Author's Preface

The present figures and knowledge are an accumulation from 35 years of professional experience in microscopic quality and damage analysis. Since there were no textbooks about this subject in the 1970s, practice-related work on plastic processing machinery and attendance at many seminars, trade fairs, conferences, and numerous technical discussions were important for a full understanding of the influences and connections.

This was followed by many years at the South German Plastic Processing Center (SKZ) as a teacher with a subsequent specialization in color and gloss tests, in artificial weathering, and in microscopic quality and damage analysis.

When I worked at the South German Plastic Processing Center, I taught foreign specialists, gave presentations to experts of the plastics industry, including at the University of Erlangen and the Technical Academy in Esslingen and Sarnen (Switzerland), gave lectures to students at the University of Applied Sciences Würzburg for years, and was involved in the master training in various chambers of commerce and industry in Bavaria and Baden-Württemberg for many years.

After retirement, I finally found the time required for writing this encyclopedia. It is a reference book for experts but also a textbook for students. The quality and damage figures (color photographs, color slides) that were chosen for the encyclopedia originate from a historical archive of lectures. The scanned and revised images, which were inspected to determine if they were applicable, include technical terms with figure numbers, captions, and notes on the cause and prevention of damage. These are alphabetically arranged in a glossary and are linked to related technical terms using arrows in the Chapter "Definitions." The technical terms "microscopic examination" (the connections) and "novice (layperson) terms" are very helpful. Students, for example, can find in their own words the correct technical terms in the table "novice terms."

Quality and damage examples from many areas of plastic processing and application are described in 74 LM (light microscopy) and SEM (scanning electron microscopy) subchapters with industrial technical terms, and any missing information was supplemented. The analyses were performed with various optical microscopes and a scanning electron microscope. Since there are often multiple reasons for an error, all or the most important ones are mentioned. This also facilitates the search for the novice. Many technical terms would have disappeared under a main heading and would have been difficult to find (see → cold flow or → error, rheological) if the book had been written in regular book form. Therefore, the logical conclusion was an alphabetically arranged encyclopedia with division into three main chapters. The technical terms were entered into the Chapter Glossary, their explanations were entered into the Chapter Definitions, and related images with captions are found in the Chapter Quality and Damage Figures.

I obtained my expertise, as already mentioned, in seminars, trade fairs, conferences, and in self-study, but particularly through countless discussions with customers, experts, and industry specialists and at the South German Plastic Processing Center. Therefore, references to "who?, what?, and when?" are not possible. The tables, diagrams, and definitions are my own contributions, and the literature in the appendix is only a recommendation.

I would like to thank all institute directors, who welcomed my public relations, my clients, and my students for contributing a large amount of information, and all employees of the South German Plastic Processing Center in Würzburg for the lively exchange of information and valuable cooperation.

I would also like to express my gratitude to my dear wife Monique and daughter Bricille.

The encyclopedia was written working long hours by a practitioner for other practitioners and provides enough knowledge to solve many problems economically and in the shortest possible time, with just a macroscope and microscope, and without expensive high-tech equipment.

If it saves you time, my work has been worthwhile.

Dipl.-Ing. Friedrich Kurr

CHAPTER 1

Technical Glossary of Quality and Damage Terms

This chapter includes over 2620 alphabetically arranged technical terms from many areas of plastic technology with references to definitions, figure numbers of the corresponding quality and damage figures, the type of plastic, processing, and mold designation, the contrasting methods used, and 74 LM and SEM subchapters (see the first page of the Chapter Quality and Damage Figures). Since there are often multiple reasons for an error, all or the most important ones are mentioned. This facilitates the search.

The numbers after the technical terms are figure numbers, and the associated figures with explanatory text are located in the Chapter Quality and Damage Figures. There the search is implemented with the figure numbers from the technical glossary or directly in the LM and SEM subchapters.

Double numbers are located after LM or SEM subchapters (for example, figure numbers 307–311 means SEM subchapter weathering with five figures). The subchapters originate from a historical archive collection that took decades to amass.

The yellow-colored cell "definition" in the column "Figure No." refers to an explanation of the technical term in the Chapter Definitions (where many technical terms are explained).

Students will find a quick introduction to the subject through "→ Novice terms" and "→ Microscopic examination" in the Chapter Definitions. They are the source of cross references with arrows through the entire encyclopedia.

For the technical terms, the associated figure numbers are found in the Chapter Glossary and the associated figures are in the Chapter Quality and Damage Figures.

Experts will find the figure with caption through a technical term and the following figure number in the Chapter Quality and Damage Figures in the Chapter Glossary. An explanation of the technical term can also be found in the Chapter Definitions, if desired.

Explanation of color coding used in Column 3 in the Chapter Glossary:

Color coding	Explanation	Thumb Index
(grey)	Technical terms, arranged alphabetically in the Chapter Glossary	Glossary
(white)	Figure numbers from 1 to 588, arranged in the Chapter Quality and Damage Figures	Figures & Text
(green)	LM subchapter with figure captions in the Chapter Quality and Damage Figures	Figures & Text
(red)	SEM subchapter with figure captions in the Chapter Quality and Damage Figures	Figures & Text
(yellow)	Explanation of the technical terms from the Chapter Glossary in Chapter Definitions	Definitions

LM = Light microscopy (or light microscope)
SEM = Scanning electron microscopy (or scanning electron microscope)

For search examples, see pages X–XII.

No.	Technical Term	Figure No.	Type of Plastic	Processing	Molded Part	Contrast
0001	Abrasion	Definition				
0002	Achromatic lens	Definition				
0003	Additive	Definition				
0004	Adhesion	Definition				
0005	Adhesion testing for paint	Definition				
0006	Adhesive application: defective	169	PUR	Thin section	Window profile	DL
0007	• missing	040	PUR adhesive	Thin section	Window profile	DL
0008	Adhesive bonding (LM subchapter)	172–176				
0009	Adhesive bonding	Definition				
0010	Adhesive drops, penetrative	173	PA6	Adhesion	Handle of car door	AL
0011	Adhesive layer with bubbles	427	PVC-U	Extrusion	Window profile	DL/POL/ λ/DIC
0012	Adhesive residues and adhesive bead are missing	175	PVC	Adhesion	Bonded socket joint	AL: 1 : 1
0013	Adhesive tape test:	Definition				
0014	• for PE	074	PE	Film blowing	Blown film	DL-POL
0015	• for thin sections	108	Thin section	Microtome	Table	Table
0016	Adhesive THF: is missing on the adhesive surface	172	PVC	Adhesion	Bonded socket joint	AL: 1 : 1
0017	• turns white with too-early contact with water	389	PVC	Extrusion	Water pipe	AL
0018	After-treatment	Definition				
0019	Aged paint system	199	PBT	Coating	Fan blade	AL
0020	Agglomeration	Definition				
0021	Aging:	Definition				
0022	• accelerated	492	SAN	Injection molding	Cup	DL
0023	• accelerated	493	SAN	Injection molding	Cup	DL
0024	• causes of	Definition				
0025	• caused by hydrolysis	415	POM	Injection molding	Switch housing	AL
0026	• caused by medium and outdoor weathering	310	PUR foam	Foaming	Bumper	SEM
0027	• caused by moisture and lubricant	416	POM	Injection molding	Surface	AL
0028	• experiment	398	SAN	Injection molding	Container	AL
0029	• protection against	Definition				
0030	• resistance to	Definition				
0031	• testing is important	022	EPDM	Extrusion	Window seal	AL
0032	• warpage	570	ABS	Injection molding	First aid kit	AL: 1 : 1
0033	Air: entrained, in ABS	227	ABS	Vacuum forming	Tray	AL
0034	• entrained, in PCTFE	165	PCTFE	Injection molding	Bushing	AL
0035	• entrained, in POM	222	POM	Injection molding	Rail	AL
0036	• entrained, in PVC	225	PVC	Extrusion	Sheet	AL
0037	• included, in the paint	355	Sheet metal	Coating	Can	SEM

