STUDIES ON EROSION WEAR IN SLURRY PIPELINES

By

RAJAT GUPTA

DEPARTMENT OF APPLIED MECHANICS

Submitted
In Fulfilment of the Requirement for the Degree
of

DOCTOR OF PHILOSOPHY

to the
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
DECEMBER 1994

CERTIFICATE

This is to certify that the thesis entitled ***'Studies on Erosion Wear in Slurry Pipelines'*** *being submitted by Sri Rajat Gupta to the Indian Institute of Technology, Delhi for the award of the Degree of Doctor of Philosophy in Applied Mechanics is a record of bonafide research work carried by him under our supervision and guidance. The thesis work, in our opinion, has reached the requisite standard fulfilling the requirement for the Doctor of Philosophy Degree.*

The results contained in this thesis have not been submitted in part or in full, to any other University or Institute for the award of any degree or diploma.

(Dr. S.N.Singh) 5/12
Associate Professor,
Deptt. of Applied Mechanics,
Indian Instt. of Technology
New Delhi- 110 016

(Prof. V.Seshadri) 5/12/94
Professor,
Deptt. of Applied Mechanics,
Indian Instt. of Technology
New Delhi- 110 016

ACKNOWLEDGMENT

I consider myself among the few privileged to get an opportunity to work under my esteemed supervisors Prof: V.Seshadri and Dr.S.N.Singh. Words are inadequate to acknowledge the great care and interest taken by them in all aspects of the present work. I express my sincerest gratitude to both of them from the core of my heart. My association with them throughout the research activity was a great process of learning.

The assistance extended by the wonderful staff of the Fluid Mechanics Laboratory is gratefully acknowledged. Thanks are also due to the staff of the workshop and the computation laboratory . This work would not have been accomplished without their co-operation.

At this point of time, when I look back upon, I am overwhelmed with the thoughts of the sacrifice made by my parents, brothers and near and dear ones throughout my educational and research pursuits. I am also very much grateful to my colleagues, friends and well wishers who have directly or indirectly helped me for the making of the thesis. Their help is a great treasure to me.

I express thanks to the Regional Engineering College, Silchar, for sponsoring and Ministry of Human Resource Development, Govt. of India, for providing financial support under Quality Improvement Programme. Sincere thanks are also due to Mr. Gulati for typing the thesis and Mr. Arora and Mr. Sarswat for tracing the diagrams.

My wife, Suchismita, deserves a special mention. She not only willingly endured hardship during my preoccupation with this work but also supported me in all possible ways to complete the thesis.

Finally, I strongly believe that without the blessings of the Almighty the thesis could not have reached in its present form.

Gupta 5/12/94

(RAJAT GUPTA)

ABSTRACT

Slurry pipelines are used to transport solid materials in bulk quantities over large distances in various chemical and mining industries. The technical knowhow associated with the design and operation of such pipelines is far from complete. Erosion wear is one of the most important parameters which a slurry pipeline designer has to estimate so as to ensure adequate life span for the pipe. In the absence of any universal relation for the prediction of erosion wear in slurry pipelines, semi-empirical methods are being practised for determining the required metal allowance in the pipe wall thickness. The present study has been aimed towards understanding of various aspects of erosion wear by employing pilot plant test loop and bench scale tests. The different aspects looked into are the uneven wear in pipelines, bend characteristics and dependence of erosion wear on various parameters.

Most of the slurry pipelines operate under a heterogeneous regime in turbulent flow with a wide particle size distribution(PSD). The existence of skewed concentration and PSD across the cross-section of the pipe results in uneven erosion of the pipe surface. Thus, uneven wear rate studies using a specially designed test rig fitted in the pilot plant test loop have been undertaken to identify the extent of uneven wear taking place on the pipe surface. The materials tested are brass and

mild steel with multisized copper tailing slurry. Measurements of wear, concentration and PSD along the circumference of the pipeline have shown that the erosion wear is maximum at the bottom and local wear in the pipeline is related to the local values of concentration and particle size distribution.

Systematic studies on erosion wear using multisized particulate slurries either in pilot plant or bench scale test rigs have not been reported in literature. A pot tester has been designed and developed as a bench scale test set-up for accelerated studies on erosion wear. This study has identified the effect of velocity, concentration and particle size for both equisized and multisized particulate slurries for two test materials, namely brass and mild steel. Based on this experimental data, correlations have been derived for brass and mild steel using equisized particles. The developed correlations have been used to predict the erosion wear for multisized slurry and it has been established that the weighted mean diameter is the best representative diameter for the multisized slurries. The proposed correlations have also been used to predict the erosion wear along the circumference of pipeline using local concentration, local PSD and average velocity. The agreement between the predicted wear and measured wear is within ± 13.5% for brass and ± 14% for mild steel. The deviations could be due to the fact that the relative motion of solid particles with respect to the wear pieces in the pot tester is not exactly identical to that existing in a slurry pipeline, in particular,

the impact angle in the two cases could be somewhat different. The deviations could also be because of the use of the weighted mean diameter and average velocity in the correlations. Inspite of the above limitations, the pot tester can be used effectively to develop empirical correlations for specific combination of solid and pipe materials to establish the local wear rate of the pipe surface with reasonable accuracy. The present study has also shown that the local wear rate in the slurry pipeline is uniquely correlated to the local values of solid concentration, PSD and velocity.

Based on the measurements of uneven wear and the empirical correlation, a design parameter has been identified. This has been defined as the ratio of bottom wear to average wear. A software has been developed which predicts the concentration and PSD across the pipe cross section and then evaluates the erosion wear of the pipe surface. Further, it evaluates the proposed design parameter. The developed software can be used as a design tool by slurry pipeline designers.

An attempt has also been made towards a better understanding of the causes of the excessive wear in pipe bends. Overall concentration profiles and PSD have been measured inside a 90^{o} bend in four planes for various combinations of concentrations and velocities. Data has been analysed to illustrate the phemonenon of redistribution of particles of various size fractions. Analysis of these data has also shown that the migration of larger fractions towards the outer wall causes

maximum wear between 0^{o} and 90^{o} on the outer surface depending upon the operating velocity, concentration and PSD.

As a part of the present study, the performance characteristics of two wedge flowmeters have been thoroughly investigated. It has been found that the value of wedge coefficient for slurry flows is more than that of water and this value increases with the increase in efflux concentration till about 10% (by weight) and then attains a constant value for higher concentrations.

CONTENTS