1

Troubleshooting Methodology

1.1 Troubleshooting

Troubleshooting is problem solving. Molding troubleshooters are called upon to resolve problems with the part, mold, machine, or process. There are many problems encountered in injection molding including these general categories:

- Cosmetic defects
- Dimensional problems
- Part breakage
- Long cycle times
- High scrap rate

All of the above lead to increased cost to manufacture a molded part, which often makes the difference between profit and loss. A molding operation that is consistently running high scrap or long cycles is going to struggle to succeed.

1.2 What Makes an Effective Troubleshooter?

The role of a troubleshooter is to find the root cause of a problem and do what is necessary to resolve the problem. Effective troubleshooters will look beyond their initial impressions and ensure that the true root cause has been addressed. Good troubleshooters take a great deal of pride in having the perseverance to solve a problem and ensure that it does not reoccur.

The Merriam-Webster dictionary defines a troubleshooter as:

A skilled worker employed to locate trouble and make repairs in machinery and technical equipment.

A person skilled at solving or anticipating problems or difficulties.

Troubleshooting is a skill that can be learned and this book is intended to help convey some of the knowledge that the authors have learned through many years of troubleshooting. Some of the key things that will help anyone improve at troubleshooting include:

- Willingness to listen to others. Anyone can provide the crucial piece of information that helps solve a problem. A good troubleshooter will listen to people.
- Being observant. A good troubleshooter will always be looking for what might have changed. Good observation skills are critical to troubleshooting. Good troubleshooters live by the motto “show me” rather than trusting that things have been set up correctly. Anyone who has spent time troubleshooting will tell you that there are plenty of cases where they were told that the material was dry or the mold was clean but verification showed otherwise.
- Willingness to learn. Many times when working on a problem a troubleshooter will have to dig deep into a subject to learn what the root cause really is. Be open to learning and use all resources available to become better at troubleshooting. There is always more to learn.
- Perseverance. This is critical to being a good troubleshooter. There are many times when standing at a molding machine for hours gets very tiring. A good troubleshooter is willing to put the time and effort in to ensure the problem is corrected. This also means that they will check back on the problem to ensure that it is corrected.
- Willingness to try things. If a troubleshooter is afraid to try something out of fear of a negative result they will struggle to reach the solution of the problem. A perfect example is a processor who is afraid to open up vents on a mold because of flash. If you do not try to fix the problem it will not be resolved.
- Taking a systematic approach. A good troubleshooter works through a problem using a systematic methodology. Change one thing at a time in an organized fashion and give the change a chance to stabilize.
- Being data driven. Good troubleshooters utilize data to make decisions, and do not rely on assumptions or opinions. If a change is made the data should provide feedback on the whether or not there was an improvement.
- Patience. This may be one of the hardest parts of troubleshooting. Often times a change is made but the troubleshooter is not patient enough to determine the effect and immediately makes another change. Allow processes to stabilize during troubleshooting to determine the ultimate impact.

1.3 What Makes an Ineffective Troubleshooter?

Many of the above characteristics help people to become effective troubleshooters. There are also many traits that make people struggle when troubleshooting including:

- The “know it all”. People that believe they know everything about every aspect of injection molding will one day be in for a rude awakening. Injection molding problems tend to have a humbling effect on troubleshooters, and everyone has something more to learn. Remember every mold, machine, and material combination can create a new opportunity.
- The “this worked last time” syndrome. Many times people get caught in an approach that completely relies on what they have experienced, which in turn puts blinders on them. First understand the problem before trying to implement what worked last time.
- The “Band-Aids and duct tape fixes everything” troubleshooter. This type of person will always look for the simplest thing that can be done whether or not they solve the problem. This mentality often happens in production where the approach can be just “get me the parts I need to make shipment.” While a “duct tape” type of fix may help to limp through a run, the root cause must be addressed and corrected. Putting “Band-Aids” on top of duct tape to keep a job running will lead to scrap and downtime.
- The “flavor of the month”. This often happens when a specific problem is identified and corrected on a given mold in the plant. Often since this solution solved that problem people will try to implement that solution everywhere whether it fits or not.

Overall many people that struggle to effectively troubleshoot are lacking either the time or the tools to be successful. There is always only going to be 24 hours in every day and customer demand for quality parts will persist. This book was written to help provide some tools that can make troubleshooting more efficient and hopefully help people wisely use their time spent troubleshooting.

1.4 Troubleshooting Methodology

As mentioned in Section 1.2, a good troubleshooter uses a systematic approach. The following is a reminder to help with keeping a systematic approach to troubleshooting;

Systematically

Think

Observe

Proceed

This STOP methodology of troubleshooting is meant to do exactly what it says and stop before jumping to conclusions.

Development of STOP

This thought process came years ago while interviewing process engineers and technicians. I would always try to gauge their knowledge by asking questions about how they would handle a problem such as a short shot. The answers I received were usually correct to a point but obviously quite diverse. Often times the answers provided could be the right ones, but, without knowing what was happening, could also lead to disaster. When I reviewed my own mentality, I came to understand that the first thing I would do when troubleshooting was to stop and really examine what was happening. The concept of STOP troubleshooting came about as an easy way to train people in the methodology of troubleshooting.

1.4.1 STOP: Systematically

In the STOP methodology, the S stands for systematically. All troubleshooting should be conducted in an organized and systematic approach. Having a systematic approach will help ensure the root cause of the problem is truly resolved. As a problem is addressed a systematic approach will make it easier to avoid missing a potential cause.

Part of the systematic approach to troubleshooting breaks the problem into four key categories. Many people are familiar with the 5M's often used for fishbone diagrams which are man, method, machine, measurement, and material. For systematic injection molding troubleshooting the 4M's we focus on are:

1. Molding process
2. Mold
3. Machine
4. Material

These 4M's are the key items that a troubleshooter can impact. The "man" is not included because a person can impact any of the 4M's. Each of the 4M's must be considered for potential root causes when troubleshooting. By reviewing the 4M's it is much easier to troubleshoot with a systematic approach. By considering which of the 4M's could contribute and working through one category at a time a list of potential root causes can quickly be gathered.

All of the defects discussed in this book will use the 4M method for description of potential causes. Utilize the possible causes to systematically work through resolving the problem. Keep asking which of the 4M's could be contributing to the defect and why. Always try to drive deeper to get to the root cause of the problem. An example of using the 4M's is when troubleshooting sink: the natural place to start is with second-stage pressure; however, if the pressure is raised to compensate for a machine problem, was the true issue resolved or are you processing around another issue? The goal of the 4M method is to avoid processing around issues. Often times molders are left trying to work "process magic" to get good parts when a tooling improvement should have been implemented. Using the 4M method helps to keep process windows as wide as possible and will lead to less scrap, waste, and PPM (defective parts per million) in the long run.

