

影印版

PLASTICS TECHNOLOGY HANDBOOK

塑料技术手册

VOLUME 2

COATING·CASTING·REACTION INJECTION MOLDING·ROTATIONAL MOLDING

涂层·浇注成型·反应注射成型·旋转成型

EDITED BY

DONALD V. ROSATO

MARLENE G. ROSATO

NICK R. SCHOTT



哈爾濱工業大學出版社
HARBIN INSTITUTE OF TECHNOLOGY PRESS

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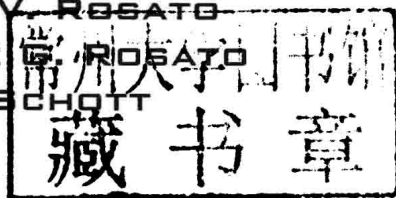
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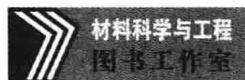
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涂层·浇注成型·反应注射成型·旋转成型

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PLASTICS TECHNOLOGY HANDBOOK

VOLUME 2

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ABBREVIATIONS

AA acrylic acid	AIMCAL Association of Industrial Metallizers, Coaters, and Laminators
AAE American Association of Engineers	AISI American Iron and Steel Institute
AAES American Association of Engineering Societies	AMBA American Mold Builders Association
ABR polyacrylate	AMC alkyd molding compound
ABS acrylonitrile-butadiene-styrene	AN acrylonitrile
AC alternating current	ANSI American National Standards Institute
ACS American Chemical Society	ANTEC Annual Technical Conference (of the Society of the Plastic Engineers)
ACTC Advanced Composite Technology Consortium	APC American Plastics Council
ad adhesive	APET amorphous polyethylene terephthalate
ADC allyl diglycol carbonate (also CR-39)	APF Association of Plastics Fabricators
AFCMA Aluminum Foil Container Manufacturers' Association	API American Paper Institute
AFMA American Furniture Manufacturers' Association	APME Association of Plastics Manufacturers in Europe
AFML Air Force Material Laboratory	APPR Association of Post-Consumer Plastics Recyclers
AFPA American Forest and Paper Association	AQL acceptable quality level
AFPR Association of Foam Packaging Recyclers	AR aramid fiber; aspect ratio
AGMA American Gear Manufacturers' Association	ARP advanced reinforced plastic
AIAA American Institute of Aeronautics and Astronauts	ASA acrylonitrile-styrene-acrylate
AIChE American Institute of Chemical Engineers	ASCII american standard code for information exchange
	ASM American Society for Metals

ASME American Society of Mechanical Engineers	CM compression molding
ASNDT American Society for Non-Destructive Testing	CMA Chemical Manufacturers' Association
ASQC American Society for Quality Control	CMRA Chemical Marketing Research Association
ASTM American Society for Testing Materials	CN cellulose nitrate (celluloid)
atm atmosphere	CNC computer numerically controlled
bbf barrel	CP Canadian Plastics
BFRL Building and Fire Research Laboratory	CPE chlorinated polyethylene
Bhn Brinell hardness number	CPET crystallized polyethylene terephthalate
BM blow molding	CPI Canadian Plastics Institute
BMC bulk molding compound	cpm cycles/minute
BO biaxially oriented	CPVC chlorinated polyvinyl chloride
BOPP biaxially oriented polypropylene	CR chloroprene rubber; compression ratio
BR polybutadiene	CR-39 allyl diglycol carbonate
Btu British thermal unit	CRP carbon reinforced plastics
buna polybutadiene	CRT cathode ray tube
butyl butyl rubber	CSM chlorosulfonyl polyethylene
CA cellulose acetate	CTFE chlorotrifluoroethylene
CAB cellulose acetate butyrate	DAP diallyl phthalate
CaCO₃ calcium carbonate (lime)	dB decibel
CAD computer-aided design	DC direct current
CAE computer-aided engineering	DEHP diethylhexyl phthalate
CAM computer-aided manufacturing	den denier
CAMPUS computer-aided material preselection by uniform standards	DGA differential gravimetric analysis
CAN cellulose acetate nitrate	DINP diisononyl phthalate
CAP cellulose acetate propionate	DMA dynamic mechanical analysis
CAS Chemical Abstract Service (a division of the American Chemical Society)	DMC dough molding compound
CAT computer-aided testing	DN <i>Design News</i> publication
CBA chemical blowing agent	DOE Design of Experiments
CCA cellular cellulose acetate	DSC differential scanning calorimeter
CCV Chrysler composites vehicle	DSD Duales System Deutschland (German Recycling System)
CEM Consorzio Export Mouldex (Italian)	DSQ German Society for Quality
CFA Composites Fabricators Association	DTA differential thermal analysis
CFC chlorofluorocarbon	DTGA differential thermogravimetric analysis
CFE polychlorotrifluoroethylene	DTMA dynamic thermomechanical analysis
CIM ceramic injection molding; computer integrated manufacturing	DTUL deflection temperature under load
CLTE coefficient of linear thermal expansion	DV devolatilization
	DVR design value resource; dimensional velocity research; Druckverformungsrest (German

