

Gate and Runner Size—Why It Matters

Ross Jones

The feed system of an injection mold is responsible for transporting molten plastic material from the machine nozzle to the mold cavity. Figure 1 shows a typical cold runner feed system for a conventional two-plate tool. The feed system consists of a sprue, runner, and gate. Improper sizing of this feed system can lead to:

- Cosmetic defects
- Reduced material properties
- Excessive part cost
- Narrow processing windows

Properly sizing the feed system for an injection molded part is not only critical to reducing part cost but crucial for manufacturing high quality parts.

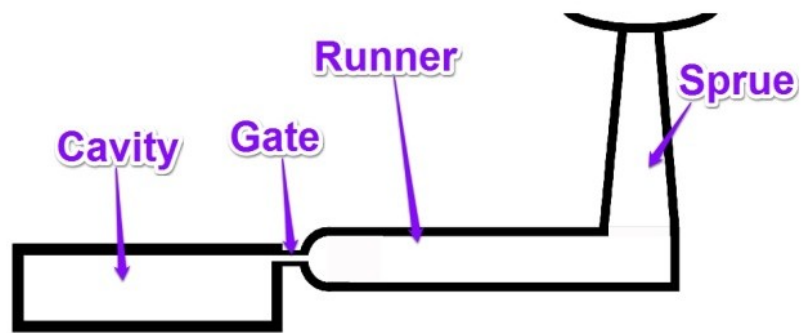


Figure 1: Schematic of a feed system for a conventional two-plate tool.

Sizing the gate:

The gate is the transition zone between the runner and the part cavity. The primary goals when optimizing gate size are maximizing control over the packing stage, avoiding excessive pressure drop, and maintaining acceptable shear rates. The larger the gate size, the longer the packing stage and the lower the pressure increase.

The injection gate is typically the region of the feed system with the smallest cross-sectional area. As a result, the gate is usually where the plastic material experiences the highest shear rate. Shear rates experienced by the material are a function of injection speed and cross-sectional area, Equation 1. In the shear rate equation, the cross-sectional area of the flow path is exponential (for a circular cross-section, the radius is cubed).

$$\dot{\gamma} = \frac{(4 \cdot Q)}{\pi \cdot R^3}$$

($\dot{\gamma}$ = Shear Rate, Q = Flow rate, R = Radius)

Equation 1: Shear rate through a circular cross-section for a Newtonian fluid

Therefore, a small change in the radius or thickness of the gate will have a dramatic effect on shear rate. Amorphous (PC, PMMA, etc.), fiber reinforced, and heavily filled resins are typically more shear-sensitive materials. Therefore, they require larger gate sizes to reduce temperature rise and pressure requirements. As a general rule the gate size for a fiber-filled resin should be 10% larger than an unfilled resin. Reducing shear on the material is vital to minimizing fiber damage during injection. Unfilled semi-crystalline materials are typically less sensitive to shear than amorphous and fiber reinforced materials. This allows for smaller gate sizes and higher shear rates.

Figure 2 displays a commonly used gate style known as the “tunnel” or “sub” gate. This gate style allows for automatic degating during part ejection and avoids a secondary gate removal

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process. Tunnel gates are typically 50-80% of the injected wall to ensure breakage at the gate and avoid excessive wear on the mold. Reducing the gate size will reduce the length of the pack cycle. However, a shorter packing stage can lead to high shrinkage, voids, and warp.

Figure 3 displays another commonly used gate style known as the “edge” gate. This gate style requires a secondary gate removal operation. When necessary, the edge gate design allows for larger gate sizes and more control over the packing stage. Additionally, edge gates help maintain lower shear rates and injection pressures. Similar to tunnel gates, edge gates are typically 50-80% of the injected wall thickness.

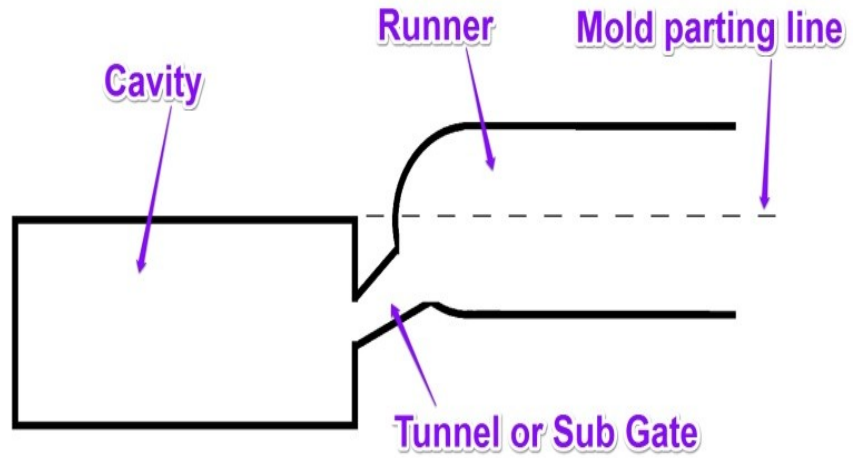


Figure 2: Schematic of a typical tunnel or sub gate.

