1 Basic Mold & Part Design Guidelines

Plastic parts and injection molds require many design considerations to meet the expectations of the consumer. The following plastic part and mold design rules should be taken into consideration when designing either a part or mold.

1.1 Uniform Wall Thickness

Design the part with the most uniform nominal wall thickness as possible. This will minimize sinking, warping, residual stresses, material usage, and improve cycle times. Ribs should be placed in areas of stress instead of increasing the wall thickness. By minimizing the wall thickness you will reduce the cycle time, shot weight, and have quicker cooling.

Figure 1a: Suggested Wall Thicknesses for Injection Molded Thermoplastic Parts

	minimum		average		maximum	
Material	**mm**	**in**	**mm**	**in**	**mm**	**in**
Acetal	0.4	0.015	1.6	0.062	3.2	0.125
ABS	0.8	0.03	2.3	0.09	3.2	0.125
Acrylic	0.6	0.025	2.4	0.093	6.4	0.25
Cellulosics	0.6	0.025	1.9	0.075	4.7	0.187
FEP	0.3	0.01	0.9	0.035	12.7	0.5
Nylon	0.4	0.015	1.6	0.062	3.2	0.125
Polycarbonate	1.0	0.04	2.4	0.093	9.5	0.375
Polyester T.P	0.6	0.025	1.6	0.062	12.7	0.5
Low Density polyethylene	0.5	0.02	1.6	0.062	6.4	0.25
High Density Polyethylene	0.9	0.035	1.6	0.062	6.4	0.25
Ethylene Vinyl Acetate	0.5	0.02	1.6	0.062	3.2	0.125
Polypropylene	0.6	0.025	2.0	0.08	7.6	0.3
Polysulfone	1.0	0.04	2.5	0.1	9.5	0.375
PPO (Noryl)	0.8	0.03	2.0	0.08	9.5	0.375
Polystyrene	0.8	0.03	1.6	0.062	6.4	0.25
Styrene Acrylo Nitrile	0.8	0.03	1.6	0.062	6.4	0.25
Polyvinylchloride (Rigid)	1.0	0.04	2.4	0.093	9.5	0.375
Polyurethane	0.6	0.025	12.7	0.5	38.1	1.5
Ionomer (Surlyn)	0.6	0.025	1.6	0.062	19.1	0.75

1.2 Corner Radii

All corners should have generous radii to avoid excessive stress concentrations. Such stress concentrations can lead to unexpected part failure and should be minimized during all parts of the plastic part production. All features such as bosses, ribs, and shut offs should have generous radii to reduce stress concentrations. To maintain uniform wall thickness and reduce stress concentrations, the use of an inside radius of ½ the nominal wall thickness and an outside radius of 1½ of the nominal wall thickness is recommended.

1.3 Ribs and Gussets

These design features should be placed anywhere the part needs increased stiffness. These features will reduce the material consumption, decrease cycle time, as well as increase the structural integrity of the part. Always avoid excessively tall, thick, thin, and sharp cornered features when possible.

1.4 Draft Angle

An appropriate draft angle will aide in the removal of the part from the mold. Without the proper draft angle parts may become hung up or stuck upon ejection and mold damage may occur. Be sure there are appropriate draft angles on all bosses, ribs, and nominal walls. The draft angle is most often between 1° and 2° depending on the material and desired surface finish.

1.5 Undercuts

Undercuts are mold features that prevent part ejection or mold opening. Undercuts such as clips are commonly added to the part design to simplify post molding operations such as assembly. Unfortunately, the features increase the cost and complexity of the mold because of the additional mechanisms needed to free the part from the mold.

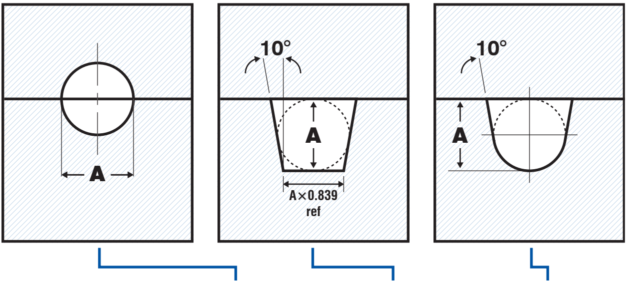
1.6 Surface Finish

Most plastic part designs call out a specific surface finish or texture. These features may significantly increase the cost of the tool and should be taken into consideration based upon the application. Highly polished molds require many hours of work to achieve a mirror finish and can be exponentially more expensive than the same tool with a rougher finish. The highest finishes require all lower grades of finishing to be performed before they can be achieved. Textured molds can be very difficult and time consuming to make and may require expensive equipment or a higher degree of skill than polishing.

