

# Fracture Resistance of Aluminum Alloys

Notch Toughness,  
Tear Resistance,  
and Fracture Toughness

J. Gilbert Kaufman

**The Aluminum Association**

Incorporated

900 19th Street, N.W., Washington, D.C. 20006



**The Materials  
Information Society**

Materials Park, Ohio 44073-0002  
[www.asminternational.org](http://www.asminternational.org)

Copyright © 2001  
by  
ASM International®  
All rights reserved

No part of this book may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the written permission of the copyright owner.

First printing, September 2001

Great care is taken in the compilation and production of this book, but it should be made clear that NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE GIVEN IN CONNECTION WITH THIS PUBLICATION. Although this information is believed to be accurate by ASM, ASM cannot guarantee that favorable results will be obtained from the use of this publication alone. This publication is intended for use by persons having technical skill, at their sole discretion and risk. Since the conditions of product or material use are outside of ASM's control, ASM assumes no liability or obligation in connection with any use of this information. No claim of any kind, whether as to products or information in this publication, and whether or not based on negligence, shall be greater in amount than the purchase price of this product or publication in respect of which damages are claimed. THE REMEDY HEREBY PROVIDED SHALL BE THE EXCLUSIVE AND SOLE REMEDY OF BUYER, AND IN NO EVENT SHALL EITHER PARTY BE LIABLE FOR SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES WHETHER OR NOT CAUSED BY OR RESULTING FROM THE NEGLIGENCE OF SUCH PARTY. As with any material, evaluation of the material under end-use conditions prior to specification is essential. Therefore, specific testing under actual conditions is recommended.

Nothing contained in this book shall be construed as a grant of any right of manufacture, sale, use, or reproduction, in connection with any method, process, apparatus, product, composition, or system, whether or not covered by letters patent, copyright, or trademark, and nothing contained in this book shall be construed as a defense against any alleged infringement of letters patent, copyright, or trademark, or as a defense against liability for such infringement.

Comments, criticisms, and suggestions are invited, and should be forwarded to ASM International.

*ASM International staff who worked on this project included Veronica Flint, Manager of Book Acquisitions; Bonnie Sanders, Manager of Production; Nancy Hrivnak, Copy Editor; Kathleen Dragolich, Production Editor; and Scott Henry, Assistant Director of Reference Publications.*

Library of Congress Cataloging-in-Publication Data

Kaufman, J.G. (John Gilbert), 1931-  
Fracture resistance of aluminum alloys/J. Gilbert Kaufman.  
p.cm.

1. Aluminum alloys—Mechanical properties. 2. Fracture mechanics I. Title.  
TA480.A6 K355 2000 620.1'866—dc21 2001022228

ISBN: 0-87170-732-2  
SAN: 204-7586

ASM International®  
Materials Park, OH 44073-0002  
www.asminternational.org

Printed in the United States of America

---

---

# Preface

On behalf of the Aluminum Association, Inc., Alcoa, Inc., and ASM International, we are pleased to provide this summary of data on the fracture characteristics of aluminum alloys. It is broadly based on a publication produced by Alcoa in 1964, called *Fracture Characteristics of Aluminum Alloys*, and we want to acknowledge the support of Alcoa, Inc., notably Dr. Robert J. Bucci and Dr. William G. Truckner, in arranging to have the copyright to that publication transferred to the Aluminum Association, Inc. Further, we acknowledge the support of Dr. John A.S. Green of the Aluminum Association, Inc. in making it available for a joint publication with ASM International.

In particular, we note the contributions of the members of the Aluminum Association Engineering and Design Task Force, Dr. Andrew J. Hinkle, Chair, through their review of and input to the organization and content of the book.

This book is unique in the degree to which it presents individual test results for many individual lots of a wide range of aluminum alloys, tempers, and products, rather than simply broad summaries of data; it is also unique for the breadth of types of fracture parameters presented. This combination provides not only the ability to dig out specific data needed to evaluate alloy and temper selections for individual applications, but also the ability to check the degree to which the various fracture parameters provide consistent relative ratings for specific alloys and tempers. We believe these capabilities will benefit a wide range of needs, from alloy evaluation and selections to design.

A word is needed about the inclusion in the book of data for a number of alloys and tempers that are considered obsolete today. Such alloys are included because they may have been used in fracture-critical structures in years past, and specialists dealing with maintenance and retrofit of those structures may be looking for data on the old alloys, even though it is unlikely that new structures will be made of them.