No.	Technical Term	Figure No.	Type of Plastic	Processing	Molded Part	Contrast
0038	Air bubble:	229	PE/GF-position/PE	Laminating	Slurry containment membrane	AL
0039	• in a C-PVC fitting	230	C-PVC	Extrusion	Fitting	AL
0040	• in Canada balsam	034	POM	Injection molding	Ring	AL
0041	Air inclusion: in a weld line	461	PB	Thin section	Mushroom valve	DL
0042	• in a weld line	487	PE100	Flame treatment	Gas pipe	AL
0043	• in a weld zone	439	PE	Filament winding	Pipe sleeve	DL-POL + λ
0044	• in PBTP	357	PBTP	Injection molding	Part	SEM
0045	• when laminating	229	PE/GF-position/PE	Blown film	Slurry containment film	AL
0046	Air induction: in PP	444	PP	Injection molding	Living hinge	DL-POL
0047	• in the surface	231	PB	Electroplating	Part	DL-POL + λ
0048	Air injection	221	POM	Injection molding	Rail	AL
0049	Air streaks:	Definition				
0050	• in PCTFE	165	PCTFE	Injection molding	Bushing	AL
0051	Aluminum layer: corroded	258	PP-R/AL/PP-R	Extrusion	Composite pipe	AL
0052	• with transverse cracks	258	PP-R/AL/PP-R	Extrusion	Composite pipe	AL
0053	Aluminum metalizing:	209	ABS	Vapor deposition, Al	Molded part	AL-DIC + λ
0054	• contaminated	278	PE	Injection molding	Fan casing	AL-DIC + λ
0055	• with yellow top coat	210	SB	Vapor deposition, Al	Molded part	AL-DIC + λ
0056	Amorphous plastics (see plastic materials, amorphous)	Definition				
0057	Amorphous structure, as opposed to semicrystalline	508	POM	Thin section	Clutch	DL-POL + λ
0058	Analysis of plastic materials	Definition				
0059	Analyzer	Definition				
0060	Angle of illumination: acute, shows internal fracture	191	PC	Injection molding	Water meter indicator	AL
0061	• important	125	ABS/PC	Injection molding	Sheet	AL
0062	Angle of inclination φ	Definition				
0063	Antioxidants	Definition				
0064	Aperture:	Definition				
0065	• numerical	Definition				
0066	Aperture angle (→ numerical aperture)	Definition				
0067	Aperture diaphragm:	Definition				
0068	• almost closed	114	POM-GF30	Thin ground sample	Cover	DL-POL
0069	• under reflecting light	106	—	Microscope		AL: 1 : 1
0070	• under transmitting light	104	—	Microscope		AL: 1 : 1
0071	Application error	566	PF-GF-Cu	Polished sample	Clutch lining	AL

No.	Technical Term	Figure No.	Type of Plastic	Processing	Molded Part	Contrast
0072	Appraiser qualities	Definition				
0073	Area of fracture with pigment conglomerates:	351	PVDF	Injection molding	Fitting	SEM
0074	• with center vacuole	536	PC	Molded part	Molded part	AL
0075	• with residual granulate	136	PE	Injection molding	Grate	AL
0076	Artifacts:	Definition				
0077	• after weathering	010	PVC-U	Extrusion	Window profile	AL
0078	• displaying microcracks caused by weathering and the influence of media	007	PA/PTFE	Injection molding	Sheet	AL: 1 : 1
0079	Assembly line demolding is better	511	PBTB	Injection molding	Piston	AL
0080	Assembly of individual parts: provides more knowledge	552	PC	Polished sample	Clutch	AL
0081	• shows pitch errors	584	PA6	Injection molding	Gear rim	AL
0082	Atomic absorption detects Cu content	259	PVC + EPDM	Extrusion	Reinforced hose	AL
0083	Audit	Definition				
0084	Audit report	Definition	—	Microscope		AL: 1 : 1
0085	Auxiliary material of a laser	Definition				
0086	Avoid costs though unnecessary examinations:	274	PA6.6	Electroplating	Clamp	AL
0087	• for a PVC-pipe	281	PVC U	Extrusion	Pipe	AL-DF
0088	Axial crack in the inner surface of a pipe:	Definition				
0089	• after outdoor weathering	019	PE-RT/AL/PE-RT	Extrusion	Composite pipe	AL
0090	• in a pipe after storage at elevated temperature	403	C-PVC	Extrusion	Water pipe	AL
0091	Axial crack with remaining adhesive	389	PVC	Extrusion	Water pipe	AL
0092	Azo crosslinking	Definition				
0093	Back injection	Definition				
0094	Barrier layer (for O_2):	Definition				
0095	• with cracks	382	PE-Xc	Extrusion	Heating pipe	AL
0096	Beam splitter (and blocking filter)	Definition				
0097	Beilby layer	Definition				
0098	Best spherulitic texture of PA6	503	PA6	Thin section	Spherulite	DL-POL + λ
0099	Black streaks	Definition				
0100	Blackening	Definition				
0101	Block ground sample:	Definition				
0102	• in a clamping block, rather than scalpel section	097	PE/PA6/PP/PE	Polishing	Packaging	AL-DIC
0103	• orientation of glass fibers	119	POM-GF30	Block ground sample	Molded part	AL
0104	• with POM-GF30	119	POM-GF30	Block section	Molded part	AL
0105	• with sink mark	517	PE	Injection molding	Hand grip	AL
0106	• with unmelted pellets	136	PE	Injection molding	Grate	AL

No.	Technical Term	Figure No.	Type of Plastic	Processing	Molded Part	Contrast
0107	Block section:	Definition				
0108	• with PBT/PC	561	PBT/PC	Block section	Housing	AL-DF
0109	Blocking filter	Definition				
0110	Blowholes (LM-subchapter)	221–230				
0111	Blowholes (SEM-subchapter)	357–357	SEM			
0112	Blowholes:	Definition				
0113	• in a deep-drawn part	228	ABS	Vacuum forming	Tray	AL
0114	• in ABS	225	ABS	Extrusion	Blend	AL
0115	• in an ABS blend	226	ABS	Injection molding	Blend	AL
0116	• in C-PVC	230	C-PVC	Extrusion	Fitting	AL
0117	• in PBTP	357	PBTP	Injection molding	Molded part	SEM
0118	• in POM	221	POM	Injection molding	Rail	AL
0119	• in POM	222	POM	Polished sample	Rail	AL
0120	• in PVC	224	PVC	Extrusion	Sheet	AL
0121	• through residual moisture	223	PVC	Extrusion	Sheet	AL
0122	• through thermal decomposition	228	ABS	Vacuum forming	Tray	AL
0123	• when extruding	226	ABS	Injection molding	Blend	AL
0124	Blow molding	Definition				
0125	Blow molding of hollow objects	Definition				
0126	Blown film: 3-layered	229	PE/GF-layer/PE	Blown film	Slurry film	AL
0127	• coextruded	085	PE	Coextrusion	Carrying bag	AL
0128	Bridge marking for: HDPE	445	HDPE	Extrusion	Sewer pipe	DL
0129	• PE-X	454	PE-X	Extrusion	Pipe	DL
0130	Bridges with: ring binding	032	POM	Injection molding	Bridge ring	AL
0131	• weld lines	032	POM	Injection molding	Bridge ring	AL
0132	Bright field contrast AL-HF and DL-HF	Definition				
0133	Bright field dark field slider	105	—	Microscope		AL: 1 : 1
0134	Brittle cracks in roof and welded sheets after outdoor weathering	309	Polymer	Extrusion	Bituminous sheeting	SEM
0135	Brittle fracture: in ASA	413	ASA	Extrusion	Sheet	AL + DL
0136	• in PE	319	PE	Injection molding	Rod	SEM
0137	Brittle molded part cross-section	508	POM	Thin section	Clutch	DL-POL + λ
0138	Bubble formation:	Definition				
0139	• electroplating bubble, opened by scalpel	270	POM	Electroplating	Door handle	AL
0140	• electroplating bubble, sharp-edged	271	POM	Electroplating	Door handle	AL
0141	• electroplating bubble, sharp-edged	275	ABS	Electroplating	Cover cap	AL
0142	• in ABS	265	ABS	Electroplating	Cover	AL
0143	• in ABS	266	ABS	Electroplating	Cover	AL
0144	• in ABS	267	ABS	Electroplating	Cover	AL
0145	• in ABS with large sharp-edged bubble	276	ABS	Electroplating	Molded recess	AL

