HANSER

Industrial Polymers

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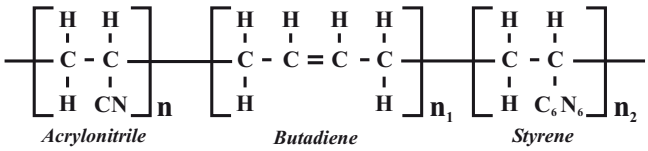
2 Polymeric Materials

2.1 Acrylonitrile-Butadiene-Styrene Copolymer (ABS)

Chemical Structure of ABS



General Properties of ABS

Type of polymer	Amorphous, blend
Specific gravity	1.05
Tensile modulus @ 73 °F (Mpsi)	0.3
Tensile strength @ yield (kpsi)	5.0
Notch Izod impact @ 73 °F (ft-lb/in)	2.50 – 12.0
Thermal limits service temp. (°F)	167 – 185
Shrinkage (%)	0.4 – 0.7
Glass trans. temperature, T_g (°F)	185 – 240
Vicat point temperature (°F)	237
Process temperature (°F)	410 – 518
Mold temperature (°F)	122 – 176
Drying temperature (°F)	176 – 185
Drying time (h)	2.0 – 4.0

The ABS resins have a well-balanced set of properties for molding close dimensional control articles with an outstanding surface finishing, good impact resistance, and metal plating characteristics. ABS resins belong to a very versatile family of thermoplastic polymers. ABS is produced by combining three monomers: acrylonitrile, butadiene, and styrene. The chemical structure of these monomers requires each monomer to be an important component of the ABS resins. Acrylonitrile contributes heat resistance, chemical resistance, and surface hardness to the system. The butadiene contributes toughness and impact resistance, while the styrene component contributes processibility, rigidity, and strength.

ABS plastics are two-phase systems. Styrene-acrylonitrile (SAN) forms the continuous matrix phase. The second phase is composed of dispersed polybutadiene particles, which has a layer of SAN grafted onto their surface. The binding matrix layer of SAN makes this polymer's two phases compatible.

The property balance of ABS is controlled by the ratio of the monomers and by the molecular structure of the two phases. Stabilizers, lubricants, colorants, and other additives can be added to the system, and while this makes the production of ABS very complex, it allows great flexibility in product property design. As a result of the unique morphology of ABS, hundreds of different products have been developed and are available commercially.

ABS resins are grouped into two major divisions: injection molding and extrusion grades. The primary difference between these grades is their melt viscosity, which is significantly lower for injection molding resins. Within each division of ABS polymers, there are the corresponding classes of grades. Standard ABS grades are grouped by impact strength into medium, high, and very high impact grades. The standard ABS versions are available in a low surface gloss, a high surface gloss, and an ultra-high surface gloss. Specialty ABS grades include high heat, plating, clear, flame retardant, and structural foam grades.

Figure 2-1 Cordless drill tool housing

Standard grades of ABS generally meet the Underwriter's Laboratories (UL) rating for slow burning (UL-94 HB). Flame retardant materials have UL-94 V0 at thicknesses as low as 0.062 in and UL-94 5V at thicknesses as low as 0.125 in. Clear ABS grades use methyl methacrylate providing light transmission of 72% and a haze level of 10%. Alloys of ABS-PVC are available in high and low gloss grades. Alloys of ABS-PC are available in injection molding and plating grades. ABS-SMA Heat resistant alloys are available in injection molding, extrusion, and plating grade versions. Alloys of ABS-PA are also available in injection molding grades.

ABS is an excellent choice for use in alloys and blends. When the plastics are combined, the positive features of each can be maintained, or even enhanced, while the negative features of each can be reduced. ABS-polycarbonate (ABS-PC) and ABS-polyvinyl chlorides (ABS-PVC) are well-established alloys. More recent innovations have resulted in ABS-styrene-maleic anhydride (ABS-SMA) and ABS-polyamide (ABS-PA) alloy products.

ABS offers superior processibility and appearance as well as low cost, along with a good balance of engineering properties.

Figure 2-2 Faucet chrome plated shell

2.1.1 Advantages of ABS

- Good impact resistance (toughness) and rigidity properties
- Low creep
- Good dimensional stability
- High strength properties
- Metal coatings have excellent adherence to ABS
- Transformed by conventional thermoplastic methods
- A lightweight plastic material

2.1.2 Disadvantages and Limitations of ABS

- ABS is resistant to acids (except concentrated oxidizing acids), alkalis, salts, essential oils, and a wide range of food and pharmaceutical products. It is, however, attacked by many solvents, including ketone and ester.
- Low dielectric strength
- Only low elongation available
- Low continuous service temperature
- While the mechanical property of the finished part is not sensitive to moisture, its presence during processing can cause part appearance problems. Maximum suitable moisture levels of 0.2% for injection molding and 0.03% for extrusion can be reached using a dehumidifying air dryer.