- compression set); dynamic value research;
dynamic velocity ratio
- E** modulus of elasticity; Young's modulus
- EBM** extrusion blow molding
- E_c** modulus, creep (apparent)
- EC** ethyl cellulose
- ECTFE** polyethylene-chlorotrifluoroethylene
- EDM** electrical discharge machining
- E/E** electronic/electrical
- EEC** European Economic Community
- EI** modulus \times moment of inertia (equals stiffness)
- EMI** electromagnetic interference
- EO** ethylene oxide (also EtO)
- EOT** ethylene ether polysulfide
- EP** ethylene-propylene
- EPA** Environmental Protection Agency
- EPDM** ethylene-propylene diene monomer
- EPM** ethylene-propylene fluorinated
- EPP** expandable polypropylene
- EPR** ethylene-propylene rubber
- EPS** expandable polystyrene
- E_r** modulus, relaxation
- E_s** modulus, secant
- ESC** environmental stress cracking
- ESCR** environmental stress cracking resistance
- ESD** electrostatic safe discharge
- ET** ethylene polysulfide
- ETFE** ethylene tetrafluoroethylene
- ETO** ethylene oxide
- EU** entropy unit; European Union
- EUPC** European Association of Plastics Converters
- EUPE** European Union of Packaging and Environment
- EUROMAP** European Committee of Machine Manufacturers for the Rubber and Plastics Industries (Zurich, Switzerland)
- EVA** ethylene-vinyl acetate
- E/VAC** ethylene/vinyl acetate copolymer
- EVAL** ethylene-vinyl alcohol copolymer (trade-name for EVOH)
- EVE** ethylene-vinyl ether
- EVOH** ethylene-vinyl alcohol copolymer (or EVAL)
- EX** extrusion
- F** coefficient of friction; Farad; force
- FALLO** follow all opportunities
- FDA** Food and Drug Administration
- FEA** finite element analysis
- FEP** fluorinated ethylene-propylene
- FFS** form, fill, and seal
- FLC** fuzzy logic control
- FMCT** fusible metal core technology
- FPC** flexible printed circuit
- fpm** feet per minute
- FRCA** Fire Retardant Chemicals Association
- FRP** fiber reinforced plastic
- FRTP** fiber reinforced thermoplastic
- FRTS** fiber reinforced thermoset
- FS** fluorosilicone
- FTIR** Fourier transformation infrared
- FV** frictional force \times velocity
- G** gravity; shear modulus (modulus of rigidity); torsional modulus
- GAIM** gas-assisted injection molding
- gal** gallon
- GB** gigabyte (billion bytes)
- GD&T** geometric dimensioning and tolerancing
- GDP** gross domestic product
- GFRP** glass fiber reinforced plastic
- GMP** good manufacturing practice
- GNP** gross national product
- GP** general purpose
- GPa** giga-Pascal
- GPC** gel permeation chromatography
- gpd** grams per denier
- gpm** gallons per minute
- GPPS** general purpose polystyrene
- GRP** glass reinforced plastic
- GR-S** polybutadiene-styrene
- GSC** gas solid chromatography

