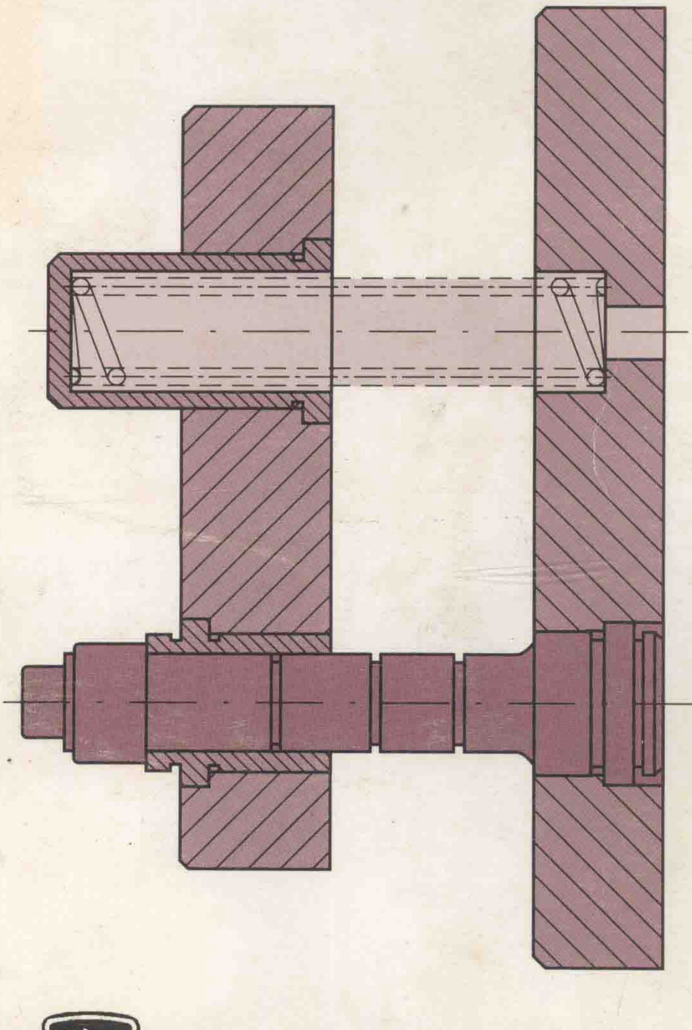
thermoplastic troubleshooting for injection molders

by douglas m. bryce



processing series

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Thermoplastic Troubleshooting for Injection Molders
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SPE Processing Series

"Thermoplastic Troubleshooting for Injection Molders" is the fourth in a series of soft cover training manuals published by SPE. This presentation is intended to provide an uncomplicated, and yet in-depth, understanding of problems that may arise in the injection molding process and to suggest solutions to these problems.

This manual has been developed primarily for the machine operator, laboratory technician, and foreman—those individuals who have traditionally been trained in SPE programs conducted at the Section level. As such, we trust that the manual will be a most valuable adjunct to these grass-roots educational programs.

The three previous manuals have treated injection molding, extrusion, and structural foam, all have proved invaluable in their role as training manuals for non-management personnel. This publication is an expansion on the injection molding manual, in which the treatment of troubleshooting is limited to but six pages.

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Introduction

The practice of injection molding thermoplastic materials has seen significant improvements since coming of age in the late 1940s. This industry has evolved from an "art" to a "science", especially with the advent of computer controls and the inclusion of plastic-oriented classes at more and more colleges across the country and around the world. Some universities are even offering degree programs in Polymer Engineering/Sciences. The infant has become an adult.

Yet, there are many engineers, technicians, press operators, mold makers, supervisors, plant managers, and salespeople who are not able to properly troubleshoot a molding problem when something does go wrong. This manual has been written mainly for those who fall into that category, but it also has been written for the person who simply wants to understand the whys and wherefores of determining the cause of a defect. And this manual is a little different from what you may have seen in the past. This manual will describe a defect, show you a picture of it, and tell you what causes it and what to do to get rid of it. As with other troubleshooting guides, this one will tell you that to get rid of splay you may need to dry the material before molding. But it goes further than that. It also tells you why the material must be dry, and what happens in the injection barrel as a result of moisture being present. It shows you a picture of splay so there is no question in your mind as to what splay looks like. And it gives you a verbal description of what is meant by splay.