2.1.3 Typical Applications of ABS

- *Refrigerators:* Doors and food liners for the interior wall of the refrigerator. Medium impact extrusions and molding grades, including clear ABS, are used in crisper pans, breaker strips, shelves, shelf supports, evaporator parts trays, and kick plates.
- *Small Appliance Housings and Power Tool Applications:* These include hair dryers, curling irons, blenders, electric can openers, coffee makers, food processors, electric fans, vacuum cleaners, electric drills, leaf blowers, and lawnmower decks.
- *Automotive Applications:* Instrument panels, armrests, interior trim panels, seat belt retainers, glove compartment doors, and lift gates. ABS plating grades are used in wheel covers, grilles, headlight, mirror housings, and decorative trim.
- *Drain:* Waste, vent pipes, pipe fittings, and pool filter housings.
- *Telecommunications:* Telephone housings, portable phones, typewriter housings, and keyboard keys.
- *Business and Consumer Electronics:* Videocassettes, televisions, audiovisual equipment, computer housings, printers, and copiers.
- *Household Items:* Countertops, sink and tub surrounds, and roof-mounted air conditioning units.
- *Recreational:* Motorcycle moldings, sailboats, airplanes, campers, hard-sided luggage, and picnic cooler liners.
- *Other Applications:* Briefcases, cosmetic cases, household packaging, toys, and photographic equipment.

Figure 2-3 Motorcycle trim/molding

Figure 2-4 Lego toys

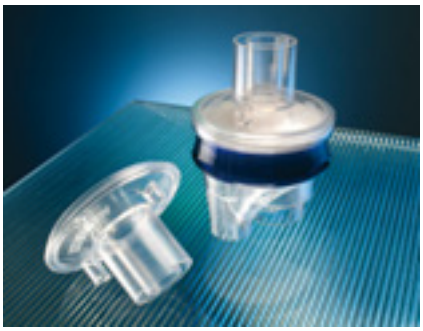
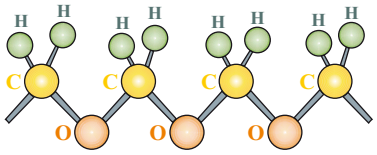
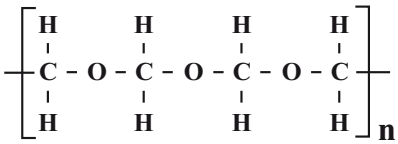


Figure 2-5 Filter for medical device

2.2 Acetal (POM, Polyacetal)

Chemical Structure of Acetal Homopolymer

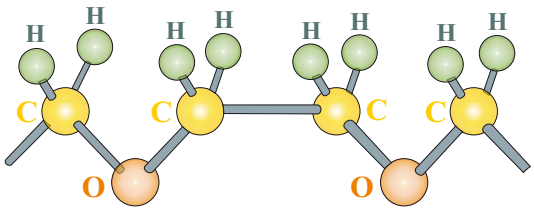


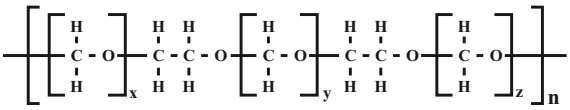


General Properties of Acetal Homopolymers

Type of polymer	Semi-crystalline
Specific gravity	1.42
Tensile modulus @ 73 °F (Mpsi)	400.00
Tensile strength @ yield (kpsi)	10.0
Notch Izod impact @ 73 °F (ft-lb/in)	1.30
Thermal limits service temp. (°F)	230 (short) – 195 (long)
Melt flow rate (g/10 min)	1.0 – 17.0
Shrinkage (%)	1.9 – 2.3
Melt temperature, T_m (°F)	350
Process temperature (°F)	375 – 450
Mold temperature (°F)	140 – 200

Chemical Structure of Acetal Copolymer





General Properties of Acetal Copolymers

Type of polymer	Semi-crystalline
Specific gravity	1.42
Tensile modulus @ 73 °F (Mpsi)	360.00
Tensile strength @ yield (kpsi)	8.5
Notch Izod impact @ 73 °F (ft-lb/in)	1.20
Thermal limits service temp. (°F)	200 (short) – 175 (long)
Melt flow rate (g/10 min)	1.0 – 10.0
Shrinkage (%)	2.0 – 2.5
Melt temperature, T_m (°F)	330
Process temperature (°F)	340 – 420
Mold temperature (°F)	125 – 185

Acetal resins provide a well-balanced set of properties including a hard self-lubricated surface, excellent chemical resistance, strength, stiffness, and toughness over a broad temperature range.

