

Index

A

- Abrasive wear, 210, 211
- Advanced thixotropic metallurgy, 129
- Alcan multi polar cell, 12
- Alloy chemistry effect on morphology
 - of chips manufacture, 297, 298
- Alloy composition
 - equilibrium solidification lever rule, 381, 382
 - non-equilibrium solidification lever rule, 383–385
 - solid fraction calculation, 381
- Alloy formation, semisolid-state mixing
 - alloy microstructure, 521–523
 - chemical compositions, 517–520
 - element proportions, 524
 - feedstock behavior, 520, 521
 - melting ranges, 525, 526
 - metal matrix composites, formation, 520–527
 - methods in, 514
 - solid-state diffusion, 523
 - structural transformation methods, 514–516
 - tensile properties, 526–532
 - mixing temperature on, 527–532
 - rule of mixtures, 532
 - strength and elongation, 526, 527
- Alloying additions (Mg), and role
 - in aluminum, 18, 20, 21
 - manganese, 20–22
 - silicon, zirconium, and beryllium, 22, 23
 - zinc, 20, 21
- Alloying systems (AS), creep resistance of, 551
- Alloy matrix, decohesion characteristics, 457–460
- Alloy microstructures, 521–523
- Alloy protection
 - environmental impact, 345, 346
 - fluorinated ketones (FKs), 343, 344
 - hydro-fluorocarbons (HFC), 344
 - inert gases, 344, 345
 - magshield, 342, 343
 - protective atmospheres for heat treatment, 345
 - solid or gaseous CO₂, 344
 - sulphur dioxide (SO₂), 342
 - sulphur hexafluoride (SF₆), 340–342
- Alloy steels
 - martensite, structure of, 183, 184
 - temperature and exposure time effects, 182, 184
- Aluminum alloys, 474, 475
 - low creep resistance of, 551
 - T4 treatment of, 554
- AM50 alloy
 - gravity filling permanent mold casting, 33
 - Searle type viscometer measurements for, 104
 - tensile ductility and porosity, relationship between, 47–49
- AM60B alloy
 - chemical composition, 495
 - tensile properties of, 527–530
- Amorphous alloys (metallic glasses)
 - compressive fracture strength and specific strength of, 38
 - embrittlement and yield stress, 39
 - thermal stability, 40
- Annealing, 62
- Archimedes method, 472
- As-cast ingot
 - compression deformation of, 357
 - melting, 392–394
 - Mg-9Al-1Zn morphologies, 394
 - for semisolid processing, 555

- ASTM E276-68 sieve test, 292
- Automotive industry and magnesium application, 73–75
- AZ91 alloy, 348, 349
- AZ91D alloy, 33, 34
- chemical composition, 495
 - compression and backward extrusion measurements of, 104
 - effect of rest time on viscosity of, 106
 - flow pattern of fully molten, 251, 252
 - rheological behavior of, 106, 107
 - tensile properties, 527–530
- AZ91D chips morphologies, 291
- AZXY alloy
- formation, 518, 519
 - tensile properties, 527
- B**
- Back extrusion viscometer
- apparent viscosity, 103
 - experimental setup, 102
 - extrusion ratio and viscosity, 101
- Barrel and screw maintenance stations, 170, 171
- Barrel temperature profile
- magnesium flow path
 - accumulation zone, 219, 220
 - melting and conditioning region, 219
 - preheat zones, 218, 219
- Basal slip, 41
- Basal systems, crystallographic slip in, 41
- Beryllium (Be), metal, 330–333
- Bingham fluids, 84, 85
- Boltzmann's constant, 545
- Brasmag process, 10
- Brittle cracking, cryogenic conditions, 459–461
- Burger's vector, 545
- C**
- Cable (tubular) heater, 158, 161
- Carbon inoculation, 25
- Carbothermic reduction, 14–16
- Casting, magnesium alloy
- chemistry of, 282
 - cold chamber die casting, 55, 56
 - experimental, 58
 - hot chamber die casting
 - heat loss minimization, 53
 - multi-slide die casting, 54, 55 - integrity testing techniques, 277–280
 - porosity measurement by Archimedes method, 280, 281
 - porosity measurement by X-ray tomography, 280
 - investment casting, 57
 - permanent mold and sand casting, 57
 - squeeze casting
 - alloy solidification, 56
 - microstructure and applied high pressure, 56, 57
- Cast structures, segregation in
- fragmentation mechanisms, 428
 - macrosegregation, 427
 - microsegregation, 426, 427
- Cavitation wear, 211
- Chemical grain refinement, 110
- Chips C2, size distribution and aspect ratio of, 295. *See also* Particulates manufacture
- Clamp (sub-system)
- hydro-mechanical design, 151
 - mold, 149
- Cleaning (surface treatment), 71
- Closed-packed hexagonal lattices, twinning in, 42
- Clutch-clamp housing, 471, 473, 474
- Coalescence ripening, 434–453
- Co based superalloys
- hardness and aging, 188
 - for Mg processing, 186
- Cold chamber die casting, 55, 56
- Cold-deformed ingot recrystallization, 367
- Cold-deformed metal phenomena, 365, 366
- Combined DTA and heat-transfer modeling, 380, 381
- Compression viscometer, 99
- Contiguity, semisolid state, 447
- Continuous rheo-conversion process, 111, 112
- Controlled slow cooling, 113
- Conventional alloys, semisolid-state mixing in, 540
- Cooling curves method, Mg–9Al–1Zn alloy, 378, 379
- Corrosion fatigue, 194
- Corrosion prevention techniques, 68–73
- Corrosion resistance
- magnesium alloy, 65, 66
 - alloy chemistry effects on, 67, 68
 - alloy microstructure, 68
- Couette method (viscosity measurement), 97
- Creep
- definition of, 194
 - deformation curve, 544–546
 - failure, 196
 - resistance alloys
 - Al₂O₃ influence on, 550

