STUDIES ON IMPULSE WATER TURBINES FOR MICRO-HYDROPOWER SYSTEMS

Thesis submitted
in fulfilment of the requirements of
the degree of
DOCTOR OF PHILOSOPHY

By
CHANDRA BAHADUR JOSHI

Department of Applied Mechanics
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

April 1992

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON IMPULSE WATER TURBINES FOR MICRO-HYDROPOWER SYSTEMS"** being submitted by Chandra Bahadur Joshi to the Indian Institute of Technology, Delhi, India, for the award of the degree of Doctor of Philosophy in Applied Mechanics Department is a bonafide research work carried out by him under my supervision and guidance. The thesis in my opinion, has reached the standard fulfilling the requirements for the Doctor of Philosophy Degree. The research report and the results presented in this thesis have not been submitted in parts or in full to any other university or institute for the award of any degree or diploma.

V. Seshadri

(V. Seshadri) 2/4/92
Professor
Department of Applied Mechanics
Indian Institute of Technology
New Delhi - 110016

ACKNOWLEDGEMENTS

It is an immense pleasure for me to express my most sincere gratitude and appreciation to Professor V. Seshadri for supervising my work during the complete research period. His unrelenting help, fruitful suggestions, friendly attitude and continued encouragement were the sources of inspiration to me at every stage of my work.

I am greatly thankful to Dr. S.N. Singh who helped me as a teacher, brother and friend and held me upright at all stages of my research work by all the possible ways and means.

I would like to extend my sincere thanks to Professor R.C. Malhotra for providing me the opportunity to carry out this study under the collaboration program between Tribhuvan University, Kathmandu, and the Indian Institute of Technology, Delhi.

I would also like to thank Mr. Sita Ram and the staffs of Fluid Mechanics Laboratory for their valuable assistance. This work would not have been completed without their help.

My special thanks are owed to the authorities of Asian Development Bank also whose financial support was of great help for me in conducting this research work.

I am extremely grateful to my old friend Dipl.-Ing. Werner Jochum of Germany for his various invaluable supports which he extended to me during my stay in India. I am also indebted to Dr. R.M. Shrestha, Dr. Allen Inversin, Mr. Ueli Meier, Dr. J. Fukutomi, Dr. J. Pokharel, Mrs. A. Kattel, Dipl.-Ing. S. Shrestha, Mr. S. Devkota and M/s Carl Duisberg Society of Germany for making me various research material available. A lot of thanks are also due to my friends Mukhtar, Nishant, Hegde and Mazumdar, whom I will be remembering for ever.

I thank Mr. Arora and Mr. Sarswat for drawing the figures and M/s Sharma Photostat for typing the thesis.

Finally the author recalls his family for their numerous sacrifices over the years. Truly, the support encouragement and the love, I received from my parents, wife Sharad and the loving sons Sachin and Sushan, which gave me tremendous strength for my work, can never be repaid.

ABSTRACT

Micro-hydropower systems have been universally recognized as an attractive alternative to conventional sources for meeting the ever increasing energy needs of the society. Impulse turbines like micro-Pelton wheels and cross-flow turbines are used quite frequently in such systems. In the present study the characteristics of both these turbines have been investigated experimentally to analyse the effect of various geometrical and dynamical parameters on their performance. For cross-flow turbine, a semi-empirical relation has also been suggested for predicting its performance under various operating conditions.

Micro-Pelton wheels, presently being used in micro-hydropower systems, are simply scaled down models of larger Pelton wheels, whose design has been standardized. Over the years experience has shown that these scaled down models do not give the same performance as the larger ones. The important parameters affecting their performance are the nozzle-diameter, nozzle-number and head. A systematic study has been carried out to establish the effect of these parameters on a proto-type model of a multi-jet micro-Pelton wheel available in the Fluid Mechanics Laboratory of I.I.T.-Delhi. The existing set-up was modified to measure the output power using a Prony brake system. From the results, it is concluded that one/two nozzles lead to maximum

efficiency and the optimum nozzle-diameter to blade width ratio is approximately 1/20. The major cause for the reduced efficiency of micro-Pelton wheel is attributed to the losses in the feed system.

Investigations on the cross-flow turbine in the present study have been undertaken to establish the effect of various design parameters on the performance. A proto-type cross-flow turbine was designed based on Banki's theory for a design head of 9 m with an output of 5 KW. It was fabricated in the Fluid Mechanics Laboratory of I.I.T.-Delhi. The set-up was fabricated in such a way that the flow could be visualised and also it was possible to systematically change the various parameters like number of blades, nozzle-entry-arc, shaft-diameter etc. The performance of the turbine at different heads was evaluated for various combinations of blade-numbers, nozzle-entry-arcs and shaft-diameters. Measurements have also been made both with and without draft tube.

Design modifications were also made to minimize the volumetric losses and thereby enhance the turbine performance.

From the results obtained it has been possible to clearly identify the effect of various geometrical parameters and a maximum efficiency of 68 % was achieved for an optimum combination of blade-number, nozzle-entry-arc and shaft-diameter. It has also been observed that draft tube had a positive effect only at low heads (below 7m). Attempted design modifications did not enhance the performance significantly.

A semi-empirical relationship for power output of a cross-flow turbine has been developed which incorporates the effect of blade-number, hydraulic and mechanical losses. The present experimental data as well as those available in literature have been used to evaluate the loss coefficients in the proposed relationship. Comparison of predicted performance of the cross-flow turbine has shown a good agreement. Thus the proposed relationship can be used for predicting the performance of any cross-flow turbine with reasonable accuracy.

TABLE OF CONTENTS

Page No.