The acetal homopolymer was first introduced in 1960 as a semi-crystalline form of polymerized formaldehyde forming a linear chain of molecules of oxymethylene. In the homopolymer process, the formaldehyde is separated from the water and purified to CH_2O gas, which is then polymerized to the polyoxymethylene molecule. In this case, the molecule is stabilized by a reaction with acetic anhydride to give acetate end groups. The acetate capped homopolymer is less resistant to attack by base, but it has a higher melting point and mechanical advantages in strength, stiffness, toughness, hardness, creep, and fatigue than the copolymer acetal.

In the acetal copolymer process, the formaldehyde is first converted to the cyclic structure of three formaldehyde molecules, trioxane. The trioxane is separated, purified and reacted with a comonomer (ethylene oxide) to prepare polyoxymethylene that has randomly distributed $–CH_2–CH_2$ groups in the chain.

This resultant raw polymer is then treated with heat and base to degrade the ends of the molecules back to a $–CH_2–CH_2$ "block" point at each end. This leaves a molecule resistant to further degradation by basic environments.

The end-capping of homopolymer and copolymer chains is necessary to prevent the irreversible depolymerization of the polymer backbone during melt processing. The thermal energy causes "unzipping" of the $–H–O–CH_2–O–CH_2–$ end group to a formaldehyde monomer.

The homopolymer grades exhibit the highest crystallinity, with good strength, stiffness, and impact resistance. The melting point is 350 °F. The high crystallinity also provides good chemical resistance, with little or no effect seen in the material after direct exposure to common hydrocarbons, aldehydes, ketones, alcohols, and fuels. The homopolymer is also resistant to aqueous solutions

Figure 2-6 Shower head

Figure 2-7 POM parts of medical enhaler

Figure 2-8 Adjustable ballcock valve

Figure 2-9 Tank filler

Figure 2-10 Self-lubricated conveyor belt

with a PH range between 4 to 10. The homopolymer is recommended for continuous service temperature in air and water up to 230 °F.

The copolymer grades have random ethyleneoxy or n-butyleneoxy units scattered throughout the polymer backbone. These comonomer units slightly disrupt the crystallinity of the polymer in the solid state, leading to slightly lowered short term strength, stiffness, impact resistance, and a melting point of 330 °F. They have good solvent resistance, because the polymer chains are not capped with an ester group and aqueous solution PH resistance is extended over a range from 4–14. The copolymer is recommended for continuous service temperatures both in air and water up to 200 °F.

Acetals are strong, stiff, and tough over a broad temperature range. They have good surface lubricity and a low coefficient of friction against metals, ceramics, and other plastics. They are creep and fatigue resistant because of low cold flow characteristics. The balanced properties and good solvent resistance of acetal make it the ideal candidate to replace materials such as metals, thermoset polymers, wood, and ceramics.

Special technology has led to impact-modified homopolymer and copolymer grades, but increased impact resistance is offset by decreased strength and stiffness. Many grades also have the approval from the Food and Drug Administration for repeated food contact, National Sanitation Foundation and Canadian Standards Association for potable water applications, and Underwriter's Laboratories UL-94 HB ratings for flammability. Special grades are also available with US Department of Agriculture approval for direct contact with meat and poultry products and Dairy and Food Industries Supply Association approval for contact with dairy products.

The following grades of acetal resins are commercially available:

- UV stabilized and weatherable grades
- Low wear and low coefficient of friction grades
- Toughened and impact modified grades
- Fiber glass reinforced grades
- Filled mineral, glass beads, milled glass filled grades
- High melt flow grades

The outstanding characteristics of this polymer include stiffness, which permits the design of parts with large areas and thin cross sections; high tensile strength and creep resistance under a wide range of temperatures and humidity conditions; high fatigue resistance and resilience for applications requiring springiness and toughness. Acetal has achieved importance in applications because of a good balance of properties. Two types of acetals are available. One is a homopolymer resin with higher mechanical properties, higher end use temperatures, and higher melt flow index, and the other is a copolymer resin with better processing characteristics and impact resistance.

