEPERATELY

Fig.7.1 and 7.2 depict the experimental results of the effect of flow rate on efficiency with Nozzle-1 and Nozzle-2 individually for two different unit discharges of 0.0614 and 0.0718 respectively. The present experimental results are also compared with Desai and Aziz (1994) which is for Q'=0.137, δ = 90°, the nozzle walls of circular arc profile and other parameters being the same as in the present study. It may be observed that for a given speed ratio, when flow rate increases, the efficiency of the CFT also increases. Similarly, for a given unit discharge efficiency of the CFT increases with increasing speed ratio and droops after reaching a maximum value. Similarity could be seen in all the curves drawn from the present experiments and also that of Desai and Aziz (1994). It is evident from the figures that with increase in unit discharge, the curves get shifted to the right. The leftward shift of the present curves when compared with Desai and Aziz (1994) is due to the lower unit discharges used in the present study.

The performances of the individual nozzle for a given unit discharge are compared as shown in Fig.7.3 and Fig.7.4. It is observed that for a given flow rate or unit discharge, Nozzle-2 performs nearly 15% to 25% higher than Nozzle-1. This could be associated due to the change in orientation and change in nozzle entry arc. It appears that the orientation of the nozzle over the runner may provide a better performance. But, unanimity does not prevail among various authors who have reported about the same. For instance, Desai and Aziz (1994) have reported that the horizontal orientation (θ_1 = 90°) of nozzle over the runner would result in better performance of CFT. However, Toyokura and Kanemoto (1987) compared the CFT performance for nozzle orientations of θ_1 = 0°, 45° and 90°, and the better performance was reported for θ_1 = 0° as observed in the present study.

The differences in maximum efficiencies obtained with nozzles 1 and 2 may also be due to the different nozzle entry arcs used (δ = 60° and δ = 36°). Joshi et al (1995) investigated the effect of nozzle entry arc (δ, varied from 23° to 36°) with a constant

