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WELD LINES

TECHNICAL ARTICLES | PROPERTIES OF PLASTICS

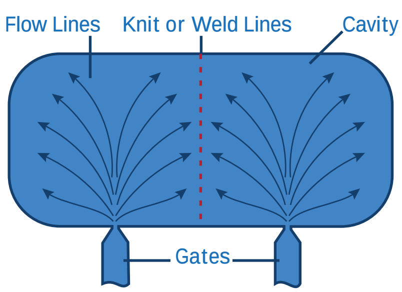
Weld Line Occurrence in Plastic Injection Molded Parts

Weld lines, also commonly known as knit lines, may be present in a plastic molded part depending on the partsí geometry. This article will review how and why weld lines occur, how mold gates effects weld line location and strength, the importance of material selection and the material impact on weld line strength as well as part design changes that can be considered to improve weld line strength.

Weld lines occur in plastic injection molded parts in the area or plane where two or more streams of material fuse together as the mold cavity fills with material. It is well know that weld lines create weak areas in molded parts. Weld lines are not caused by any deficiencies in material, machine, mold or process and are difficult to eliminate. Weld lines are inherent in the design of the component itself although they can be mitigated with proper part design, material selections and processing considerations.

If good weld line strength is desired for the specific part application the designer should first consider a design that would eliminate or mitigate weld lines in the part specifically in areas where the part strength is critical. In complex large parts the designer should be sure to design the part thick enough so that the mold cavity can be filled using only one gate as opposed to two or more gates. Molding parts with multiple gates will almost certainly produce a weld line at right-angles to the line joining the two gates which could cause the weld lines to be exceptionally weak (see Figure 1.0 and Table 1).

Figure 1



Knit line in a multi-injection-point cavity.
From Plastic Materials and Processing by A. Brent Strong, p. 453.

Table 1

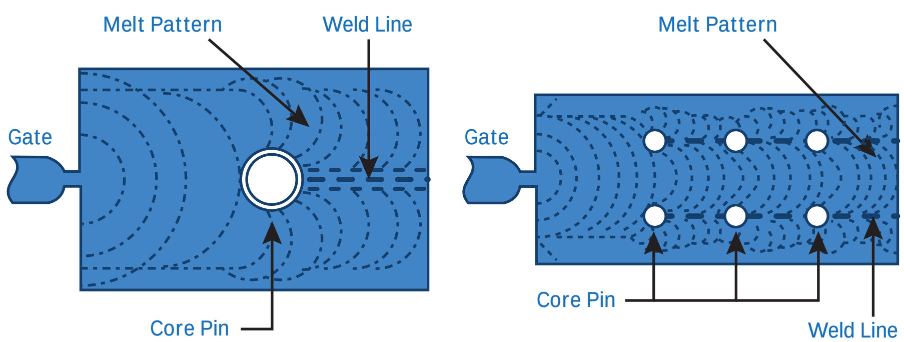
Effects of Resins on Weld Line Strength

Resin	Reinforcement	Fillers	Tensile Strength 1 Gate Kpsi	Tensile Strength 2 Gate Kpsi	Tensile Strength % Retained
PSU	None		9.6	9.6	100
PSU	30% glass fiber		16.8	10.4	62
SAN	None		11.3	9.0	80
SAN	30% glass fiber		16.2	6.5	40
PP	None		5.4	4.7	86
PP	20% glass fiber	15% glass beads	91	4.3	47
PP	15% glass fiber	15% PTFE	6.5	2.7	42
PP	30% glass fiber		9.7	2.8	29
PPS	None		8.8	7.3	83
PPS	10% glass fiber		10.3	3.9	38
PPS	40% glass fiber		20.5	41	20

The weld line location on any particular part is determined by the part geometry and chosen gate location. Weld line locations can be moved throughout the part by choosing alternate gate locations; however, changing gate locations can also affect part shrinkage, molding efficiency and part performance.

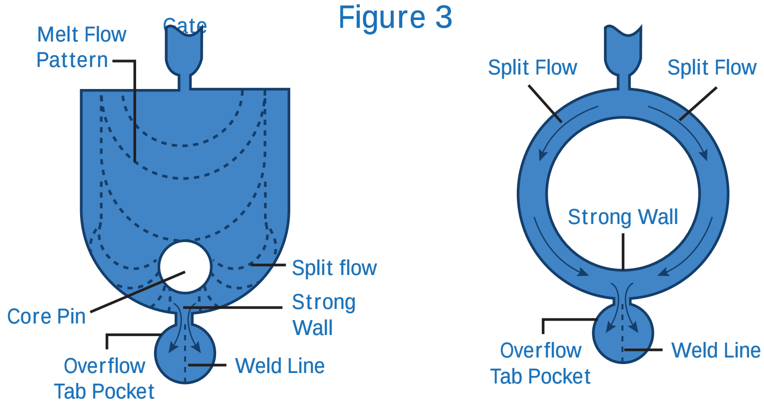
It is common practice for the gate to be placed at the thickest section of the part which allows the resin to flow freely mitigating the resin from freezing off in a thin section permanently before the thick section is filled. If the thin section were to be filled first this could lead to warp or distortion of the part. Weld lines cannot be avoided in all part designs specifically in designs requiring holes. As material fills the mold cavity it will split into two flow fronts as it passes around core pin required for the hole. A weld line will then be created as the two flow fronts meet on the opposite side of the core pin (see Figure 2.0). When holes must be a part of the component design the designer may want to consider options such as post machining the holes in the parts, designing over-flow wells into the parts (see Figure 3.0) or adding a thicker rib to the opposite side of the hole from the melt flow direction for extra strength (see Figure 4.0).

