MECHANICS AND THERMODYNAMICS OF PROPULSION



PHILIP G. HILL University of British Columbia

CARL R. PETERSON Massachusetts Institute of Technology

ÞC

Original Edition entitled *Mechanics And Thermodynamics Of Propulsion, Second Edition,* by Hill, Philip; Peterson, Carl, published by Pearson Education, Inc, publishing as Prentice Hall, Copyright © 1992.

Indian edition published by Dorling Kindersley India Pvt. Ltd. Copyright © 2010

All rights reserved. This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, resold, hired out, or otherwise circulated without the publisher's prior written consent in any form of binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser and without limiting the rights under copyright reserved above, no part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise), without the prior written permission of both the copyright owner and the above-mentioned publisher of this book.

ISBN 978-81-317-2951-9

First Impression, 2010 Nineteenth Impression, 2013 Twentieth Impression, 2014

This edition is manufactured in India and is authorized for sale only in India, Bangladesh, Bhutan, Pakistan, Nepal, Sri Lanka and the Maldives. Circulation of this edition outside of these territories is UNAUTHORIZED.

Published by Dorling Kindersley (India) Pvt. Ltd., licensees of Pearson Education in South Asia.

Head Office: 7th Floor, knowledge Boulevard, A-8(A) Sector-62, Noida (U.P) 201309, India Registered Office: 11 Community Centre, Panchsheel Park, New Delhi 110 017, India.

Printed in India at Shree Maitrey Printech Pvt. Ltd., Noida

6.2 SUBSONIC INLETS

area to inlet area. The internal pressure rise depends on the reduction of velocity between entry to the inlet diffuser and entry to the compressor (or burner, for a ramjet). Nacelle size required for low drag can be quite strongly dependent on the degree of external deceleration. In realistic analyses one must consider compressibility effects.

Inlet Performance Criterion

As Chapter 5 showed, one may characterize the differences between actual and ideal performance of aircraft engine inlets by a "diffuser efficiency" or by a stagnation pressure ratio. We define these as follows:

a. Isentropic efficiency. Referring to Fig. 6.5, we can define the isentropic efficiency of a diffuser in this form:

$$\eta_d = rac{h_{02s} - h_a}{h_{0a} - h_a} pprox rac{T_{02s} - T_a}{T_{0a} - T_a}.$$

State (02s) is defined as the state that would be reached by isentropic compression to the *actual* outlet stagnation pressure. Since

$$\frac{T_{02s}}{T_a} = \left(\frac{p_{02}}{p_a}\right)^{(\gamma-1)/\gamma}$$
 and $\frac{T_{02}}{T_a} = 1 + \frac{\gamma-1}{2}M^2$,

the diffuser efficiency η_d is also given by

$$\eta_d = \frac{(p_{02}/p_a)^{(\gamma-1)/\gamma} - 1}{[(\gamma - 1)/2]M^2}.$$
(6.4)

b. Stagnation pressure ratio, r_d . The stagnation pressure ratio,

$$r_d = p_{02}/p_{0a}, (6.5)$$



225

226 CHAPTER 6 AEROTHERMODYNAMICS OF INLETS, COMBUSTORS, AND NOZZLES



FIGURE 6.6 Typical subsonic diffuser performance; $\gamma = 1.4$.

is widely used as a measure of diffuser performance. Diffuser efficiency and stagnation pressure ratio are, of course, related. In general,

$$\frac{p_{02}}{p_a} = \frac{p_{02}}{p_{0a}} \cdot \frac{p_{0a}}{p_a} = \frac{p_{02}}{p_{0a}} \left(1 + \frac{\gamma - 1}{2} M_2\right)^{\gamma'(\gamma-1)},$$

and, with Eqs. (6.4) and (6.5),

$$\eta_d = \frac{\left(1 + \frac{\gamma - 1}{2} M^2\right) (r_d)^{(\gamma - 1)/\gamma} - 1}{[(\gamma - 1)/2] M^2}.$$
(6.6)

Because η_d will be primarily affected by the internal deceleration ("diffusion"), it is unfortunate that these criteria are based on overall deceleration rather than on internal deceleration. The relationship between internal and external deceleration depends on engine mass flow rate as well as flight Mach number M. But for illustrative purposes Fig. 6.6 gives typical values of stagnation pressure ratio r_d . The diffuser efficiency η_d was calculated from r_d , with the use of Eq. (6.6).

6.3 SUPERSONIC INLETS

Even for supersonic flight it remains necessary, at least for present designs, that the flow leaving the inlet system be subsonic. Compressors capable of ingesting a supersonic airstream could provide very high mass flow per unit area and, theoretically at least, very high pressure ratio per stage. However, the difficulty of passing a fully supersonic stream through the compressor without excessive shock losses (especially at off-design conditions) has so far made the development of fully supersonic compressors a possibility that is somewhat remote. As we will see in Chapter 8, the Mach number of the axial flow approaching a subsonic

Find authenticated court documents without watermarks at docketalarm.com.