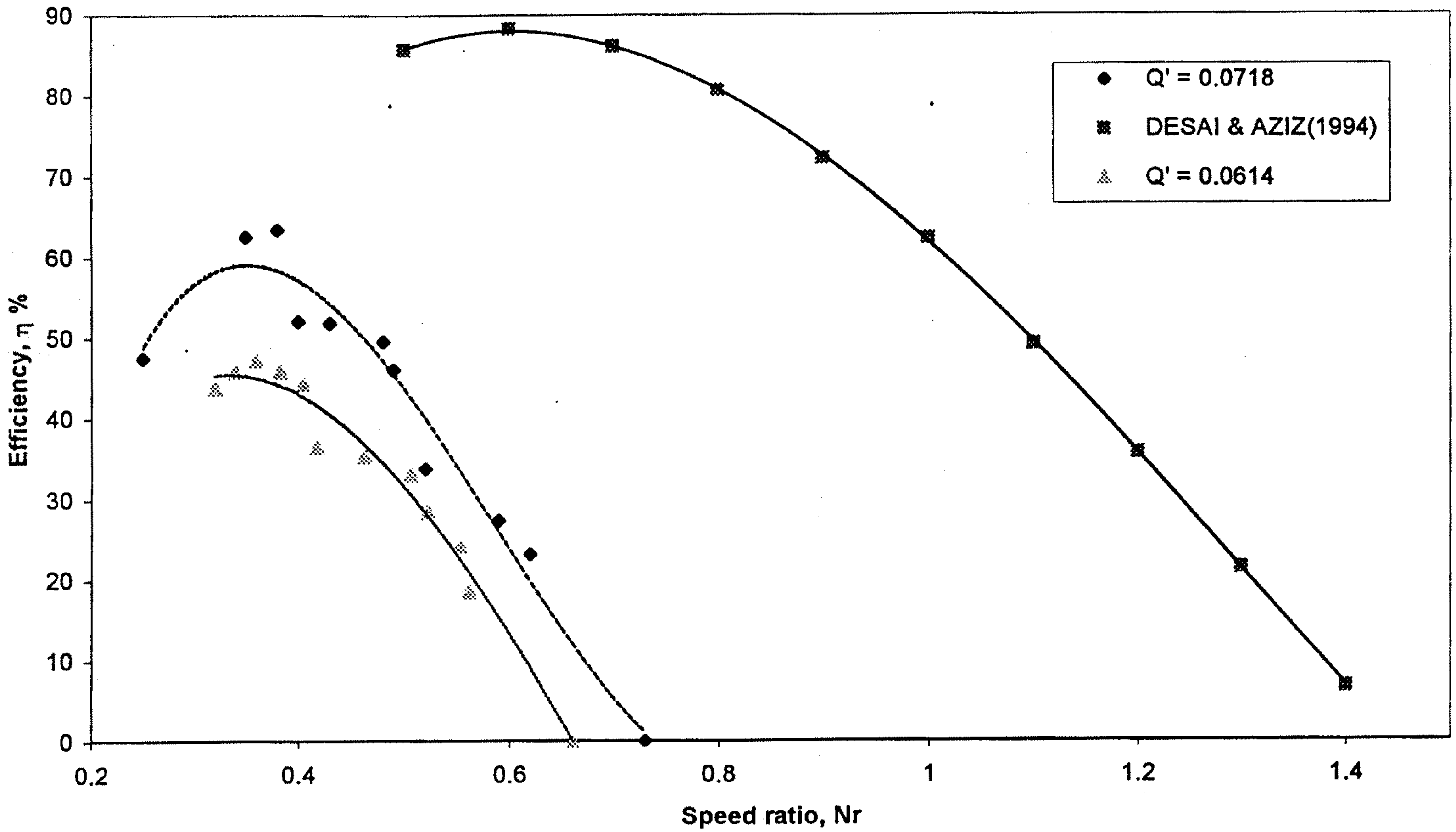

Fig.7.1 EFFECT OF FLOW RATE ON EFFICIENCY FOR NOZZLE -1

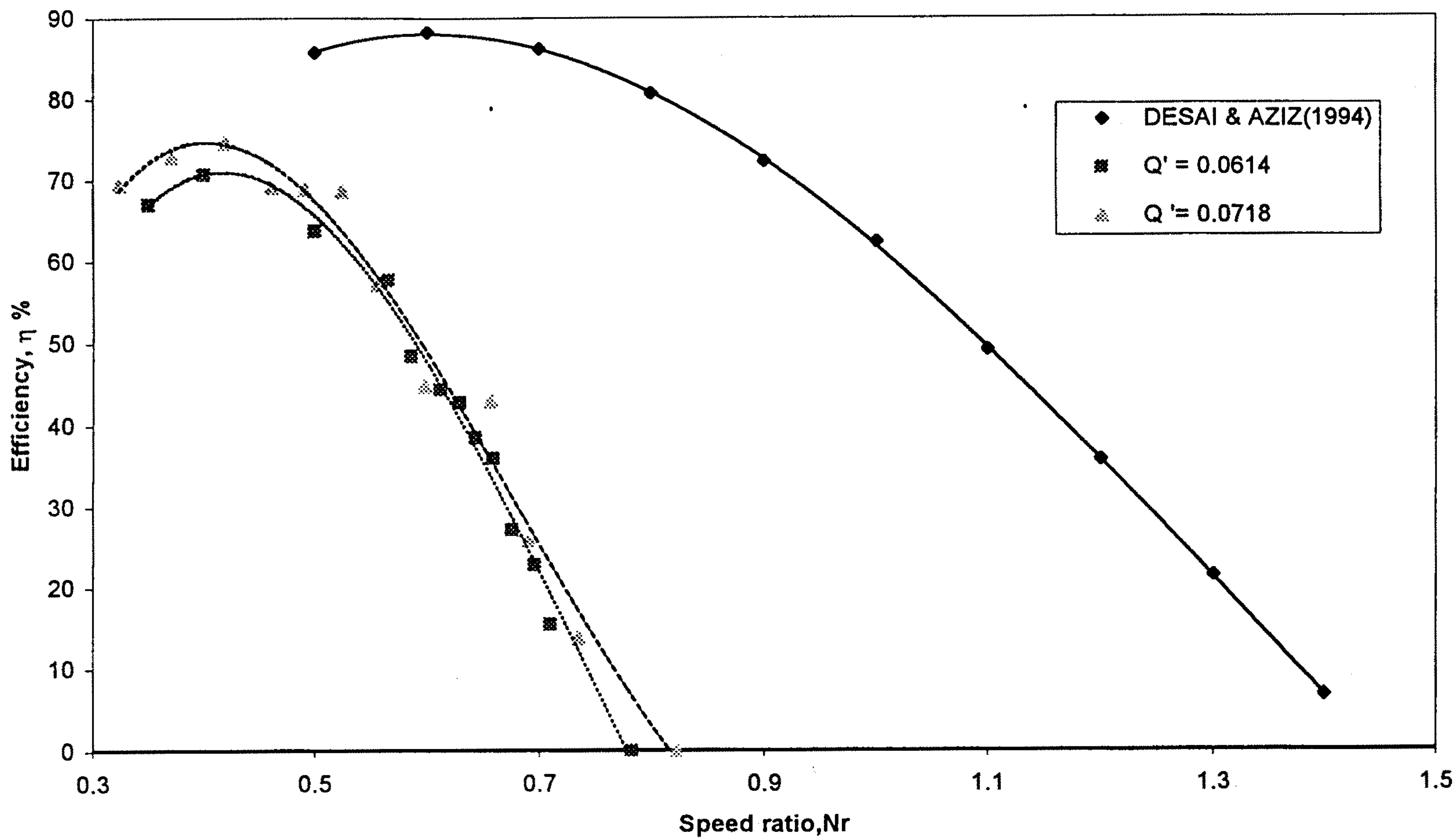

Fig.7.2 EFFECT OF FLOW RATE ON EFFICIENCY FOR NOZZLE - 2

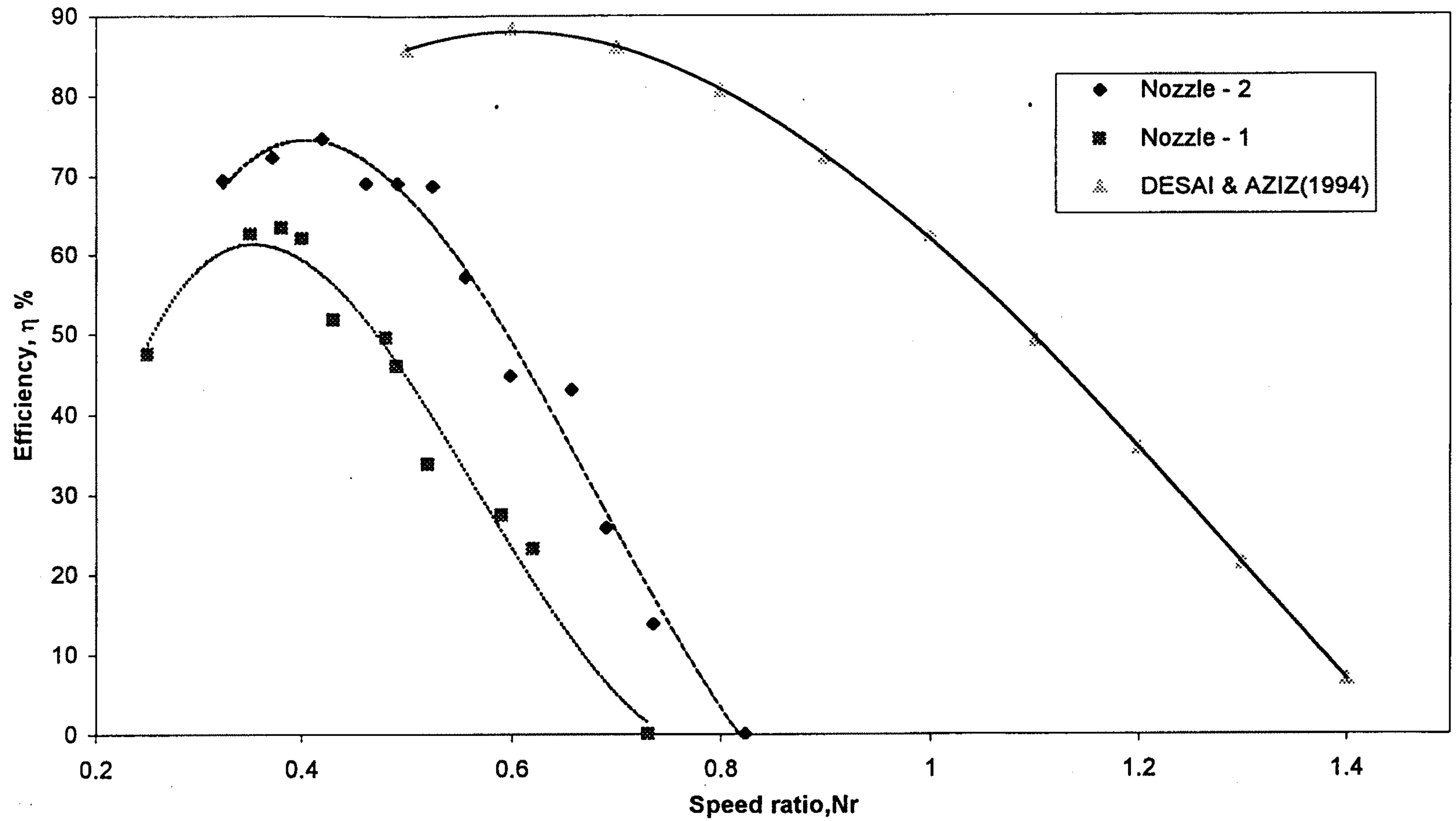

Fig.7.3 PERFORMANCE OF INDIVIDULAL NOZZLES FOR Q' = 0.0614

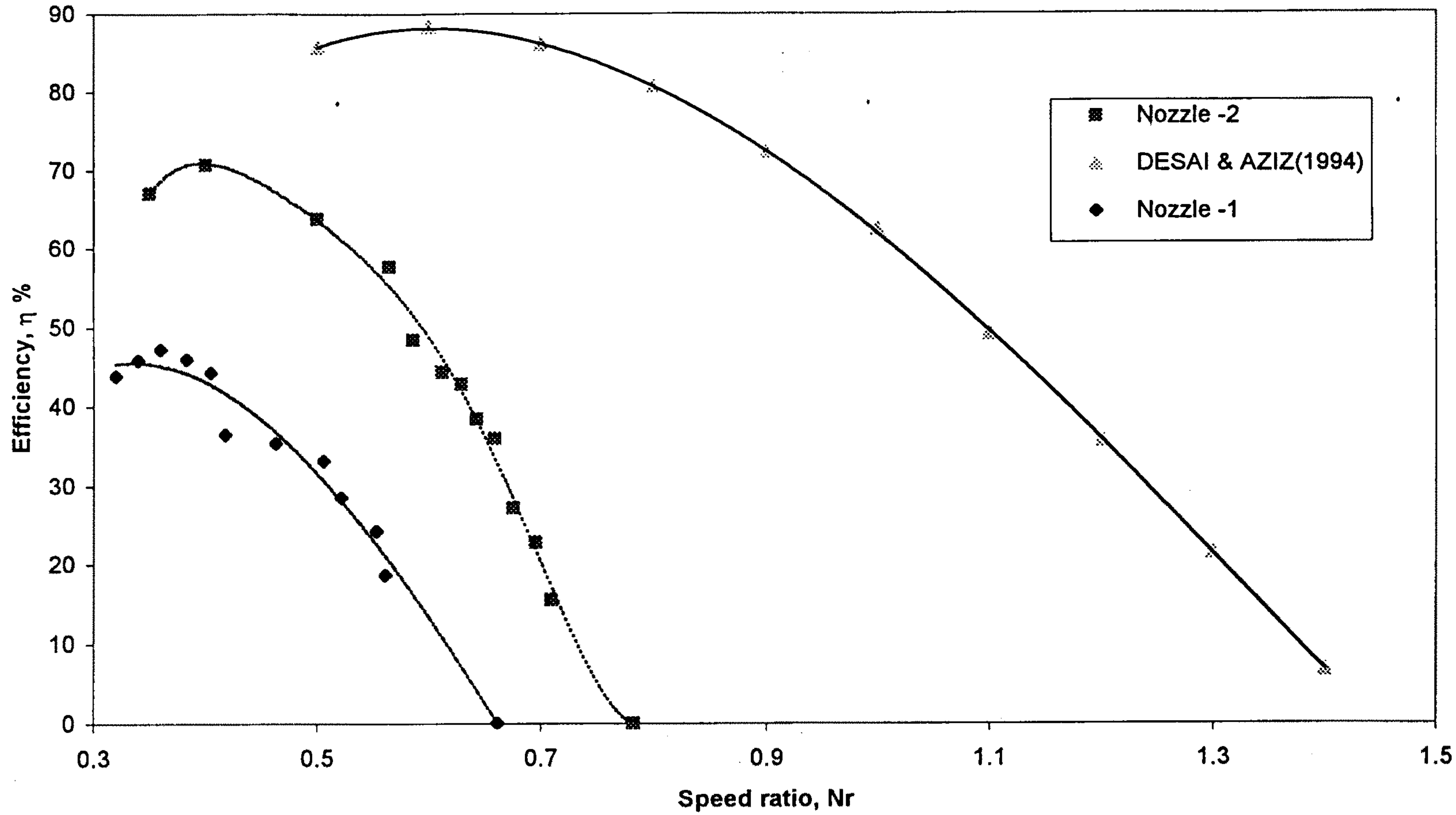

Fig.7.4 PERFORMANCE OF INDIVIDUAL NOZZLES FOR Q' =0.0614

angle of attack ($\alpha_1 = 16^o$). It is reported that the maximum efficiency increases with increase in δ. The highest efficiency of 63% was reported with $\delta = 36^o$. Desai and Aziz (1994) studied the effect of angle of attack ($\alpha_1 = 