- commercial alloys control, 550
- alloying systems, 551–553
- alloy processing role, 553, 554
- die casting, 543
- diffusion-controlled, 544
- in magnesium
- factors affecting, 548–550
- pure magnesium, 548
- mechanisms, 546, 547
- pre-aging, 554
- stages in, 544–546
- CRP. *See* Continuous reo-conversion process
- Crystallographic slip, 40, 41
- Cushion size, 220
- Cyclic cooling, 192
- Cylindrical viscometer
 - based on Couette method, 98
 - shear rate generated by, 97
- D**
- Damping capacity
 - sand cast alloys, 50
 - vibration energy absorption, 49
- Decohesion characteristics, alloy, 457
- Dendrite arm spacing (DAS), 426
- Dendrites formation, factors affecting, 426
- Die casting alloys
 - fluidity and flow length, 33, 34
 - Mg₁₂Al₁₁Zn₅Sn and Mg₁₂Al₁₃Zn₅Sn alloys, 34
 - thin wall applications, 33
- Die casting cycle
 - packing, 221
 - phases of, 220, 221
- Differential scanning calorimetry (DSC)
 - method, 378
- Differential thermal analysis (DTA) method, 377, 380, 381
- Diffusional creep, 546, 547
- Direct semisolid forming, 130
- Direct structure theories
 - rate of structure breakdown, 89
 - viscosity, 90
- Drop forge viscometer
 - designed on, 99
 - shear rates and viscosity, 100, 101
- E**
- Electric resistance heaters
 - cable (tubular) heater, 158, 161
 - mica band heaters, 158
- Electrolytic/ion plate coating, 68–70
- Electrolytic isolation, magnesium, 10–12
- Electrolytic microplasma anodizing, 70
- Electromagnetic interference (EMI) shielding, metal, 51
- Electroplastic deformation, of grain contacts, 470
- Erosive wear, 211
- Evaporation characteristics, magnesium, 332–334
- External characteristics, injection molding applications, 308–310
- Extruded pellets
 - annealing phenomena in
 - general microstructure development, 370
 - grain growth, 373, 374
 - intermetallic phases changes of, 371–373
 - microstructure evolution during, 361
 - thermal instability of, 362
- Extrusion
 - AZ31 alloy, 61
 - billet breaking, cast structure of, 469
 - direct and indirect, 60, 61
 - plastic deformation process, 469
- F**
- Feedstock
 - conveying
 - compaction stage, 224, 225
 - initial forwarding, 223, 224
 - solid bed conveying, 225
 - loading devices, 166–168
 - mechanical effect on, 409
 - melting
 - behavior of, 355
 - dissipative and conduction melting, 226
 - microstructure evolution during, 374
 - extruded pellets, 387–392
 - liquid penetration along grain boundaries, 375, 376
 - mechanically comminuted chips, 385–389
 - non-equilibrium melting, 375
 - solid to liquid ratio, 376–385
 - thermal conductivity, 225
 - oxidation
 - behavior of, 315
 - growth morphologies, 320–324
 - kinetics, 315–318
 - layers internal structure, 324, 325
 - mechanism, 334–338
 - phase composition, 326–329
 - surfaces, 319, 320

Feedstock (*cont.*)
 selection, 285–313
 thermal instability, factors affecting,
 355–364
 transformation of, 408

Feret's diameter, 482
 particles size characterization, 443

FLOW-3D software applications
 magnesium alloy filling pattern evaluation
 cell phone housing, 92–94
 laptop case cover, 92, 95

