SERIES ON HYDRAULIC MACHINERY – VOL. 2

Abrasive Erosion & Corrosion of Hydraulic Machinery

Editors

C. G. Duan | V. Y. Karelin

Imperial College Press

Abrasive Erosion & Corrosion of Hydraulic Machinery

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Abrasive Erosion & Corrosion of Hydraulic Machinery

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Foreword of the Editor

This book entitled *Abrasive Erosion and Corrosion of Hydraulic Machinery* is one of the many volumes of the Book Series on Hydraulic Machinery organised and edited by its International Editorial Committee. This volume deals with the abrasive erosion and corrosion of hydraulic machinery, the theory 'and practical subjects being arisen from the engineering reality.

The abrasive erosion damage is one of the most important technical problem for hydro-electric power stations working in silt laden water, and the pumping plants to be employed in diversion of solid particle-liquid two phase flow in many industrial and agricultural sectors. In countries with rivers of high silt content the exploitation of those rivers are inevitably faced with the silt erosion problem.

From the point of view of the requirements from industry and the achievements attained from research on the abrasive erosion and corrosion, a volume on generalization and summarization of this subject should be worth much. The works of this volume try to expound the fundamental theory, research situation, and achievements from laboratory and practice engineering of the abrasive erosion and corrosion of hydraulic machinery.

This volume consists of seven chapters. Chapter 1 describes the fundamentals, the abrasive erosion theory, and the abrasive erosion of hydraulic turbines and pumps. Chapter 2 analyses the influence factors on silt erosion. Chapter 3 describes the particles laden flow analyses. Chapter 4 deals with the design of hydraulic machinery working in silt laden water. In Chapter 5, the anti-abrasive erosion materials used for manufacturing and site repair of hydro-electric plants and pumping stations are described. Chapter 6, discusses the inter-relation between abrasive erosion and cavitation erosion. The corrosion of hydraulic machinery is discussed in Chapter 7.

This Volume is written by 7 authors from 4 countries who are long time experts in the field of abrasive erosion and corrosion. Most chapters of this volume were written by two or three authors and composed of their contributions. The editor's work was to draw up the frame outline of the chapters and sections, invite authors, and composting the contents of the whole book including making some necessary readjusting among the works contributed by different authors.

In the case of different authors approaching the same subject, they may offer different point of view and materials collected from different sources, which really are useful for a better understanding on the subject.

When this Volume is completed, we are deeply obliged to Prof. S. C. Li and Dr. A. P. Boldy of University of Warwick, Prof. Y.L. Wu and Prof. Z.Y. Mei of Tsing Hua University, for their valuable works not only in this volume, but also in their devotion to the work for our International Editorial Committee of Book Series on Hydraulic Machinery.

For this Volume, our colleagues in the International Research Centre on Hydraulic Machinery especially Prof. Y.L. Wu and Miss Q. Lei who rendered great assistance in the editing of camera ready manuscript of this volume. Here, we wish to extent our sincere thanks to them.

Duan C G and V Y Karelin, Editors

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Chapter 1

Fundamentals of Hydroabrasive Erosion Theory

V. Ya. Karelin, A. I. Denisov and Y.L. Wu

1.1 Introduction

Hydraulic abrasion of the flow-passage components of hydraulic machines (hydro-turbines, pumps) should be interpreted as a process of gradual alteration in state and shape taking place on their surfaces. The process develops in response to the action of incoherent solid abrasive particles suspended in the water or in another working fluid and also under the influence of the fluid flow. Whilst the abrasive particles present in the flow act upon the circumvented surfaces mechanically, the effect of pure water on the surfaces is both mechanical and chemical (corrosive action). Therefore, Hydraulic abrasion can be considered as a compound mechanical-abrasive process.

Under the action of abrasive particles on the metal surface in contact with the fluid, wear in hydraulic machinery is primarily a result of particle erosion, the mechanisms of which typically fall into one of two main categories: impact and sliding abrasion.

Impact erosion is characterized by individual particles contacting the surface with a velocity (V) and angle of impact (α) as shown in Figure 1.1a. Removal of material over time occurs through small scale deformation, cutting, fatigue cracking or a combination of the above depending upon the properties of both the wear surface and the eroding particle.