22^o$ to 32^o) keeping the nozzle entry arc ($\delta = 90^o$) constant. It was reported that the maximum efficiency obtained increases with decrease in α and the highest efficiency of 83% with $\alpha_1 = 22^o$. It is inferred from above that δ and α_1 are inter-related and necessitates the finding of the optimum combination of them for better performance for a given CFT.

7.5 EFFECT OF FLOW FRACTION ON CFT PERFORMANCE

The effect of flow fraction on CFT performance is presented in Fig.7.5 and Fig.7.6 for the constant unit flow rates of 0.0718 and 0.0614 respectively. The cross plot of maximum efficiencies obtained with various flow fractions is shown in Fig.7.7. All the flow fraction curves witness a similar trend of conventional bell shape. Further, with the reduction of flow fraction from 100% to about 40-50%, a decrease in efficiency is witnessed. It is due to the interaction of the two streams from the nozzles at the interior of the runner after respective first stages. This interaction probably reduces the momentum of the stream and thereby the second stage work done.

When the flow fraction is reduced further, the flow from the nozzle-1 decreases, resulting in reduced interaction between the two streams, which in turn increases the efficiency of the turbine. The increase in efficiency continues up to a flow fraction of about 15%. At this condition the flow from the Nozzle-1 does not cross the runner and leaves uncrossed. i.e., it does not disturb the flow from the nozzle-2 and thereby has a cumulative effect on work output. When the flow fraction is reduced further from 15% to 0%, the augmentation effect from the nozzle-1 decreases resulting in reduced maximum efficiencies.

Also, it is quite evident that the efficiency values obtained with Q_f = 15% is comparatively 5-20% more than the efficiency values obtained with any one of the nozzles individually (Q_f = 0, and 100%) for the given head and flow rate.