An explanation is also needed about the treatment of units in this book. Because all of these data were generated in an environment of the usage of English/engineering units, and because of the mass of data involved, almost the entire book is presented in those units. While this is contrary to the normal ASM International and Aluminum Association, Inc. policies to present engineering and scientific data in both Standard International (SI) and English/engineering units, it saves a prodigious amount of expense related to both time for conversion and to the space required for dual presentation. Further, it avoids the inevitable compromises surrounding rounding techniques for such conversions in a multitude of units. Additional help for those interested in SI conversion is provided in Appendix 2.

J. Gilbert Kaufman

---

---

# ASM International Technical Books Committee (2000–2001)

**Sunniva R. Collins (Chair)**

Swagelok/Nupro Company

**Charles A. Parker (Vice Chair)**

Allied Signal Aircraft Landing  
Systems

**Eugen Abramovici**

Bombardier Aerospace (Canadair)

**A.S. Brar**

Seagate Technology

**Ngai Mun Chow**

Det Norske Veritas Pte Ltd.

**Seetharama C. Deevi**

Philip Morris, USA

**Bradley J. Diak**

Queen's University

**James C. Foley**

Ames Laboratory

**Dov B. Goldman**

Precision World Products

**James F.R. Grochmal**

Metallurgical Perspectives

**Nguyen P. Hung**

Nanyang Technological University

**Serope Kalpakjian**

Illinois Institute of Technology

**Gordon Lippa**

North Star Casteel

**Jacques Masounave**

Université du Québec

**K. Bhanu Sankara Rao**

Indira Gandhi Centre for Atomic  
Research

**Mel M. Schwartz**

Sikorsky Aircraft Corporation  
(Retired)

**Peter F. Timmins**

Risk Based Inspection, Inc.

**George F. Vander Voort**

Buehler Ltd.

---

---

# Contents

<b>CHAPTER 1: Introduction</b>	<b>1</b>
Synopsis	1
Introduction	2
<b>CHAPTER 2: Definition of Terms Related to Fracture Behavior</b>	<b>5</b>
<b>CHAPTER 3: Tensile Properties as Indicators of Fracture Behavior</b>	<b>11</b>
<b>CHAPTER 4: Notched-Bar Impact and Related Tests for Toughness</b>	<b>13</b>
<b>CHAPTER 5: Notch Toughness and Notch Sensitivity</b>	<b>15</b>
Wrought Alloys	18
Cast Alloys	19
Welds	19
ASTM Standard Notch-Tensile Test Methods	22
<b>CHAPTER 6: Tear Resistance</b>	<b>37</b>
Wrought Alloys	43
Cast Alloys	44
Welds	45
<b>CHAPTER 7: Fracture Toughness</b>	<b>75</b>
Theory	76
Test Procedures	80
$K_{Ic}$ and $K_c$ Data	84
Discussion of $K_{Ic}$ and $K_c$ Data	85
Industry $K_{Ic}$ Database, ALFRAC	87
Typical and Specified Minimum Values of $K_{Ic}$ and $K_c$ Fracture Toughness	88
Crack-Resistance Curves	88
Use of Fracture-Toughness Data	90
Discussions of Individual Alloys	96

Understanding the Effect of Residual Stresses on Fracture-Toughness Values . . . . .	96
<b>CHAPTER 8: Interrelation of Fracture Characteristics . . . . .</b>	<b>105</b>
<b>CHAPTER 9: Toughness at Subzero and Elevated Temperatures . . . . .</b>	<b>111</b>
Wrought Alloys at Subzero Temperatures . . . . .	118
Wrought Alloys at Elevated Temperatures . . . . .	122
Cast Alloys at Subzero Temperatures . . . . .	123
Welds at Subzero Temperatures . . . . .	123
<b>CHAPTER 10: Subcritical Crack Growth . . . . .</b>	<b>147</b>
Fatigue Crack Growth . . . . .	147
Creep Crack Growth . . . . .	149
Stress-Corrosion Cracking . . . . .	152
<b>CHAPTER 11: Metallurgical Considerations in Fracture Resistance . . . . .</b>	<b>157</b>
Alloy Enhancement . . . . .	157
Enhancing Toughness with Laminates . . . . .	162
<b>CHAPTER 12: Summary . . . . .</b>	<b>167</b>
<b>CHAPTER 13: References . . . . .</b>	<b>169</b>
<b>APPENDIX 1: Notch-Tensile, Tear, and Fracture Toughness Specimen Drawings . . . . .</b>	<b>175</b>
<b>APPENDIX 2: Metric (SI) Conversion Guidelines . . . . .</b>	<b>183</b>
<b>ALLOY INDEX . . . . .</b>	<b>185</b>