Most people are familiar with the "5 Why" approach that was developed at Toyota. This approach is a tool that systematically drives toward asking questions about the root cause. In this approach, the goal is to get to the true root cause by asking why after every answer when problem solving. Many people find this technique useful.

One key to a systematic approach to troubleshooting is to review what has possibly changed in the mold, molding process, material, or machine. Frequently people will work on trying to fix a problem but not address what had actually changed that originally led to the problem. In other words, sometimes technicians are struggling to solve the wrong problem. A common example of this is someone slowing first-stage velocity to fix a burn that was actually caused by dirty mold vents. Using a systematic approach will help to focus on the true root cause of the problem and not to process around an issue.

The mentality to keep when troubleshooting should be to try to remove one potential root cause at a time. Until an issue has been proven to have no effect it remains a potential root cause. Using a systematic approach allows a troubleshooter to remove one cause at a time, focusing initially on the most likely causes and working from there. Always remember though that data is key to proving a root cause.

Change one thing at a time and determine the impact. If a troubleshooter changes multiple things at a time it is impossible to determine what the root cause was. After making a change, always give the molding machine time to stabilize before evaluating the impact of the change. If the process change shows no impact on the defect, it can be reset to the original documented process.

It is also vital to make changes that are large enough to have a potential impact. Frequently processors will make an adjustment to a process and when they do not see an impact they scratch that variable off the list of potential causes. Remember that if the change is too large and causes other concerns it can be adjusted back towards the original setting. Make sure a parameter has been thoroughly evaluated before it is removed as a potential root cause.

1.4.2 STOP: Think

Think is the step to make sure that a troubleshooter has mentally reviewed the defect and the potential causes that were systematically determined. Before making a change, it is critical to think through what the expected result is as well as potential side effects. Always begin the think step with the question of “is this a new problem or has it been ongoing?” If it is a new problem focus on what changed; with an ongoing problem the focus is more on what needs to be corrected.

Sometimes in the think step of troubleshooting it is necessary to think outside of the box. Many problems encountered in molding are not easily solved and may require a creative approach to resolve. Willingness to not be constrained by comments such as “that’s not the way we do it” is key to resolving problems. As Albert Einstein said, “we cannot solve our problems with the same thinking we used when we created them.” There are many examples of molds where someone said that an area cannot be vented or cooled but through some ingenuity a solution was found. Remember that there are many exceptions to the general “rules of thumb”; critical thinking is vital.

Also, when thinking through a problem, think bigger than the current defect that is in front of you. Always ask if this problem may be happening elsewhere but has not been detected there. In the case of the 4M machine category, any mold that runs in that particular machine may be having problems but some will be worse than others. If one drying hopper is feeding multiple machines a splay problem may start to show up in multiple parts. Think about the root cause and what else it may impact and examine other parts that could be experiencing similar problems.

When thinking about a problem look for opportunities to push the thought process as far up front as possible. Effort put into part and mold design will result in improved process windows, reduced scrap, and more efficient launches. It is much more cost effective to ensure that the initial design is suitable for manufacturing rather than trying to correct mistakes after the mold has been built and run.

1.4.3 STOP: Observe

Observation is critical to solving problems. Much like Sherlock Holmes, a good molding troubleshooter must observe as much as they can regarding the problem and environment.

Observation should be a multiple sense process, meaning look, listen, and even smell what is happening at the molding machine. Visual examination of the parts, the equipment, and the process will most often provide valuable clues. However, when observing a molding machine in operation, the smell of degraded plastic may be an overwhelming indicator of a problem. Strange noises can also be an indication of something wrong in the process. Always observe with all senses to try to discover any clues to the cause.

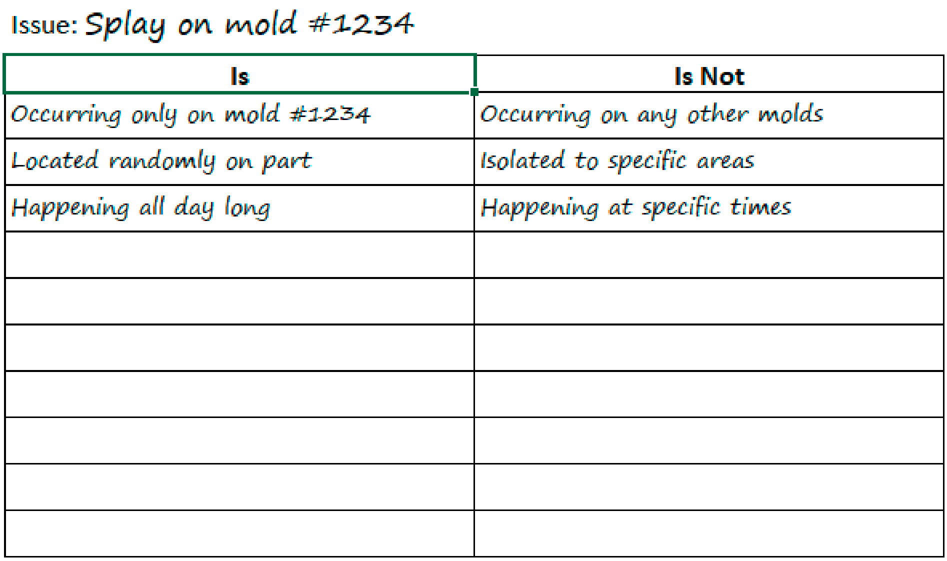
When observing a molding process, a walk around the machine is usually a good practice. A quick walk can often highlight a concern that must be addressed. Key things to look for include:

- Auxiliary setpoints and actual values
  - Hot runner controllers
  - Thermolator
  - Chiller
  - Dryer
  - Gas assist equipment
- Clamp and robot movements
- Trimming operations
- Operator handling
- Material identified and correct
- Clear standards available?
- Anything that is damaged or out of place

Figure 1.1 shows a simple chart called the 4M Basic 8. These are the basic items that need to be observed during initial troubleshooting. Many problems can be resolved by simply working through these eight questions, and a “no” answer for any of these questions indicates a likely starting point for resolving the problem. The 4M Basic 8 is a very simple procedure that all molders should be able to work through and answer prior to calling for technical support. Utilizing the 4M Basic 8 or something similar as a starting point for troubleshooting puts good habits in place for troubleshooters.

1.4.7.6 Is/Is Not

Is/is not can be applied as a simple tool to help narrow the scope of a problem. The way to conduct an is/is not evaluation is to make a chart with headings of "is" and "is not". The problem is then broken down into statements about what it is or is not, as shown in Figure 1.7.