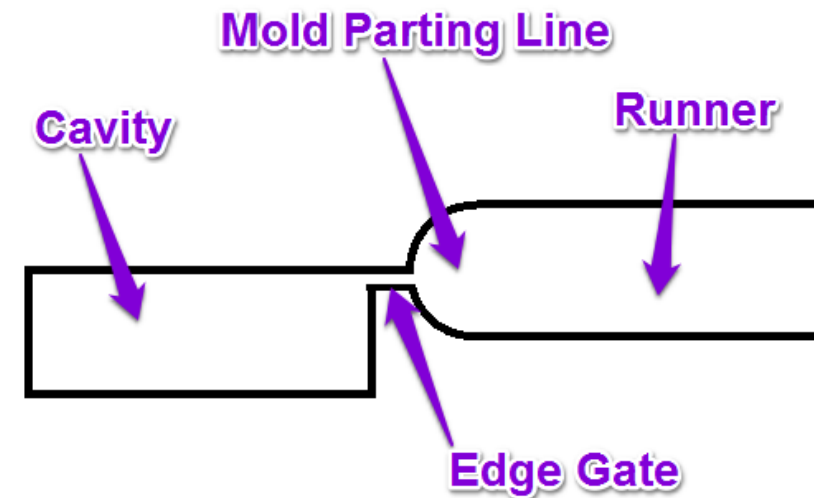


Figure 3: Schematic of a typical edge gate.

Sizing the runner:

The runners in a mold are the flow channels that connect the injection unit or nozzle to the injection gate, see Figure 1. The primary goal for optimizing a runner system is to achieve a balanced fill pattern for all cavities. Proper sizing of the runner balances the benefit of shear heating in the resin with the increased pressure requirement to fill the runner. An optimized runner will allow the molten plastic to increase in temperature improving flow-ability while not requiring excessive pressures to fill. Ideally, the pressure requirement to fill the runner should be less than 25% of the pressure to fill the mold. However, practicality and cost considerations often make this a difficult parameter to meet.

Proper runner sizing is dependent on material morphology and part thickness. Similar to gate sizing, amorphous materials require larger runners to reduce pressure requirements and temperature rise, whereas semi-crystalline materials can utilize smaller runner sizes.

When designing for a multi-cavity tool it is critical to fill all the cavities at the same time to manufacture consistent parts. Many multi-cavity molds utilize a naturally balanced runner layout where the flow distance is the same to each cavity, Figure 4. When designing the feed system each runner/branch should progressively decrease in size the closer to the injection gate. The smallest runner section should not freeze off before the injection gate. This will help

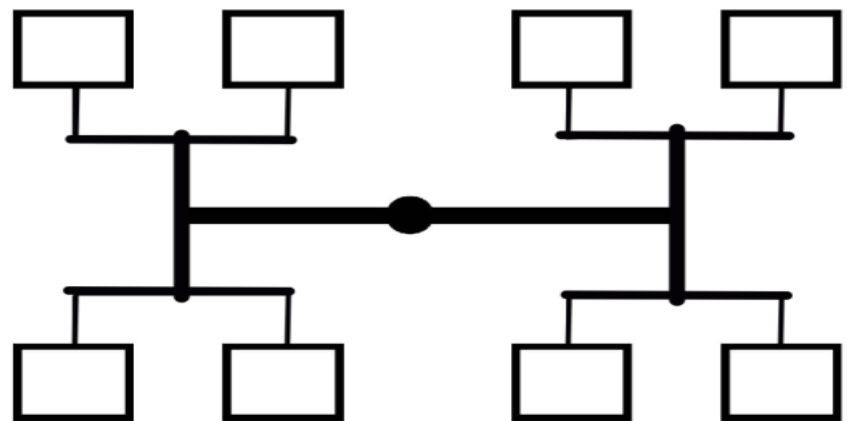


Figure 4: Schematic representation of a naturally balanced feed system.

prevent excessive pressure requirements, temperature rise, and material degradation due to an undersized runner.