# Figures

<b>Fig. 4.1</b>	Notched bar impact data for aluminum alloys, transverse direction . . . . .	14
<b>Fig. 5.1</b>	Similarity of ratings of alloys with respect to notch sensitivity . . . . .	17
<b>Fig. 5.2</b>	Notch-yield ratios versus tensile yield strength of 0.250 in. plate. Transverse direction . . . . .	18
<b>Fig. 5.3</b>	Notch-yield ratios versus tensile yield strength for wrought aluminum alloys. Transverse direction (Table 5.5) . . . . .	19
<b>Fig. 5.4</b>	Notch-yield ratios (notch tensile strength/tensile yield strength) for cast slabs and separately cast tensile bars of aluminum sand and permanent mold cast slabs. . . . .	20
<b>Fig. 5.5</b>	Notch-yield ratio versus tensile yield strength for aluminum alloy castings from notched round specimens (Fig. A1.7a) . . . . .	20
<b>Fig. 5.6</b>	Ratings of aluminum alloy welds based on notch-yield ratios from sheet-type specimens (Fig. A1.4b) . . . . .	21
<b>Fig. 5.7</b>	Notch-yield ratio versus tensile yield strength for welds in wrought and cast alloys (Tables 5.8 and 5.9). Specimens per Fig. A1.7(b). . . . .	21
<b>Fig. 6.1</b>	Tear-test specimen and representation of load-deformation curves . . . . .	37
<b>Fig. 6.2</b>	Ratings of 0.063 in. aluminum alloy sheet based upon unit propagation energy . . . . .	40
<b>Fig. 6.3</b>	Ratings of aluminum alloy plate, extruded shapes, and forgings based on unit propagation energy . . . . .	41
<b>Fig. 6.4</b>	Ratings of aluminum alloy sand and permanent-mold cast slabs based on unit propagation energy . . . . .	42
<b>Fig. 6.5</b>	Ratings of welds based on unit propagation energy . . . . .	42
<b>Fig. 6.6</b>	Unit propagation energy vs. tensile yield strength of 0.063 in. aluminum alloy sheet . . . . .	44
<b>Fig. 6.7</b>	Unit propagation energy vs. elongation of 0.063 in. aluminum alloy sheet . . . . .	45
<b>Fig. 6.8</b>	Unit propagation energy vs. tensile yield strength for aluminum alloy castings . . . . .	45
<b>Fig. 6.9</b>	Unit propagation energy vs. tensile yield strength for welds in wrought aluminum alloys . . . . .	46