H hysteresis; hydrogen	ISO International Standardization Organization or International Organization for Standardization
HA hydroxyapatite	IT information technology
HAF high-abrasion furnace	IUPAC International Union of Pure and Applied Chemistry
HB Brinell hardness number	IV intrinsic viscosity
HCFC hydrochlorofluorocarbon	IVD in vitro diagnostic
HCl hydrogen chloride	J joule
HDPE high-density polyethylene (also PE-HD)	JIS Japanese Industrial Standard
HDT heat deflection temperature	JIT just-in-time
HIPS high-impact polystyrene	JIT just-in-tolerance
HMC high-strength molding compound	J_p polar moment of inertia
HMW-HDPE high molecular weight-high density polyethylene	JSR Japanese SBR
H-P Hagen-Poiseuille	JSW Japan Steel Works
HPLC high-pressure liquid chromatography	JUSE Japanese Union of Science and Engineering
HPM hot pressure molding	JWTE Japan Weathering Test Center
HTS high-temperature superconductor	K bulk modulus of elasticity; coefficient of thermal conductivity; Kelvin; Kunststoffe (plastic in German)
Hz Hertz (cycles)	kb kilobyte (1000 bytes)
I integral; moment of inertia	kc kilocycle
IB isobutylene	kg kilogram
IBC internal bubble cooling	KISS keep it short and simple
IBM injection blow molding; International Business Machines	Km kilometer
IC <i>Industrial Computing</i> publication	kPa kilo-Pascal
ICM injection-compression molding	ksi thousand pounds per square inch ($\text{psi} \times 10^3$)
ID internal diameter	lbf pound-force
IEC International Electrochemical Commission	LC liquid chromatography
IEEE Institute of Electrical and Electronics Engineers	LCP liquid crystal polymer
IGA isothermal gravimetric analysis	L/D length-to-diameter (ratio)
IGC inverse gas chromatography	LDPE low-density polyethylene (PE-LD)
IIE Institute of Industrial Engineers	LIM liquid impingement molding; liquid injection molding
IM injection molding	LLDPE linear low-density polyethylene (also PE-LLD)
IMM injection molding machine	LMDPE linear medium density polyethylene
IMPS impact polystyrene	LOX liquid oxygen
I/O input/output	LPM low-pressure molding
ipm inch per minute	m matrix; metallocene (catalyst); meter
ips inch per second	
IR synthetic polyisoprene (synthetic natural rubber)	
ISA Instrumentation, Systems, and Automation	

mm	micromillimeter; millicron; 0.000001 mm	NBR	butadiene acrylonitrile
μm	micrometer	NBS	National Bureau of Standards (since 1980 renamed the National Institute Standards and Technology or NIST)
MA	maleic anhydride	NC	numerical control
MAD	mean absolute deviation; molding area diagram	NCP	National Certification in Plastics
Mb	bending moment	NDE	nondestructive evaluation
MBTS	benzothiazyl disulfide	NDI	nondestructive inspection
MD	machine direction; mean deviation	NDT	nondestructive testing
MD&DI	Medical Device and Diagnostic Industry	NEAT	nothing else added to it
MDI	methane diisocyanate	NEMA	National Electrical Manufacturers' Association
MDPE	medium density polyethylene	NEN	Dutch standard
Me	metallocene catalyst	NFPA	National Fire Protection Association
MF	melamine formaldehyde	NISO	National Information Standards Organization
MFI	melt flow index	NIST	National Institute of Standards and Technology
mHDPE	metallocene high-density polyethylene	nm	nanometer
MI	melt index	NOS	not otherwise specified
MIM	metal powder injection molding	NPCM	National Plastics Center and Museum
MIPS	medium impact polystyrene	NPE	National Plastics Exhibition
MIT	Massachusetts Institute of Technology	NPFC	National Publications and Forms Center (US government)
mLLDPE	metallocene catalyst linear low-density polyethylene	NR	natural rubber (polyisoprene)
MMP	multimaterial molding or multimaterial multiprocess	NSC	National Safety Council
MPa	mega-Pascal	NTMA	National Tool and Machining Association
MRPMA	Malaysian Rubber Products Manufactur- ers' Association	NWPCA	National Wooden Pallet and Container Association
Msi	million pounds per square inch ($\text{psi} \times 10^6$)	OD	outside diameter
MSW	municipal solid waste	OEM	original equipment manufacturer
MVD	molding volume diagram	OPET	oriented polyethylene terephthalate
MVT	moisture vapor transmission	OPS	oriented polystyrene
MW	molecular weight	OSHA	Occupational Safety and Health Administration
MWD	molecular weight distribution	P	load; poise; pressure
MWR	molding with rotation	Pa	Pascal
N	Newton (force)	PA	polyamide (nylon)
NACE	National Association of Corrosion Engineers	PAI	polyamide-imide
NACO	National Association of CAD/CAM Operation	PAN	polyacrylonitrile
NAGS	North America Geosynthetics Society		
NASA	National Aeronautics Space Administration		