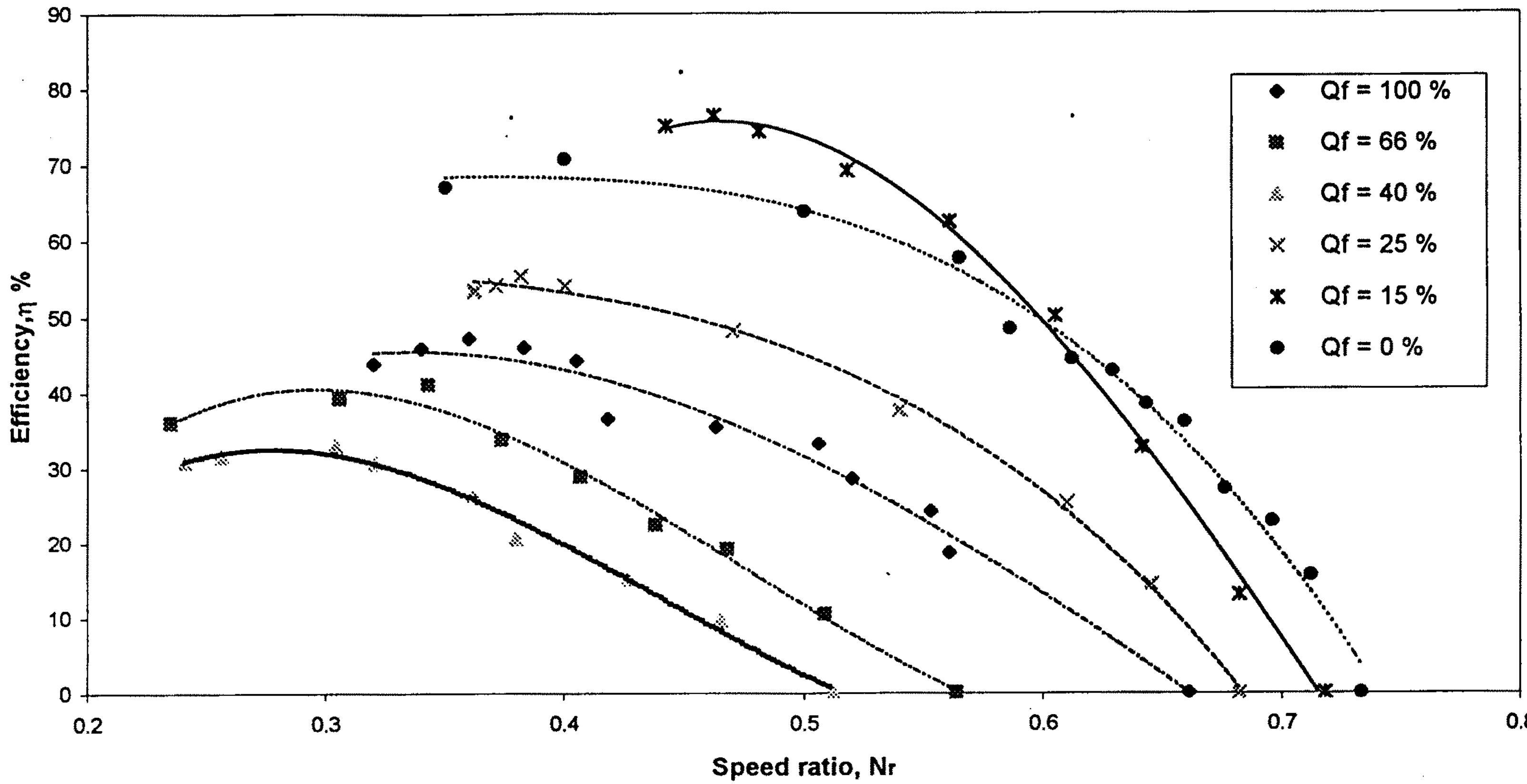

Fig.7.5 EFFECT OF FLOW FRACTION ON EFFICIENCY FOR Q' = 0.0614