Sliding abrasion is characterized by a bed of particles bearing against the wear surface with a bed load (s) and moving tangent to it at a velocity (Vs) as shown in Figure 1.1 b. The formation of the concentration gradients causing the bed and the resultant bed load are both due to the centrifugal forces acting on the flow with the curved surface. Removal of material over time occurs through small scale scratching similar to the free cutting mode of impact erosion [1.1, 1.13].

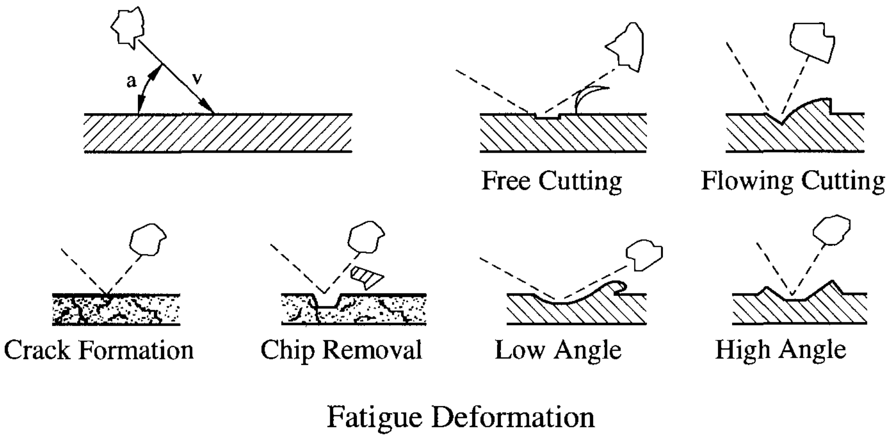

Figure 1.1 a Impact erosion

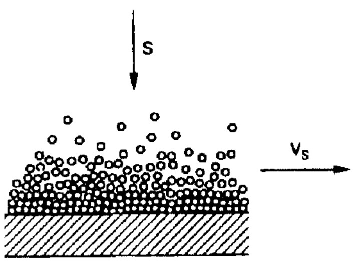

Figure 1.1 b Sliding abrasion

Mechanism of hydraulic abrasion of particles has been reviewed recently by Visintainer, et al. (1992) [1.1], Addie et al. (1996) [1.2] and J. Tuzson and H. McI. Clark [1.3]. A relatively recent studies of the status of two-phase, solid-liquid flow were presented by Pagalthivarthi et al. (1990) [1.4] and Wu Y.L. et al (1998) [1.5]. Most studies assume dilute suspensions or single particle, and do not take into account that the maximum packing density limits solid concentration. Virtually solid (closely packed) particle layers can accumulate in certain boundary regions as pointed out by Tuzson (1984) [1.6]. Ore beneficiation slurries are concentrated to 30 to 50% by volume, the maximum packing corresponding to about 75%. Particle impact dynamics have been studied in detail, (Brach, 1991) [1.7]. Energy loss and restitution theories are supported by tests with steel balls. The specific case of a two-dimensional cylinder in a uniform flow was analyzed by Wong and Clark (1995) [1.8] and was used to model conditions in a slurry pot erosion tester.

The study of Wong and Clark also includes comparisons with slurry erosion rate data from slurry pots and therefore addresses the material removal issue. Satisfactory correlation of an energy dissipation model with erosion rates was found especially for particles larger than 100 mm. Pagalthivarthi and Hemly (1992) [1.9] presented a general review of wear testing approaches applied to slurry pump service. They distinguished between impact erosion and sliding bed erosion. Tuzson (1999) investigated the specific case of sliding erosion using experimental results from the Corolis erosion-testing fixture, which produces pure sliding erosion [1.3]. These studies have been also supplemented (Clark et al, 1997) [1.10]. Knowledge of the relationship between the fluid and particle flow conditions near the wall and the material removal rate is essential for erosion estimates. It appears that the specific energy - the work expended in removing unit volume of material - provides a satisfactory first measure of the erosion resistance of the material. However, its general use must be qualified since values are known to vary with, for example, erodent particle size.

Abrasive erosion of hydraulic machinery has been reviewed extensively by Duan C.G. in 1983 [1.11] and in 1998 [1.12].