Process*

After proper material selection and design, the responsibility shifts from the designer to the plastic processor. The most innovative design and a very careful material selection cannot make up for poor processing practices. Molded-in stresses, voids, weak weld lines, and moisture in the material are some of the most common causes for premature product failures. Ignoring sound processing techniques in order to produce aesthetically pleasing parts generally results in parts lacking physical quality and disappointing production levels (13).

The latest advancement in process control technology allows the processors to control the process with a high degree of reliability and also helps in record keeping should a product fail at a later date. Mold cavities should be fitted with date code inserts that allow changing of the date and other information easily with a screw driver and without taking the mold apart. Such records of processing parameters are invaluable to a person conducting failure analysis. Any assembly or secondary operation on processed part must be evaluated carefully to avoid failures. Many failures arise from stress cracking around metal inserts, drilled holes and welded joints. Part failure resulting from poor processing practices is shown in Figure 15-20.

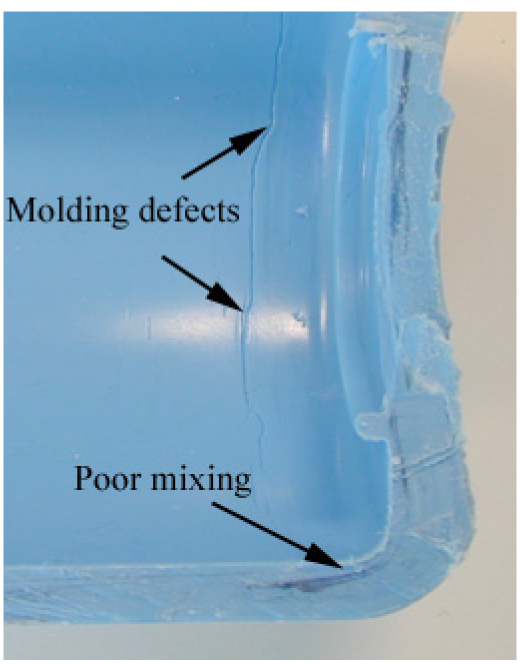


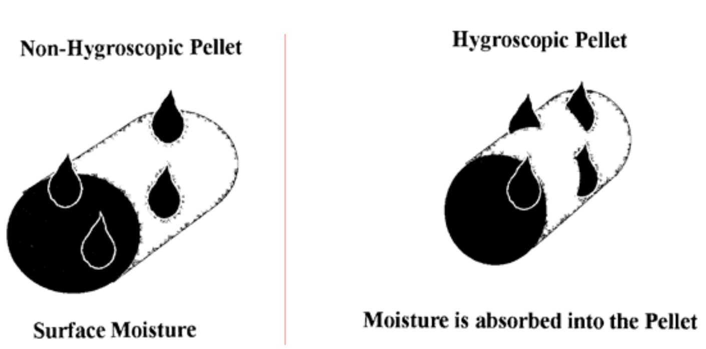
Figure 15-20

Proper molding practice begins with processor making sure that the correct material is utilized. Historically, many plastic parts failure can be traced back to the processor simply using the wrong material. If mixing of color, additives or regrind is required, processor must make sure that the proper ratio is maintained. Appropriate use of automatic material loaders, color mixers and blenders generally minimize the errors created by manual operation. If material is hygroscopic in nature, dehumidifying dryer and recommended drying procedures must be carried out. Poorly maintained and aging machinery cannot produce quality parts despite using the most advanced processing techniques. In injection molding process, check ring assembly, screw and barrels are considered to be the most critical components. Worn out components can lead to material degradation, poor mixing of additives, non-homogenized melt, under packing and other related issues. Processors often deviate from recommended processing parameters and optimum processing conditions to make up for the deficiencies in tooling and process equipment. Such practices are likely to produce physically inferior quality parts and result in untimely failures. For example, a molder may try to minimize flash created by worn out or poorly constructed tooling by underpacking and produce parts that are visually acceptable. However, underpacking can result in the formation of micro voids that act as stress concentrators and crack initiation sites.

Process related failures generally arise from four major categories:
(a) Improper material drying
(b) Under or over packing
(c) Cold or overheated material
(d) Improper additives/regrind mixing and utilization

Drying

The majority of plastic materials absorb moisture to some degree. The degree of absorption depends strictly on the chemical structure of the material. Non-polar materials such as, polypropylene, polyethylene, polystyrene, PVC, etc have low affinity for moisture and only contain surface moisture. Simple hot air drying is sufficient in this case. Conversely, polar materials are hydrophilic is nature and therefore they have a high affinity for moisture. Materials like nylons, polycarbonate, polyesters, polyurethanes, are considered hydroscopic and must be thoroughly dried using a dehumidifying dryer prior to processing. When exposed to high humidity these materials get fully saturated with moisture and the moisture is trapped inside the resin pellet. This is illustrated is figure 15-21 (a) and (b).



Two things can happen if moisture is not removed completely prior to processing. Parts molding with inadequate drying can have voids and bubbles along with visible splay on the outside of the part. However, lack of visible splay does not necessarily validate proper drying. Moisture laden parts molded from materials such as polyester may not show splay but can be full of voids within the walls of the parts. Voids and bubbles act as stress concentrators and reduce ability to sustain load causing unexpected failures. The second and more severe problem arising from improper drying is one of hydrolysis. Plastics materials like nylons and polyesters that are produced using condensation polymerization technique are susceptible to hydrolysis. During condensation polymerization process water and macromolecules are formed. The water is then removed and the process repeats itself. The water molecules separated during the reaction must be constantly removed in order to allow the reaction to continue and form a very long chain molecule. If the material is processed wet, the condensation polymerization process can reverse itself (hydrolysis) and long chain molecules will split into numerous smaller molecules (14). Hence forth, hydrolysis causes reduction is molecular weight, which in turn results in drastic loss of physical properties and increase in melt viscosity. Note that this process is nonreversible, which means if the molder molds hygroscopic material wet, the molded parts will be weak, brittle, and regrind generated from the parts and runners is degraded and cannot be reused. Loss of properties cannot be recovered by drying and reprocessing.