Figure 1b: SPI Surface Finishes

SPI Finish	Finishing Method	Visual Description	Roughness R.A.
A-1	Grade #3 Diamond	Mirror/Lens – 420 SS material	0-1
A-2	Grade #6 Diamond	Highly Polished	1-2
A-3	Grade #15 Diamond	High Polish	2-3
B-1	600 Grit paper	Medium - High Polish	2-3
B-2	400 Grit paper	Medium Polish	4-5
B-3	320 Grit paper	Med – Low Polish	9-10
C-1	600 Stone	Low - Med Polish	10-12
C-2	400 Stone	Low Polish	25-30
C-3	320 Stone	Lower Polish	35-45
D-1	Dry Blast Glass Bead	Satin Finish	High/Variable
D-2	Dry Blast #240 Oxide	Dull Finish	High/Variable
D-3	Dry Blast #24 Oxide	Coarse Finish	High/Variable

Figure 1c: Runner Shapes and Dimensions



A		Full Round		Modified Trapezoid		Modified Trapezoid	
in	mm	in^2	mm^2	in^2	mm^2	in^2	mm^2
1/8	3.2	0.012	8.0	0.016	10.4	0.015	9.7
3/16	4.8	0.028	18.1	0.036	23.4	0.033	21.8
1/4	6.4	0.049	32.2	0.063	41.6	0.059	38.7
5/16	7.9	0.077	49.0	0.099	63.4	0.092	59.0
3/8	9.5	0.110	70.9	0.143	91.6	0.133	85.3
7/16	11.1	0.150	96.8	0.194	125.1	0.181	116.4
1/2	12.7	0.196	126.7	0.254	163.8	0.236	152.4
5/8	15.9	0.307	198.6	0.397	256.7	0.369	238.9

Figure 1d: Suggested Circular Runner Dimensions

Material	DIA. (in)	DIA. (mm)
ABS	.187-.375	4.7-9.5
Acetal	.125-.375	3.1-9.5
Acrylic	.321-.375	7.5-9.5
Ionomer	.093-.375	2.3-9.5
Nylon	.062-.375	1.5-9.5
Polycarbonate	.187-.375	4.7-9.5
Polyester	.187-.375	4.7-9.5
Polyethylene	.062-.375	1.5-9.5
Polypropylene	.187-.375	4.7-9.5
Polyphenylene Oxide	.250-.375	6.3-9.5
Polysulfone	.250-.375	6.3-9.5
Polystyrene	.125-.375	3.1-9.5
Polyvinylchloride	.125-.375	3.1-9.5
Styrene Acrylonitrile	.187-.375	4.7-9.5

Figure 1e: Suggested Vent Depths

Material	in	mm	in	mm
ABS	0.001	0.03	0.002	0.050
Acetal	0.0005	0.01	0.0015	0.040
Acrylic	0.0015	0.04	0.002	0.050
EVA	0.0005	0.01	0.0007	0.020
HDPE	0.0008	0.02	0.001	0.025
Ionomer	0.0005	0.01	0.0007	0.020
LDPE	0.0005	0.01	0.0007	0.020
Nylon 6/6	0.0005	0.01	0.002	0.050
PBT	0.0005	0.01	0.0015	0.040
PC	0.001	0.03	0.003	0.075
PC/ABS	0.0015	0.04	0.003	0.075
PC/SAN	0.0015	0.04	0.003	0.075
Polyester	0.0005	0.01	0.001	0.025
PEEK	0.0005	0.01	0.0007	0.020
PEI	0.001	0.03	0.0015	0.040
PES	0.0005	0.01	0.0007	0.020
PP	0.0005	0.01	0.002	0.050
PPO	0.001	0.03	0.002	0.050
PPS	0.0005	0.01	0.001	0.025
PS	0.001	0.03	0.002	0.050
PSU	0.001	0.03	0.0015	0.040
PVC (Flexible)	0.001	0.03	0.0015	0.035
PVC (Rigid)	0.0015	0.04	0.002	0.050

1.7 Tool Steels

Tool steels for a particular application are typically chosen based on their hardness, abrasion resistance, machining rate, resistance to deformation at elevated temperatures (red-hardness), and/or chemical resistance. Tool steel is generally heat-treated and annealed to produce the desired properties. The table below is a listing of common tool steels from DME Company LLC used for various structural and holder block applications.