Issue: Splay on mold #1234

Is	Is Not
Occurring only on mold #1234	Occurring on any other molds
Located randomly on part	Isolated to specific areas
Happening all day long	Happening at specific times

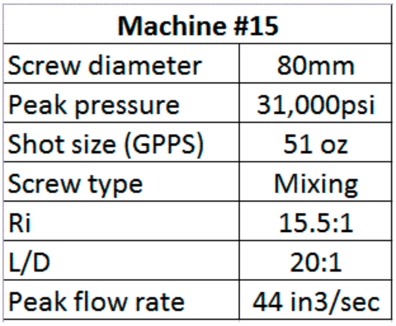
Figure 1.7 Is/Is Not example

1.4.7.7 Change Log

A change log can be used to help keep troubleshooting systematic by providing a way to track the changes made. A change log can be something such as Figure 1.8, which provides a simple sheet to record any changes and the impact that they had on the defect. This can be handy for communicating across shifts so everyone can see what was adjusted and the impact the change had on the problem.

- Distance between tie bars
- Screw type
- Screw L/D
- Screw compression ratio
- Screw diameter
- Intensification ratio
- Tonnage
- Shot size
- Maximum fill rate
- Maximum injection pressure

For ease of access create plaques that can be mounted on the machine to provide key data. Figure 8.18 is an example of machine data that can be posted on a molding machine. A key to people using machine data is making it readily accessible.



Machine #15	
Screw diameter	80mm
Peak pressure	31,000psi
Shot size (GPPS)	51 oz
Screw type	Mixing
Ri	15.5:1
L/D	20:1
Peak flow rate	44 in3/sec

Figure 8.18 Example of a machine data plaque

Repeatable molded parts need to be produced with a repeatable process and a repeatable process requires a repeatable machine. Avoid processing around machine problems or otherwise the process window will be reduced, which will result in scrap and PPM problems.

If a mold is to be validated in multiple machines the lowest common denominator will be what the process should be established at. For example, if a mold is validated in a primary and secondary machine the first-stage speed cannot be set faster than both machines can obtain. Clear documentation of machine details provides for quick analysis of whether a job will run in a given machine.

References

[1] Bozzelli J., Groleau R., and Ward N. “The Machine Audit: A Systematic Evaluation of Injection Molding Machines: How to Tell a Good Machine—Old or New” Antec 1993.

[2] Doyle K., “Know Your Machine”, *Plastics Technology*, May 2014.

[3] Bozzelli J., “Know the Basics of Machine Evaluation, Part 1”, *Plastics Technology*, June 2010.

9 Drying

9.1 Introduction

Removal of moisture prior to processing is absolutely critical for molding success. Moisture in plastic pellets will turn to gas when subjected to molding temperatures. This gas will be contained in the plastic melt until the plastic enters the mold where the depressurization on the melt stream will allow the gas bubbles to reach the surface of the mold, leaving behind the streak of splay. Hygroscopic materials such as ABS, polycarbonate, nylon, TPU, polyesters, cellulosics, or PC/ABS absorb moisture from the environment and require drying.

Some additives including fillers and impact modifiers can result in non-hygroscopic materials needing to be dried. There will be cases when non-hygroscopic materials are literally soaking wet (for example from a roof leak), and in these cases the material will need to be dried prior to molding.

Material suppliers will provide a recommended drying temperature and time for hygroscopic materials. It is critical to follow these drying specifications to ensure that the material is dry enough to successfully process (see below for drying requirements).

9.2 Keys to Drying

Successful drying requires the following:

- Correct temperature
- Dry air
- Air flow
- Time under the above conditions

To ensure adequate drying it is critical to have all four of these conditions met. Four hours of drying time is meaningless if the temperature requirement is not met. A typical desiccant dryer will provide an air dew point of −40 °F. Keep in mind that the dryer temperature will help release the moisture from the pellets, the low dew point will allow the air to pick up the moisture, and the air flow exposes more of the pellets to the warm/dry air. Figure 9.1 shows an example of a typical drying hopper.

Figure 9.1 Typical drying hopper

There are many ways that incomplete drying can occur that relate back to the four key drying parameters.

9.2.1 Temperature

Too low a temperature can come from the following problems:

- Drying temperature set too low:

  It is vital to follow the material suppliers recommended dryer temperature settings. If the temperature is set too low the moisture will not be released by the plastic resulting in lack of drying.
- Incorrect location of dryer control thermocouple or RTD:

  The temperature should be measured at the hopper inlet. If the temperature is measured at the dryer outlet there will be a drop in temperature before the air reaches the material. The temperature set point must account for this temperature drop if you are controlling based on dryer outlet rather than hopper inlet. For improved efficiency use insulated hoses between the dryer outlet and the hopper inlet as this will limit the amount of heat loss.
- A burned-out heater can prevent a dryer from achieving the set process temperature. If the dryer is alarming for low temperature the heater may need to be checked and possibly replaced.

Bear in mind that a higher drying temperature is not the route to faster drying! If a material is dried at too high of a temperature it will become tacky or even melt, which will result in what is often called a “hard ball”, which is when the material pellets stick together and will not feed through the drying hopper. A “hard balled” or “rocked” drying hopper means hours’ worth of difficult work trying to remove the stuck plastic. This is an experience that creates a wonderful learning opportunity, and the person who set the temperature too high should be the one who has to remove the melted plastic; chances are they will not repeat this mistake!

9.2.2 Dry Air

As the moisture is released from the material by heating the moisture must be carried away. Moving dry air through the drying hopper will allow the moisture to be carried away from the plastic. Without providing the dry air the water molecules have nowhere to go and as a result the material will stay wet.

The dryness of air is measured by its dew point, the temperature at which moisture in the air will condense. The dew point of the air should be between −20 and −40 °F for effective drying. Common reasons for not reaching the required dew point include:

- Bad desiccant, either due to the age of the desiccant or desiccant that has been contaminated with plastic fines or byproducts not filtered out of return air. As desiccant pellets can and will go bad, use a dew point meter to determine if there are issues achieving a low enough dew point. Some dryers have dew point meters built into them or portable units can be utilized to monitor a dryer.

- On dryers with multiple desiccant beds you must verify the dew point from each of the beds, and you may find one bad and one good desiccant bed. This means that you will need to verify the dew point over a time period. One way to verify the dew point over time is to purchase a chart recorder to connect to the dew point meter. Another method is to connect the dew point meter to a data monitoring system such as RJG eDART®.
- Return air too hot:

  For optimal performance of a desiccant the return air should be between 120 and 150 °F. If drying set points are above 180 °F the return air will probably be too high for optimal performance. When drying at temperatures above 180 °F an after cooler should be used to cool the return air to below 150 °F. Also keep in mind that return air hoses should not be insulated as this will allow the return air to cool as it travels back to the dryer.
- Burned out regeneration heaters will not provide enough heat to remove the absorbed water from the desiccant. If the regeneration heaters are not working you will see a high dew point.
- Make sure that there are no leaking seals or holes in the drying hoses that would allow moist ambient air to be introduced into the drying hopper.