Packing

Molded plastic parts achieve their highest physical properties when the molecules are tightly packed. This is generally accomplished by injecting material into the mold and immediately followed by packing and holding under pressure until the gate seal has taken place. Maintaining sufficient pressure on the melt as it cools and solidifies is extremely critical due to the high volumetric shrinkage of plastic material. If adequate packing pressure is not maintained, molded plastic part will experience uneven shrinkage. Most significant effect of this shrinkage is residual stresses and warpage. By packing out the parts properly, the molder can also eliminate voids and bubbles. Failure analyst routinely section molded parts and view them under magnification to determine the presence of micro bubbles and voids. Underpacking also creates weak weld lines, a major cause for failures around cored out holes and bosses. Over packing is equally detrimental to the quality of the molded parts. Over packing results in highly stressed parts that are susceptible to warpage, mechanical failure, and are likely to be attacked by chemical and solvents. Figure 15-22 shows a failed part as a result of voids created by underpacking.

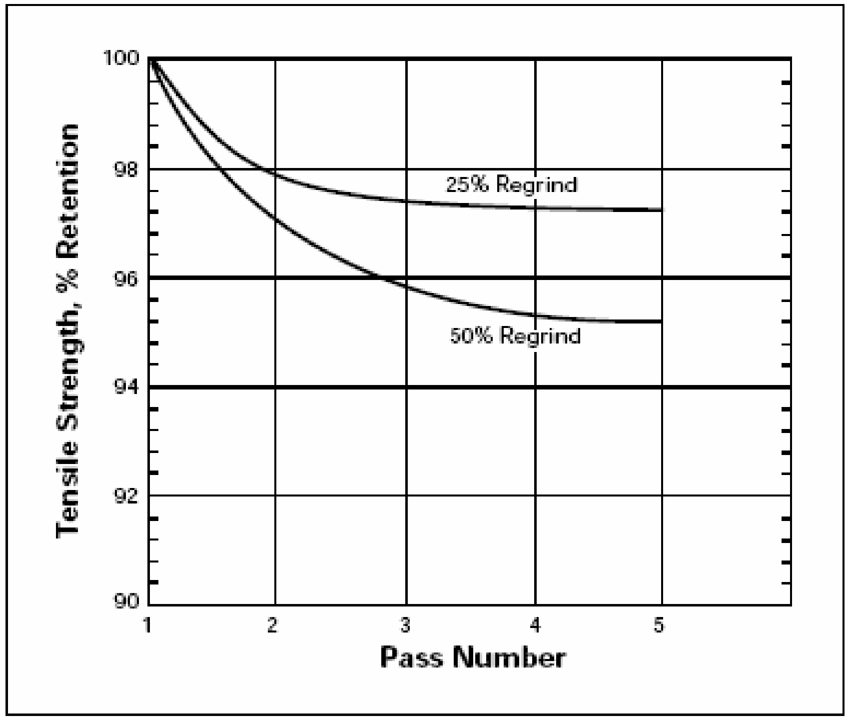
Cold or Overheated Material

Optimum melt temperature is the key to molding physically strong and mechanically sound parts. Amorphous materials soften gradually and subsequently have a wide processing temperature range, while crystalline materials have a sharp melting point and a narrow processing range. Too often molders rely on barrel temperature settings and do not make an effort to measure actual melt temperature. The actual melt temperature can be higher by as much as 50 to 70 degrees Fahrenheit due to the frictional heat generated by the screw and temperature controller inconsistency. Additionally, material can pick up 20 to 30 degree Fahrenheit from the frictional heat generated from high speed injection through a very small nozzle into the mold cavity contributing to the degradation process. Material degradation resulting from overheating lead to molecular breakdown and loss of physical properties. In case of heat and shear sensitive materials like PVC, overheating the melt brings about actual separation of hydrogen and chlorine molecules and formation hydrochloric acid.

This triggers an exothermic reaction which accelerates the degradation process until a complete breakdown of the polymer all the way back to carbon occurs. Finally, overheating can also consume or deplete important additives like antioxidant and weaken the polymer. Conversely, too cold a melt does not allow the material to fuse properly and create homogenized mix.

Improper additive/regrind mixing and utilization

Colors and additives are added to the base polymer for the aesthetic appeal, improve processibility, and enhance performance. Therefore, the proper mixing of the additives is very critical. Additives can generally be viewed in a broad sense as contaminants. Too much or too little can have detrimental effect on the end product. For example, poor dispersion of antioxidant can result in embrittlement in polyolefin films. Regrind generated from the sprue, runners and rejected parts are generally fed back into the machine at a predetermined virgin/regrind mix ratio. Controlled laboratory tests have shown declining physical properties with successive generation of regrind usage. Figure 15-23 shows the results of the experiment graphically. Along with declining properties, there is also marked depletion of the additives such as antioxidants and lubricants which in turn create more processing and product performance issues. Cross contamination resulting from grinding mistakes and inadequate cleaning of the grinder bins and hoppers in between jobs have contributed to many part failures. Proper level of regrind usage and through and uniform mixing is paramount to maintaining integrity of the product.



*Based on maintaining all feed moisture less than 0.1%

Figure 15-23

* From ***Handbook of Testing and Failure Analysis***, 3rd edition by Vishu Shah, John Wiley & Sons.