PB polybutylene	PMMI Packaging Machinery Manufacturers' Institute
PBA physical blowing agent	PO polyolefin
PBNA phenyl- β -naphthylamine	POE polyolefin elastomer
PBT polybutylene terephthalate	POM polyoxymethylene or polyacetal (acetal)
PC permeability coefficient; personal computer; plastic composite; plastic compounding; plastic-concrete; polycarbonate; printed circuit; process control; programmable circuit; programmable controller	PP polypropylene
PCB printed circuit board	PPA polyphthalamide
pcf pounds per cubic foot	ppb parts per billion
PCFC polychlorofluorocarbon	PPC polypropylene chlorinated
PDFM Plastics Distributors and Fabricators Magazine	PPE polyphenylene ether
PE plastic engineer; polyethylene (UK polythene); professional engineer	pph parts per hundred
PEEK polyetheretherketone	ppm parts per million
PEI polyetherimide	PPO polyphenylene oxide
PEK polyetherketone	PPS polyphenylene sulfide
PEN polyethylene naphthalate	PPSF polyphenylsulfone
PES polyether sulfone	PPSU polyphenylene sulphone
PET polyethylene terephthalate	PS polystyrene
PETG polyethylene terephthalate glycol	PSB polystyrene butadiene rubber (GR-S, SBR)
PEX polyethylene crosslinked pipe	PS-F polystyrene-foam
PF phenol formaldehyde	psf pounds per square foot
PFA perfluoroalkoxy (copolymer of tetrafluoroethylene and perfluorovinylethers)	PSF polysulphone
PFBA polyperfluorobutyl acrylate	psi pounds per square inch
phr parts per hundred of rubber	psia pounds per square inch, absolute
PI polyimide	psid pounds per square inch, differential
PIA Plastics Institute of America	psig pounds per square inch, gauge (above atmospheric pressure)
PID proportional-integral-differential	PSU polysulfone
PIM powder injection molding	PTFE polytetrafluoroethylene (or TFE)
PLASTEC Plastics Technical Evaluation Center (US Army)	PUR polyurethane (also PU, UP)
PLC programmable logic controller	P-V pressure-volume (also PV)
PMMA Plastics Molders and Manufacturers' Association (of SME); polymethyl methacrylate (acrylic)	PVA polyvinyl alcohol
	PVAC polyvinyl acetate
	PVB polyvinyl butyral
	PVC polyvinyl chloride
	PVD physical vapor deposition
	PVDA polyvinylidene acetate
	PVdC polyvinylidene chloride
	PVDF polyvinylidene fluoride
	PVF polyvinyl fluoride
	PVP polyvinyl pyrrolidone