How to Use an RJG eDART® as a Dryer Monitor

Connect the output from the dew point meter to a 0–10 V analog input module. You can also use a dew point meter from RJG that will connect directly to the eDART® without the analog input module.

Anywhere that you wish to collect temperature data from can have a thermocouple installed, and the thermocouples can then be connected to an RJG Quad Temp Module. You could measure hopper inlet temperature, dryer outlet temperature, and maybe even regeneration temperature.

With the above information you can establish full time monitoring with a permanent eDART® or setup a portable dryer qualification methodology where you monitor the dryer for 24 hours to determine how well it is working.

Checking Desiccant

To verify if a desiccant is working conduct the following experiment: Dry desiccant can be taken from a dryer desiccant canister or it can be dried in an oven for 2 hours at 400 °F (placed in an appropriate container). Allow the desiccant to cool to room temperature and then pour some water into the container with the desiccant. If the desiccant is active there will be a violent exothermic reaction (use caution!) as the desiccant absorbs the water, steam will be observed, and a significant temperature rise will be detected (> 20 °F). If the desiccant is not active there will be no reaction or temperature rise.

An inactive desiccant should be replaced in the dryer because it will not obtain an adequate dew point with a bad desiccant.

9.2.3 Air Flow

Poor air flow can come from the following issues:

- Plugged filters restricting the air flow:

  All dryer filters must be kept clean. Do not run dryers without filters or the desiccant bed will become contaminated and not be capable of achieving adequate dew points.
- Feed hoses can become crushed, which restricts the air flow. Verify that all hoses are free of crushed areas and holes.
- Too small of a dryer for the drying hopper:

  Dryers are measured in cubic feet per minute (CFM) of airflow. If the dryer is undersized relative to the hopper there will not be enough air movement in the hopper to effectively reach much of the material.
- A burned-out blower will result in no air flow. Check that the blower is running and has not burned out. Verify that the dryer is not wired with reverse polarity or the blower will run backwards.
- Most modern dryers will alarm if the airflow is inadequate. Do not make a habit out of silencing alarms on equipment: It is ringing to tell you something.

9.2.4 Time

Lack of drying time typically comes from the following:

- Simply starting up the machine prior to the required amount of drying time:

  This is a plant discipline issue, and processors must know that the material has had adequate residence before starting the press.
- Allowing hoppers to run down before filling them:

  If they run too low you will have material that has not dried long enough. This is also a plant discipline issue. Material handlers cannot be allowed to let hopper volumes run down.
- Material flow:

  Molding expert John Bozzelli has conducted studies that show that some dryer designs will tend to have a “rat hole” flow where the center pellets travel much faster than the outer pellets in the hopper [1]. This is a hopper design problem

3. Valve gates are used to direct the gate onto the part with minimal vestige and are also used to control the flow when using multiple valve gates. Because they can be shut off independently you can control flow fronts and knit line. When doing a color change with a valve gate the previous color may stick to the pin and continue to drag out. Cycling the valve open and closed can help with breaking free of the previous material or color.

11.5 Drooling, Stringing, and Sprue Sticking

Drooling from the hot drop tip or sprue is usually a result of a lack of cooling or lack of bearing surface. Tip designs over the years have incorporated insulator gaps and minimal contact with the tip to prevent freeze off and heat transfer to the cavity blocks. In many cases and with some materials this is a good thing. But with some materials an increased contact surface with the cavity steel along with cooling lines around the hot drop is necessary to prevent drooling, stringing, and sprues from sticking.

11.6 Freeze Off

Freeze off in the tip area is usually caused by a lack of heat or the orifice size being too small. With some materials, especially semi-crystalline polymers such as nylon, temperature control at the tip is critical. This is when you want minimal contact surface with the tip and the cavity steel. Many hot runner suppliers use different tip designs to increase temperature control at the orifice. Low vestige tips have a pointed insert, typically called a spreader tip, that is designed to maintain temperature control at the orifice to prevent freeze off. The location of this spreader tip in relation to the orifice is critical and manufacturer specifications should be followed.

11.7 Orifice Size

The orifice size will depend on the material, wall stock, and tip style being used. It is important to keep an open mind with orifice sizes when addressing issues with pressures, high gates, drooling, freeze off, and scrap.

Selection of proper orifice size must be analyzed carefully to ensure a balance between all factors. Computer-aided flow analysis can help with predictions of how well a given gate orifice will be at filling and packing a mold. Consult with material suppliers and hot runner manufacturers for recommendations on orifice sizes.

Case Study

This concerns a part having a scrap issue with splay where the orifice size ended up being the solution. This was a part with four low vestige tips that had a spreader tip in the center of the gate orifice. Many will just consider the orifice diameter and not include the area of the spreader tip that reduces the volume. In this case the orifice diameter was 0.050″ and the spreader tip in the center of the gate was 0.025″ diameter. The area of the spreader tip reduced the area/volume by 25%. The fill speeds with this gate needed to be on the high end to make a good part but we struggled with a lot of splay. We opened the orifice diameter to 0.060″, which was an increase of 55% in area/volume when considering the area that the spreader tip took away. This allowed us to adjust the fill speed and eliminate our splay/shear issue.

11.8 Leakage

Hot runner leakage can be a major problem that will shut down a mold. A big development toward reducing hot runner leakage occurred when the hot drops started being threaded to the manifold versus relying on the stack height, seal rings, and bolt patterns in the mold plates to hold the hot runner together. Some toolmakers complained from a maintenance perspective that this was more difficult to work on when the drops had to be removed for service. In some cases this was true with threads getting galled up and creating another mess. But improvements with thread designs and coatings have reduced this concern among toolmakers. So in the big picture of hot runner issues this has been a big improvement for maintaining molds.

Another observation over the years, but not a common one recently, is with support in the hot half. If the areas cleared out for the hot runner are excessive, cavity pressure can lead to deflection within the mold plates leading to leakage.

11.9 Zones and Wiring

Hot runners have zones, typically identified with numbers, which are dependently controlled with a heater and a thermocouple. It is important to have the wires labeled for each zone so it is easier to troubleshoot versus having to chase wires down, especially when multiple zones are used. A hot runner schematic should be on the side of the tool showing each zone, location, and the heater watts.

The power plug/connection and the thermocouple plug/connection are also identified by zones. So, for example, the zone 1 heater leads would be to zone 1 on the power plug and the thermocouple to zone 1 on the thermocouple plug. The two wires coming off the heater are the same but on the thermocouple they are not. The thermocouple has a positive and negative wire that must be wired to the correct location on the plug or it will not function properly. Similar to the battery in your car, it is not complicated but will not work if wired in reverse. Also, thermocouples come in different types but the J type with the red and white wires is most common. The positive wire is magnetic, and is the white wire for the typical J type, and the red one is the negative. If you are ever in doubt which one is the positive wire you can use a magnet to find out. Make sure to use the proper thermocouple for the chosen hot runner controller. With thermocouples be cautious adding wire extensions unless you are experienced with proper methods and problems with cold junctions. With the heater and thermocouple any connections with extensions must be insulated.