The purpose of this approach is to give you food for thought when you need to troubleshoot. I want to help you understand the relationships between machine, mold, material, and operator. Then, you will be able to work your way through a problem situation using a systematic method.

The information in this handbook was derived from over 30 years of personal experience and involvement in the plastics industry. It became apparent to me that there were many troubleshooting guides available, but none of them actually detailed how part defects were created during processing nor what happened when the recommended corrective actions were taken. I saw the need for such a manual — and this is the result of my efforts. This book is intended to be used as a guide for both the seasoned veteran as well as a textbook reference for the beginning student.

The manual is written so that a full chapter is dedicated to each defect. I have selected these defects based on their frequency of appearance during my experience as a molder (since 1960). The causes and remedies are listed in order of probability. Thus, they are classified by Machine, Mold, Material, and Operator. You will find that approximately 60% of all problems are machine related. You also will find that 20% of all problems are mold related, and the rest of the problems are divided equally between material and operator. So, when you approach a molding problem, you should investigate the machine conditions first, since you will find the cause of the problem there 6 out of 10 times.

I must take a minute to discuss part design. I have not included that area as a cause of defects for two very good reasons. First, the person on the floor trying to solve a problem with a product usually has no chance of convincing a part designer that the part should be redesigned. That had to have taken place many months before. The time constraints are such now that no one will be able to make a change if it will alter the production schedule. Second, I am one of those rare people who believes that ANY part design can be molded. Of course, that may mean some exotic mold designs are required and the cost of such a venture may be extremely high; but if the product demands it, then we should mold it. Please look the design over, however, and see if there are any areas that need to be discussed, such as zero-draft walls. It may make your job a little easier in the long run.

One thing you will definitely notice. The same remedy will be used to solve a multitude of defect problems. You will see how that is to be expected once you understand the interactions of all the processing variables.

I have enjoyed many years in this industry and look forward to many more. One thing that I have learned, however, is that no given remedy solves any given problem every single time. This is why some of the guides you read will tell you to raise the temperature of the melt to increase flow, and if that doesn't work, lower it. What I have attempted to do in this guide is to give you the alternatives as I see them, and also to show you the interactions of all the variables so that you will be able to decide on the right remedy for your particular situation. You will "think through" the problem to the best possible solution, and you won't be blindly turning dials and flipping switches without understanding why.

If you are new to the business, welcome. I hope you enjoy your stay. And if you have been around a while, I know you have enjoyed your stay. And, if you are here but are not sure you want to stay, stick with it a little longer because I can safely say to all of you...the best is yet to come.

I hope you enjoy the manual and find it rewarding. I certainly encourage you to write and tell me what works for you, and what doesn't. Also, let me in on any personal solutions you may have developed so that I might share those ideas with others in future editions.

Douglas M. Bryce

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1 Black Specks or Streaks

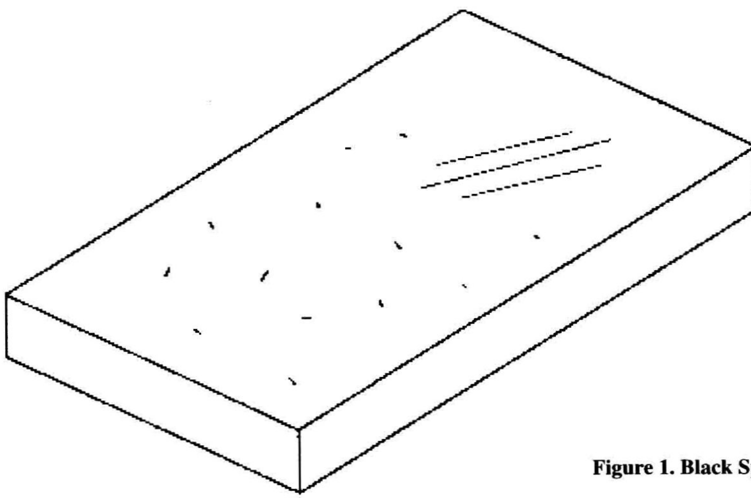

Figure 1. Black Specks

DEFINITION: small dark particles or short dark streaks on the surface of an opaque part and throughout a transparent part.

