HANSER

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Runner and Gating Design Handbook

Tools for Successful Injection Molding

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Vorwort

Preface

Quality management methods, such as *Design for Six Sigma,* stress the critical review of fundamentals in order to identify and eliminate potential problems before they take their toll on the manufacturing process. In developing a mold design to produce an injection molded plastic part, one of the most fundamental and influential components is its melt delivery system. It also turns out that the melt delivery, or runner, system is probably the most misunderstood component of the injection mold. This makes it a prime candidate for critical review, particularly for the conscientious molder striving to improve his bottom line.

The melt delivery system begins with the injection molding machine nozzle and continues into the mold, progressing through the sprue, runner, and gate. Though the melt may only experience these flow channels for a fraction of a second, their effects are dramatic and result in the most extreme conditions experienced by the plastic melt in any phase of nearly any plastics processing method. Shear rates in gates commonly exceed 100,000 s^{-1} and localized melt temperature in high shear laminates can spike at as much as 200 °C, at rates of 2000 °C/s. Due to the extremity of these conditions, the actual effect of these conditions on the melt is not well understood. Most material characterization methods do not even come close to measuring melt conditions under these extremes. Viscosity vs. shear rate data is generally developed at a maximum of 10,000 s^{-1}, DSC data at less than 32 °C/min, and PVT data at 3 °C/min. As a result of the limitations of material characterization methods as well as solution modelling and meshing issues, today's injection molding and fluid flow simulation programs are unable to accurately predict the extreme asymmetric melt conditions developed in a branching runner. The challenge of dealing with these conditions has generally been underestimated and seems to exceed the capabilities of today's technology.

The influences of these extreme melt conditions developed in the runner are just beginning to be understood. One of the most significant is the realization that the combination of laminar flow and high perimeter shear in a runner results in extreme non-homogenous melt conditions across a runner. Not only can a 200 °C variation in melt temperature exist but, as a result of the non-Newtonian characteristics of the melt, the viscosity may easily vary 100 fold from the zero shear conditions in the center of a flow channel to the extreme shear conditions around the perimeter. This creates significant asymmetric melt conditions when the melt branches in a runner or part-forming cavity. The conditions developed in the runner continue into the part, corrupting the expected filling pattern and influencing how the part is packed, its mechanical properties, shrinkage, and warpage. These are all factors that are hardly known by most in the molding industry and their dramatic effects are rarely fully appreciated. The influence can be particularly acute in two-stage injection processes such as gas assist, structural foam, MuCell®, and co-injection.

As stated earlier, the melt delivery system consists of the molding machine's nozzle, sprue, runner, and gate. Each of these components, or regions, can have a significant influence on both the process and the molded part. Process effects include the ability to fill and pack the part, the injection fill rate, the clamp tonnage, and the cycle time. Effects on the part include size, weight, mechanical properties, and variations in these characteristics between parts formed in different cavities within a multi-cavity mold.

Despite the significant influence that the melt delivery system has on the molding process, its various components are generally poorly designed relative to the time, effort, and cost put into the other components/regions of a mold and molding machine. This book bridges the critical gap left by other publications dealing with injection molding, which generally touch only briefly on the design of the melt delivery system and its relationship to successful injection molding. In particular, the lack of information on cold runners needed to be addressed. Though a fair amount of published data on hot runners is available, these data are generally heavily influenced by the bias of companies that sell these systems. There are over 50 companies offering hot runner systems and components commercially, while there is no company at all offering cold runner systems. As a result, one can imagine the lackluster image of cold runners, as there is no company commercially promoting them.

Evidence of the lack of understanding of runners includes the fact that the significant effects of shear-induced flow imbalances in runners was not documented, or clearly understood, until 1997 when I published the first journal article on this phenomenon. For the first time, it became obvious that the industry standard "naturally balanced" runners were creating significant imbalances. Melt filling imbalance, developed from shear-induced melt variations, were found to be the norm in most of the industry standard geometrically balanced runner designs being used. This phenomenon was being overlooked by nearly the entire molding industry for both cold and hot runner molds. In addition, the industry's leading state-of-the-art mold filling simulation programs had been developed without the realization of the shear-induced imbalance. As a result, these programs did not predict the imbalance and left the analyst with a false impression that these runners provided uniform melt, filling, and packing conditions. The problem still exists today and should be considered when using analysis programs.

Of particular interest is the evolution of the runner from a basic necessity required to connect the injection unit and the molds cavity to its emergence as a significant process tool. Newer melt rotation technologies, such as MeltFlipper® and iMARC™, have introduced the concept of 3D injection molding.

This book takes an independent view of both hot and cold runners, trying not to make a judgment as to which is best for a given application. Rather, it addresses some of the critical design issues unique and common to both. The early chapters lay a foundation for designing runners by establishing an understanding of the rheological characteristics of plastic melt and how the influence of runner design and gating positions can affect the molded part. Chapter 4 provides important strategies for runner designs and gating position, which are critical to the successful molding of a plastic part. Chapter 5 provides an overview of the melt delivery system followed by Chapter 6 and 7, which teach the development and solutions to shear-inducted imbalances. These three chapters (5, 6 and 7) address issues, which are common to both cold and hot runners, blending basic geometrical channel issues with melt rheology. Chapter 8 focuses on cold runner designs including specific guidelines for runner and a wide variety of gate designs. Chapters 9 through 13 provide a close look at the design of hot runner systems and their unique capabilities and challenges. Chapter 14 provides a summary on the process of designing and selecting a runner system. Finally, the book concludes with an extensive trouble-shooting chapter with contributions from John Bozzelli and Brad Johnson.

This book is intended to provide the reader a better understanding of the critical role the runner plays in successful injection molding. It is hoped that this understanding should go a long way toward reducing mold commissioning times, improving product realization, increasing productivity, improving customer satisfaction, and achieving quality goals such as Six Sigma.