Weld Properties of Plastics

R&D Center

KOREA ENGINEERING PLASTICS CO.,LTD.

1. Occurrence of Weld Lines

This phenomenon occurs when the melt flow front divides into two flows and rejoins at the same point. The division of a melt flow front occurs due to cores/obstacles, thickness changes or runner branching (multi-gates).

2. Type of Weld Line

Weld is divided by the quantity of flows when melt flow fronts rejoin after division.

(1) Butt or cold weld

This occurs when two flows meet but are not immediately mobilized.

(2) Meld line

A weld line formed by an additional flow after two original flows recombined.

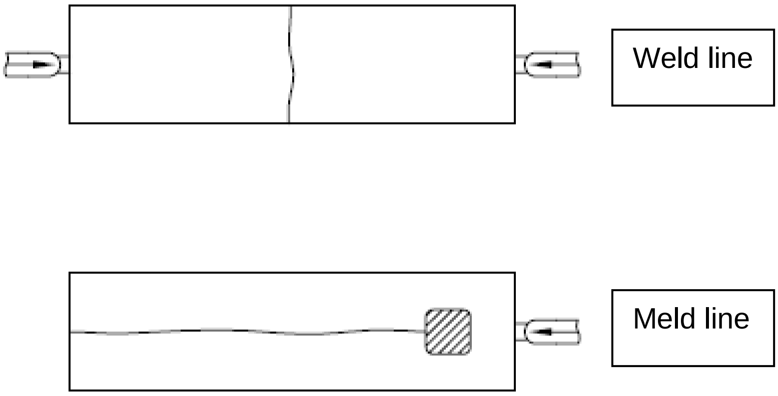
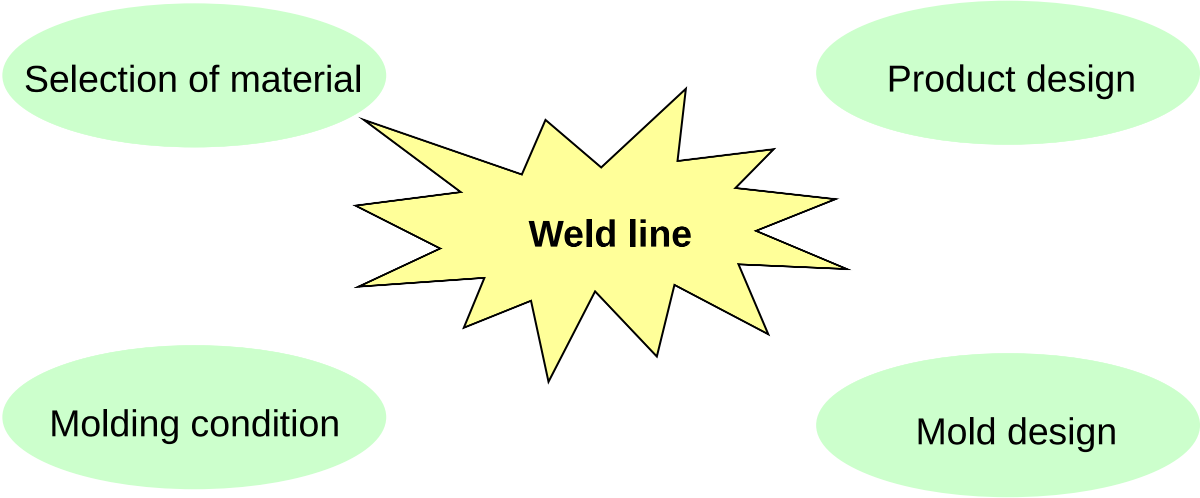


Figure 1. Weld type (Weld line and Meld line)

Adapted from Robert A. Malloy, Plastic Part Design for Injection Molding (1994)

3. Causes of Weld Lines



(1) Structural cause (product design)

1) Weld lines occur because of holes or thickness differences within a product.

2) This turns the weld line invisible and is quite difficult to remove without changing design to shift the weld lines position.

(2) Cause of resin

1) If resin lacks flow-ability, melt resin flows by the weld. It makes the weld line clear when it finally joins

2) One cause is poor compatibility of the resin with the additive agent

3) Another is fast consolidation of a resin by fusion with a semisolid

4) Resin can flow by weld parts if too many releasing agents are added to the cavity during injection molding. This will hinder combination of weld parts and cause weld lines.