Flow length, expression for, 256

F1-MEZ and F2-AZ91 flakes, 292

Forging, magnesium alloy
 grain structure, 59
 open-die and close-die, 58, 59

G

Gate velocity, 258

Gating equation, for die casting
 amount of heat available, 256
 component of, 257
 semisolid processing applications, 258

Globular structures generation techniques
 chemical grain refinement, 110
 continuous rheo-conversion process (CRP),
 111, 112
 controlled slow cooling, 113
 crystallization front morphology and
 temperature gradient, 425
 liquid phase sintering (LPS), 115
 liquidus/sub-liquidus casting/pouring, 112
 melt stirring/agitation
 magnetohydrodynamic agitation
 (MHD), 108, 109
 mechanical stirring, 107, 108
 ultrasonic agitation, 109, 110
 rapid slug cooling technology (RSCT),
 112, 113
 spray forming, 113, 114
 stress induced melt activation (SIMA), 115
 swirl enthalpy equilibration, 110, 111

Grain boundary sliding and strengthening
 in creep process, 546, 547
 deformation mechanism, 45, 46
 flow stress, grain-size dependence of, 24
 grain size control, 24, 25

Grain growth, 373, 374

Grain-refining techniques, 25, 26

Granule G1 of Mg-9Al-1Zn during melting
 evolution of microstructure, 398

Gravity cast alloys, 33

Growth restriction parameter (Q), 26

H

Harper–Dorn creep, 546, 547

Heat checking, 192, 269

Heat dissipation, magnesium alloys, 51, 52

Herschel-Bulkley fluids, 84, 85

High temperature effects, on materials
 corrosion fatigue, 194
 creep and stress rupture, 194–196
 fatigue phenomenon, 188–192
 oxidation, 196
 Fe-Cr alloys, 198
 Ni-based superalloys, 198, 199
 property degradation
 alloy steels, 182–184
 Co based superalloys, 186–188
 Ni based superalloys, 184–186
 reduction, dolomite, 10
 thermal fatigue, 192–194

High temperature fatigue, 188, 189

High temperature steels, temperature effect
 on tensile properties of, 183–185

Holding pressure, 222

Homologous temperature, 188

Hot chamber die casting
 molten metal, 53
 multislid dies, 54, 55

Hot runners, 172–174
 exit plug and thermal sealing in, 251
 processing benefits of, 251
 slurry distribution to mold, 249

Hot sprue, 172
 benefit of, 246–249
 slurry transfer using, 246
 thermal gating during molding, 246

Husky machines, 134

Hydrostatic extrusion, 60, 61

I

Ignition behavior, magnesium alloys, 338, 339

Immiscible alloys, semisolid-state mixing in,
 540, 541

Inconel 718 alloy
 creep crack growth, 196
 high-temperature exposure, 186
 tensile properties, 186

Indirect microstructural theories, 88, 89

Inductive heaters, 161, 162

Inert gas apparatus, 288

Injection molded alloys, microstructures of,
 407, 415, 418

Injection molding, 469
 alloy degradation from, 347–352
 application characteristics, 308

- mechanically fragmented chips, 309
 - rapidly solidified granules, 309, 310
 - defects
 - causes of, 269–276
 - and flow modeling, 277
 - gas porosity, 266, 268
 - shrinkage porosity, 265, 266
 - injection cycle, 215, 216
 - die casting cycle, 220, 221
 - holding pressure, 222
 - screw velocity and packing, 221
 - transition position, 221, 222
 - injection screw functions
 - alloy metering, 226, 227
 - feedstock conveying, 223–225
 - feedstock melting, 225, 226
 - output of, 227–229
 - shear function of, 229–232
 - Mg–5Al–2Sr alloy for
 - alloy chemistry and melting range, 554, 555
 - Sr effect on phase composition, 555–557
 - microstructure development, 407
 - slurry generation, 408
 - solidification conditions and secondary changes, 409
 - practice implications, 346, 347
 - product quality control
 - dimensional verification and surface quality, 277
 - internal integrity examination, 277–281
 - recovery, 223
 - thermal gating with hot sprue, 246
 - various stages of, 217
 - X-ray diffraction pattern of, 565
- Injection molding machine**
- barrel and screw maintenance stations, 170, 171
 - clamping force, 152
 - clamp (sub-system)
 - hydro-mechanical design, 151
 - mold, 149
 - feedstock drying and preheating devices, 168, 169
 - feedstock loading devices, 166–168
 - heating systems for barrel assembly components
 - electric resistance heaters, 158–161
 - inductive heaters, 161, 162
 - process monitoring systems, 162–165
 - hydro-electric machine platform, 151
 - injection screw assembly
 - injection screw, 164, 165
 - non-return valves, 165, 166
 - injection units
 - injection loads, 155
 - single-stage and two-stage plunger, 154
 - machine barrel assembly
 - barrel and barrel head, 155, 157
 - injection nozzle, 157, 158
 - mist filtration devices, 169
 - processing route selection, factors affecting, 436
 - thick wall components, 436, 437
 - thin wall components, 437–439
 - protective gas supply to barrel, 169
 - robots, 169, 170
 - slurry distribution systems
 - cold sprue, 171, 172
 - hot runners, 172–174
 - slurry transfer using hot sprue, 246
- Injection screw, 164, 165**
- alloy metering
 - Poiseuille flow, 226
 - feedstock conveying, 223–225
 - feedstock melting, 225, 226
 - output of
 - machine throughput, 227
 - volumetric metering rate, 226, 227
 - shear function of
 - polymer and metal molding, 229, 230
 - shear rate in screw channel, 231, 232
- Injection units**
- flow path of magnesium alloy through, 216, 217
 - injection loads, 155
 - single-stage and two-stage plunger, 154
- Internal defect**
- component scrapping, 269
 - X-ray detection of, 278, 279
- Inverted-stream apparatus, 289**
- Investment casting, 57**
- J**
- JSW machines, 134**
- L**
- Lanthanum, for creep properties, 552
 - Laths separation, 560, 561
 - Liquid fraction, solidification microstructure of, 429
 - Liquid metal forging. *See* Squeeze casting
 - Liquid phase sintering (LPS), 115