MACHINE

1. EXCESSIVE RESIDENCE TIME IN BARREL

Ideally, a shot size should represent up to (approximately) 80 % of the capacity of the barrel; a mold requiring a 4-ounce shot should be run in a machine that has a 5-ounce capacity. This is a fairly general statement, because, depending on the heat sensitivity of the material, the ratio can be as small as 20%. However, as the ratio drops, the time of residence in the barrel increases, and so does the likelihood for the material to degrade. This may result in discolored, specked, or streaked resin.

Strive for a 50% to 80% shot to barrel ratio. This is ideal but it can go as low as 20% if the material is not too heat sensitive.

2. "HANG-UP" OF MOLTEN MATERIAL SOMEWHERE IN THE INJECTION BARREL OR RUNNER SYSTEM

Material may get "hung up" in a crack or nicked area of the injection barrel or runner system. If so, the hung-up material will decompose and carbonize. Then it may break loose in small pieces and enter the flow stream of molten material. The hung-up material will not melt but it will appear as a streak or speck.

Inspect the barrel liner, nozzle, check valve, and check ring for nicks, cracks, rough surfaces or stuck resin. Stone and polish as required; replace any damaged shutoff mechanisms; and inspect the main and secondary runners for nicks, rough surfaces or sharp corners. Round off sharp corners and radius corners where possible in order to minimize hang-up points.

3. CONTAMINATION OF INJECTION BARREL

Any type of contamination in the injection barrel may be the cause of streaks and specks. This contamination might be dust particles that dropped from the ceiling, pellets from other materials, residual resin from an improper changeover, or even pieces of food that accidentally fell into the hopper.

To remove this contamination, increase the temperature of the injection unit and, using a purging material with a wide melt range, purge the contaminate(s) from the system.

4. DEGRADATION OF MATERIAL DUE TO LOOSE, WEAK OR UNCONTROLLED HEATER BANDS OR THERMOCOUPLES

Improper or loose heater bands or thermocouples can cause localized degradation if the material is exposed to extreme heat. Even a heater band that's not working can be the cause of overheating. The reason is that the adjacent bands overheat to compensate for the nonworking band.

Check each heat zone to ensure that all bands are working properly, are properly controlled, and are tight. Remove loose bands and thoroughly clean the barrel surface that comes into contact with the loose bands.

5. DEFECTIVE NOZZLE SHUTOFF MECHANISM

Lengthy exposures that are caused by damaged shutoff systems can trap and degrade molten material.

Repair or replace damaged nozzle shutoff system and replace defective check rings or valves.

6. INEFFICIENT INJECTION CONDITIONS

Excessive turbulence in the flow path may cause pockets of air that travel along the liner of the injection barrel. These pockets of air signal the heater bands to increase temperature in small localized areas. When this occurs, degraded material can form and travel into the mold.

A decrease in injection pressure or a decrease in booster time will minimize the amount of turbulence in the material's flow path.

7. CRACKED INJECTION CYLINDER OR PITTED SCREW

A cracked cylinder or pitted screw is the cause of material hang-up and degradation. Eventually, this material breaks loose and enters the melt stream, showing up as specks or streaks.

Inspect the injection unit for cracks or nicks in the walls.

Sometimes the cylinder walls can be welded, but it usually is more efficient to place a "sleeve" liner in the cylinder.

8. OIL LEAKING INTO THE INJECTION UNIT

The above is seldom considered as a possibility, but it happens much more often than is imagined. Hydraulic components or fittings in the vicinity of the injection unit are potential sources of oil contamination. Oil that is subjected to the temperatures found in the injection unit quickly degrades and chars, resulting in black specks or streaks.

The obvious solution is to eliminate the leaks.

MOLD

1. SPRUE BUSHING NICKED, ROUGH, OR NOT SEATING

Either of the above will cause the material to degrade. The reason is that the material is trapped and held in residence until it becomes overheated. The degraded resin will eventually break loose and enter the melt stream, showing up as black specks.

Inspect internal surface of sprue bushing. Remove any nicks or other imperfections. Check with thin paper, or blueing ink, to see that the nozzle is centered against the sprue bushing and that the radius of the nozzle (and its smallest internal diameter) is equal to (or smaller than) that of the sprue bushing to ensure a good seal.