Properly sizing the gate and runners in a feed system is critical to reducing processing requirements, increasing manufacturability, and reducing part cost. Utilizing injection molding simulation can be a cost effective tool for optimizing the runner and gate sizing of injection molded parts.

If you would like more information regarding injection molding simulation, runner optimization, or other processing issues, please contact The Madison Group at 608-231-1907, or email at ross.jones@madisongroup.com.

For further information regarding the capabilities of injection molding simulation read the following papers authored by the staff at The Madison Group (click on the link to access the document).

[Simulate Your Way to a Better Mold \(Cooling Layout Optimization\)](#)

[Using Computer Simulation to Solve Warpage Problems](#)

“Upcoming Society of Plastics Engineers Webinars”

Educational Opportunities - SPE Webinars

Webinars provide a cost effective way to expand knowledge of plastics. The Society of Plastics Engineers (SPE) offers a wide selection of high quality webinars, many of which are taught by Jeffrey A. Jansen from The Madison Group. Below is a list of the upcoming webinars:

Thermal Analysis in Failure and Compositional Analysis

Thursday, March 20, 2014 10:00 AM Central Time

Creep Rupture Failure of Plastics

Thursday, April 10, 2014 10:00 a.m. Central Time

Plastic Material Selection

Thursday, May 15, 2014 10:00 a.m. Central Time

Plastic Failure - A 3-Part Series

September 11, 17, and 25, 2014 10:00 a.m. Central Time

Understanding Plastic Failure Rate

Thursday, November 20, 2014 10:00 a.m. Central Time

For more information on the courses or to register, contact SPE's Scott Marko at 203-740-5442 or smarko@4spe.org.

Webinars that have been previously given are also available as a recorded DVD. One that may be of interest is:

Basic Rubber Technology

For more information contact SPE's Scott Marko at 203-740-5442 or smarko@4spe.org.

The Rules of Failure Analysis

Jeffrey A. Jansen

When I first started performing failure analyses in 1995, I was fortunate to work with a very experienced and talented engineer, Manfred Sues. Fred was the founder and owner of the engineering firm, and I greatly benefitted from his tutelage. While he was a metallurgist and I was a polymer engineer, I learned a great deal from him about conducting a failure analysis. He had a set of rules, much like Gibbs' rules on the TV show NCIS, that governed failure analysis. They have always benefited me, and I wanted to pass some of them along.

"Start and maintain an open mind. Emotion obscures objectivity and must be expunged from the investigation."

Having a preconceived notion regarding the basis of the failure will obscure the failure analyst's ability to be dispassionate and arrive at the true root cause. The failure analysis must be conducted from a neutral standpoint, otherwise the investigator's judgment will be clouded. Pursuing pet theories significantly reduces the efficiency and effectiveness of the investigation, leading to delays, or worse, arriving at the wrong conclusion.

"The failure investigator has only one objective, to determine the failure mechanism that caused the failure and to use that knowledge to prevent another occurrence."

The failure analyst should have no other agenda besides finding the truth regarding the failure. That information is required to solve the problem at hand and prevent future occurrences.

"One test result is worth one thousand expert opinions."

Werner von Braun
NASA Rocket Scientist

"Allow the science to direct the investigation."

Extending the previous rule, the failure analyst must make decisions based upon sound scientific principles. The investigator should not pursue hypotheses just because they are popular or proposed by supposedly knowledgeable individuals. Allow the test results obtained during the analysis to direct the flow of the investigation and to determine the best course of action.

"A closed mouth ingests no food."

Failure analyses are often conducted in a sequential manner, whereby an examination or analysis is performed which provides information that provides a direction for further tests. As individual test results are obtained, it can be tempting to want to draw conclusions prematurely and share those inferences. However, conducting a failure analysis is like putting together a jigsaw puzzle. The picture does not become clear until all of the pieces are in their proper place. The pieces in a failure analysis are the individual tests and when all of that data is laid out, the nature and cause of the failure becomes clear.

"Eating your words is never palatable, especially if they are someone else's."

Never allow someone else to influence your judgment. The failure analyst should come to their own conclusions based upon the evidence. Do not allow anyone else to persuade your judgment. Likewise, while it is often helpful to find the counsel of others, draw your own conclusions, based on the scientific evidence.

"The simplest solution is the best solution."

It is often tempting to draw exotic conclusions regarding a failure analysis. However, simplicity is often the key. There is an old saying, "When you hear hoofbeats, think of horses not zebras". Look for the simplest answers when determining how and why a component failed.

"Truth is ever to be found in the simplicity, and not in the multiplicity and confusion of things."

— Isaac Newton

"Major incidents are often triggered by very minor or apparently innocuous details."

