Analysis of Surge

Macmillan Civil Engineering Hydraulics

General Editor: E. M. Wilson, PH.D., M.SC., F.I.C.E.

Reader in Civil Engineering, University of Salford

FLOW IN CHANNELS: *R. H. J. Sellin*

ENGINEERING HYDROLOGY: *E. M. Wilson*

COASTAL HYDRAULICS: *A. M. Muir Wood*

Analysis of Surge

John Pickford, M.Sc.(Eng.), C.Eng., M.I.C.E.

Department of Civil Engineering

Loughborough University of Technology

Macmillan

© John Pickford 1969

Softcover reprint of the hardcover 1st edition 1969

First published 1969

Published by

MACMILLAN AND CO LTD

Little Essex Street London WC2

and also at Bombay Calcutta and Madras

Macmillan South Africa (Publishers) Pty Ltd Johannesburg

The Macmillan Company of Australia Pty Ltd Melbourne

The Macmillan Company of Canada Ltd Toronto

Gill and Macmillan Ltd Dublin

ISBN 978-1-349-00162-0

ISBN 978-1-349-00160-6 (eBook)

DOI 10.1007/978-1-349-00160-6

Preface

Many engineers claim that they “do not understand surge”, but for many others there is a fascination in the varying surge pressures resulting from changes of flow. It is hoped that this book will satisfy both groups by providing clear explanations of surge phenomena, and by investigating a variety of methods of dealing with the subject.

The material is presented in such a way that it should be a valuable textbook for undergraduates dealing with surge problems for the first time. Postgraduate students and practising engineers should find it a useful reference for detailed study and a guide for design analysis.

Waterhammer is investigated from first principles along well-trodden paths. Particular reference is given to graphical analysis.

In the chapters devoted to surge tanks a number of methods of calculating surge heights are considered, and special attention is given to the ‘logarithmic method’, and to finite difference methods which are particularly suitable for computer analysis.

The author has carried out an intensive investigation of mass oscillations in surge tanks: over 20 000 measurements of surge heights were taken in a laboratory model, and several thousand surge heights were obtained by analogue and digital computers. The methods described in this book have been well-tried, and have been included only when they have proved satisfactory.

Many worked examples are given and S.I. units are used throughout, although traditional British units are mentioned when it is thought that familiar quantities may be helpful.

The material has been selected so as to deal with the practical aspects of surge which are most useful for civil engineers. Reference is made throughout the book to the literature of the subject so that readers wishing to know more about particular aspects can readily find further information.

John Pickford

Loughborough

Contents

Preface	v
1 Waterhammer, surge tanks and open channel surge	1
2 Introduction to waterhammer	5
2.1 Incompressible water column theory	
2.2 Valve movement	
2.3 Limiting pressures	
2.4 Equivalent length of pipe	
3 Elastic theory for a simple pipe	18
3.1 Sudden closure	
3.2 Pressure increase in a rigid pipe	
3.3 Strain energy waterhammer theory	
3.4 Fundamental differential equations of water-hammer	
3.5 Velocity of propagation	
3.6 Direct application of elastic waterhammer theory	
4 End conditions	32
4.1 Reflection at a reservoir	
4.2 Reflection at a dead end	

4.3	Effects of changes of pipe	
4.4	Effect of junction	
4.5	Effect of restriction	
4.6	Oscillation of the pressure wave	
5	Non-instantaneous closure and opening	42
5.1	Rapid closure of downstream valve	
5.2	Slow closure of downstream valve	
5.3	Other types of valve movement	
6	Graphical analysis	50
6.1	Pressure-velocity diagrams at fixed points	
6.2	Pressure-discharge diagrams at fixed points	
6.3	Schnyder–Bergeron diagrams	
6.4	Surge diagrams for uniform pipe with hypothetical conditions	
6.5	Comparison of surge diagram with analytical method	
6.6	Intermediate times and positions	
6.7	Series pipes	
6.8	Branched pipes	
6.9	Effect of hydraulic losses	
6.10	Other conditions	
7	Waterhammer in pumping mains	70
7.1	Sudden stopping of pumping	
7.2	Separation of water columns	
7.3	Pump with inertia	
7.4	Reverse flow	
	Surge control	78
7.5	Air vessels	
7.6	Pump by-passes and feeder tank	
7.7	Parallel pumps	
7.8	Waterhammer in delivery pipe from reciprocating pump	

8	Waterhammer in hydro-electric supply pipes	87
8.1	End conditions at a surge tank	
8.2	Simple tank near valve	
8.3	Throttled tank near valve	
8.4	Tank between pipeline and penstock	
9	Introduction to surge tanks	98
9.1	Purpose of surge tanks	
9.2	Oscillation phenomena	
9.3	Design considerations	
9.4	Effect of friction	
9.5	Surge tank types	
10	Theory of mass oscillation	108
10.1	Fundamental equations	
10.2	Simple undamped oscillation	
10.3	Logarithmic equations	
10.4	Logarithmic curves	
10.5	Stability	
11	Finite difference methods I	129
11.1	Outline of the methods	
11.2	Fundamental finite difference methods	
11.3	Successive trials (Pressel's method)	
11.4	Simple arithmetic method	
11.5	Jakobsen's method	
11.6	Escande's method	
11.7	Effect of friction	
12	Finite difference methods II	141
12.1	Modifications	
12.2	Flow to turbines during oscillation: sudden valve movements	

12.3	Linear change of flow	
12.4	Constant valve opening	
12.5	Constant power output	
12.6	Flow from several sources	
12.7	Variable area tank	
12.8	Spilling tank	
12.9	Differential tank	
12.10	Branching tank	
12.11	Tail race tank	
12.12	Multiple tanks	
13	Approximate methods	162
13.1	Relative values—simple tank	
13.2	Other approximate equations for simple tanks	
13.3	Classified diagrams for throttled tanks	
14	Graphical methods	175
14.1	Schoklitsch method	
14.2	Calame and Gaden radial method	
14.3	Surge height trace by analogue computer	
15	Open channel surge	184
15.1	Unsteady flow in open channels	
15.2	Backwater surges	
	<i>List of Notations</i>	193
	<i>Index</i>	197

A list of references and Suggestions for further reading is given at the end of each chapter.