No.	Technical Term	Figure No.	Type of Plastic	Processing	Molded Part	Contrast
0146	• in ABS/PC caused by part defect	272	ABS/PC	Electroplating	Bushing	AL, diagonal
0147	• in PA6.6 (in part)	274	PA6.6	Electroplating	Clamp	AL
0148	• in PA-GF35 after storage at 285 °C	428	PA-GF35	Polished sample	Glass holder	AL
0149	• in PB caused by entrapped air	231	PB	Electroplating	Molded part	DL-POL + λ
0150	• in POM with sharp-edged bubble	270	POM	Preparation	Door handle	AL
0151	• in PP	269	PP	Electroplating	Mounting plate	DL-POL
0152	• large and sharp-edged	276	ABS	Electroplating	Molded recess	AL
0153	Bubble packaging	540	PVC	Bubble technology	Conveyor belt	DL-POL
0154	Bubble: in 1C-lacquer	355	Sheet Metal	Painting	Can	SEM
0155	• in 2C-lacquer	356	ABS	Painting	Cover	SEM
0156	• in laminating film 50 µm	040	PVC-U + PMMA	Extrusion	Window profile	DL
0157	• void with bubble/bulge	042	TEEE	Thin section	Line	AL
0158	• void with bubble/bulge	041	TEEE	Extrusion	Compressed air line	AL
0159	Bubbles (LM subchapter):	036–042				
0160	• visible after stripping of electro-plating coats	273	SB	Electroplating	Housing	AL
0161	Bubbles, series in electroplating layers	275	ABS	Electroplating	Cover cap	AL
0162	Bulge (warpage)	569	PBT T40	Injection molding	Lid	AL: 1 : 1
0163	Burn streak(s):	Definition				
0164	• barely visible	458	PC	Injection molding	Housing	AL
0165	• cloud-like	450	PC	Injection molding	Filter housing	DL
0166	• in PC	449	PC	Injection molding	Filter housing	DL
0167	• in SAN	448	SAN	Injection molding	Spacer	DL
0168	• in the sprue	264	PP	Pinpoint gate	Pinpoint gate	AL
0169	• in the sprue area	539	ABS	Injection molding	Plate	AL
0170	• in the paint	547	—	Coating	Coated surface	AL-DF
0171	• PC	459	PC	Injection molding	Housing	AL
0172	• through obstruction of the flow in the extrusion blow head	091	PE	Extrusion blow molding	Multilayer film	DL-POL
0173	Burning (LM subchapter)	537–539				
0174	Burr formation	Definition				
0175	Butadiene from etched SB	358	SB	Polished sample	Container	SEM
0176	Buttress thread	407	PE	Polished sample	Sealing cap	AL
0177	Ca scale crystals in drinking water at 90 °C	354	Crystals		Drinking water	SEM
0178	Calcium particle:	553	PVC	Extrusion	Water pipe	DL
0179	• in PVC	554	PVC	Extrusion	Water pipe	DL + POL
0180	Calendering	Definition				
0181	Camera switch	Definition				
0182	Canada balsam:	Definition				
0183	• thin section placement 1st step	067	PE	Preparation	Water pipe	DL

CHAPTER 2

Definition of Terms in the Technical Glossary

This chapter contains, in alphabetical order, explanations of the technical terms (definitions) in the Technical Glossary with links (arrows) to related quality and damage causes, manufacturing processes, and microscopy accompanying studies.

If a technical term cannot be found in this chapter, then the search can be continued in the Technical Glossary (Chapter 1).

Learners will also find unknown technical terms, and thus a quick introduction to the subject through "→ novice terms" and "→ microscopic examination" in this chapter. These terms are the source of the network with arrows through the entire encyclopedia. This chapter is especially suited for learning. It also contains brief description of key manufacturing processes and microscopy accompanying studies.

Using the technical terms and the corresponding figure numbers from the Technical Glossary, the associated figures can be found in the Chapter Quality and Damage Figures (Chapter 3).

In an examination, experts quickly recognize the technical word that is relevant to the distinctive feature and thus find it in the Technical Glossary, and from the given figure number the associated figure with figure caption in the Chapter Quality and Damage Figures, and, if desired, an explanation of the technical word in the Chapter Definitions.

Color coding	Explanation	Thumb Index
(grey)	Technical terms, arranged alphabetically in the Technical Glossary	Glossary
(white)	Figure numbers from 1 to 588, arranged in the Chapter Quality and Damage Figures	Figures & Text
(green)	LM subchapter with figure captions in the Chapter Quality and Damage Figures	Figures & Text
(red)	SEM subchapter with figure captions in the Chapter Quality and Damage Figures	Figures & Text
(yellow)	Explanation of the technical terms from the Technical Glossary in the Chapter Definitions	Definitions

LM = Light microscopy (or light microscope)
SEM = Scanning electron microscopy (or scanning electron microscope)

For search examples, see pages X–XII.

Novice terms are words for striking features of a sample that the student can see directly (visually) or under the microscope. There are external and internal striking features. Internal striking features are examined, for example, in a thin section or a fracture surface. The following table connects colloquial, novice words with the corresponding technical terms. In the technical terms glossary, the corresponding quality or damage image can be found through the figure number, and more explanations can be found in chapter definitions.

Novice Terms	Place	Technical Terms e = external and i = internal striking features
Abrasion	e	Damages, mechanical
Appearance, old	e	Aging
Back injection	i	Fig. 430
Bead	e	Welding bead comparison, welding bead
Bonding	e	Bonding, residue
Brittleness	i	Fracture, embrittlement
Break	I	Fracture, fracture types, fractures, cracks, embrittlement
Browning	e/i	Diesel effect, overheating
Bubble(s)	e	Bubble, bubble formation, mold venting
Burning	e/i	Burning, burn streak, decomposition, thermal
Cavity	i	Blowhole, vacuole
Chatter marks	e	Slip-stick effect
Chemical attack	e/i	Resistance to chemicals, media attack
Coating	e	Coating, laminating, surface refining
Color changes	e	Aging, color change, surface discoloration
Color streaks	e	Color streaks, streaks
Contrast	e	Illumination, contrast, contrast processes in microscopy
Crack	i	Cracks, fractures, types of fractures, media that can cause stress cracking
Cut	e/i	Thin section, cutting, cutting injury, scalpel cut
Damage	e	Surface error, damages, mechanical
Deflection	e	Shrinkage, post-crystallization, plastic deformation, tempering, warpage
Deformation	e/i	Deformation, post-crystallization, plastic deformation, warpage
Dent	e	Dent, notch, surface error, groove, damages, mechanical
Deposition	e	Particle, residue
Deposits of grease	e	Wettability, residue
Dimensional error	i	Deformation, free-fall demolding, design error, dimensional error, warpage
Discoloration	e	Aging, color change, migration, surface discoloration, overheating
Displacement	e	Delamination, painting error, surface error, layer displacement
Dissolving	e	Dissolving
Dots, also dark spots	e/i	Particle, pigment conglomerate, carbon black pigments
Edge, sharp	e	Burr formation, web, burr
Embrittlement	i	Aging, moisture influence, media attack, embrittlement, predrying
Error	e/i	Surface error, error, human, rheological and systematic
Fading	e	Efflorescence, fading
Filament	e/i	Gate filament, fibrils
Flow direction, different	i	Reversal of the flow front, mass inversion
Flow front	i	Reversal of the flow front, mass inversion, cold flow front, cold flow area
Fracture	e	Aging, artifact, cracks, embrittlement
Furrows	e	Gate grooves, cold flow lines
Gate filament (string)	e	Gate, runner
Glass fibers	i	Glass fiber length distribution, glass fiber breakage
Gloss change	e	Gloss measurement, spots
Gold plating	e	Sputtering, scanning electron microscopy
Goose bumps	e	Orange skin, cold flow, surface error