2. BURNED MATERIAL CAUSED BY IMPROPER VENTING

Improperly vented areas show up as a whitish ashing on the mold steel. Ashing is caused by the ignition and burning of air that has been trapped in the mold. The air is forced into "blind" corners; the air ignites after being subjected to the extreme pressures that are created in the molding process.

Place vents in the mold, positioning them as close as possible to the areas that appear to be burned. Sometimes venting the runner system is very effective in eliminating trapped air. Also, a slight increase in material's processing temperature will absorb the trapped air in the molten stream.

3. CONTAMINATION CAUSED BY GREASE OR LUBRICANTS

Occasionally, excessive use of mold release will clog the vents; the clogged vents trap air and the trapped air burns. Also, grease that is used to lubricate cams and slides can seep into the mold cavity and contaminate the molded part.

The remedy is to keep the mold as clean as possible. Make an effort to minimize use of external mold releases and clean the vents when needed.

4. MOLD TOO SMALL FOR MACHINE SIZE

If the total shot size for a specific mold is less than 80% of the barrel size, the greater the likelihood of material degradation, resulting in black specks, streaks, or discolored material.

Using the mold with a smaller machine will help to minimize this condition. A rule of thumb is to use a mold with a machine that injects 20% to 80% of its barrel volume per cycle.

MATERIAL

1. CONTAMINATED RAW MATERIAL

The common causes of black specks and streaks are molding material contamination. Such contamination is as a result of dirty regrind, improperly cleaned hoppers or grinders, open or uncovered material containers, and poor quality virgin material as supplied by the manufacturer.

The above can be minimized by dealing with high quality suppliers and by using good housekeeping practices. Properly training material handlers will also help to reduce contamination.

OPERATOR

1. INCONSISTENT PROCESS CYCLE

It is possible that the machine operator is the cause of delayed or inconsistent cycles. This results in excessive residence time of the material in the injection barrel. If such a condition exists, heat sensitive materials will degrade, resulting in black specks.

If at all possible, run the machine on automatic cycle, using the operator only to interrupt the cycle if an emergency occurs. If it is determined that an operator must be used to start and restart the cycling of the press, try to attain consistent cycles.

2 Blisters

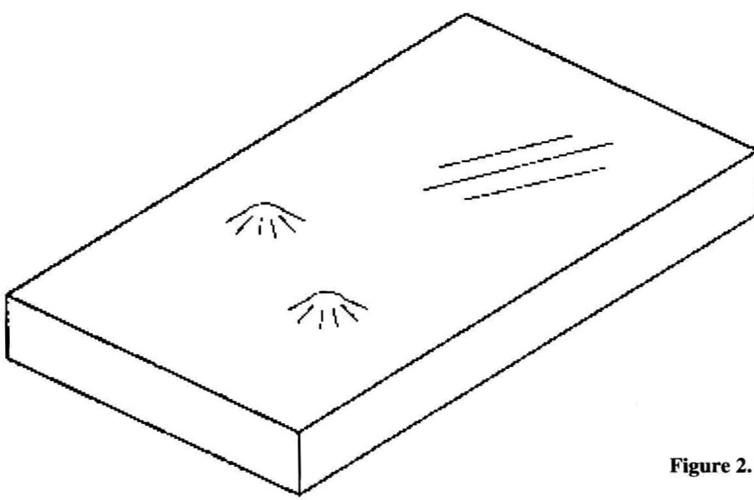

Figure 2. Blisters

DEFINITION: a raised defect on the surface of a molded part caused by trapped gases in the part that could not escape before the surface began to "skin" during the molding process.

MACHINE

1. INJECTION SCREW ROTATION (RPM) TOO HIGH

This will tend to "whip" air into the molten plastic. Excessive air cannot be drawn out during the normal processing of the material. Pockets of trapped air may be forced to the surface which results in blisters being formed. Another result of high rpm is overheating of the material due to excessive shearing action of the screw. This causes gases to develop which may be trapped.

Slowing down the screw rpm will minimize the amount of air that is drawn into the material. It will also minimize screw shear and eliminate any overheating of material.

2. SCREW BACK PRESSURE TOO LOW

The back pressure control of the machine causes a resistance to build up on the material, making the material much more dense. This tends to force out the air that has been trapped in the material and also helps keep additional air from being trapped.