11.10 Hot Runner Troubleshooting

There are some things you can do in the molding machine to troubleshoot hot runners instead of pulling the mold for repair. A first thing to try when having hot runner issues is to change out the cables and controller. Long experience has shown that the controller or cables are often the source of the issue. Also, just because the controller shows a zone at the proper set temperature does not necessarily mean that this is the case if you are having an issue. Also verify the pins in the plugs, because at times they can get pushed in not making contact with the connection on the cable plug.

Use a pyrometer with a 0.040″–0.060″ diameter sheath thermocouple to verify temperatures inside the hot drops or the inlet channel. With valve gates you pull the valve pin back to get inside the drop flow channel (note: always use proper safety precautions including face shields and move the injection unit away from the mold to avoid a blowout while probing tips). Make sure to contact the steel in

23 Contamination

23.1 Description

Contamination is a broad term that covers visual defects that appear in a molded part. Contamination may show up as specks of discoloration, streaks, splay, delamination, etc. See Figure 23.1 for an example of material contamination.

Also known as: black specks, black/brown streaks, color swirls

Mistaken identity: splay

Figure 23.1 Material contamination

23.2 Contamination Troubleshooting Chart

Table 23.1 shows the contamination troubleshooting chart.

Table 23.1 Contamination Troubleshooting Chart

Molding Process	Mold	Machine	Material
poor changeover	hot runner hang up	hang up areas	improper storage
high melt temperature	high hot runner temperature	anti-seize	regrind
	wear surfaces	robot contamination	incoming contamination
	lubricants		mixed materials
	cleaning		

23.3 Contamination Troubleshooting

There are a wide variety of ways that material can become contaminated. It can be a major challenge to try to work through all the possible routes of contamination. Most of the time the best place to start is with the material being brought to the molding machine and work backward from there.

23.3.1 Contamination Troubleshooting Molding Process Issues

Contamination can be brought on by several process issues including:

- Poor changeover
- High melt temperature

23.3.1.1 Molding Process: Poor Changeover

When a molding machine is stopped and goes through a material or color change there are many opportunities for contamination to occur. The entire feed system and melt delivery system must be thoroughly cleaned out to ensure that there is no residue of the prior material. Some of the key areas to examine include:

- Drying hopper. The drying hopper has several hang up areas including along the door edge, in the hopper loader, around the dispersion cone, the sample/drain tube, and in the distribution box. When conducting a material change all of these areas must be cleaned of all remains of the previous material. Hoppers can be vacuumed out to help with clean out. Watch out for areas such as the sample tube because this is a spot that is often forgotten.

- Feed lines. Whether feeding the machine from the drying hopper, gaylord, or bag, it is critical to ensure that all of the material has been cleaned out. This is usually as simple as removing the feed line and allowing the vacuum loader to suck all of the material out of the feed lines. There have been cases were the material handler does a nice job of cleaning everything out but forgot the feed lines and when the new material was introduced all of the previous material was pulled in with it, contaminating the material.
- Machine hopper. The machine hopper will have a variety of locations where material can collect. Make sure to remove the magnet and clean out around the magnet drawer (see Figure 23.2). The hopper should be completely cleaned of all residue from the previous material. Also be sure to watch for any mismatch ledges between components such as the feed throat and hopper.
- Loaders. Loaders can also be a location that will trap material pellets. All loaders must be cleaned as part of the material changeover process.
- Additive feeder bins. Additive feeder bins must be cleaned when swapping colors. The feed screw on a volumetric feeder must also be removed and cleaned to avoid contamination.

Figure 23.2 Pellets stuck in magnet drawer

Often times molding shops will provide very little training for material handlers. If a material handler does not understand the importance of thorough cleaning during material changes they may cut corners which will lead to contamination. Provide a formal training for everyone in the shop that is responsible for loading materials to ensure that changeovers are executed correctly.

23.3.1.2 Molding Process: High Melt Temperature

When plastics are overheated they can degrade and contaminate the material with black specks or streaks. See Chapter 15 on black specks for more information about this problem.

23.3.2 Contamination Troubleshooting Mold Issues

Mold-related concerns that can cause contamination include:

- Hot runner hang up
- High hot runner temperatures
- Wear surfaces
- Lubricants
- Cleaning

23.3.2.1 Mold: Hot Runner Hang Up

Any areas in a hot runner system that can trap material can lead to contamination. Material trapped in hang up areas can continue to bleed into the melt stream long after the material change has been completed. When dealing with materials that are more temperature sensitive the trapped material may degrade and contaminate the parts with charred black specks. Figure 23.3 shows contamination from a hot drop tip.

Hot runner assemblies should be built in a way that at running temperatures there will be neither ledges nor mismatch locations that would hang up material. Drops must be securely assembled to the manifold so as to not leave any gaps between the drop and the manifold body.

Corners in hot runner manifolds can easily lead to dead spots where material hangs up. Depending on the hot runner design some manifolds will have corners that are gun drilled at 90° intersections. With a 90° intersection the outside of the corner will end up as a dead spot and material will be trapped in this location. Better designs have machined corner plugs with a curved corner, no dead spots.

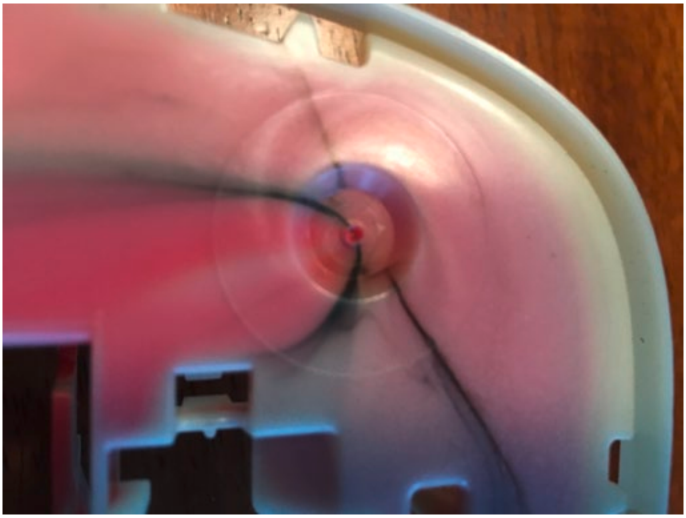


Figure 23.3 Contamination at hot tip

A manifold can be damaged and cracked which will provide a gap at the crack that will allow material to become trapped. Cracking a manifold is usually a result of a cold start where the manifold was not given enough time to heat soak. Cracked manifolds often need expensive and time-consuming repairs; therefore, educate process technicians to give a hot runner plenty of soak time before injecting plastic through the manifold.