Novice Terms	Place	Technical Terms e = external and i = internal striking features
Graining	e	Orange skin
Granulate contamination	e/i	Granulate contamination
Grip	e	Haptic, surface refining
Groove	e	Groove, surface error
Hole	e/i	Sprue, gate, blowhole, vacuole
Image resolution	e	Resolution, illumination, image resolution, contrast
Layer displacement	e	Coating, laminating, surface refining, layer formation
Lines, bright	e/i	Streaks, homogenization, microcracks
Lines, colored	i	Isochromatics, polarization optics
Lines, dark	i	Spherulite streaks, pigment streaks, carbon black streaks
Lines, mechanical	e	Coldflow line, scratch, surface error, polishing, groove, grinding
Marking	e	Ejector mark, surface error
Material change	i	Masterbatch change
Matte spot	e	Moisture, moisture streaks, shape stains, matte spots
Metallized surface	e	Electroplating
Mold change	e	Deformation, dimensional change, shrinkage, tempering, warpage
Notch	e	Notch, surface error, groove
Over-injection	e	Weight change, material residue transfer, particle, over-injection
Particle	e/i	Particle, pigment conglomerate, carbon black pigments, over-injection
Pressure point	e	Dent, surface error, damages, mechanical
Record groove	e	Gate grooves, cold flow lines
Roughness	e	Orange skin, cold flow, surface error
Scratch	e	Scratch, groove, cold flow line, surface error, polishing, grinding
Sensitivity to fracture	i	Aging, moisture influence, notch, media attack, embrittlement
Shaping	e	Molded part quality, mold impression, mold filling
Shrinkage	i	Shrinkage, volume shrinkage
Shrinking	i	Shrinkage, post-crystallization, plastic deformation, tempering, warpage
Sink marks	e	Weld line, sink mark, shrinkage
Solution	e	Dissolving
Spots	e	Orange skin
Stains	e	Shape stains, matte spots, media streaks, surface error, residue
Streaks	e/i	Streaks, hot-cold streaks, pigment streaks, thermal streaks, burn streaks, surface discoloration
Strips	e	Strips, streaks, black streaks, pigment streaks, surface discoloration
Surface error	e	Surface error
Swirls of color	i	Large and small spherulites, inversion layers
Thin ground sample	e/i	Thin ground sample, thin grinding device
Thin section	e/i	Thin section, thin section device (microtome)
Thorough mixing	i	Homogenization
Tip	e/i	Fibrils, stretching tip (Fig. 46)
Track	e	Surface error, grinding, damages, mechanical
Warp	e	Cold flow line, cold flow, paint warp, streaks
Waves	i	Fig. 458, grooves, tear (Fig. 322), bead
Weathering	e	Weathering, artificial
Wetting	e	Wettability, wetting test, test pins, test ink

Definitions

Technical Terms	Explanation of Terms
Abrasion	Abrasion is surface wear, for example due to reinforcing materials in the screw and in the cylinder (see also → glass fibers).
Achromatic lens	In an achromatic lens, the objective is corrected in the two colors, red and blue, so that both will be reflected in the focal plane without distortion (see also → Neofluar lenses, → objective, and → plan apochromatic objective).
Additive	Additives are added to plastics to improve their properties and service life (aging). Additives include antioxidants (inhibitors, light stabilizers, fire protection equipment, radiation protection, UV stabilizers, heat stabilizers), filler materials (nanofillers, glass fibers, kaolin, chalk, magnesia, sand), lubricants, and nucleating or reinforcing materials (see also → antioxidants, → fire prevention equipment, → filler materials and reinforcing materials, → GC analysis, → glass fibers, → lubricants, → HPLC analysis, → inhibitors, → IR analysis, → analysis of plastic materials, → light stabilizers, → nanofillers, → nucleating agents, → radiation protection, → UV spectroscopy, → UV stabilizers, → reinforcing materials, and → heat stabilizers).
Adhesion	Diffusion-based acrylic adhesives have particularly proven their worth for adhesion of thin ground samples onto glass slides. Depending on the sample hardness and requirements, EP and UP resins with and without filler materials are also used. A sample glued with a diffusion-based acrylic adhesive can be carefully removed with a preparation needle from the glass slide after 10 minutes immersion in ethanol. Many plastics have adequate resistance. Then the exposed thin ground sample is fixed onto a glass slide with Canada balsam or Eukitt and is covered with a cover glass. This is how clean thin ground samples can be manufactured in thin section quality, without air bubbles, peeling places, and coolant back migration (see also → thin grinding device and → adhesive bonding).
Adhesion testing for paint	→ Microscopic examination
Adhesive bonding	Adhesive bonding is the bonding of similar or dissimilar joining partners with crosslinking or solvent-containing adhesives, with or without filler material content. Thin sections are bonded onto glass slides with Canada balsam or Eukitt and protected with a cover glass. For thin sections, the abrasive samples are bonded onto glass slides with two-component adhesives on an EP-/UP- and acrylic-base or one-component cyanoacrylate adhesive and are then ground. If thin section samples are difficult to handle, are sensitive, and have multiple edges, they are still bonded onto glass slides with the above-mentioned adhesives and are cut afterwards. One- or two-component adhesives can be used (see also → adhesion, thin ground sample, → thin section, → glass slide, → Canada balsam, → polishing, → preparation techniques, and → grinding).
Adhesive tape test	The adhesion of paints and film coatings is measured with the adhesive tape test (also adhesive tape method). For example, an adhesive tape is rubbed free of air onto the paint layer and is then suddenly torn off perpendicular to the surface. The more paint particles adhere, the worse the adhesion strength.
After-treatment	→ Pre- and post-treatment
Agglomeration	Agglomeration is a secretion of microparticles by efflorescence and chalking of ingredients (see also → efflorescence).
Aging	Aging is a degradation, destruction, or discoloration of the matrix (matrix degradation) or molding surface by additives, agglomeration, aging causes, segregation, color change (molded part), moisture, molded part stresses, hydrolysis, inhomogeneities, media influences (ozone, acids, alkalis, cracking under stress, swelling), migration, holding pressure error, post-crystallization, post-shrinkage, surface defects (porosity, paint influence, color and gloss changes), orientational stresses, oxidation, polymerization, relaxation, stress corrosion cracking, ultraviolet or ionizing radiation (α-, β-, and γ-rays), and alternating temperatures. The higher the temperature, the faster a plastic ages. Changing temperatures cause faster aging by stretching and shrinkage stresses. Chemical, thermal, and or physical-mechanical tests are carried out to test the aging resistance, often mixed as accelerated aging tests (media, causing cracking under stress, cooking test, weathering, MFR analysis, VZ analysis, heat exposure as well as tensile, pressure, and bending tests, etc.). Additional factors are the type of plastic and quality, the mechanical load, the miscibility of the additives, and microbes (see also → additives, → agglomeration, → aging resistance, → aging influences, → aging protection, → causes of aging, → weathering, artificial, → segregation, → color change (molded part), → moisture, → molded part stresses, → hydrolysis, → inhomogeneities, → cooking test, → media, causing cracking under stress, → media influence, → MFR analysis,