Liquidus/sub-liquidus casting/pouring, 112
 Lost wax process. *See* Investment casting
 Low-temperature Pouring (LTP), 397
 LSW theory, 433, 434

M

Machine barrel assembly

barrel and barrel head, 155, 157
 injection nozzle, 157, 158
 semisolid-state transformations within
 under partial melting, 414–416
 thixotropic slurry formation, 412, 413
 solid-state transformations, feedstock,
 409–412

Machine nozzle

alloy flow path, 216, 218
 hot sprue, 172

Magnesia. *See* Magnesium oxide

Magnesium

alloys solid fraction and temperature data,
 385
 cold deformation of, 356, 357
 corrosion resistance of, 65
 etching chemicals for, 283
 evaporation, 348–350
 extrusion deformation features, 360, 361
 flow path for injection
 melting, conditioning and accumulation
 zone, 219, 220
 preheat zones and, 218
 thermal profiles along, 419, 555
 galvanic corrosion, 66, 67
 particulates, global manufacturing market
 of, 310–312
 production techniques, 9
 carbothermic reduction, 14, 15
 electrolytic isolation, 10–12
 Mintek Thermal Magnesium Process
 (MTMP), 12, 13
 recycling, 15–18
 thermal processes, 10
 using solid oxide membrane (SOM),
 12–14
 properties of pure, 19, 20
 recrystallization phenomena, 366
 Magnesium alloys, 18, 474, 475
 amorphous alloys (metallic glasses)
 compressive fracture strength and
 specific strength of, 38
 embrittlement and yield stress, 39
 thermal stability, 40
 application markets
 aerospace industry, 75

automotive industry, 73–75
 general purpose market, 76
 casting alloys, 29–32
 die, 33–35
 gravity, 33
 wrought, 35–38
 in composites matrix, 533–535
 corrosion prevention
 cleaning and protective painting, 71, 72
 electrolytic/ion plate coating, 68–70
 electrolytic microplasma anodizing, 70
 surface passivation, 71
 corrosion resistance of, 66, 67
 alloy chemistry effects, 67, 68
 alloy microstructure, 68
 creep in, 547–549
 dark matrix of, 559
 deformation mechanisms
 basal slip, 41
 slip displacement, 40
 superplastic deformation, 44, 46
 texture effect on plastic deformation,
 44, 45
 twinning, 42–44
 etching chemicals for, 283
 fluidity of, 256
 grains, 566
 heat treatment of, 61, 554
 annealing and stress relieving, 62
 solution treatment and aging, 62–65
 high temperature, 549, 550
 ignition behavior, 338, 339
 impurities, 23, 24
 low creep resistance of, 551
 mechanical properties
 alloy integrity effect on, 46–49
 damping capacity, 49
 electromagnetic interference (EMI)/
 radio interference frequency (RFI)
 shielding, 49, 51
 heat dissipation, 51, 52
 mixing
 distributive and dispersive mixing, 233
 mechanisms, 233, 234
 particle size effects, 236, 237
 re-solidification (re-melting), 238
 in screw channel, 234, 235
 segregation, 235
 wall slip effect, 236
 processing techniques
 casting, 53–58
 extrusion, 60, 61
 forging, 58, 59
 rolling, 59, 60