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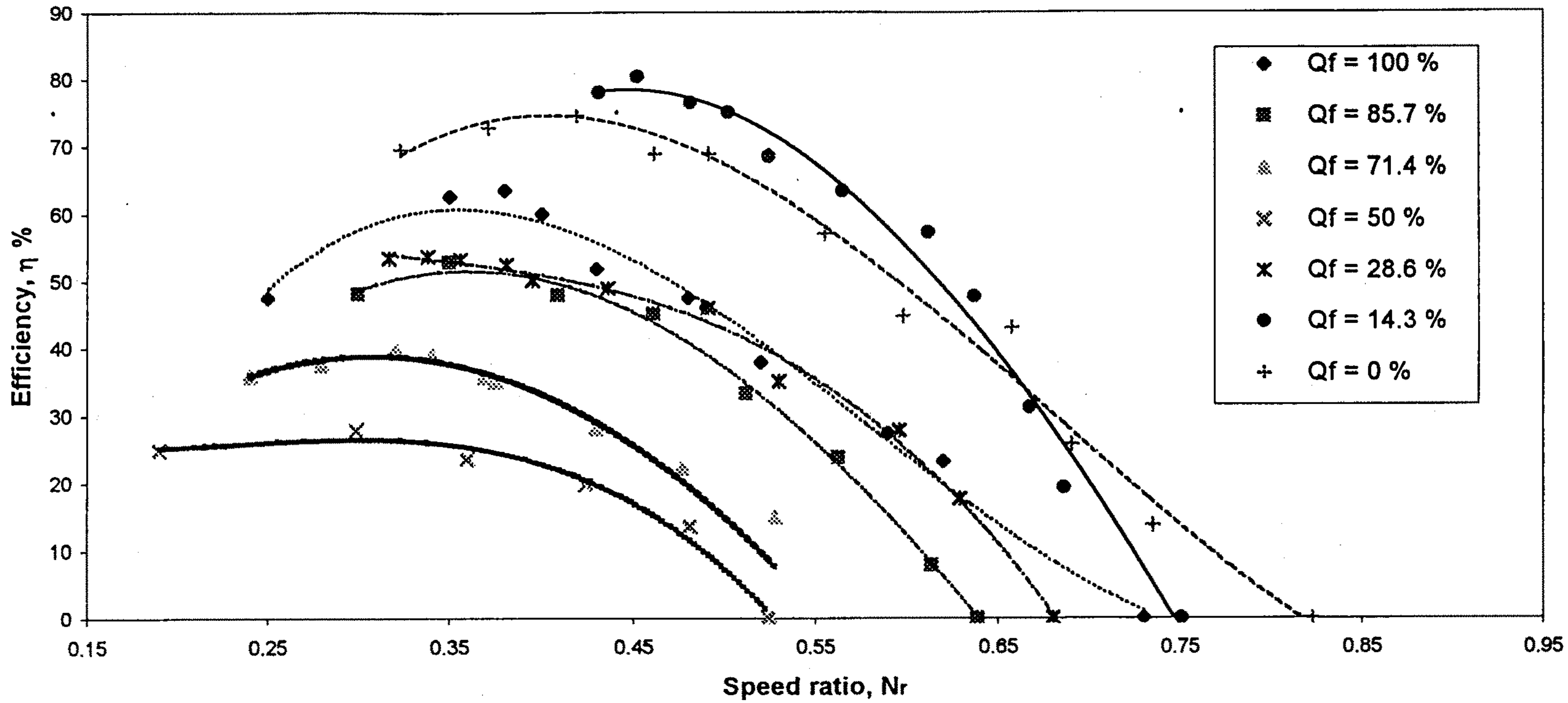