2.2.1 Advantages of Acetal

- High mechanical properties, tensile strength, rigidity, and toughness
- Glossy molded surfaces
- Low static and dynamic coefficients of friction
- Retains electrical and mechanical properties up to 230 °F
- Low gas and vapor permeability
- Approved for applications used in contact with food
- Excellent chemical resistance to common hydrocarbons, aldehydes, ketones, alcohols, and fuels

Figure 2-11 Needle-bearing liners

2.2.2 Disadvantages and Limitations of Acetal

- Poor resistance to acids and bases
- High mold shrinkages
- Subject to UV degradation, if special acetal grades are not used
- Flammable (UL-94 HB)
- Excessive process melt temperatures over 450 °F can result in significant thermal degradation of the material, with the release of formaldehyde gases
- Violent thermal degradation (explosion) if acetal melt is contaminated with PVC
- Difficult to bond when the acetal surface is not treated

2.2.3 Typical Applications of Acetal

- *Industrial:* Conveyor links and slats, cams, bearings, wear stops, hose connectors, valve bodies, pumps (housings, pistons, valves, and impellers) and gears.
- *Automotive:*
  - Fuel handling systems: Filler caps, level sensors, floats, pumps, and reservoirs
  - Trims: Seat belt buckle housings, window cranks, shift lever handles, knobs, buttons, mounting clips, visor mounting brackets, levers, exterior door pulls, mirror housings, brackets, bumper strip end plugs, and antenna bases
  - Instrument panel components: Cluster gears, bearings, housings, cable connectors, slide plates, and panel locks
  - Under the hood components: Fans, fan blades, snap-fitting housings, and tubing connectors

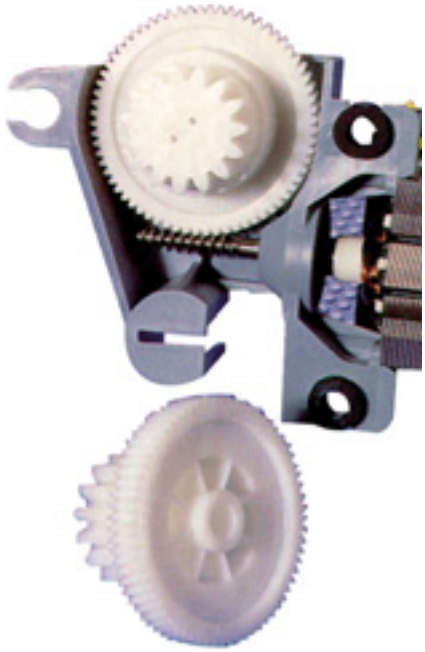


Figure 2-12 Worm gear motor

Figure 2-13 Automotive fuel level sensor

Figure 2-14 Gas tank cap with override cams

Figure 2-15 Automotive end ball joint bearing

- *Appliances:*
  - Refrigerators: Shelving clips, brackets, bearings, and gears
  - Washers and dryers: Gears, bearings, wear strips, instrument housings, and hose connectors
  - Dishwashers: Rack rollers, spray nozzles, soap dispensers and filter supports
- *Home Electronics:*
  - Keyboards: Key caps, plungers, guides, and base plates
  - Telephones: Push buttons, gears, bearings, and springs
  - Modular components: Clips, peg boards, connectors, wear strips for drawers, latch springs, and clamps
  - Audio and video DVD players and recorders: Tape hubs, guide rollers, cams, gears, bushings, and bearings
- *Plumbing:*
  - Water meters: Housings, cams, gears, dials, and pressure plates
  - Faucets: Underbodies, cartridges, stems, packing nuts, and waterways
  - Water softeners: Pump housings, pistons, impellers, and valves
  - Filters: Bodies, plates, and screens
  - Pressure regulators: Bodies, stems, knobs, and pressure plates
  - Potable water distributors: Fittings, drain valves, stop valves, and metal pipe adapters
- *Consumer:*
  - Personal care: Mascara, perfume, and deodorant containers, combs, aerosol valves, soap dispensers, and cosmetic applicator handles
  - Small appliances: Motor gears, cams, bearings, pumps, glue applicators, housings, and springs
  - Toys: Shells, frames, gears, bearings, cams, springs, wheels, and connectors
  - Sporting goods: Ski bindings, gears, bearings, guides, wear plates, clamps, pump components, valves, and buckles
- *Hardware:* Drapery and Venetian blind guides, hangers, rollers, bearings, furniture casters, slide plates and locks, tool holders, bearings, gears, and housings
- *Irrigation:* Sprinkler nozzles, arms, gears, housings, waterways, pump housings, impellers, pistons, metering valve bodies, knobs, stems, and internal components
- *Agriculture:* Shift levers and housings, hydraulic connectors, bearings, gears, and seed application disks