Many details will be uncovered as part of the failure analysis, both by elucidating background information and testing. All of these details represent clues that help point to the true nature and cause of the failure. The failure analyst should not ignore information because it is thought to be unimportant. As a whole, and given the proper context, some of these seemingly insignificant details may prove later to be the key.

"The theory, however elegant, must agree with the observed evidence, however humble."

Many failure analysts derive conclusions that are appealing and well stated. However, it is important that these conclusions correlate with the evidence obtained during the failure analysis. A theory that satisfies only half of the data can, at best, only be half correct.

"Having the wrong solution is frequently much worse than having no solution."

This is perhaps the single most important rule of failure analysis. If the wrong conclusion is reached, then it is probable that the corresponding corrective action will be ineffective. The time, effort, and money wasted to implement the erroneous corrective action will be very costly, and delay the true solution.

I find that these rules form the basis of conducting a proper and thorough failure analysis. They are not complicated. However, they are essential to the integrity of the investigation. I hope that they serve you as well as they have served me.

If you would like more information regarding failure analysis or other plastics issues, please contact The Madison Group at 608-231-1907, or email jeff@madisongroup.com.

For further information regarding plastic failure analysis read the following papers authored by the staff at The Madison Group (click on the link to access the document).

[The Role Of Multiple Factor Concurrency And Statistical Distribution In Plastic Part Failure](#)

[Finding Fault: Impartial Failure Analysis Needed To Solve Part Problems](#)

[Failure Analysis as the First Step in Problem Solving](#)

"It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts."

Sherlock Holmes Quote
-A Scandal in Bohemia

The Madison Group ANTEC Paper



The Madison Group will be presenting at SPE ANTEC 2014

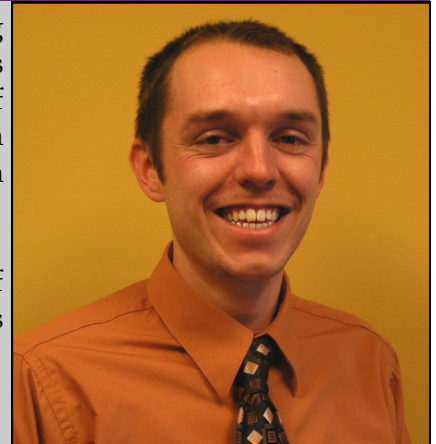
The Madison Group will be presenting the paper “Creep Rupture Under Conditions of Static Strain” at the Society of Plastics Engineers Annual Technical Conference (ANTEC), which will be held April 28–30 in Las Vegas, Nevada. This paper, coauthored by Jeffrey A. Jansen and Jacob N. Nemec, will be presented at 2:30 p.m. on Tuesday, April 29, and will review the failure of plastic components via creep rupture under constant strain. The abstract of the paper is:

“The long-term material response of polymeric materials will vary due to several interrelated factors including time, temperature, and the loading experienced by the material. A common long-term failure mode encountered in plastic parts is creep rupture, slow-crack growth failure through molecular disentanglement over time while exposed to continuous stress. This time-related phenomenon can lead to unexpected failures in plastic parts after days, months, or years in service. Creep rupture resulting from a constant strain condition is frequently encountered in several applications. This failure mode is relatively complex due to the competing mechanisms of plastic creep and stress relaxation.”

The Madison Group Adds Engineering Staff

We are pleased to announce that Ryan Amundson has joined our growing team of plastics engineers at The Madison Group. Amundson received his B.S. from the Department of Plastics Engineering at the University of Wisconsin–Stout in the spring of 2013 and joined The Madison Group team after graduation. His responsibilities include performing failure analysis on thermoplastic and composite parts.

“Ryan’s solid training and background in the processing and behavior of plastics will help bolster our capabilities to solve our client’s plastics problems,” said Bruce Davis (CEO).



The Madison Group Teaches Failure Analysis Course

October 13-15, 2014

The University of Wisconsin–Milwaukee School of Continuing Education is offering a 3-day course entitled, “**Plastic Part Failure: Analysis, Design & Prevention**” taught by The Madison Group Engineers Antoine Rios, Erik Foltz, Javier Cruz, and Jeffrey Jansen. The course will cover a broad range of topics essential to understanding and preventing plastic failure. Get introduced to the strategies behind analysis, design and prevention with course material that includes:

- Essential knowledge of why plastic components fail
- The five factors affecting plastic part performance
- The process of conducting a failure investigation
- The importance of ductile-to-brittle transitions and their role in plastic component failure
- Methods for understanding how and why a product has failed
- Approaches to more quickly respond to and resolve plastic component failure

For more information contact:
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