Principles and Applications of Metal Rolling

This is a book written by a practitioner. It is somewhat different from a normal textbook involving machines and equipment in the field of Mechanical Engineering. Generally stress is given to the theories and principles involved and processes are explained in great detail. There is no doubt that these are essential for an engineer. But it is equally important for an engineer to know the basic design, working principle and operation of various machines/equipment used for conversion of raw materials into desired products. The introduction of laboratories, workshops and industrial tours help fill this void to some degree. Yet, engineering curriculum retains the deficiency.

Meant for undergraduate and graduate students, this book attempts to fill the void in the sub-field 'Rolling Process'. It also intends serving as a reference book for practicing engineers. It begins with comprehensive coverage of rolling processes and the mechanics of rolling, which is the theoretical content of the subject. This is followed by a chapter on 'rolling practices' that highlights plant level procedures and practices employed by the rollers for producing desired products. The book concludes with the description, operation and design principles of various equipment, mechanisms and systems used inside a rolling plant.

Siddhartha Ray is professor in the Mechanical Engineering Department and Dean (UG Programmes) at Heritage Institute of Technology, Kolkata. Earlier he taught, for a decade, at the National Institute of Technical Teachers' Training & Research, Kolkata, where he also served as the Director for about two and half years. Before joining the academia in 2001 Ray spent more than thirty years in various industries, designing and developing machines and systems for rolling mills and other kinds of material handling plants. He has published a number of technical and research papers, and he also holds two patents. Besides teaching and research, he enjoys writing popular science books and articles in Bengali.

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CAMBRIDGE UNIVERSITY PRESS

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4843/24, 2nd Floor, Ansari Road, Daryaganj, Delhi - 110002, India

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107076099

First published 2015

Printed in India

A catalogue record for this publication is available from the British Library

Library of Congress Cataloging-in-Publication Data
Ray, Siddhartha.
Principles and applications of metal rolling / Siddhartha Ray.
pages cm
Includes bibliographical references and index.
Summary: "Discusses the entire gamut of rolling process and the practices followed in rolling industry and operation and use of various rolling mill equipment and systems"-- Provided by publisher.
ISBN 978-1-107-07609-9 (hardback)
1. Rolling (Metal-work) I. Title.
TS340.R39 2015
671.3'2--dc23
2015004528

ISBN 978-1-107-07609-9 Hardback

This book is dedicated to the memory of my mother

Sadhana Roy

She remains the main source of inspiration in my life.

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List of Symbols

x,y,z	three rectangular coordinates
F	force
F_R	repulsive force
F_A	attractive force
r_o	inter-atomic distance
τ_o	ultimate shear stress
G	modulus of rigidity
Hi	abbreviation of "High", signifying number of rolls in a mill stand
h	thickness of stock/workpiece
h_1	input thickness
h_2, h_0	output thickness after deformation through rolling
h_n	thickness at neutral axis
w,b	width of stock/workpiece
w_1,b_1	Input width
w_2,b_2	output width after deformation
w_m,b_m	mean width
A_1	cross sectional area of stock/material at input
A_2	cross sectional area of output after deformation
L_1	length of stock/workpiece at input
L_2	length of stock at output after deformation
α	contact angle or angle of bite/contact
Δh,(h_1-h_2), δ	draught or reduction in height/thickness
E′	elongation factor
Δw, Δb_m, (b_2-b_1)	spread
R,r	roll radius
D	roll diameter
l	projected length of arc of contact
μ	coefficient of friction
N	neutral point
α_n, γ	neutral point angle
v_1	stock velocity at entry
v_2	stock velocity at output

h_g	set roll gap
γ	poisson ratio
E	Young's modulus
Δf	mill stretch
R', r'	Deformed roll radius
h_m	mean thickness of stock/workpiece
v_n, v_r	roll surface velocity
v_x	roll surface velocity in the direction 'x'
ϕ	angle subtended by a point on roll surface within roll bite
ϕ_x	Angle subtended by a point on roll surface at a distance x from roll axis.
σ_x, σ_y, σ_z	normal stresses
k, τ_s	shear yield stress
τ_x	contact shear stress
σ_1, σ_2, σ_3	principal normal stresses
τ_{xy}, τ_{yz}, τ_{zx}	Shear stresses
τ_1, τ_2, τ_3	principal shear stresses
σ	yield stress
σ_a	actual resistance to deformation (tensile yield stress)
σ_t	ultimate strength
σ_A	tensile stress due to back tension
σ_B	tensile stress due to front tension
η	coefficient of viscosity
F	horizontal projection of contact area
σ_s	tensile yield stress of annealed metal
T	absolute temperature
s	specific heat of metal
t	rolling temperature, ^{0}c
Δt	time interval, seconds
A	energy required to deform metal
W	weight of metal in kg
u, $\dot{\varepsilon}$	strain rate, sec^{-1}
ε	Strain
p	contact pressure between roll and stock,
a	Length of lever arm
λ	lever arm coefficient
T	Torque
kw	Kilo-watt
HP	horse power
HAGC	Hydraulic automatic gauge control
EDC	Edge drop control