23.3.2.2 Mold: High Hot Runner Temperatures

When hot runners are running at higher temperatures than is required for a material the odds of degrading material increase. As the material degrades in the hot runner system the result can be brown streaks or black specks contaminating the part.

Verify that the hot runner temperatures are set correctly and that actual temperatures are reading accurately. If a hot runner zone is constantly calling for heat it may indicate that a zone is either wired incorrectly or has a thermocouple misplaced.

23.3.2.3 Mold: Wear Surfaces

Any surfaces on a mold that rub against another surface have the opportunity to wear. Over time the metal dust or flakes that are worn from the surface can contaminate the cavity of the mold. This metallic dust will contaminate the molded part and may produce a visual defect.

Wear surfaces to keep an eye on include gibs, wear plates, die locks, cavity locking angles, and shutoffs. The dust that appears is often an early sign of galling starting so it is important to address any wear problems when they are detected.

23.3.2.4 Mold: Lubricants

Any of the lubricants used on a mold can lead to contamination of a molded part. Whether it is grease or oil, when excess lubricants reach the cavity they can contaminate the part producing scrap.

A key item to watch for is over-lubricating a mold. Frequently when a mold comes back from service, all moving components will have too much grease on them. There can be cases where a mold will bleed grease for hours of molding, producing nothing but scrap. Work with tooling sources to establish a standard method of lubricating a mold. It is not as simple as smearing some grease on the pins; grease should be lightly applied because over-greasing can lead to problems.

It is also important to find lubricants that work best for a given application. There is a wide variety of lubricants available and some perform better for specific applications.

23.3.2.5 Mold: Cleaning

Mold cleaning or lack of cleaning can both lead to contamination. For optimized processing a mold should be kept clean. Molds that are dirty can lead to surface contamination of molded parts. Caution must be used when cleaning molds, though, because mold wipes can leave behind fibers that can then be molded onto the surface of a part resulting in a squiggly, worm-like defect (see Figure 23.4).

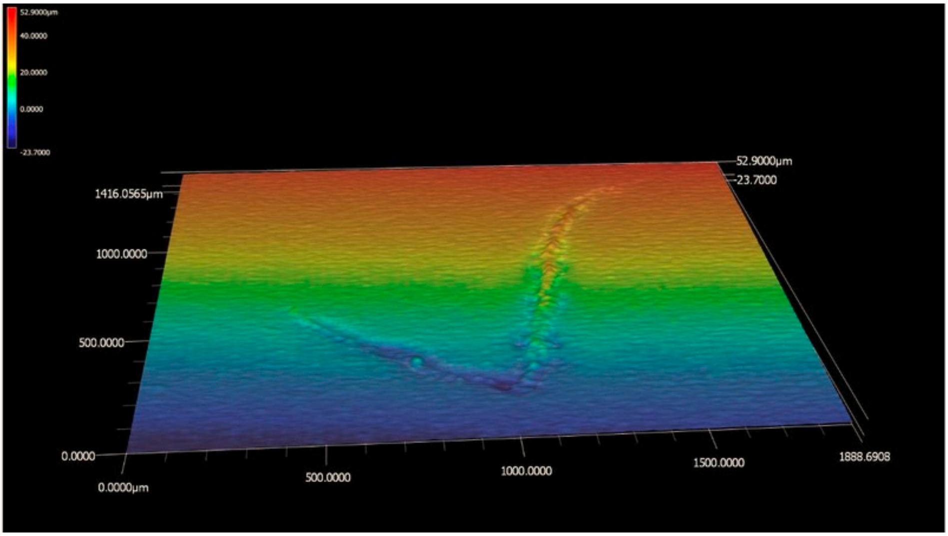


Figure 23.4 Surface scan of a mold wipe fiber molded onto a part surface

When wiping a mold surface, use clean lint-free wipes to minimize the opportunity for contaminating the mold surface. A dirty wipe not only leaves behind contaminants but may also scratch the mold surface.

Be aware that there are cases where the grease in the mold breaks down due to chemical contact. This can be magnified if someone sprays mold cleaner directly on the ejector half of the mold. The cleaner solvents can impact the viscosity of the grease leading to contamination of the molded part from the broken-down grease.

23.3.3 Contamination Troubleshooting Machine Issues

Some of the machine factors that can lead to contamination include:

- Hang up areas
- Anti-seize
- Robot contamination

23.3.3.1 Machine: Hang Up Areas

Any areas in the melt delivery system that have a mismatch can cause material to hang up. Some of the key areas that should be evaluated for hang ups include:

- Hopper to feed throat
- End cap to barrel
- Nozzle adapter to end cap
- Nozzle to nozzle adapter
- Nozzle tip to nozzle
- Nozzle tip to sprue bushing
- Damaged spots on screw, barrel, non-return valve, and end cap

It is a time-consuming process to disassemble these components and inspect for hang up areas but sometimes it is necessary to get to the root cause. Prior to shutting down for disassembly run another color of material through the barrel. This alternate color can help highlight spots where the original color is being trapped. Also look for areas of charred material when conducting this inspection. Again, this is a time-consuming process so make sure other potential causes are investigated first.

Examination of nozzle tips of different style will show locations where material can become trapped. See Figure 23.5 for cross sections of common nozzle tips: notice the potential dead spot at the ball end of the general-purpose style tip. General-purpose tips can cause contamination and streaking issues due to this dead spot.

Figure 23.5 Nozzle tips: general purpose, nylon, and full taper

23.3.3.2 Machine: Anti-seize

If people are conducting proper installation of new nozzles and nozzle tips they are applying thread anti-seize molded onto the nozzle threads to prior to assembly. If too much anti-seize is applied to the component it is possible to contaminate the plastic melt stream with the anti-seize (see Figure 23.6, for example). Anti-seize will usually result in dark streaks in the part.

Figure 23.6 Nozzle tip with excess anti-seize (top) and appropriate amount of anti-seize (bottom)

Anti-seize is an item where “if a little is good a lot is better” does not apply. Teach processors to use an appropriate amount of anti-seize to avoid running scrap at startup.

23.3.3.3 Machine: Robot Contamination

Take a look at the robots in the shop. Are they dusty with grease drips in various locations? When a robot enters the mold to pick a part it can contaminate the mold. One example of this is when a dirty air line brushes up against the cavity, because this will transfer some of the dirt and potentially lead to a cosmetic defect.

Another factor to consider with the robot is the condition of the end-of-arm tooling. If it is very dirty the vacuum cups can leave a surface contamination on the part. Also if components from the end of arm tooling touch the mold surface they may leave behind contamination that can end up in the cavity.