5) Resins which include aluminum and pearl coloring agent are another possible cause

(3) Injection molding condition

1) This causes weld lines by decreasing resin temperature when a melt flow front rejoins with a cool resin

2) Low injection speed or pressure can result in weld lines from a decrease of resin temperature when it rejoins

3) Weld lines result from gas generation when injection molding in poor conditions

(4) Mold causes

1) Bad gate design results in weld lines because the distance between gates is too distant or installation of a gate to the thin side of a product

2) When mold resistance is high and the flow of a resin is poor, weld lines result from low temperature of melt flow front

3) Once air or volatile material within a mold gathers at the weld of a resin, weld lines result if there is no way to ventilate the gas

4. Problems

(1) Looks like a crack
(2) Low mechanical properties at weld line
(3) Decreased chemical resistance
(4) Decreased dimensional resistance and accuracy

5. Meeting Angle and Weld Line

Weld lines can disappear at particular flow front meeting angles. This angle is called the "Vanishing Angle" and is usually 120^{o} ~ 150^{o} according to each resin. This weld angle concept can be used for qualitative interpretation or removal of weld lines from filling simulation.

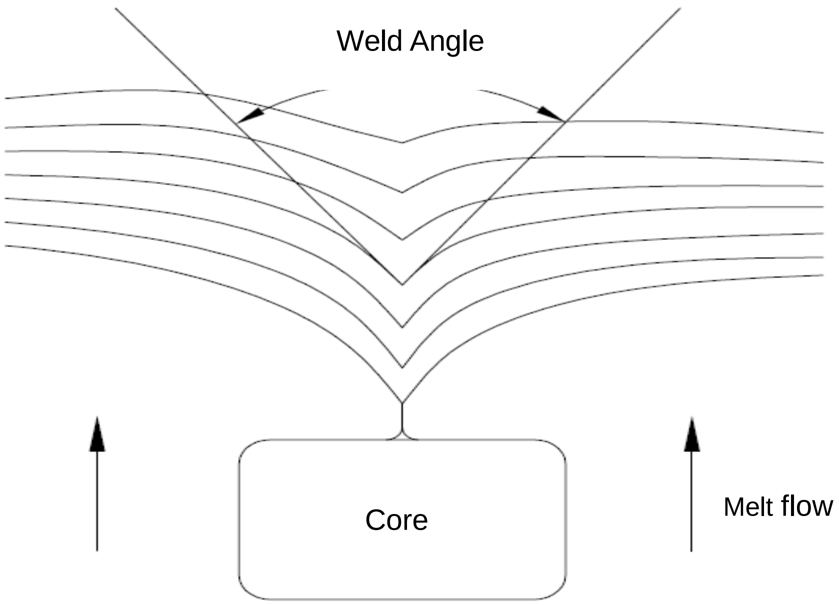


Figure 2. Weld Vanishing Angle

Adapted from Robert A. Malloy, Plastic Part Design for Injection Molding (1994)

6. Weld Lines and Mechanical Properties

Having many high cohesive weld lines is usually better for mechanical properties than having fewer low-cohesive weld line properties. However, it is difficult to evaluate mechanical properties at the weld line.

- Weakness of weld line can cause the following:

(1) Insufficient entanglement and diffusion between molecules

(2) Unfavorable, frozen molecular (or fiber) orientation

(3) V-notches at weld surface

(4) Foreign substances or voids

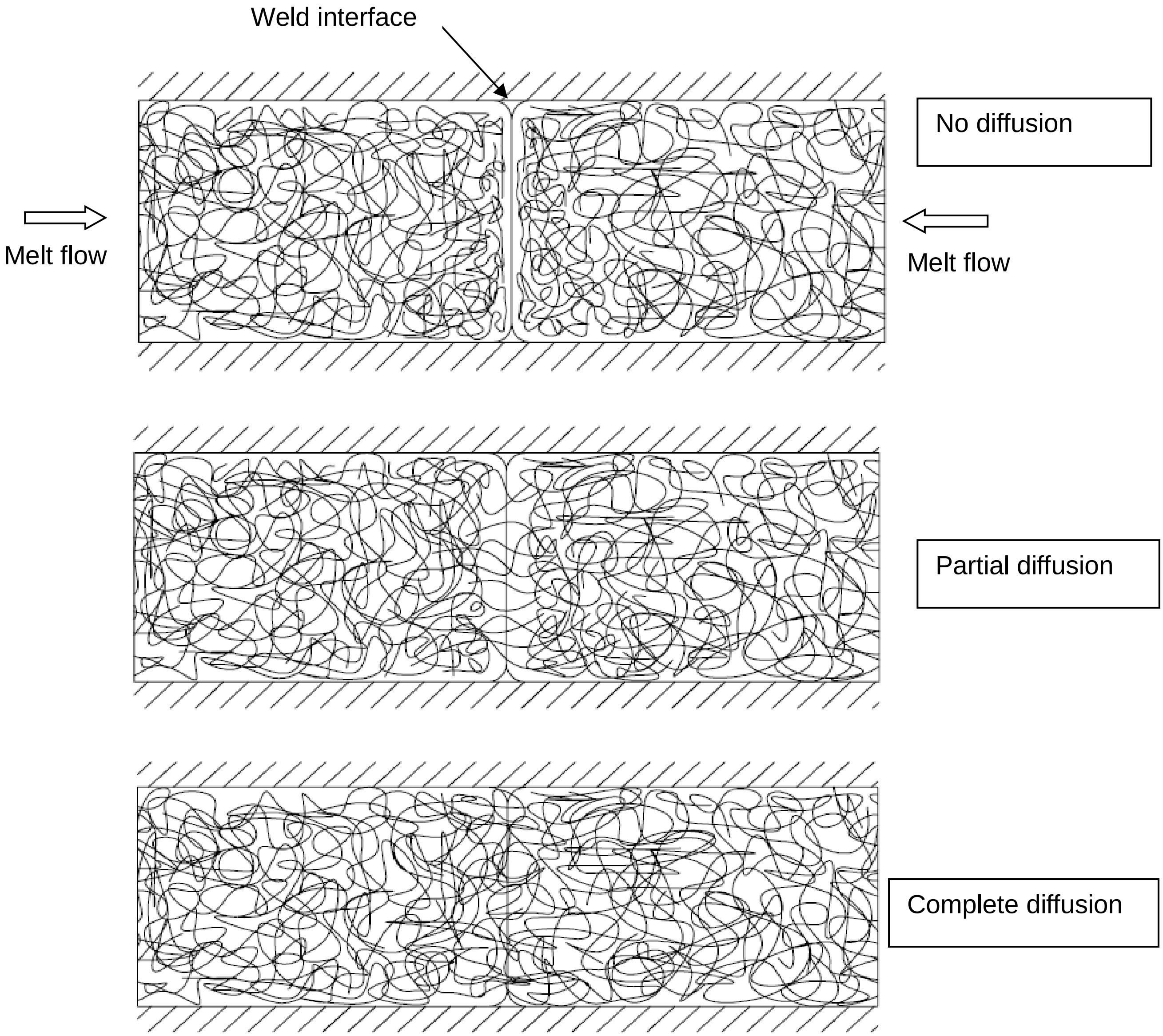


Figure 3. Molecular Diffusion and Entanglement

Adapted from Robert A. Malloy, Plastic Part Design for Injection Molding (1994)

From the figure, mechanical properties of weld lines depend on entanglement and molecular diffusion within molecules. To increase entanglement and diffusion, the temperature must be high as molecular motion is active. To have good mechanical properties at the weld line positon, the pressure must also be high for the same reason.