- strengthening mechanisms for
 - grain boundary strengthening, 24–26
 - particle dispersion strengthening, 28
 - solid solution strengthening, 26–28
- thermal diffusivity and thermal conductivity of, 52, 53
- Magnesium industry
 - application markets
 - aerospace industry, 75
 - automotive industry, 73–75
 - general purpose market, 76
 - market development
 - raw metal consumption, 4–9
 - raw metal production, 1–4
- Magnesium molding
 - advantages of, 130
 - automotive applications, 142–144
 - commercialization, 134, 135
 - consumer electronics applications, 135–137
 - manufacturing challenges, 138–142
 - market geography and structure, 142
 - general purpose equipment, 144
 - technological origin of, 130–134
- Magnesium molding system. *See* Injection molding machine
- Magnesium oxide
 - carbothermic reduction of, 14
 - direct magnesium production using SOM from, 12–14
- Magnetherm process, 10
- Magneto-hydrodynamic agitation
 - molten metals, vibration of, 108
 - non-dendritic structures generation, 109
- Magnola electrolysis system, 10–12
- MagShield protection method, 342
- Mechanically comminuted chips annealing phenomena
 - grain size-chip size correlation, 369, 370
 - recrystallization microstructure, 368, 369
- Mechanically cut chips deformation, 357, 358
- Mechanical stirring, 107, 108
- Melting temperature (T_m), 332, 365, 375, 391
- Melt superheating, 25
- Metallic glasses, 38, 39, 534
- Metallic slurries
 - rheological behavior of
 - apparent viscosity vs. solid fraction, 86
 - steady state apparent viscosity vs. shear rate, 87
 - viscosity measurements of
 - back extrusion viscometer, 101–103
 - compression viscometer, 99
 - Couette method, 97
 - drop forge viscometer, 99–101
 - rotational viscometers, 97, 98
 - wall slip effect in flow, 236
- Metallographic image analysis of Mg–9Al–1Zn alloy, 378
- Metal matrix composites (MMCs), formation
 - injection molding, 536–539
 - magnesium alloys in, 533–535
 - processes in, 536
 - reinforcements application of magnesium, 535
 - semisolid-state mixing in, 541
- Mg–5Al–2Sr alloy
 - for high temperature applications, 554
 - ingredient proportions, 524
 - semisolid molding effect on, 563, 564
 - general microstructure, 565–568
 - phase composition, 564, 565
 - phase morphology, 569, 570
 - SEM micrographs of, 558
 - thermal analysis of, 556
 - X-ray diffraction pattern of, 557, 565
- Mg–9Al–1Zn alloy
 - color etching technique, 500
 - cooling rate in, 479
 - crack propagation, 459
 - decohesion surfaces, 502, 503
 - ingredient proportions, 524
 - migrating boundaries, 483
 - spheroidal structure, distribution of shape factor, 444, 445
 - structural integrity, 496, 497
 - tensile strength, 457
 - thixotropic microstructures, 449
 - eutectic component within, 450
 - TEM microstructure of, 454–456
 - X-ray diffraction pattern of, 480, 500–502
- 1Mg–9Al–1Zn and Mg–6Al alloys
 - comparisons, 507, 508
 - microstructures, 521–523
 - mixing in alloy formation, 517–520
 - preheating range, 493, 494
 - tensile properties, 526–532
 - tensile strength, 504
 - yield stress vs. corresponding elongation, 505
- MHD. *See* Magneto-hydrodynamic agitation
- Mica band heaters, 158
- Mintek Thermal Magnesium Process, 12
- Mist filtration devices, 169
- Mixing
 - distributive and dispersive mixing, 233
 - mechanisms, 233, 234
 - particle size effects, 236, 237