Case Study: Robot Contamination

This example was on a single-cavity ABS part that was experiencing what appeared to be splay. Examinations of drying conditions, moisture content, venting, process settings, and melt temperatures all led nowhere. Utilizing the STOP methodology and observing the process showed that when the robot picked the part it backed away from the ejector and a dirty air line brushed against the cavity. The cycle was stopped and a small smudge of grease/dirt was detected on the cavity. The part was molded and it was scrap due to the contamination. A couple of cable ties and some cleaning resolved the issue. In this case utilizing the STOP methodology earlier would have led to quicker effective troubleshooting.

23.3.4 Contamination Troubleshooting Material Issues

There are many ways that a material can become contaminated including:

- Improper storage
- Regrind
- Incoming contamination
- Mixed materials

23.3.4.1 Material: Improper Storage

In every molding shop there are a wide variety of foreign contaminants including:

- Dirt, dust, and pollen
- Other plastics

33 Gloss Variation

33.1 Description

Variations in gloss on a part will lead to cosmetically unacceptable parts. If the part has areas that are glossy and areas that are dull the variation in appearance can be very unattractive. Figure 33.1 shows an example of gloss variation.

Also known as: spotty, glossy, dull

Mistaken identities: sink, scuff

Figure 33.1 Gloss variation

33.2 Gloss Variation Troubleshooting Chart

Table 33.1 shows the gloss variation troubleshooting chart.

Table 33.1 Gloss Variation Troubleshooting Chart

Molding Process	Mold	Machine	Material
second-stage pressure	mold surface finish	machine performance	material type
second-stage time	cooling		additives
fill velocity	venting		
fill only weight	inconsistent wall stock		
mold temperature			
melt temperature			

33.3 Gloss Variation Troubleshooting

Gloss is determined by the nature of the surface of the mold, i.e. polished or grained, and how well the plastic replicates the mold surface. The first step of troubleshooting gloss problems is to establish if the mold surface is being replicated. As an example, if a mold surface is a sand-blast finish the part will be dull no matter what the process is (see Chapter 6 for more on mold finish).

Another item to keep in mind when reviewing gloss callouts is that parts that are on the two ends of the gloss spectrum will tend to show scratch and mar defects easier than parts with a more mid-range of gloss. Sometimes the difference between a 2.5 and 3.5 gloss reading can make a major difference in the appearance of the part and the ability of the part to look good after handling. Extremely low gloss levels such as a 2.5 can make it very challenging to get a good-looking part.

It is important to understand that in many cases gloss problems are actually truly a read-through (difference in gloss due to differential pack and shrink at wall stock transitions).

33.3.1 Gloss Variation Troubleshooting Molding Process Issues

Common molding process related problems include:

- Second-stage pressure
- Second-stage time

- Fill velocity
- Fill only weight
- Mold temperature
- Melt temperature

33.3.1.1 Molding Process: Second-Stage Pressure

The most important process setting for gloss on molded parts is the pressure applied to the plastic in the cavity. If not enough pressure is applied to the plastic the molded part will not replicate the finish of the mold well. This applies for polished surfaces, textures, and sand-blasted finishes. Think about the surface of the molded part compared to the mold surface: is the plastic being packed into all of the microscopic surface detail of the surface of the mold?

Examining mold surfaces under magnification will show a series of polish scratches on polished surfaces and a series of peaks and valleys on a textured part. To have adequate replication of these microscopic surface details the plastic has to be pressurized at the appropriate levels. If the pressure is not high enough, the surface will not reflect the details of the mold surface.

Variation in pressure across a mold will result in a potential variation in gloss levels across the part. Low-pressure areas will not replicate the surface as well, and will typically have a different gloss appearance when compared to better-pressurized areas. This can often manifest as a distinct difference between areas near and farthest from the gate. Also watch for areas that fill quickly and freeze before being packed out.

One of the challenges faced in injection molding is trying to minimize the pressure drop across the mold cavity. Some of the keys to minimizing pressure drop include filling fast to avoid viscosity variations during first-stage injection. Proper gate placement is also critical to ensuring a minimized pressure drop. To determine gate quantity and location a flow analysis software such as Moldflow® is a valuable first step before steel is cut.

When troubleshooting for gloss problems check that the second-stage pressure is set at the correct value (do not forget to account for intensification ratio). Also check to see if the correct nozzle and nozzle tip are being used because a mixing nozzle will result in a large pressure drop between the machine and the end of the cavity.

Cavity pressure transducers will provide very useful data on the actual pressure within the mold. If a transducer is located near the gate and at the end of fill location, accurate data on what is occurring in the cavity will be easy to obtain.

33.3.1.2 Molding Process: Second-Stage Time

Second-stage time that is not long enough to ensure gate seal can lead to a glossy area near the gate. If the plastic is not retained in the cavity until gate seal there will be a depressurization of the plastic near the gate. The release of plastic near the gate will create a localized low-pressure area that will typically have a different gloss level than the rest of the part.

Verify that the second-stage time is set correctly per the documented process. A gate seal study should be conducted during process development to determine the appropriate second-stage time. If a gate seal study was not conducted take the time to complete a gate seal study to understand the correct time required for establishing gate seal.

33.3.1.3 Molding Process: Fill Velocity

Generally, a faster fill velocity will provide less pressure drop and yield better surface replication. Faster fill rates tend to provide a glossier surface whereas surfaces obtained with slow fill rates tend to be duller. Faster fill velocities also lead to a part that will pack out more uniformly.

Verify that the fill time is correct according to the documented process. Fill velocity settings may not match, but fill time should. If fill time and fill only weight replicate the desired process that ensures that the same volumetric flow rate occurred.

33.3.1.4 Molding Process: Fill Only Weight

If the fill only (95–98%) shot is too light due to an early transfer there may be a gloss difference that forms in a sharp line where transfer occurred. An early transfer can create a very distinct area at end of fill that looks different.

Check the fill only weight to ensure that the part is filled to 95–98% during first stage. If the shot is short the transfer position should be adjusted to provide an adequate fill shot. Be aware that filling too short can lead to a lag in second-stage pressurization. Figure 33.2 shows process monitoring data on a process with an early transfer. Note how the screw travel curve moves significantly after transfer. As the screw continues to move forward the machine is trying to reach the set second-stage pressure but it takes several seconds. Early transfer creates many issues but gloss variation is an often-overlooked problem.