<b>Fig. 7.1</b>	Schematic drawing of large, elastically stressed panel containing a crack . . . . .	76
<b>Fig. 7.2</b>	Schematic representation of influence of thickness on strain-energy release rate . . . . .	78
<b>Fig. 7.3</b>	Fracture-toughness specimen in 3 million lb testing machine . . . . .	81
<b>Fig. 7.4</b>	Typical autographic load-deformation curves from fracture toughness tests . . . . .	82
<b>Fig. 7.5</b>	Schematic of typical <i>R</i> curves . . . . .	84
<b>Fig. 7.6</b>	<i>R</i> -curves for 2024-T3 and 2524-T3 clad sheet . . . . .	89
<b>Fig. 7.7</b>	<i>R</i> -curves for 7475-T7351, 7475-T7651, 7475-T651, and 7075-T7351, 7075-T651 plate . . . . .	90
<b>Fig. 7.8</b>	Gross-section stress at onset of rapid fracture vs. crack length . . . . .	91
<b>Fig. 7.9</b>	Gross-section stress at initiation of slow crack growth or rapid crack propagation under plane-strain conditions versus crack length . . . . .	92
<b>Fig. 7.10</b>	Illustrations of potential residual stresses in fracture toughness specimens . . . . .	95
<b>Fig. 8.1</b>	Notch-yield ratio in relation to elongation and reduction of area for aluminum alloy plate . . . . .	105
<b>Fig. 8.2</b>	Critical stress-intensity factor, $K_{Ic}$ , versus notch-yield ratio (edge-notched specimen) for aluminum alloy and plate . . . . .	106
<b>Fig. 8.3</b>	$K_{Ic}$ and $K_{Ic}$ for 1 in. thick panels (Fig. A1.9b) versus unit propagation energy from tear tests for aluminum alloy plates . . . . .	106
<b>Fig. 8.4</b>	Relationship between plane-strain fracture toughness and unit propagation energy from tear tests for aluminum alloy products . . . . .	107
<b>Fig. 8.5</b>	Correlation of plane-strain fracture toughness and notch-yield ratio (specimens per Fig. A1.7a) for 2024 and 2124 plate . . . . .	108
<b>Fig. 8.6</b>	Correlation of plane-strain fracture toughness with notch-yield ratio (specimens per Fig. A1.7a) for 7075 and 7475 plate . . . . .	108
<b>Fig. 8.7</b>	Relationship between ratio of fatigue strength of notched specimens to tensile yield strength and notch-yield ratio for aluminum alloy plate . . . . .	109
<b>Fig. 8.8</b>	Relationship between unit propagation energy and fatigue-crack growth rate . . . . .	109
<b>Fig. 8.9</b>	Comparison of fracture toughness and stress-corrosion resistance for some aluminum alloys . . . . .	110
<b>Fig. 9.1</b>	Notch-yield ratios for 1/8 in. aluminum alloy sheet at various temperatures . . . . .	113

<b>Fig. 9.2</b>	Notch-yield ratios for plate at various temperatures . . . . .	114
<b>Fig. 9.3</b>	Notch-yield ratios for welds in 1/8 in. aluminum alloy sheet at various temperatures. . . . .	114
<b>Fig. 9.4(a)</b>	Notch-yield ratio versus temperature for sand cast aluminum alloy slabs . . . . .	115
<b>Fig. 9.4(b)</b>	Notch-yield ratio versus temperature for permanent mold cast aluminum alloy slabs. . . . .	115
<b>Fig. 9.4(c)</b>	Notch-yield ratio versus temperature for premium strength cast aluminum alloy slabs . . . . .	116
<b>Fig. 9.5</b>	Notch-yield ratio versus temperature for groove welds in wrought and casting alloys . . . . .	116
<b>Fig. 9.6</b>	Tear resistance versus temperature for aluminum alloy sheet and plate . . . . .	117
<b>Fig. 9.7</b>	Unit propagation energy versus temperature for welds in wrought aluminum alloy plate . . . . .	118
<b>Fig. 9.8</b>	Plane-strain fracture toughness versus temperature for aluminum alloy plate . . . . .	119
<b>Fig. 9.9</b>	Notch-yield ratio versus tensile yield strength for 1/8 in. aluminum alloy sheet at -423 °F . . . . .	120
<b>Fig. 9.10</b>	Notch-yield ratio versus tensile yield strength for aluminum alloys at -452 °F . . . . .	121
<b>Fig. 9.11</b>	Estimated (conservative) fracture stress versus flaw size relationship for 5083-O plate and 5183 welds . . . . .	121
<b>Fig. 9.12</b>	Cross section of 125 ft diam tank for shipboard transportation of liquefied natural gas . . . . .	122
<b>Fig. 9.13</b>	Notch-yield ratio versus tensile yield strength for cast aluminum alloys at -320 and -423 °F. . . . .	124
<b>Fig. 9.14</b>	Joint yield strength versus notch-yield ratios for groove welds in wrought and cast aluminum alloys at -452 °F . . . . .	125
<b>Fig. 10.1</b>	Fatigue crack growth rate data for 2124-T851 plate and comparison to data for 2024-T851 plate . . . . .	148
<b>Fig. 10.2</b>	Fatigue crack growth rates for 7050-T7451 plate (5.67 and 5.90 in. thick) . . . . .	149
<b>Fig. 10.3</b>	Crack growth rates ( $da/dt$ ) for 2124-T851 and 2219-T851 plate at 300 °F . . . . .	150
<b>Fig. 10.4</b>	$K_{Ic}$ versus temperature for 2124-T851 and 2219- T851 plate . . . . .	150
<b>Fig. 10.5</b>	Effects of notches on stress-rupture strengths of 2219-T851 plate (1 in. thick) at 300 °F . . . . .	151
<b>Fig. 10.6</b>	Effects of notches on stress-rupture strengths of 5454-O and 5454-H32 plate (0.750 in.) at 300 °F . . . . .	152
<b>Fig. 10.7</b>	Crack propagation rates in stress-corrosion tests using precracked specimens of 2xxx and 7xxx series aluminum alloys . . . . .	153