- Mixing (*cont.*)
 re-solidification (re-melting), 238
 for screw
 shear strain, 235
 striation thickness, 234
 segregation, 235
 wall slip effect, 236
- Mold filling
 characteristics
 flow mode role, 476
 high-solid slurries, flow behavior of,
 471, 472
 part integrity, 472–474
 surface region, microstructure
 of, 475
 structural transformations
 phase composition, 480
 solidification, general microstructure
 after, 477, 478
 during SSEM, 476, 477
 time, 256
- Mold processing, 251
 mold filling time
 gate velocity, 258
 gating equation for die casting,
 256–258
 metal injection pressure, 260
 metals, flow modes of, 259, 260
 process operating window, 260
 mold spraying, 261
 heat transfer during, 262–264
 mold lubricants, 262
 part cooling after ejection, 264
 mold temperature, 260, 261
 molten alloy fluidity
 magnesium, 256
 and solidification time, 255
 surface tension, 252, 254
- Mold spray equipment
 needle-type and spool type poppet shutoff
 nozzles, 177
 parameters affecting spray, 177–178
- Mold temperature
 cavity filling characteristics and
 solidification structures, 260
 cycle time and, 261
- Mold (tool)
 heating-cooling systems, 175–177
 mechanisms and features of, 174, 175
 temperature control methods, 176, 177
 temperature distribution, 176
- Mold vacuum systems
 static and dynamic valves, 179, 180
 vacuum molding, 178
- Molten magnesium alloys, corrosive behavior of
 reactivity with iron and steel, 199–202
 reactivity with nickel-containing alloys,
 202–210
- Monotonic reduction, in solid content, 481
- M-S theory of alloy, 488, 489
- MTMP. *See* Mintek Thermal Magnesium Process
- Multi-slide die casting, 54, 55
- N**
- Near-liquidus molding
 application areas, 508, 509
 globular structures growth, 487–492
 microstructure, 494, 495
 alloy structural integrity, 495–497
 crystallographic orientation, 500
 decohesion features, 502, 503
 die cast microstructure characteristics, 499
 matrix morphology, 497, 498
 phase composition, 500–502
 solid particles morphology, 498, 499
 structure-property correlation, 505–508
 tensile properties, 504, 505
- New rheocasting, 126, 127
- Newtonian/non-Newtonian fluids
 apparent viscosity, 84
 shear stress, 83, 84
- Nickel based superalloys
 chemistry of, 187
 creep crack growth, 196
 high-temperature exposure, 186
- NLM. *See* Near-liquidus molding
- Non-return valve
 magnesium molding, role in, 241, 242
 plastics injection and, 241
 role in die casting, sleeve sealing, 238–241
- Nozzle plug
 formation of, 242, 243
 induction heating, 245, 246
 release and disintegration mechanism, 245
 temperature and microstructure, 243, 244
 as thermal shut off valve, 242
 transformations associated with
 alloy temperature and plug
 microstructure, 420
 microstructure effect on flow behavior,
 423–425
 plug, decomposition and microstructure
 of, 421, 422
 release behavior during preheating,
 420, 421
- NRC. *See* New rheocasting
- Nucleus, solid-liquid interface, 490

O

- Ostwald ripening
 - for coarsening in semisolid mixtures, 402
 - Gibbs–Thompson effect, 433
- Oxidation
 - failure mechanisms, 196
 - resistance
 - at high temperatures, 198
 - nickel-based superalloys, 198, 199
 - of steels, 198
 - volumetric change, 198

P

- Particle coarsening
 - shear and coalescence effects, 436
 - temperature gradients effect on, 435
- Particle dispersion strengthening, 28
- Particulates manufacture
 - by mechanical fragmentation
 - bulk density, 295
 - external defects, 295, 296
 - morphological features, 290–292
 - phase composition and microstructure, 296, 297
 - sieve analysis, 292–295
 - techniques
 - mechanical comminution, 285–288
 - rapid solidification, 288–290
- Particulates, non-conventional morphologies of, 292
- Pellets
 - microstructure of, 389
 - P1-AZ91D, 292, 299
- Permanent mold casting, 57
- Phase diagrams
 - Al–Fe equilibrium, 201
 - Mg–Al equilibrium, 20
 - Mg–Al–Zn equilibrium, 450, 493, 518, 520
 - Mg–Fe equilibrium, 200
 - Mg–Mn equilibrium, 22
 - Mg–Si equilibrium, 23
 - Mg–Zn equilibrium, 21
 - Ni–Al equilibrium, 206
 - Ni–Mg equilibrium, 205
- Pidgeon process, 10, 11
- Pilling–Bedworth ratio (PBR), 198
- Pismatic systems, crystallographic slip in, 41
- Plastic deformation processes
 - extrusion, 60
 - rolling, 59
- Post-molding heat treatment and mechanical properties modification, 466
- PQ2 diagram. *See* Process window

- Precipitation phenomena in magnesium alloy, 63, 64
 - Primary solid
 - characterization of, 481–484
 - and matrix, internal structure
 - entrapped liquid, 452, 453
 - molded structures features, 454–456
 - Strontium effect on, 567, 568
 - Primary solid phase evolution, 429
 - mechanisms controlling, 431–433
 - coalescence ripening, 434, 435
 - high solid fractions coarsening, 435
 - Ostwald ripening, 433, 434
 - temperature gradients effect on particle coarsening, 435, 436
 - microstructure, 430
 - particle size vs. solid volume fraction, 430, 431
 - Process window, 260
 - Protective painting, 71, 72
 - Pseudoplasticity. *See* Shear thinning
 - Pure magnesium, properties of, 19, 20
 - Pyramidal slip system, polycrystalline structures, 40, 41
- R**
- Rapidly solidified granules heating phenomena, 394
 - as-solidified microstructure features of, 395, 396
 - granule melting, 396–398
 - heating in solid state, transformations during, 396
 - particulate feedstock, melting features of, 398, 399
 - Rapid slug cooling technology
 - globular dendrites production, 112
 - temperature effects, 113
 - Rapid solidification
 - casting of large droplets, 288–290
 - granulation using inert gas apparatus, 288, 289
 - granules characterization
 - bulk density, 301
 - chemical composition and, 303–304
 - dimensional features, 299–301
 - external defects, 301–303, 307, 308
 - internal microstructure, 305–307
 - morphological features, 297–299
 - phase composition, 304, 305
 - Reactive element effect, Beryllium (Be), 331
 - Recrystallization temperature (Tr), 365, 366