Figure 1f: Steels for Structural and Holder Block Applications

#1 Steel	SAE 1030 Type easy to machine but is not "sticky", permitting faster and smoother cuts.
#2 Steel	AISI 4130 Type pre-heat treated specified for durability and structural applications. High strength steel good for cavity and core retainer plates, clamping plates, and support plates.
#3 Steel	P-20 Type pre-heat treated is exceptionally clean and can be heat treated for additional hardness and polished. Good cavity steel. This steel is commonly used for insert molding applications.
#5 Steel	Thermal Shock resistant AISI- H-13 type steel annealed for easy machinability and heat treated for hardness. Has good polishability and hardness. Used for die casts and injection molds where hardness and a highly polished surface is necessary.
#6 Steel	Modified AISI 420 Stainless supplied fully annealed. Unlike No. 7 Steel this stainless steel is cavity grade and can be subsequently heat treated for a desired hardness, it also has exceptional polishability.
#7 Steel	Modified AISI 400 Stainless pre-heat treated for holder block applications. Corrosion resistant with great machinability but cannot be further hardened.

Figure 1g: Common Mold Steels & Important Characteristics

Steel	Hardness (Rockwell C)	Thermal Conductivity (BTU/hr/ft°F)	Description
1045	15-16	29	High strength low cost carbon steel. Poor corrosion and wear resistance but can be nitrided.
4140	31-35	24.5	High strength with good fatigue, abrasion, and impact resistance. Common mold base steel.
410 Stainless	40-45	14.4	Excellent polishability and corrosion resistance with good hardness. Commonly used for highly polished applications such as lenses and optics.
420 Stainless	54-57	14.4	Excellent polishability & corrosion resistance with good hardness. Commonly used for cavity and core inserts, ejector pins, and ejector sleeves.
A6	61-62	18.5	Heat-treatable, good wear resistance and toughness. Commonly used for ejection components.
D2	62-64	12.1	High Carbon/Chromium heat treatable steel with good wear, shock, and abrasion resistance & high toughness. Used for gate blocks, high speed molding, and anything else needing great wear resistance.
H13	50-54	15.5	Heavily alloyed versatile steel with excellent high temperature and wear resistance & excellent toughness. This steel is commonly used for high-speed machining of cavity and core plates.
P20	30-32	18.5	Common mold steel with good fatigue abrasion and impact resistance. Typical uses include: mold bases, ejector plates, and larger core and cavity blocks which do not need heat treatment.
S7	57-60	16.5	Excellent impact resistance, strength, heat transfer, and toughness with low wear resistance. Uses include cavity plates, core plates, laminates, and thin wall sections.
A2	60-62	15	This steel has good corrosion resistance and excellent wear resistance. Occasionally used for core and cavity blocks where polishing is not required. Most commonly used for high-wear mold components such as lifters and slide blocks.
M2	63-65	12.1	This high hardness steel has excellent wear resistance which is very difficult to machine. Often used for pre-manufactured components such as ejector pins and ejector sleeves.

Figure 1h: Common Non-Ferrous Injection Mold Metals & Important Characteristics

Metal	Hardness (Brinell)	Thermal Conductivity (BTU/hr/ft°F)	Description
AL 7075-T6 (Aluminum)	150	75	High strength and corrosion resistance with good machinability. This aircraft grade aluminum costs more than QC-7 and is used for mold cavities.
Al QC-7 (Aluminum)	167	82	High strength, hardness, and excellent texturing characteristics. Developed for molds and inserts.
Cu 940 (Copper)	210	150	Berrillium-free copper alloy with high strength and thermal conductivity. Used for cooling inserts and shut offs.
BeCu (Beryllium Copper)	371	100	BeCu has excellent fatigue resistance and thermal conductivity. Beryllium copper is used for core and cavity components.