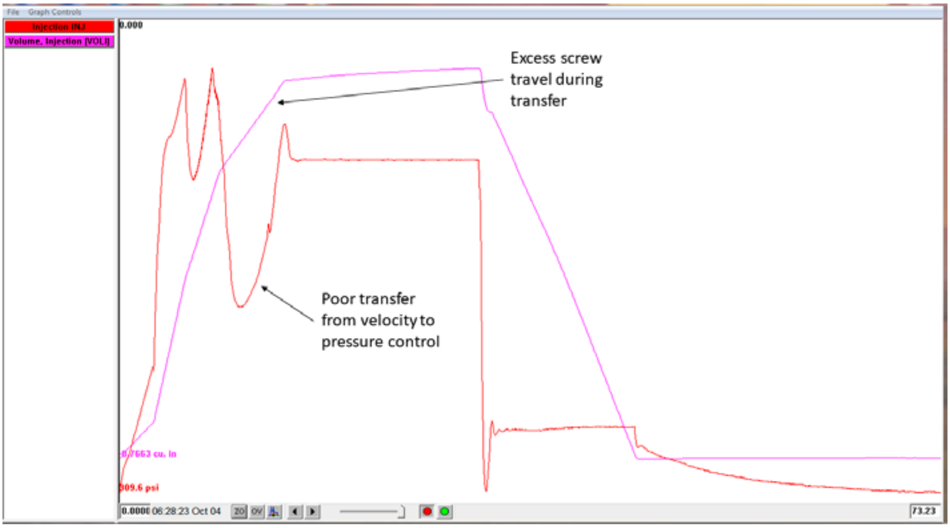


Figure 33.2 Process monitoring curves showing an early transfer

33.3.1.5 Molding Process: Mold Temperature

A low mold temperature can tend to produce a lower gloss level whereas a higher mold temperature can produce a higher gloss level. However, this is another factor that impacts how well the plastic replicates the mold surface, and hotter mold surfaces lead to better replication of the mold surface.

In recent years rapid mold heating and cooling systems have been used to improve the replication of the mold surface. The extra heat that is applied to the mold surface allows the plastic to pack out against the steel much better. Use of rapid mold heating and cooling can yield very high-gloss surfaces when molded on a polished surface. If the mold has a micro texture the replicated surface can be very low in gloss.

There are times when high mold temperatures lead to a rippled surface that will show variation in gloss. The heat of the mold creates an effect where the wall is collapsing away from the mold surface that is sometimes referred to as “heat sink”. Reducing the mold temperature or adding second-stage pressure will often resolve this defect.

33.3.1.6 Molding Process: Melt Temperature

When molding with a low melt temperature the pressure drop across the mold will be increased. With the increase in pressure drop many times a variation in gloss will occur. If the mold is not pressurized at a uniform level there is likely going to be variation in gloss levels.

Verify that the melt temperature matches the documented process. If the melt temperature is wrong then evaluate the following:

- Barrel temperatures set point versus actual
- Back pressure
- Screw recovery rate

33.3.2 Gloss Variation Troubleshooting Mold Issues

One of the biggest impacts on gloss levels of a molded part is the mold itself. The main factors that impact the gloss level are:

- Mold surface finish/texture
- Cooling
- Venting
- Inconsistent wall stock

33.3.2.1 Mold: Surface Finish/Texture

One of the biggest contributors to the gloss of a molded part is the mold surface finish. A sand-blasted mold surface will not produce a high-gloss piano black gloss level no matter what is done to the process.

There is a wide range of finishes that can be used for an injection mold. They include:

- Polish
- Texture
- Sand/glass blast

All three of the above options also have many different levels that can impact the part appearance. For example, a polished surface can be polished to a variety of gloss finishes.

If nonuniform gloss is a problem on a part, the surface of the mold should be inspected for areas of variation on the surface. To effectively do this a strong light is often needed to avoid shadows on the surface. Many times upon inspecting the mold surface, areas of worn texture or buildup will be visible. Sometimes a thorough cleaning of the mold surface will eliminate the variation and other times the mold will need to be sand blasted. Inspecting the mold surface can eliminate a lot of troubleshooting time because if the gloss problem is on the mold surface, processing will not resolve it. Buildup can also be an issue on polished surfaces (see Figure 33.3).

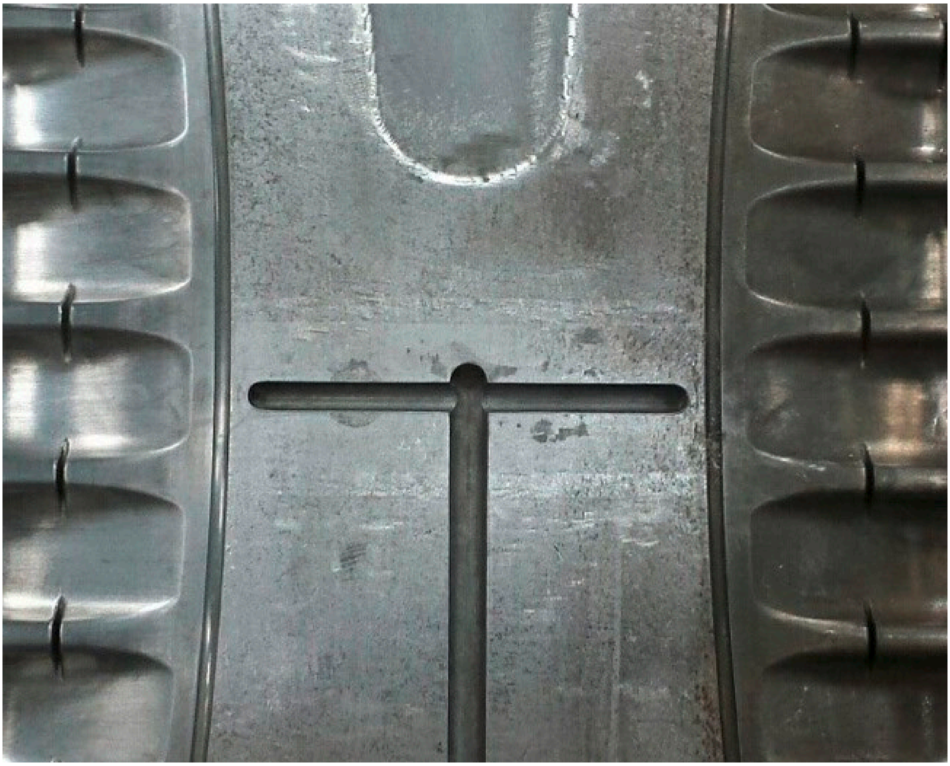


Figure 33.3 Mold surface buildup (right) versus clean surface (left)

Case Study: Polish Buildup

In this case the material being molded was a wood-filled polypropylene. The mold had a polish level of approximately SPI A3, which produced nice glossy black parts when molded with straight polypropylene. An extended run was conducted for a special order of wood-filled polypropylene parts that molded well; however, when the material was changed over to the black polypropylene the gloss level of the parts was dull and inconsistent. Examination of the mold surface showed there was a large amount of buildup on the mold surface and the steel had even tarnished from the gases from the wood-filled material. After many hours of scrubbing with polishing paste, the mold was finally ready for running at high gloss.

Often when a mold texture is used there will either be a secondary micro texture or a sand-blasted finish that creates additional small details that the plastic must be packed into. Under magnification these peaks and valleys will be easy to see and examine for detail. In Figure 33.4 texture details can be viewed under 200× magnification: notice the peaks and valleys that the material must replicate.

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