PVT pressure-volume-temperature (also P-V-T or pvT)	SES Standards Engineering Society
PW <i>Plastics World</i> magazine	SF safety factor; short fiber; structural foam
QA quality assurance	s.g. specific gravity
QC quality control	SI International System of Units
QMC quick mold change	SIC Standard Industrial Classification
QPL qualified products list	SMC sheet molding compound
QSR quality system regulation	SMCAA Sheet Molding Compound Automotive Alliance
R Reynolds number; Rockwell (hardness)	SME Society of Manufacturing Engineers
rad Quantity of ionizing radiation that results in the absorption of 100 ergs of energy per gram of irradiated material.	S-N stress-number of cycles
radome radar dome	SN synthetic natural rubber
RAPRA Rubber and Plastics Research Association	SNMP simple network management protocol
RC Rockwell C (R_c)	SPC statistical process control
RFI radio frequency interference	SPE Society of the Plastics Engineers
RH relative humidity	SPI Society of the Plastics Industry
RIM reaction injection molding	sPS syndiotactic polystyrene
RM rotational molding	sp. vol. specific volume
RMA Rubber Manufacturers' Association	SRI Standards Research Institute (ASTM)
RMS root mean square	S-S stress-strain
ROI return on investment	STP Special Technical Publication (ASTM); standard temperature and pressure
RP rapid prototyping; reinforced plastic	t thickness
RPA Rapid Prototyping Association (of SME)	T temperature; time; torque (or T_i)
rpm revolutions per minute	TAC triallylcyanurate
RRIM reinforced reaction injection molding	T/C thermocouple
RT rapid tooling; room temperature	TCM technical cost modeling
RTM resin transfer molding	TD transverse direction
RTP reinforced thermoplastic	TDI toluene diisocyanate
RTS reinforced thermoset	TF thermoforming
RTV room temperature vulcanization	TFS thermoform-fill-seal
RV recreational vehicle	T_g glass transition temperature
Rx radiation curing	TGA thermogravimetric analysis
SAE Society of Automotive Engineers	TGI thermogravimetric index
SAMPE Society for the Advancement of Material and Process Engineering	TIR tooling indicator runout
SAN styrene acrylonitrile	T-LCP thermotropic liquid crystal polymer
SBR styrene-butadiene rubber	TMA thermomechanical analysis; Tooling and Manufacturing Association (formerly TDI); Toy Manufacturers of America
SCT soluble core technology	torr mm mercury (mmHg); unit of pressure equal to 1/760th of an atmosphere
SDM standard deviation measurement	

TP thermoplastic	V vacuum; velocity; volt
TPE thermoplastic elastomer	VA value analysis
TPO thermoplastic olefin	VCM vinyl chloride monomer
TPU thermoplastic polyurethane	VLDPE very low-density polyethylene
TPV thermoplastic vulcanizate	VOC volatile organic compound
T_s tensile strength; thermoset	vol% percentage by volume
TS twin screw	w width
TSC thermal stress cracking	W watt
TSE thermoset elastomer	W/D weight-to-displacement volume (boat hull)
TX thixotropic	WIT water-assist injection molding technology
TXM thixotropic metal slurry molding	WMMA Wood Machinery Manufacturers of America
UA urea, unsaturated	WP&RT World Plastics and Rubber Technology magazine
UD unidirectional	WPC wood-plastic composite
UF urea formaldehyde	wt% percentage by weight
UHMWPE ultra-high molecular weight polyethylene (also PE-UHMW)	WVT water vapor transmission
UL Underwriters Laboratories	XL cross-linked
UP unsaturated polyester (also TS polyester)	XLPE cross-linked polyethylene
UPVC unplasticized polyvinyl chloride	XPS expandable polystyrene
UR urethane (also PUR, PU)	YPE yield point elongation
URP unreinforced plastic	Z-twist twisting fiber direction
UV ultraviolet	
UVCA ultra-violet-light-curable-cyanoacrylate	

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Dr. Donald V. Rosato, Coeditor and President, PlastiSource, Inc.