Fig.7.6 EFFECT OF FLOW FRACTION ON EFFICIENCY FOR Q' =0.0718

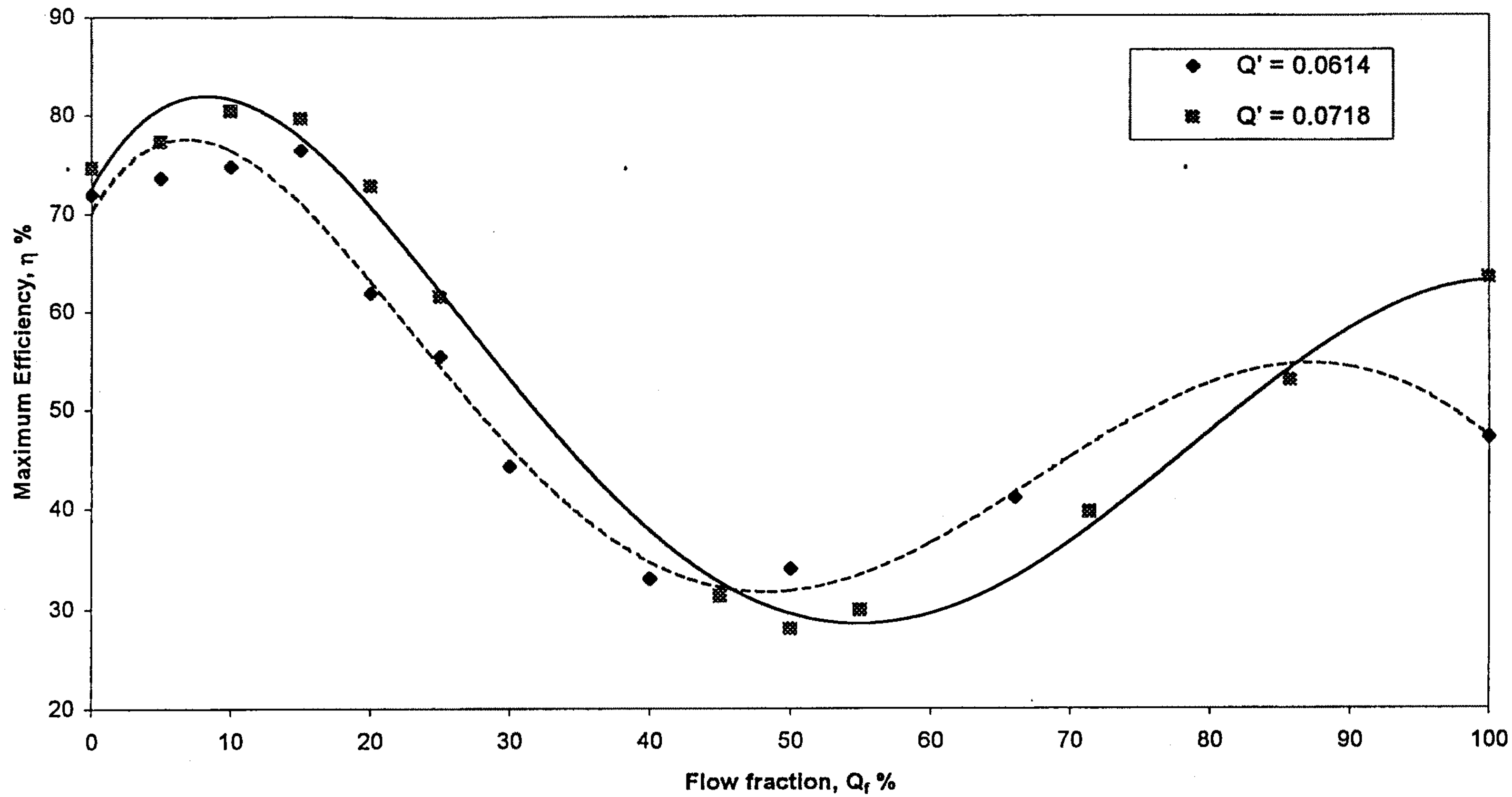

Fig.7.7 EFFECT OF FLOW FRACTION ON MAXIMUM EFFICIENCY OF 'CFT'

7.6 CLOSING REMARKS

For a selected angle of attack there exists an optimum nozzle entry arc. This fixes the minimum nozzle throat width (S_0). Thus maximum discharge through single nozzle is fixed for the given head and thus the power output. By introducing the second nozzle for the same turbine, for the same head, an additional discharge can be accommodated resulting in the corresponding increase in efficiency. But such an augmentation in efficiency could be possible only with the proper choice of the flow fraction. For the present CFT with two nozzles under investigation, such an optimum flow fraction is around 15%.

In a nut shell, for a selected angle of attack in design, if there were an optimum nozzle entry arc as discussed earlier, the maximum flow through a single nozzle is limited for a given head. To accommodate more discharge at this condition, introduction of a second nozzle with optimum flow fraction will be a suitable choice to derive higher power outputs from the same CFT.