Technical Terms	Explanation of Terms
Aging (*continued*)	→ migration, → holding pressure error, → post-crystallization, → post-shrinkage, → surface defects, → orientation stresses, → oxidation, → polymerization, → relaxation, → stress corrosion cracking, → ultraviolet UV radiation, → UV stabilizers, → viscosity number, → pre- and post-treatment, → heat exposure, → changing temperatures).
Air inclusion	An air inclusion is formed in a mold with insufficient ventilation because the air cannot escape fast enough when injecting the molding compound. Air inclusions are also possible during welding when the joint partners have a strong topography and the welding parameters (temperature, pressure, and time) are not sufficient (see also → air streaks and topography).
Air streaks	Air streaks (air inclusions) are caused in the mold by entrained air during injection molding of poorly degassed molding compound, insufficient nozzle position, and a knocked-out bushing or nozzle (see also → air inclusion).
Analysis of plastic materials	Plastics, its additives, and its properties can be determined for example with the following tests: → density determination, → DMA analysis, → DSC analysis, → ESCA analysis, → FTIR analysis, → determine fillers and reinforcing materials, → GC analysis, → glass transition temperature range, → GPC analysis, → gravimetry (weight determination), → HPLC analysis, → IR analysis, → MFR analysis, → molecular weight is determined, → monomers, → MVR analysis, → ODSC analysis, → oxidation stability, → determine polymer blends, → measure residues, → TG analysis, → thermogravimetry, TG, → TMA analysis, → UV spectroscopy, → Vicat temperature, → viscosity measurement, → viscosity number, → determine thermal stability, and → determine plasticizer.
Analyzer	→ Polarizer, → universal microscope, → Wollaston prism
Angle of inclination φ	→ Knife angle
Antioxidants	Antioxidants are antiaging agents (antiozonant and antioxidant) to protect the plastic from oxygen and ozone attack. Antioxidants delay aging (see DIN 50035-1) in the manufacture and application of plastic. Antioxidants are inhibitors, light stabilizers, radiation protection, UV stabilizers, and heat stabilizers (see also → aging and → causes of aging, → inhibitors, → light stabilizers, → radiation protection, → UV stabilizers, and → heat stabilizers).
Aperture	The aperture (opening) should be large enough that the rays of light entering the objective will give a bright, sharp picture. In transmitted light, the light through the particles (e.g., pigments, spherulites) is refracted and diffracted in a thin section or thin ground sample. The smaller the particles are, the greater the light is refracted. A condenser is used so that no light is lost. It has the same aperture as the objective. A further improvement of the aperture is achieved by immersion oils. They have a refractive index of n = 1.51 (like glass). These oils reduce the reflection of light at the boundary layers of glass slide/cover glass/air/objective, and the light behaves as if all the boundary layers are made of glass. The numerical aperture NA grows with the objective and condenser aperture; a high refractive index (immersion optics); the cleanliness of the slide, objective, and cover glass; the correct cover glass thickness (0.15 mm); “Köhler illumination;” decreasing light wavelength λ (e.g., blue light); and the magnification of the objective number V_{OB} (see also → aperture, numerical, → aperture diaphragm, → image resolution, → resolution, microscopic, → refractive index, → Köhler illumination, → condenser, → microscope, and → lens).
Aperture angle	→ Aperture, numerical
Aperture diaphragm	The aperture diaphragm in the pupil’s optical path controls the resolution, contrast, and depth of field. It is not visible in the picture, only its effect. While it affects the brightness, it is not responsible for it. When dimmed, the diffraction (diffraction margin) increases and thus the image quality decreases. The adjustment of the aperture to the objective aperture is done through the aperture diaphragm. In reflected light, the following order applies: lamp – aperture – field diaphragm, and in transmitted light: light – field diaphragm – aperture diaphragm. The aperture diaphragm should only be closed to about one-third; otherwise the image quality drops due to diffraction margins and image dimming. But it is only closed until the best or desired image contrast is achieved (see also → hatch optical path, and → optical path of the pupil).
Aperture, numerical	The numerical aperture $NA = n \cdot \sin\alpha$ (α = aperture, n = refractive index, n_{air} = 1). An objective comparison is achieved via the numerical aperture NA. Theoretically NA reaches the value 1 in air, which corresponds to an opening angle of 180°. The maximum angle is 142°, that is, the numerical aperture reaches a maximum of 0.95. The magnification numbers and NA, such as 20x/0.5, are given on the objectives. The highest resolution achieved is the currently strongest immersion optic of 40x/1.4 i.

Technical Terms	Explanation of Terms
Appraiser qualities	→ Microscopic examination
Artifact	An artifact is an outbreak in the molded part surface.
Audit	→ Report and → report preparation, fast and competent
Axial crack in the inner surface of a pipe	The outside surface of heating pipes is compressed during calibration and is rapidly frozen with compressive stresses in the water bath, while the uncooled, warmer inner surface of the pipe further shrinks under tensile stresses. With hot water use, or in 150 °C heat exposure, the stress decrease between the outer pipe and the inner pipe surface and the resulting decrease in compression stresses enlarge the outside diameter of the pipe again and the "tempered" inner diameter of the pipe (spring back). Therefore, axial cracks sometimes only develop in the inner surface of the pipe, without a connection to the outside (see Fig. 403, → heat exposure, and → water bath).
Azo crosslinking	→ Plastics, crosslinked
Back injection	Back injection occurs when, for example, a film preformed in a vacuum process is placed into an injection mold and back-injected with polyamide for reinforcement, or if an elastic material is injected or back-injected to the molded part on a following shot (see also Fig. 430 and → following shot).
Barrier layer	→ Diffusion barrier
Beam splitter (blocking filter)	In an incident light microscope, a beam splitter is used to guide the bulb light to the sample. From there it passes through the beam splitter (reflective) and passes into the ocular. In fluorescence contrast, a part of the blue excitation light is reflected from the beam splitter onto the sample, and the other part passes through the beam splitter to the ocular as green excitation light with changed wavelength λ (Stokes shift). Thereby a barrier filter filters out blue components (UV components), and the fluorescent image glows green against a black background image (see also → contrast processes in microscopy).
Beilby layer	→ Polishing
Black streaks	→ Overheating, thermal
Blackening	Blackening occurs through a burning of the molding compound (diesel effect) or in PVC window profiles through the reaction of lead or cadmium with sulfides to form black lead sulfide or cadmium sulfide, respectively (see also → diesel effect, → surface discoloration, and → red coloration of PVC).
Block ground sample (ground sample)	A block ground sample is formed by hand-grinding a sample and is also that what remains in the grinding machine when a thin ground sample is produced. After removal of the sample, it is usually only ground on one side with a grain size 320, 500, 800, and 1200 (grain size 15 microns), and then directly analyzed in the light microscope. The block ground sample shows the orientation and distribution of the fillers and reinforcing materials after a short preparation time. Should, after grinding, polishing be done with alumina Al_2O_3 (grain size of 1 micron), the less frequently used wet grit paper with a graining of 4000 (grain size 5 micron) reduces the grain-jump from 5 microns to only 1 micron, instead of 15 microns to 1 micron. Typical grain sizes of alumina are 0.25, 0.5, and 1 micron (see also → thin grinding device, → orientation, and → grinding).
Block section	A block section is the remaining specimen that is left in the microtome after a thin section is cut. Its surface is smooth, as if polished. PVC integral-rigid foams (KG pipes with PVC rigid foam between the inner and outer layer) can be cut very well and are thus much quicker to manufacture than with a polished sample (see also → thin section, → thin section device (microtome), and → polished sample).
Blocking filter	→ Beam splitter
Blow molding	The blow molding of hollow bodies (bottles with a threaded neck) is performed on an injection molding machine in a special mold. For example, PET bottles are produced in a two-stage process. First, a preform is injected into a 5 to 8 °C warm mold half. It is then inserted into the mold blow half after rewarming to 90 to 120 °C and is there inflated by a blast of compressed air to form the bottle and is ejected after cooling. The wall thickness of the preform is 4 mm (see also → Fig. 48, → extrusion blow molding, → injection molding, and → rotational molding).
Blow molding of hollow objects	During blow molding of hollow objects, a pipe is extruded from the extruder, guided into a shaping opened mold through an angle head, inflated with compressed air after closing, and demolded as a hollow body (molded part) (see also → film blowing, → blow molding, → extrusion, → injection, and → rotational molding).
Blowhole	→ Vacuoles and blowholes