- Recrystallized alloy
 boundaries in, 411
 equiaxed grains of, 410, 411
- Recycled feedstock (R1-AZ91D), 292
- Recycling, magnesium
 coating removal methods, 17
 flux-based batch wise and fluxless
 continuous method, 17
 recycling circuit, 18
 scrap classification, 15–17
- Remnant liquid, solidification of, 429
- Rheocasting, 124–126
- Rolling
 hot and cold, 59, 60
 magnesium alloy sheet production, 60
- RSCT. *See* Rapid slug cooling technology
- S**
- SAD diffraction pattern
 α Mg matrix grain, 561
 Sr containing precipitates, 563
- Sand casting, 57
- Scheil model, 381
- Screw velocity reduction, 472
- Searle viscometer, 97
- Semisolid extrusion molding
 application areas for, 484, 485
 as-cast Mg–5Al–2Sr ingot, micrographs
 of, 558
 EDAX energy spectra view, 559
 features, 469, 470
 semisolid molded microstructure, 567
 structural transformations, 476, 477
 temperature requirements for, 471
- Semisolid magnesium alloys, rheological
 measurements
 continuous cooling measurements
 apparent viscosity, 104
 shear rate, 106
 isothermal holding measurements
 apparent viscosity, 103
 extrusion and Searle type viscometer, 104
- Semisolid metallurgy (SSM). *See* Semisolid
 metal processing
- Semisolid metal processing
 advanced thixotropic metallurgy, 129
 benefits of, 115, 116
 and component's integrity and
 microstructure, 118, 119
 direct semisolid forming, 130
 for magnesium alloys
 alloy composition, 123
 processing techniques, 123
 microstructure evolutions, factors
 affecting, 407
 mechanical effect, 409
 slurry generation, 408, 409
 thermal effect, 408
 new rheocasting process (NRC), 126, 127
 reduced temperature effects on hardware
 performance, 116–118
 rheocasting, thixocasting, and thixoforging,
 124–126
 semisolid rheocasting (SSR), 127, 128
 semisolid slurry, 83
 shear rate, 87
 solid fraction and, 269
 sub-liquidus casting (SLC), 128, 129
 suitability criteria of alloys for, 119
 morphological and rheological
 characteristics of slurry, 122
 solidification range, 120
 temperature sensitivity of solid fraction,
 121
 thermodynamic characteristics, 121, 122
- Semisolid processing, contiguity phenomenon,
 446
- Semisolid rheocasting
 cycle time, 128
 graphite agitator and superheated alloy,
 127
- Semisolid slurries
 flow modeling of, 92
 heat and shearing force effects on, 428
 mixing, 232
 morphology of, 122
 partial cooling of, 415
 rheological behavior of
 flow characteristics of, 91–96
 Newtonian and non-Newtonian fluids,
 83–85
 thixotropy and pseudoplasticity, 85, 86
- Semisolid-state mixing in alloy formation,
 513–516
 advantages of, 540, 541
 alloy microstructure, 521–523
 chemical compositions, 517–520
 element proportions, 524
 feedstock behavior, 520, 521
 melting ranges, 525, 526
 metal matrix composites, formation,
 520–527
 solid-state diffusion, 523
 tensile properties
 mixing temperature on, 527–532
 rule of mixtures, 532
 strength and elongation, 526, 527