PREFACE

This book, as a two-volume set, offers a simplified, practical, and innovative approach to understanding the design and manufacture of products in the world of plastics. Its unique review will expand and enhance your knowledge of plastic technology by defining and focusing on past, current, and future technical trends. Plastics behavior is presented to enhance one's capability when fabricating products to meet performance requirements, reduce costs, and generally be profitable. Important aspects are also presented to help the reader gain understanding of the advantages of different materials and product shapes. The information provided is concise and comprehensive.

Prepared with the plastics technologist in mind, this book will be useful to many others. The practical and scientific information contained in this book is of value to both the novice, including trainees and students, and the most experienced fabricators, designers, and engineering personnel wishing to extend their knowledge and capability in plastics manufacturing including related parameters that influence the behavior and characteristics of plastics. The toolmaker (who makes molds, dies, etc.), fabricator, designer, plant manager, material supplier, equipment supplier, testing and quality control personnel, cost estimator, accountant, sales and marketing personnel, new venture type, buyer, vendor, educator/trainer, workshop leader, librarian, industry information provider, lawyer, and consultant can all benefit from this book. The intent is to provide a review of the many aspects of plastics that range from the elementary to the practical to the advanced and more theoretical approaches. People with different interests can focus on and interrelate across subjects in order to expand their knowledge within the world of plastics.

Over 20000 subjects covering useful pertinent information are reviewed in different chapters contained in the two volumes of this book, as summarized in the expanded table of contents and index. Subjects include reviews on materials, processes, product designs, and so on. From a pragmatic standpoint, any theoretical aspect that is presented has been prepared so that the practical person will understand it and put it to use. The theorist in turn will gain an insight into the practical

limitations that exist in plastics as they exist in other materials such as steel, wood, and so on. There is no material that is “perfect.” The two volumes of this book together contain 1800-plus figures and 1400-plus tables providing extensive details to supplement the different subjects.

In working with any material (plastics, metal, wood, etc.), it is important to know its behavior in order to maximize product performance relative to cost and efficiency. Examples of different plastic materials and associated products are reviewed with their behavior patterns. Applications span toys, medical devices, cars, boats, underwater devices, containers, springs, pipes, buildings, aircraft, and spacecraft. The reader’s product to be designed or fabricated, or both, can be related directly or indirectly to products reviewed in this book. Important are behaviors associated with and interrelated with the many different plastics materials (thermoplastics [TPs], thermosets [TSs], elastomers, reinforced plastics) and the many fabricating processes (extrusion, injection molding, blow molding, forming, foaming, reaction injection molding, and rotational molding). They are presented so that the technical or nontechnical reader can readily understand the interrelationships of materials to processes.

This book has been prepared with the awareness that its usefulness will depend on its simplicity and its ability to provide essential information. An endless amount of data exists worldwide for the many plastic materials, which total about 35000 different types. Unfortunately, as with other materials, a single plastic material that will meet all performance requirements does not exist. However, more so than with any other materials, there is a plastic that can be used to meet practically any product requirement. Examples are provided of different plastic products relative to critical factors ranging from meeting performance requirements in different environments to reducing costs and targeting for zero defects. These reviews span products that are small to large and of shapes that are simple to complex. The data included provide examples that span what is commercially available. For instance, static physical properties (tensile, flexural, etc.), dynamic physical properties (creep, fatigue, impact, etc.), chemical properties, and so on, can range from near zero to extremely high values, with some having the highest of any material. These plastics can be applied in different environments ranging from below and on the earth’s surface to outer space.

Pitfalls to be avoided are reviewed in this book. When qualified people recognize the potential problems, these problems can be designed around or eliminated so that they do not affect the product’s performance. In this way, costly pitfalls that result in poor product performance or failure can be reduced or eliminated. Potential problems or failures are reviewed, with solutions also presented. This failure-and-solution review will enhance the intuitive skills of people new to plastics as well as those who are already working in plastics. Plastic materials have been produced worldwide over many years for use in the design and fabrication of all kinds of plastic products. To profitably and successfully meet high-quality, consistency, and long-life standards, all that is needed is to understand the behavior of plastics and to apply these behaviors properly.

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