Technical Terms	Explanation of Terms
Bright field contrast AL-HF and DL-HF	The bright-field contrast AL-HF is the simplest microscopic contrast process with normal incident light (without lambda plate or polarizer). The bright field contrast is suitable for transmitted or not-transmitted samples and the bright-field contrast DL-HF only for transmitted samples (see also → thin section, → contrast processes in microscopy).
Bubble	→ Bubble formation
Bubble formation	Fine bubbles in the molded part surface are caused by high residual moisture. Therefore, a plastic granulate is basically predried in drying devices (e.g., 4 h at 60 to 80 °C). In addition, a degassing screw may be useful (see also → electroplating error, → painting error, → residual moisture, and → predrying).
Burn streak(s)	Burn streaks are brown streaks or black streaks. They develop through overheating or thermal decomposition (see also → brown streaks, → black streaks, and → overheating).
Burr formation	A burr formation (web or burr) is created during the mold separation by mold breathing, on ejectors (through wear) and areas of ventilation, particularly for easily flowing molding compound, at high injection and holding pressures, insufficient clamping force, slow-moving molding compound, and high pressure or high mass temperature (see also → holding pressure).
Calendering	Calendering is the manufacture of smooth and embossed films of a high surface quality on a large roller system. Calendered films have more precise wall thicknesses than extruded and blown films.
Camera switch	The camera switch switches the amount of light from the ocular to the image camera in a universal microscope (Fig. 105).
Canada balsam	Canada balsam and Eukitt are embedding agents. They are used for the adhesion of thin sections and to improve the contrast, because their refractive index corresponds to the one of glass (microscope slides and cover glass). Canada balsam contains toluene, dries very slowly, and can be thinned with alcohol. Eukitt dries very quickly (even in the bottle) and has an unpleasant odor. A fresh thin section can still be examined immediately (see also → diffusion adhesive, → thin grinding device, → thin section, → embedding media, and Fig. 103). Source: Merck Eurolap (Laboratory supplies, microtomes, slide, Canada balsam, Tel: +49 911/64208040).
Carbon black streaks	Carbon black streaks are black pigment streaks. They develop with subsequent coloring and lack of homogenization (see also → coloring, → homogenization, → masterbatch, and → decomposition, thermal).
Cause of cracking	Possible crack causes are molded part stresses in production (injection molding, extrusion, etc.), high screw tightening torque, design error, media attack, mechanical stress during use, UV and radioactive radiation, processing forces (drilling, thread cutting), embrittlement, alternating pressures, alternating loads, changing temperatures (see also → aging, → extrusion, → molded part stresses, → design error, → media attack, → sample preparation, machining, → cracks, → redirecting the crack, → injection molding, → embrittlement, and → changing temperatures).
Causes of aging	Aging causes are agglomeration (efflorescence of additives), limited miscibility of individual additives to the plastic, residual stress (caused by uneven cooling and density distribution, often leading to stress cracks), poor homogenization of additives, mechanical stress (fatigue cracks), media influences (oil, solvents, and wetting agents, ozone, acids and alkalis, autocatalytic oxidation (O_2), and hydrolysis by H_2O), migration of additives or plasticizers, microbes, post-crystallization, post-shrinkage, orientation stresses (through macromolecule orientations generating stress cracks), temperature change, incomplete polymerization, addition and condensation, embrittlement, heat, and ultraviolet or ionizing radiation. Stress corrosion arises when corrosion and stress are interacting. Other causes: see also → additives, → aging, → aging resistance, → aging influences, → aging protection, → antioxidants, → efflorescence, → vaporizing, → coating protects from light, UV, and media influence, → electroplating, → inhibitors, → painting, → light stabilizers, → quality influences during extrusion, → quality influences during injection molding, → radiation protection, → tempering, → heat stabilizers, → heat exposure).
Causes of fracture	See also → embrittlement and influences, → holding pressure, → hold pressure, → holding pressure error, → lack of holding pressure, → pigment streaks, → relaxation, → tempering, and → heat exposure.
Cavitation	Cavitation generates erosion and cavity formation, simply by a flow of liquid or in conjunction with foreign objects, such as sand in PVC water pipes (see also Fig. 559).
Cavity	The mold cavity is a formed hollow chamber in the mold. A mold can have many cavities, spread across different levels (stack mold), to get higher quantities or time. In the molded parts, the mold cavity numbers are already embossed into the mold. Thereby a defective molded part can be assigned to the cavity in which it was prepared by the cavity number. This is also important, for example, for a filling study.

Technical Terms	Explanation of Terms
Center vacuole	A center vacuole usually occurs in thick-walled, symmetrical molded parts. The core remains plastic longer and the plastic volume has more time to disappear in large wall thicknesses. The vacuoles become particularly large at a too-short holding time in the center of large-volume cross-sections (see also → shrinkage, → core, plastic, and → holding pressure time).
Certificate, testing	→ Test certificate
Chalk in PVC-U	Chalk is a filling and processing aid (see also Fig. 337). The chalk content in plastics (e.g., PVC-U) is calculated stoichiometrically from the sulfated ash content with ≅ 1.36 × chalk content% (SKZ formula; see also → filler materials and reinforcing materials testing).
Changing temperatures	Changing temperatures are rapidly varying temperatures in use or periodically created temperature changes in laboratory studies to determine the aging resistance of, for example, water pipes. Long-lasting, rapidly changing temperatures shorten service life through structure degradation (see also → aging, → aging resistance, → matrix degradation, → service life, and → temperature influence).
Chemical baths	In chemical baths, an increase in the → wettability occurs through an O_2 involvement.
Clamping block method (Measuring the film layer thicknesses)	With the clamping block method, layer thicknesses for multilayer films are examined much faster than after embedding in epoxy resin EP or by thin section. Between two PVC clamping blocks (see also Fig. 96), equally sized film cuts are inserted into both clamping sides so they remain parallel when tightening the brass screws. Both excess films are cut off (dragging diagonally) with a scalpel, flush with the PVC surface. Thereby, the developing cut grooves are located diagonally to the individual layers and do not simulate more layers than available. The scalpel cut is then measured microscopically. Caution: a thin section is suitable to identify the layers, but never shows the exact layer thickness due to an unavoidable transverse contraction like a scalpel or block section (sample residue between the clamping blocks or in the microtome).
Clamping force	→ Mold clamping force
Cleaning agent influence	Release agent residues on the molded parts should be washed thoroughly with suitable cleaning agents, even against manufacturer's instructions. Influences can be seen under → fading, → solvent evaporation, → delamination, → release agents, → color change, → electroplating error, → thread overload, → painting error, → surface discoloration, → preparation agents, → release agent, and → packaging and transportation.
Clouding	When clouding on the molding surface occurs, the following processing parameters are too low: → injection rate (injection pressure), bulk temperature, or → mold temperature.
Coating	Plastic surfaces are coated to beautify and to improve the feel, aging, sliding properties, and abrasion. The coating also protects against light, UV, and media influences (see also → haptics and → surface refining).
Cold embedding	→ Embedding
Cold flow	Cold flow is the generic term for cold flow areas and cold flow errors due to a reduced molding compound flow. Cold flow is, to our knowledge, one of the most common causes for damage. It is created during injection molding through cold processing and too-slow mold filling due to a low injection rate, molding compound temperature, narrow pinpoint gate, poor mold venting, defect jacket heating, high molding compound viscosity (filler and reinforcing materials, type of plastic), roughness of the flow path (polish sprue/gate, nozzle, and channels), core flowing, metal inserts (insert, without preheating), mold temperature, long flow paths, very thin flow cross-sections, and wall thickness as well as film hinges. See also → weld line with V-shaped collection of the surface and structures, which are similar to the weld line, → delamination (only through hot-cold streaks), → sink mark, → error, rheological, → molding compound, frozen, → inversion layers, → cold flow area, → cold flow front, → cold flow lines (record grooves), → cold plugs (cold particle), → flaking, → surface, tortured, → orange skin, → mold filling, poor (see also → extrusion, → error, rheological, → reversal of the flow front, → mass inversion, and → injection molding).
Cold flow area(s)	→ Cold flow
Cold flow errors	→ Cold flow
Cold flow line(s)	A cold flow line is a warp in the molded part surface (see also → cold flow).
Cold particles	→ Cold plug, → particle

CHAPTER 3

Quality and Damage Figures

This chapter contains 588 figures from many areas of plastics technology, each with an explanation of the cause of damage, and in 74 historically evolved subchapters.

Each page has a header with a page number and a subchapter (LM or SEM) and contains two images of damage causes and damage avoidance, contrast processes, magnifications, type of plastic materials, molded part term, figure numbers, and the keywords from the glossary. These analyses were performed with various optical microscopes and a scanning electron microscope.

Searching of quality and damage figures is done with the figure number after the technical term in the Chapter Glossary or directly in the alphabetically arranged subchapters in the following table.