Increasing the back pressure minimizes this trapped air volume.

3. INJECTION SPEED TOO HIGH

Sometimes, due to turbulence, trapped air in the mold itself can be mixed into the molten material if it is injected into the mold at too high a rate. The air does not have a chance to escape through normal venting processes and may show up as a blister.

Reducing the injection speed gives the trapped air a chance to escape.

4. CYCLE TIME TOO SHORT

In the process of minimizing overall cycle times in an effort to reduce manufacturing costs, many molders reduce the cooling portion of the cycle which results in the surface skin of the part not being fully solidified when the part is ejected from the mold. Because of this, any gases that are formed during molding and not vented out are allowed to expand against this soft skin. This results in the formation of blisters.

Although it will increase the manufacturing cost, the way to minimize blisters caused by too short of a cooling time is to increase the "mold closed" portion of the cycle. In some cases, it may help to reduce the temperature of the mold instead, but that may introduce unwanted stresses in the part.

MOLD

1. MOLD TEMPERATURE TOO LOW

As a material is injected into a mold it starts to cool immediately and a "skin" begins to form on the surface of the part. If this skin forms too quickly, any air that is mixed into the material will not be allowed to escape through the surface as is intended in the molding process. A mold that is too cool will cause the skin to form too soon.

Increasing the temperature of the mold will help allow trapped air to escape by delaying the hardening of that skin.

2. IMPROPER GATE LOCATION

As material enters the gate, it seeks the path of least resistance. If the gate is located improperly, the material may not take the proper path to "push" trapped air ahead of itself toward mold vents.

Consideration of material flow paths and vent locations at the mold design stage will minimize trapped air blister problems on "new" molds. Existing molds may require relocating the gate, but this should be done only if deemed absolutely necessary as it can be expensive and may alter the physical properties of the molded part. It is better to attempt to solve this problem by altering molding conditions if at all possible.

3. INSUFFICIENT VENTING

Proper venting is a very important part of building a mold. Unfortunately, it usually is not properly utilized. The correct size, location, and shape of a vent all need to be considered and analyzed in the mold design stages. Inadequate venting will not allow trapped air to escape from a mold, and this will result in blisters, burns, or other defects.

If venting is not allowed in a specific location of the part, it even will help to vent just the runner system. In fact, that is a good idea at any time. Venting is a very important part of the whole molding process. Sometimes there is a question as to where a vent should be placed, but a good rule of thumb is, "If in doubt, vent it."

MATERIAL

1. USE OF REGRIND THAT IS TOO COARSE

This practice increases the amount of air that gets trapped in the melt because the coarse, uneven particles of regrind create "pockets" of air between them and the smaller, consistently sized particles of base material.

One remedy is to use a finer gauge screen in the regrind; Another remedy is to limit the amount of regrind that is used to less than 5%; or one can increase the amount of back pressure on the injection screw, assuming the base material is not too heat sensitive; and the final solution is to use only virgin material. In fact, sometimes this can be done to start the run and regrind (even coarse) can be successfully salted in as the run progresses.

2. USE OF HIGHLY VOLATILE MATERIALS

Some molding compounds, such as liquid crystal polymers release volatile gases during the polymerization process and these gases need a chance to escape from the injection barrel before being injected into the mold.

This is usually done through back pressure control, but some success has been achieved through the use of a vented barrel system. When using back pressure control, care must be taken not to overheat the material, which results in thermal degradation.

3. EXCESSIVE MOISTURE

Improperly dried or stored molding compound will contain excessive moisture because all plastics have a tendency to absorb moisture from the air, or hold moisture that has been accumulated. When processed, this moisture turns to steam in the melt flow and, if not removed through venting, will form a pocket of trapped gas (steam). This shows up as a blister on the part.

The way to minimize blistering due to excessive moisture is to properly dry the material before processing and store it correctly to minimize the future absorption of moisture. Your material supplier will be happy to share the drying information with you.

OPERATOR

There is no certain operator practice that might influence the formation of blisters on injection molded thermoplastic parts. There is a slight possibility that blisters might form if the operator were to open the gate too soon, thus not allowing the part to cool long enough in the mold. But this would have to be very precisely timed, as the part probably would warp, twist, or otherwise deform drastically before blisters would form.