<b>Fig. 10.8</b>	Stress-corrosion safe-zone plot . . . . .	154
<b>Fig. 10.9</b>	Composite stress-stress intensity-SCC threshold safe-zone plot for two aluminum alloys exposed in a salt-dichromate-acetate solution . . . . .	155
<b>Fig. 11.1</b>	Average plane-strain fracture toughness data for production lots of 4 to 5.5 in. thick 2024 plate . . . . .	158
<b>Fig. 11.2</b>	Comparisons of $K_{Ic}$ values for commercial production lots of 2419-T851 and 2219-T851 plate . . . . .	158
<b>Fig. 11.3</b>	Plane-strain fracture toughness, $K_{Ic}$ , for production lots of 7075-T73651 plate in L-T orientation. . . . .	159
<b>Fig. 11.4</b>	Plane-strain fracture toughness of 7075 and 7175 die forgings of the same configuration. . . . .	159
<b>Fig. 11.5</b>	Plane-strain fracture toughness, $K_{Ic}$ , of 7475 plate compared to band of data for conventional high- strength aluminum alloys . . . . .	160
<b>Fig. 11.6</b>	Critical stress-intensity factor, $K_{Ic}$ , versus tensile yield strength for 0.040 to 0.188 in. aluminum alloy sheet. . . . .	160
<b>Fig. 11.7</b>	Gross section stress at initiation of unstable crack propagation versus crack length for wide sheet panels of four aluminum alloy/temper combinations . . . . .	161
<b>Fig. 11.8</b>	Crack resistance curves for 7475 sheet . . . . .	162
<b>Fig. 11.9</b>	Results of fracture-toughness tests of plain and laminated panels of 7075-T6 and 7075-T651 sheet and plate (transverse) . . . . .	163
<b>Fig. A1.1</b>	Orientations of tear specimens in aluminum alloy products . . . . .	175
<b>Fig. A1.2(a)</b>	Crack plane orientation code for fracture toughness specimens from rectangular sections . . . . .	176
<b>Fig. A1.2(b)</b>	Crack plane orientation code for fracture toughness specimens from welded plate. . . . .	176
<b>Fig. A1.3</b>	Sheet-type notch-tensile specimen, 1/2 in. wide test section . . . . .	176
<b>Fig. A1.4(a)</b>	Sheet-type notch-tensile specimen, 1 in. wide test section. . . . .	177
<b>Fig. A1.4(b)</b>	Sheet-type notch-tensile specimen, 1 in. wide test section, from welded panels. . . . .	177
<b>Fig. A1.5</b>	Sheet-type notch-tensile specimen, 3 in. wide test section . . . . .	178
<b>Fig. A1.6</b>	Center-slotted sheet-type notch-tensile specimen, 3 in. test section . . . . .	178
<b>Fig. A1.7(a)</b>	Cylindrical notch-tensile specimen, 1/2 in. test section . . . . .	178
<b>Fig. A1.7(b)</b>	Cylindrical notch-tensile specimen, 1/2 in. test section, from welded panels . . . . .	179

<b>Fig. A1.8</b>	Tear specimen from unwelded and welded panels . . . . .	179
<b>Fig. A1.9(a)</b>	Small center-notched fracture toughness specimen . . . . .	179
<b>Fig. A1.9(b)</b>	Large center-slotted fracture toughness specimen . . . . .	180
<b>Fig. A1.10</b>	Single-edge-notched fracture toughness specimen . . . . .	180
<b>Fig. A1.11(a)</b>	Notched-bend fracture toughness specimen . . . . .	180
<b>Fig. A1.11(b)</b>	Large notched-bend fracture toughness specimen used for 5083-O plate . . . . .	181
<b>Fig. A1.12(a)</b>	Compact tension fracture toughness specimen . . . . .	181
<b>Fig. A1.12(b)</b>	Small compact tension fracture toughness specimen used for 5083-O plate . . . . .	181
<b>Fig. A1.12(c)</b>	Large-plate 4 in. thick, compact tension specimen used for 5083-O plate . . . . .	182