Table of LM and SEM subchapters:

Subchapter	Figure No.	LM/SEM	Subchapter	Figure No.	LM/SEM
Adhesive Bonding	172–176	LM	Glass fibers	331–339	SEM
Blowholes	221–230	LM	Granulate	123–136	LM
Blowholes	357–357	SEM	Implant	342–349	SEM
Bubbles	36–42	LM	Isochromatics	137–142	LM
Burning	537–539	LM	Laminating	169–171	LM
Cold flow	143–168	LM	Lasering	214–220	LM
Cold flow	350–350	SEM	Layers	421–444	LM
Coloring	79–79	LM	Marginal zone	299–306	LM
Comparison	540–556	LM	Mass inversion	99–102	LM
Conglomerate	351–351	SEM	Mass swivel	231–232	LM
Contrast	183–191	LM	Media	233–262	LM
Cracks	382–419	LM	Media attack	358–360	SEM
Cracks	369–370	SEM	Metal abrasion	263–264	LM
Crystals	192–194	LM	Metallization	265–278	LM
Crystals	352–354	SEM	Microbes	361–362	SEM
Damage	557–564	LM	Mold	574–588	LM
Damage	377–381	SEM	Over-injection	511–515	LM
Deformation	53–63	LM	Painting	197–213	LM
Delamination	64–65	LM	Painting	355–356	SEM
Delamination	324–324	SEM	Particle	279–294	LM
Design	177–182	LM	Particle	363–364	SEM
Diffusion layer	66–66	LM	Plastic materials	195–196	LM
Discharge	80–81	LM	Reinforcement	565–567	LM
Electron beam	325–325	SEM	Spherulites	501–510	LM
Embedding	73–78	LM	Sprue	01–05	LM
Equipment	103–110	LM	Streaks	445–460	LM
Extrusion	82–85	LM	Stresses	485–500	LM
Fillers	328–330	SEM	Thin section	67–72	LM
Films	86–98	LM	Thread	326–326	SEM
Foams	420–420	LM	Vacuoles	516–536	LM
Foams	371–374	SEM	Vacuoles	375–376	SEM
Fractures	43–52	LM	Warpage	568–573	LM
Fractures	312–323	SEM	Warps	327–327	SEM
Fungi	295–298	LM	Weathering	06–27	LM
Fungi	365–368	SEM	Weathering	307–311	SEM
Glass balls	340–341	SEM	Weld line	28–35	LM
Glass fibers	111–122	LM	Welding	461–484	LM

LM = light microscopy (or optical microscopy)
SEM = scanning electron microscopy

For search examples, see pages X–XII.

LM Subchapter: Sprue

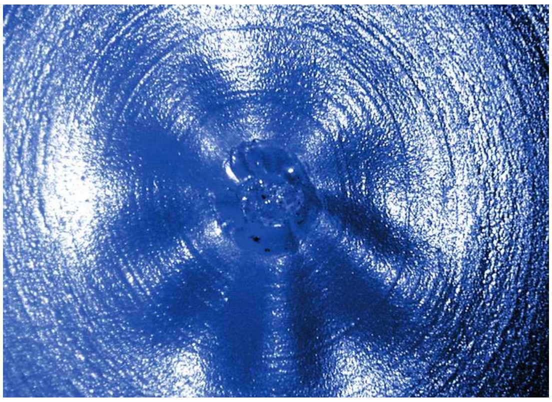

Figure 1, PP water protection bell (M = 12, AL) pinpoint gate with high gate stresses (floral structure). The frozen gate stresses cause, after demolding, a strong shrinkage and a wavy surface in the gate area. This phenomenon was first observed after a seven-day-use period. Cause was a mold temperature that was too low. Such a gate “flower” usually only develops in thin-walled molded parts.

Figure 1

- Gate stresses,
- Shrinkage,
- Mold temperature is too low

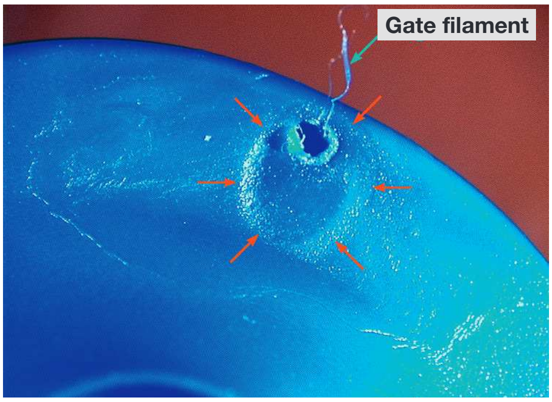

Figure 2, PE nozzle (M = 10, AL) with gate sink mark (red arrows) orange skin, and cold-flow areas around the deeply torn pinpoint gate. This indicates a too-low temperature of the mold and/or molding compound. The gate filament indicates a premature mold ejection, and the gate sink mark implies an insufficient holding pressure time.

Figure 2

- Gate filament,
- Gate sink mark,
- Demolding, too early,
- Cold-flow areas
- Holding pressure, dropped too soon
- Orange skin,
- Pinpoint gate, deeply torn

LM Subchapter: Sprue

Figure 3

- Runner with 10 mold cavities,
- Symmetry balance through polishing,
- Flow paths, different,
- Mold cavity filling has to be optimized

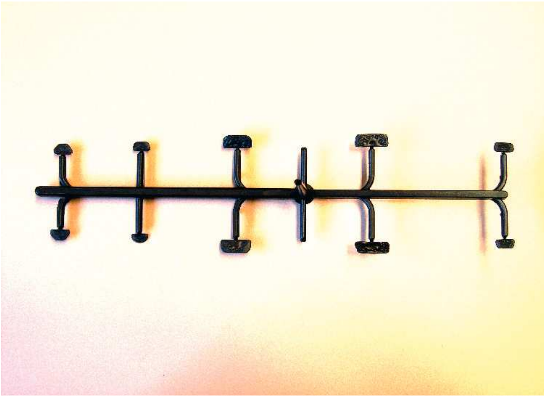

Figure 3, PA/PTFE runner (M = 1 : 1) with 10 mold cavities and symmetry balance through polishing. The molded part quality improves in all 10 cavities through balancing the gates in the runner. For this, the gates were partially polished to varying degrees because different flow path lengths are present between the direct gate and the mold cavities. The goal was an equally fast filling of the mold cavities.

Figure 4

- Forming, cold,
- Gate area with orange skin,
- Weld line with crack

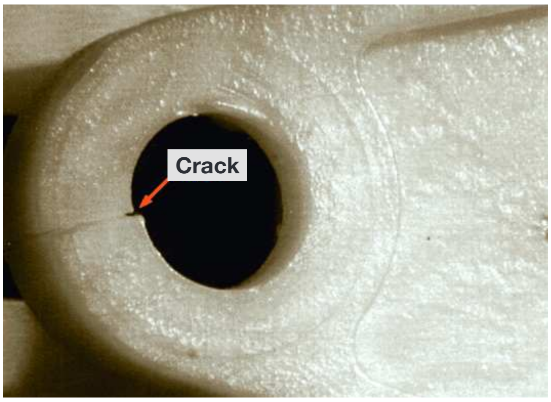

Figure 4, POM clamp (M = 18, AL). Through the gate area (left eye), a crack develops in the weld line, and the molded part surface shows a very cold impression of the mold surface (see also → weld line and → orange skin).

LM Subchapter: Sprue/Weathering

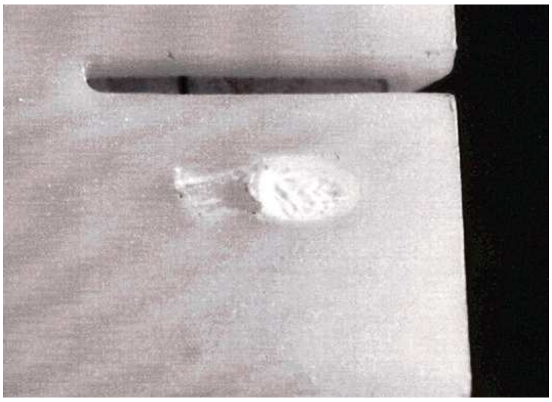

Figure 5, PA6 molded part (M = 20, AL) with pinpoint gate. The pinpoint gate is torn out to the left of the picture. This indicates a somewhat late demolding in connection with a cold mold temperature. Such a visual error usually leads to complaints, particularly when a surface finishing follows, such as painting, plating, or metallizing.

Figure 5

- Pinpoint gate is torn,
- Demolding somewhat late

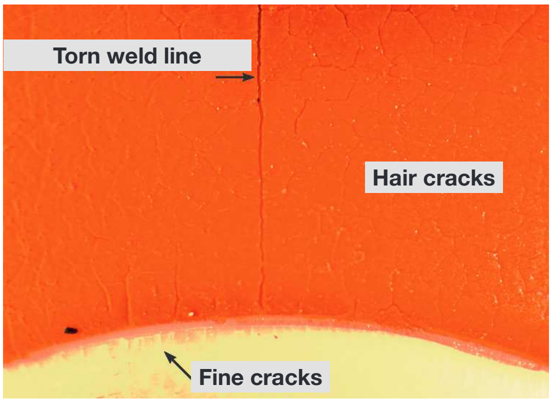

Figure 6, Bottle stopper, made of glass ceramic (M = 31, AL), damaged part as delivered, with white centering cap made of PP (white) and red thermoplastic elastomer (TPE) sealing washer. By exposure to UV radiation during outside storage and solvent-containing cleaning agents, the polymer matrix is embrittled, arising from hair cracks, and cracks at the weld line of the TPE sealing washer.