- Semisolid-state transformations, feedstock
 under complete melting and partial re-solidification
 overheating level above liquidus, 417, 418
 residency in screw, 418
 sub-liquidus cooling range in barrel, 416, 417
 under partial melting, 414–416
 shear during mold filling, 418, 419
 thixotropic slurry formation, 412, 413
- Shear thinning, 86
- Shot size, 220
- SiC particles in MMCs formation, 537, 538
- SIMA. *See* Stress induced melt activation
- Simple viscosity theories
 rate of change of viscosity, 90
 thixotropic breakdown, 91
- SLC. *See* Sub-liquidus casting
- Slip systems for hcp magnesium lattice, 40, 41
- Slurries, deformation behavior of, 470, 471
- Slurry distribution systems
 cold sprue, 171, 172
 hot runners, 172–174
- Solid and semisolid state
 microstructure correlation between, 399
 internal changes of globular solid, 403
 size-evolution of solid phase within slurry, 401, 402
 solid-state grain and semisolid-state solid globule, 400, 401
- Solidification range, 120
- Solidification rate, 477–479
- Solidification time, 255
- Solid oxide membrane
 direct magnesium production from magnesium oxide using, 12, 13
 experimental electrolytic SOM cell, 12–14
- Solid solution strengthening
 alloying elements on magnesium, 26, 27
 for AZ91D alloy, 28
 hardening and softening, 26, 27
- Solid-state mechanical comminution
 fragmentation and chipping, 286, 287
 solid-state extrusion, 287, 288
- Solid-state transformations
 feedstock, 409, 410
 during heating, 364–374
- Solution treatment and aging
 precipitates, crystallography of, 64
 precipitation phenomena in magnesium alloy
 alloy strengthening, 63
 continuous and discontinuous, 64
 temperature-time parameters of, 62, 63
- SOM. *See* Solid oxide membrane
- Spray forming
 liquid metal, atomization of, 113
 rapid solidification, 114
- Squeeze casting
 direct and indirect, 56
 high pressure effects, 57
- SSEM. *See* Semisolid extrusion molding
- SSP. *See* Semisolid metal processing
- SSR. *See* Semisolid rheocasting
- Steady state creep rate, 545
- Steels
 erosive wear and impact wear of, 213
 oxidation resistance of, 198
- Stellites
 fatigue crack, 192
 fatigue failure, 195
 hot hardness of, 191
 wear resistance, 211, 212
 wear resistance and ductility, 186
- Strain-hardening rate, magnesium alloys, 27
- Stress induced melt activation, 115
- Stress relieving, 62
- Stress-strain curves, 470
- Strontium effect
 liquid fraction, 568
 primary solid, 567, 568
- Sub-liquidus casting
 grain refinement, 128
 shot piston and sleeve wall temperatures, 129
- Superplastic deformation, magnesium alloys, 45, 46
- Surface defects
 analysis, 277
 component scrapping, 269
 sub, 275
 thin wall components molded using AZ91D alloy, 273
- Surface oxidation, 196
- Surface passivation, 71
- Surface treatments, corrosion prevention, 70–73
- Swirl enthalpy equilibration, 110, 111
- T**
- TEM images
 island of platelets, 561
 α Mg matrix grain, 561
 of secondary α Mg grain, 572
 Sr containing precipitates, 563

- Temperature sensitivity of solid fraction, 120, 121
 - Tempering effect, 182
 - Tensile properties, as-cast alloys, 456, 457
 - alloy matrix, role of, 462
 - solid particle content, role of, 463
 - solid particle substructure, role of, 462, 463
 - Texture effect on plastic deformation, 44, 45
 - Thermal fatigue
 - cyclic stresses, 192
 - of H13 steel, 192, 193
 - service parameters, 194
 - Thermal shock, 192
 - Thermal stress, 196
 - Thin-wall molding, 508
 - Thixocasting, 125, 126
 - methods, 119
 - Thixoforging, 125, 126
 - Thixotropic
 - alloys, 470
 - materials, 85
 - microstructures of magnesium alloys, 447
 - phase composition, 449–451
 - primary solid particles, characteristics of, 448
 - solidified liquid, 448, 449
 - structural integrity, 451, 452
 - structure–property relationship
 - semisolid techniques, 465, 466
 - structure–property relationship, 463, 464
 - Thixotropic slurry
 - melting and formation of, 412, 413
 - partial melting, 414
 - residency time of, 418
 - Thixotropic structures, after solidification
 - interfaces, 446, 447
 - primary solid particle
 - entrapped liquid volume, 446
 - size and shape of, 443–445
 - volume fraction of, 442
 - Thixotropy, 81, 82
 - floc structural arrangement, changes in, 85
 - structure models
 - direct structure theories, 89, 90
 - indirect microstructural theories, 88, 89
 - simple viscosity theories, 90, 91
 - Thorium, 551
 - Torque dynamometer, 97
 - Transient-state viscosity, 87
 - T6 treatment, creep rate reduction, 554
 - T4 treatment, in Mg–Al alloys, 554
 - Twinning deformation
 - for Mg–Zn alloy, 42–44
 - shear and shape change, 42
- U**
- Ultrasonic agitation, 109, 110
- V**
- Vacuum molding
 - entrapped gases in mold cavity, 178
 - vacuum system, 179, 180
 - Volumetric metering rate, 227
- W**
- Wall slip effect, 236
 - Wear mechanisms, classification of, 210, 211
 - Wrought alloys, 35–38
- Z**
- Zn based alloys, tear-drop-like shape particulates, 299