# Tables

<b>Table 5.1</b>	Results of tensile tests of smooth and 0.5 in. wide, edge-notched sheet-type specimens of aluminum alloy sheet . . . . .	23
<b>Table 5.2</b>	Results of tensile tests of smooth and notched 1 in. wide, edge-notched sheet-type tensile specimens of aluminum alloy sheet . . . . .	24
<b>Table 5.3</b>	Results of tensile tests of 3 in. wide, edge-notched sheet-type specimens of aluminum alloy sheet . . . . .	27
<b>Table 5.4</b>	Results of tensile tests of smooth and center-notched sheet-type specimens of aluminum alloy sheet and plate . . . . .	29
<b>Table 5.5</b>	Results of tensile tests of smooth and 0.5 in. diameter, notched round specimens from aluminum alloy plate . . . . .	30
<b>Table 5.6</b>	Results of tensile tests of smooth and 0.5 in. diameter, notched round specimens from aluminum alloy castings . . . . .	33
<b>Table 5.7</b>	Results of tensile tests of smooth and notched 1 in. wide, edge-notched sheet-type tensile specimens from welds in 0.125 in. aluminum alloy sheet . . . . .	34
<b>Table 5.8</b>	Results of tensile tests of smooth and 0.5 in. diameter, notched round specimens from welds in aluminum alloys. . . . .	35
<b>Table 5.9</b>	Results of tensile tests of smooth and 0.5 in. diameter, notched round specimens from welds in aluminum alloy sand castings. . . . .	35
<b>Table 6.1</b>	Results of tensile and tear tests of 0.063 in. thick non-heat-treated aluminum alloy sheet . . . . .	47
<b>Table 6.2</b>	Results of tensile and tear tests of 0.063 in. thick heat treated aluminum alloy sheet. . . . .	51
<b>Table 6.3</b>	Results of tensile and tear tests of aluminum alloy plate. . . . .	57
<b>Table 6.4</b>	Results of tensile and tear tests of aluminum alloy extruded shapes . . . . .	62
<b>Table 6.5</b>	Results of tensile and tear tests of aluminum alloy forgings . . . . .	68
<b>Table 6.6</b>	Results of tensile and tear tests of aluminum alloy castings . . . . .	71

<b>Table 6.7</b>	Tensile and tear tests of groove welds in wrought aluminum alloy sheet, plate, and extrusions . . . . .	72
<b>Table 6.8</b>	Tear tests of groove welds in cast-to-cast and cast-to-wrought aluminum alloys. . . . .	74
<b>Table 7.1</b>	Results of fracture toughness tests of thin, center-cracked panels of aluminum alloy sheet and plate. . . . .	97
<b>Table 7.2</b>	Results of fracture toughness tests of 1 × 20 in. center slotted panels of aluminum alloy sheet and plate center cracked specimens. . . . .	99
<b>Table 7.3</b>	Results of fracture toughness tests of aluminum alloy sheet and plate, single-edge-cracked specimens. . . . .	100
<b>Table 7.4</b>	Results of fracture toughness tests of aluminum alloy plate and of welds in plate-notched bend and compact tension specimens. . . . .	101
<b>Table 7.5</b>	Representative summary of plane-strain fracture toughness test data for 7475-T7351 plate . . . . .	102
<b>Table 7.6</b>	Published typical $K_{Ic}$ and $K_{Ic}$ values for aluminum alloys . . . . .	102
<b>Table 7.7</b>	Published minimum values of plane-strain fracture toughness for aluminum alloys . . . . .	103
<b>Table 7.8</b>	Published specified minimum values of plane-stress fracture toughness, $K_{Ic}$ , for aluminum alloys . . . . .	104
<b>Table 9.1</b>	Results of tensile tests of smooth and notched 1 in. wide, edge-notched sheet-type tensile specimens from 0.125 in. sheet at sub-zero temperatures. . . . .	126
<b>Table 9.2</b>	Results of tensile tests of smooth and notched 0.5 in. diam, round specimens from aluminum alloys at subzero temperatures . . . . .	128
<b>Table 9.3</b>	Results of tensile tests of smooth and notched 1 in. wide, edge-notched sheet-type tensile specimens from welds in 0.125 in. aluminum alloy sheet at subzero temperatures . . . . .	130
<b>Table 9.4</b>	Results of tensile tests of smooth and 0.5 in. diam, notched round specimens from welds in aluminum alloys at subzero temperatures . . . . .	132
<b>Table 9.5</b>	Results of tensile tests of smooth and 0.5 in. diam, notched round specimens from aluminum alloy castings at subzero temperatures. . . . .	133
<b>Table 9.6</b>	Results of tensile tests of smooth and 0.5 in. diam, notched round specimens from welds in aluminum alloy sand castings at subzero temperatures . . . . .	135
<b>Table 9.7</b>	Results of tensile and tear tests of aluminum alloy sheet at various temperatures . . . . .	136