Figure 6

- Weld line is torn,
- UV exposure outdoors,
- Cleaning agent attack

LM Subchapter: Weathering

Figure 7

- Samples and insular microcracks after media exposure and 15,000 MJ/m^2 weathering,
- Shrinkage stresses due to manufacturing

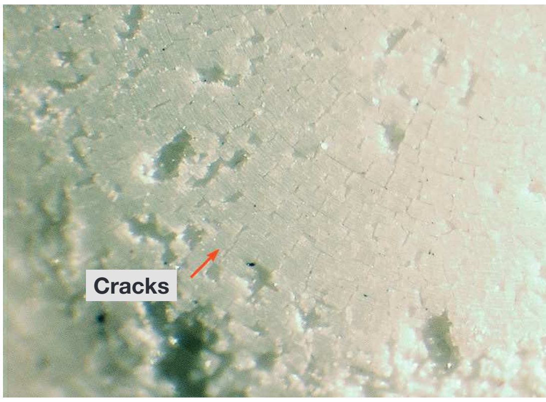

Figure 7, PA/PTFE sheet (M = 1 : 1) with samples and microcracks after media exposure and a weathering dose of 15,000 MJ/m^2 in a Xenon tester 1200 CPS. The insular microcrack formation was also benefiting from an increased molded part stress in the surface due to shrinkage stresses and a too-rapid cooling in injection molding.

Figure 8

- Surface, weathered and original

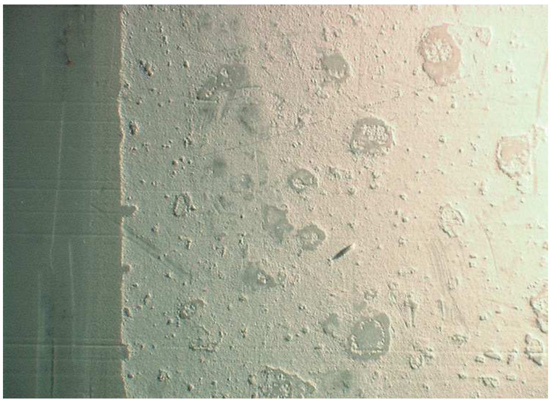

Figure 8, PVC-U window profile (M = 31, AL) with weathered surface after 8000 MJ/m^2 in a Xenon tester beta LM. The original surface can still be detected on the left side of the figure (see also Fig. 9).

LM Subchapter: Weathering

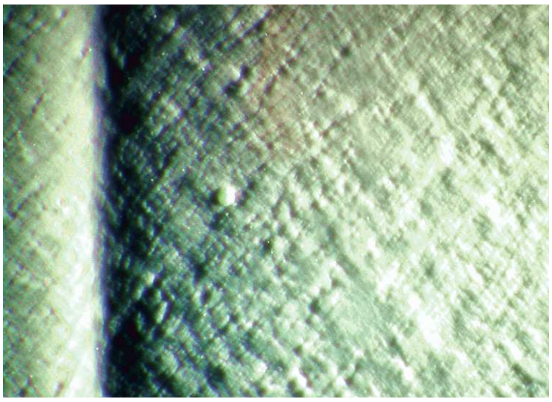

Figure 9, PVC-U window profile section (M = 31, Al) after 8000 MJ/m^2 in a Xenon tester 1200 CPS. A heat treatment using a hot air gun at 230 °C generates a highly roughened surface profile (approximately 45° to the extrusion direction) through released internal stresses, following the flow fronts. The surface roughness was created through a low level of gelling, which should be at about 60 to 70% (see also Fig. 8 and → level of gelling).

Figure 9

- Weathering, 8000 MJ/m^2 (4074 h),
- Internal stresses,
- Level of gelling,
- Surface roughness,
- Heat treatment with hot air gun

Figure 10, PVC-U window profile, laminated with decorative film (M = 28, AL). After 8000 MJ/m^2 of artificial weathering in a Xenon tester 1200 CPS, the 50 µm thick PMMA layer started to develop cracks, artifacts (outbreaks), and peel off the surface on the decorative foil (lamination) (see also → weathering, artificial and → laminating).

Figure 10

- Specimens after weathering 8000 MJ/m^2 (4074 h),
- Laminating with decorative film,
- PMMA layer 50 µm

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Figure 11

- Weathering 9818 MJ/m^2 (5000 h),
- Contrast process AL combined with DL,
- Hair cracks after weathering

Figure 11, GF-UP sheet, transparent (M = 20, AL + DL). The cracks (hair cracks) in the sample surface developed after 5000 hours of weathering in a Xenon tester 1200 CPS. The crack depth is no deeper than about 35 μm. During recording, a low level of transmitted light has been combined with incident light.

Figure 12

- Outdoor weathering, 4 years,
- Surface with dirt deposits,
- UV stabilization is poor

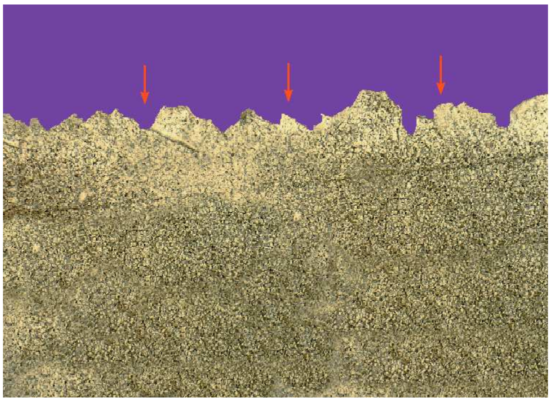

Figure 12, PP lounge seat (M = 100, AL) with UV stabilization. A rough PP surface developed after four years of outdoor weathering in Würzburg, Germany. Thus the dirt deposits cannot be removed with the cleaning products that were recommended by the manufacturer, and the rough PP surface retained a gray appearance.

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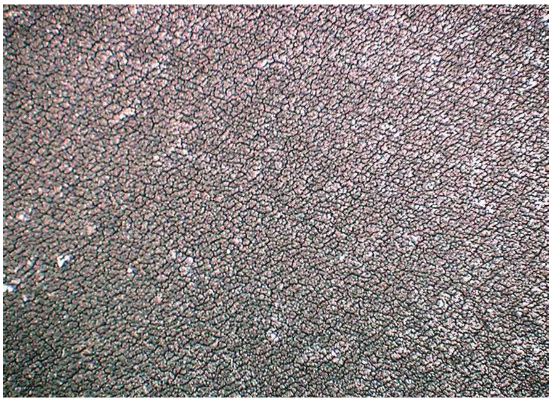

Figure 13, EPDM gasket profile for PVC windows (M = 30, AL). After 8000 MJ/m^2 artificial weathering in a Xenon tester beta LM the surface embrittled and caused formation of cracks and microcracks. An assessment of whether cracks are present or not is done by a combination bending of the sample ends in soft samples. Then the cracks opened and become gapingly visible.

Figure 13

- Weathering 8000 MJ/m^2 (4074 h),
- Microcracks,
- Bend specimen with cracks

Figure 14, PVC mesh chair with Al frame (M = 1 : 1) after two years of use in outdoor weathering. The PVC braid is colored black, embrittled, and has cracks, particularly on the left arm edge and on the arm-rest. With IR and DSC analyses of the braid, plasticizer migration was detected in the disputed areas through a decrease of the plasticizer from the inside out. The causes of cracks and blackening are therefore plasticizer relocation through migration and the reaction of the oily substance with effects under sunlight and media, such as cleaning agents, sun, oils, and gases (see also → IR analysis, → DSC analysis, and → migration).

Figure 14

- Outdoor weathering and the influence of media after two years,
- IR analysis,
- Migration of plasticizers,
- Microcracks,
- Blackening,
- Embrittlement