Figure 2



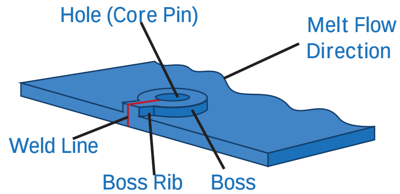
Weld line forms when melt flow splits around core pins.
From The Complete Part Design Handbook by E. Alfredo Campo, p. 541.

Figure 3



Improved weld line by using overflow tab pocket.
From The Complete Part Design Handbook by E. Alfredo Campo, p. 542.

Figure 4



Improve boss stength using a rib one weld line location.
From The Complete Part Design Handbook by E. Alfredo Campo, p. 542.

Material selection can also be a critical contributor to a weak weld line. Weld line integrity will depend on the ability for the two melt fronts to knit together homogenously. The presence of large concentrations of solid and liquid additives can greatly influence the formation of entanglements across the weld line interface and therefore affect weld line strength. Fibrous reinforcement can greatly reduce weld line strength. Sabic Innovative Plastics completed tests on several materials to determine the weld line strength integrity of each material. There results of these tests are shown in the tables below.

Table 2

Type	%	Single Gate Psi	Double Gate Psi	%
-	-	11,560	11,170	-
Glass Fiber	10	13,980	13,060	1.0
Glass Fiber	20	19,280	14,425	20
Glass Fiber	30	24,200	14,760	30
Glass Fiber	40	28,830	14,990	40
Carbon Fiber	30	33,500	13,400	30
Mineral	40	14,500	11,500	40

Weld line strength vs. reinforcement type and amount in nylon 6 / 6.
From Understanding Weld-line Integrity by Sabic Innovative Plastics, p. 3.

Table 3

Type	%	Reinf.	%	Single Gate Psi	Double Gate Psi	% Reinf.
-	-	-	-	11,560	11,170	-
Glass Fiber	30	-	-	11,400	10,840	1.0
Glass Fiber	20	-	-	12,750	12,150	20
Glass Fiber	30	-	-	9,630	8,860	30
Glass Fiber	15	Glass Fiber	15	16,560	14,140	40
Carbon Fiber	15	Glass Fiber	30	22,560	11,750	30
Mineral	10	Glass	30	22,590	13,250	40

Effects of fillers and / or reinforcements on weld-line strength of nylon 6 / 6.
From Understanding Weld-line Integrity by Sabic Innovative Plastics, p. 3.

The results shown above prove that the addition of fibrous reinforcement and fillers in any particular base resin will reduce weld line strength. The losses of strength at the weld line in parts molded from filled resins are primarily a result of improper orientation of the fibers at the weld plane. As the flow fronts meet that fibers will turn 90 degrees from the flow direction. If the force is applied to a part in the same direction as the melt flow this will result in the greatest loss of weld strength. Also the size and shape of the filler will have an adverse effect on the weld strength. Particulate fillers such as Talc, Milled Glass and PTFE have L / D or aspect ratios considerable less than 20:1. Particulate fillers of this size are independent of their filler orientation resulting in behavior very similar to base resins.

In conclusion plastic part designers should carefully determine any possible locations where weld lines may form during the injection molding process and work closely with the plastic injection molder and tool builder to choose the best possible gate location. This will help prevent weld lines from forming in critical areas of the part which require high strength in their application. The designer should also carefully choose the best material for the application which will not leave an exceptionally weak weld line in a critical area. If this is unavoidable the designer may want to look at adding additional material to strengthen the part at the flow front plane.

[1] Bown, John (1979). Injection Moulding of Plastic Component. Berkshire, England: McGraw-Hill Book Company (UK) Limited.
[2] Campo, E. Alfredo (2006). The Complete Part Design Handbook. Munich, Germany: Hanser Publishers.
[3] Strong, A. Brent (1996). Plastics Materials and Processing, 2nd Edition. Upper Saddle River, NJ: Prentice Hall.
[4] Rosato, Dominick V., & Rosato, Donald V. (1986). Injection Molding Handbook. New York, NY: Von Nostrand Reinhold Company.
[5] Sabic Innovative Plastics. (2008). Understanding Weld-Line Integrity. Retrieved August 22, 2011, from http://www.fist.si/db/fist/File/Sabic/LNP_Weld_Line_Integrity.pdf

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