<b>Table 9.8</b>	Results of tensile and tear tests of aluminum alloy plate at subzero temperatures . . . . .	139
<b>Table 9.9</b>	Tensile and tear tests of groove welds in wrought aluminum alloy sheet and plate at subzero temperatures. . . . .	141
<b>Table 9.10(a)</b>	Results of tensile tests of aluminum alloy plate at sub-zero temperatures . . . . .	143
<b>Table 9.10(b)</b>	Results of notched bend and compact tension fracture-toughness tests of aluminum alloy sheet and plate at subzero temperatures . . . . .	144
<b>Table 9.11</b>	Summary of toughness parameters for thick 5083-O plate and 5183 welds in 5083-O plate . . . . .	145
<b>Table 11.1</b>	Results of fracture toughness tests of 7075-T6 and 7075-T651 sheet, plate, and multilayered adhesive-bonded panels bonded with two-part epoxy . . . . .	164



**ASM International** is the society for materials engineers and scientists, a worldwide network dedicated to advancing industry, technology, and applications of metals and materials.

ASM International, Materials Park, Ohio, USA  
[www.asminternational.org](http://www.asminternational.org)

This publication is copyright © ASM International®. All rights reserved.

Publication title	Product code
<b>Fracture Resistance of Aluminum Alloys</b>	<b>#06042G</b>

**To order products from ASM International:**

**Online** Visit [www.asminternational.org/bookstore](http://www.asminternational.org/bookstore)

**Telephone** 1-800-336-5152 (US) or 1-440-338-5151 (Outside US)

**Fax** 1-440-338-4634

**Mail** Customer Service, ASM International  
9639 Kinsman Rd, Materials Park, Ohio 44073-0002, USA

**Email** [CustomerService@asminternational.org](mailto:CustomerService@asminternational.org)

**In Europe** American Technical Publishers Ltd.  
27-29 Knowl Piece, Wilbury Way, Hitchin Hertfordshire SG4 0SX,  
United Kingdom  
Telephone: 01462 437933 (account holders), 01462 431525 (credit card)  
[www.ameritech.co.uk](http://www.ameritech.co.uk)

**In Japan** Neutrino Inc.  
Takahashi Bldg., 44-3 Fuda 1-chome, Chofu-Shi, Tokyo 182 Japan  
Telephone: 81 (0) 424 84 5550

**Terms of Use.** This publication is being made available in PDF format as a benefit to members and customers of ASM International. You may download and print a copy of this publication for your personal use only. Other use and distribution is prohibited without the express written permission of ASM International.

No warranties, express or implied, including, without limitation, warranties of merchantability or fitness for a particular purpose, are given in connection with this publication. Although this information is believed to be accurate by ASM, ASM cannot guarantee that favorable results will be obtained from the use of this publication alone. This publication is intended for use by persons having technical skill, at their sole discretion and risk. Since the conditions of product or material use are outside of ASM's control, ASM assumes no liability or obligation in connection with any use of this information. As with any material, evaluation of the material under end-use conditions prior to specification is essential. Therefore, specific testing under actual conditions is recommended.

Nothing contained in this publication shall be construed as a grant of any right of manufacture, sale, use, or reproduction, in connection with any method, process, apparatus, product, composition, or system, whether or not covered by letters patent, copyright, or trademark, and nothing contained in this publication shall be construed as a defense against any alleged infringement of letters patent, copyright, or trademark, or as a defense against liability for such infringement.