1.8 Basic Heat Treatment

Heat-treating is the act of heating and cooling the steel at predetermined temperatures and times to adjust its' hardness and strength. Steels that consist of 0.4% carbon or more can be heat-treated.

During the heat-treating process, the chemical structure and dimensions of the steel are changed. As the steel is hardened, it typically increases in size and may cause distortion. The amount of dimensional change is case dependent. For example; an increase in hardness of 20 Rockwell C during heat treatment will result in a more severe change than an increase of 10.

When heated, the steel reaches a specific hardening temperature which transforms it to an austenite state. In the austenite state, the carbon is dispersed within the steel and then must be cooled.

When cooled slowly, or annealed, the steel is changed into a softened state, called pearlite. Annealing involves placing the steel into a medium, such as hot oil, warm air, or salt. This process is used to soften the steel before machining, or to significantly reduce the stresses within the steel after machining.

When the steel is cooled quickly from the austenite state, it changes to a very hard, yet brittle, state called martensite. Hardening is performed in a medium, such as cold oil, air, or water, which quickly removes the heat from the steel.

Tempering involves heating the steel to a temperature slightly below the hardening temperature. In this process the steel slowly cooled to reduce hardness and to increase durability.

As with tempering, stress-relieving involves heating to a temperature slightly below the hardening temperature and then slowly cooling the steel. This reduces stresses within the steel before hardening to help reduce distortion. Stress-relieving is performed after a large amount of steel is removed, or after welding.

1.9 Common Surface Treatments

Surface hardening heats the surface of the steel to above the hardening temperature through the use of lasers or electron beams. The surface cools quickly and a hardened layer of steel is formed. As with heat-treating, this procedure can be performed on steels having a carbon content equal to or greater than 0.4%.

Steels that cannot be surface hardened are sometimes carburized. This process heats the steel in the presence of a high-carbon medium, such as leather or charcoal. The carbon-rich surface is then cooled quickly for hardening.

When processing corrosive materials such as PVC and acetals; mold components are often nitrided. This process involves heating the steel in an ammonia-rich environment to incorporate nitrogen into the surface.

Boriding involves surrounding the steel with boron-rich metal plates. The boron migrates to the surface of the steel being treated and creates a thin, yet hard layer of iron boride. This process cannot be used for components having complex geometry, since the steel must come in contact with the boron-rich plates.

1.10 Common Surface Coatings

To increase the surface hardness of steel, a layer of titanium carbide or titanium nitride is often added. Titanium carbide is among the hardest coatings available and is applied to prolong the life of high-production cores and cavities. Titanium carbide or titanium nitride coatings are commonly used with abrasive additives, such as glass fibers, talc, and mica.

Nickel or nickel-teflon plating is used to improve the chemical resistance and to reduce the surface friction of the steel. These are commonly used in applications to improve the speed of part removal due to sticking to either the core or cavity.

Adding a layer of chrome to the surface of the steel increases both its' hardness and its' chemical resistance. Chrome plating is usually reserved for treating highly polished core and cavity surfaces, or for use with polymers which create residue, such as ABS, PVC and polyethylene.

1.11 Wear Considerations

Galling occurs when mold materials of similar hardness wear together though contact. This results in the two mating surfaces balling up and creating large grooves on either side. To prevent galling, mating materials must have a difference of at least 6 Rockwell C hardness.

To help reduce wear on actions, wear plates made of softer materials should be used whenever possible. These should be checked frequently and replaced whenever excessive wear is detected. Brass is commonly used for high wear components since it is easy to machine and will wear away before the harder steel components. Brass plated steel components are even more effective, having the wear characteristics of brass with the increased strength of steel.

Although expensive, graphite impregnated materials should be considered whenever possible. These materials contain graphite inserts imbedded into the metal, which lubricate the surface and provide superior wear resistance.

1.12 Porous Metals

Porous metals allow gas to vent through the metal and are available in both porous steel and aluminum. To prevent volatile build up, pressurized air should be forced through the porous metal between each cycle.

Porous metals must be machined using either wire EDM or die sinking EDM machines. Other machining methods, such as milling and grinding, damage the surface by covering the pores. Since porous metals tend to be expensive, they are commonly reserved for small mold cavities, or used as inserts where localized venting is desired.