Preface

Organization of this book is somewhat different from a normal textbook involving machines and equipment, in the field of mechanical engineering. Generally, stress is given to the theories and principles involved and the processes are explained to a great detail. There is no doubt that these are essential for an engineer. But it is equally important for an engineer to know the basic design, working principles and operations of the various machines and equipment which are used in the practical field for conversion of the raw materials into desired products. Baring the subject of 'Machine Tools', in most other fields of manufacturing processes, available textbooks seem to be rather miserly in thorough discussions on the description, design, working principles of various machines and systems involved and practices followed in actual operation.

An attempt has been made to bridge this gap by introducing laboratory exercises and workshops along with industry visits, in the engineering curricula. More often than not these prove to be inadequate. It is next to impossible that an equipment or machine like a turbine, an extrusion press or a rolling mill can be installed in an academic institution. By observing the operation of a machine or system during a visit to an industrial plant, definitely a lot can be learned about the manufacturing process, but seldom can it give an idea about the working principles of the various mechanisms, their design details or about the intricacies of operational practices.

While teaching 'Manufacturing Technology' to MTech students at the National Institute of Technical Teachers' Training and Research (NITTTR), Kolkata, I observed this shortcoming in my students and cherished the desire to bridge the gap as soon as possible. With 30 years' experience in the industry in design, development and commissioning to operation plant and machinery (out of which more than half the period was in the field of Rolling Mills), I decided to write this book titled *Principles and Applications of Metal Rolling*.

This book is intended to cover undergraduate and postgraduate engineering curricula for 'Rolling Technology' in India and in other countries. It is also meant to be a reference book for practicing engineers working in the field of rolling mills. The first two chapters cover the rolling process and mechanics of rolling comprehensively, which is the theoretical content of the process of rolling. The third chapter on 'Rolling Practices' highlights plant level procedures and practices employed by the rollers for producing desired products. The whole of the fourth chapter on 'Rolling Equipment and Systems' is devoted to the description, operation and design principles of various equipment, mechanisms and systems used in a rolling plant.

In preparing the book, help has been taken from some specialized books written and edited by experts and from the literature of equipment manufacturers. Acknowledgement and references to such books and literature have been made at appropriate places.

Suggestions and comments on the organization and contents of the book are welcome and may kindly be sent to the publisher or the author.

Acknowledgments

While writing this book I have received help, suggestions and encouragement from many of my ex-colleagues, friends and well wishers, which I gratefully acknowledge.

At the very outset I would like to express my appreciation to my MTech students of Manufacturing Technology course offered by the National Institute of Technical Teachers' Training and Research (NITTTR), Kolkata. While teaching and discussing the subject of Rolling Technology with them, I got impetus to write the present book. I am indeed thankful to them.

During the writing of this book I have drawn upon the knowledge and experience I received while working with M/s Davy Ashmore India Ltd., in close contact with their collaborators in the UK – Davy Lowey Ltd. and Loewy Robertson Engineering Company of the UK, and later with M/s Tata Construction and Projects Limited. I would like to acknowledge my deep sense of gratitude to the following persons, who gave me the opportunity to work in the field of design and operation of Rolling Mills and also gave me all possible help and cooperation during the writing of this book: Late P. Sen, Ex.-M. D. of Davy Ashmore India Ltd. and my ex-colleagues P. K. Bera and A. K. Mitra. I am particularly indebted to S. Bhattacharya from the same organization, who advised me while writing the topic on Mill Electrics.

I am also grateful to friends from the Davy Group of companies in the UK, namely: T. Shiemeld, T. Smith, A. F. Uff, D. Fretwell and others who helped me with information and material on the subject as and when I needed them. I am thankful to S. Majumdar, Ex President of Hindalco and colleagues at NITTTR, Kolkata and Heritage Institute of Technology, Kolkata for advising and encouraging me during the preparation of the book.

My thanks are also due to T. K. Dutta, an ex-colleague of Davy Ashmore, who joined later M/s. SMS Demag, India, for giving me valuable suggestions on Roll Lubrication and Cooling System.

I am thankful to Kingshuk Ghosh, the DTP operator of my department at NITTTR, who untiringly finished the entire manuscript, working beyond his working hours. My thanks go to G. Patra for preparing some of the diagrams using CAD.

I am grateful to my wife Dipali Ray and other family members for their constant encouragement and sacrifices during the preparation of the book.

Finally, my thanks are to the Cambridge University Press for readily accepting to publish the book.