Molding process variables affecting impact strength of weld lines

(1) Melting point
  1) Too high temperature can degrade resin and produce gas
  2) Mold designer often increase the number of gates to shorten flow length, this causes the melt flow front to transfer temperature and pressure well
(2) Injection speed
(3) Packing pressure
(4) Cavity wall temperature, holding pressure and holding time

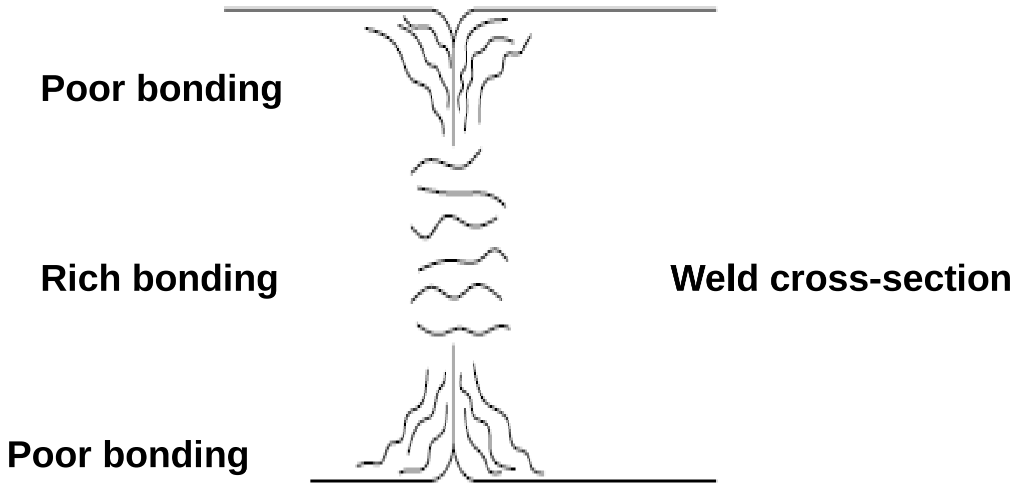


Figure 4. V-notch Shape of Weld Line

Adapted from Robert A. Malloy, Plastic Part Design for Injection Molding (1994)

The above figure shows that the side of weld line and pre-crack is a form of frozen molecular orientation by fountain flow behavior of the melt flow front. This notch type defect sticks out in appearance and acts as a sharp stress focus. This notch formation results from the difficulty of getting gas out of the melt flow front.

Mechanical property changes within weld line

Mechanical properties vary with the number and position of cores within the weld line according to the flow direction of a product. For example, impact strength of weld lines is weaker because the temperature of the melt flow front is lower as the distance between the core and gate increases. Simple cores' mechanical properties internals are not changed by the shift of position. However, multiple cores' mechanical properties are related to positional changes.

Mechanical properties of weld lines with plastics, additive agents and reinforcing agents

Plastics are more affected by weld lines than other materials. In engineering plastics, we have to particularly consider degradation of mechanical properties as well as appearance. The table below displays the degradation of mechanical properties to butt welds formed by end gate specimens.

Weld properties can vary with geometry, flow length, and weld angle

The retention factor of a non-reinforced product is about 80 - 100 %.

The greatest impact on weld property for non-reinforced amorphous plastics is its melting point. However, it rarely affects mold temperature. In other words, although mold temperature of amorphous resin is high it rarely affects anything as the temperature is lower than Tg.

However, melting point, mold temperature, injection speed, and annealing can affect weld strength in crystalline plastics.

The above retention factor is not absolute. It means that each case must be individually considered in terms of impact, long-term fatigue, and contact with chemicals.

The impact by additive agents and reinforcing agents is significant. A lubricant, a mold release, and a flame retardant have negative impact on weld properties. Although reinforcing agents(glass fiber, mineral filler) can come to increase mechanical properties according to addition, it has a relatively low retention factor at the same time. Loss of weld properties increases according to a reinforcing agent and an increase of aspect ratio. In fiber-reinforced plastics, degradation of weld properties is higher on weld lines by poorly orientated in regards to fountain flow.

The figure below shows mechanical properties of flow direction and vertical direction in glass fiber-reinforced plastics according to changes of flow on the weld line

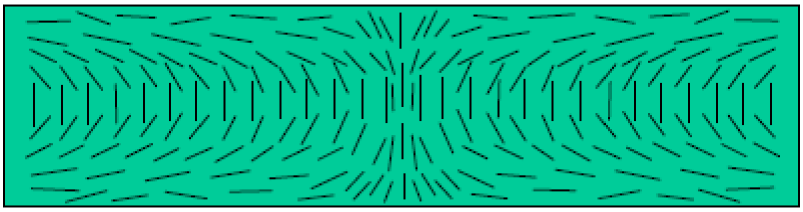


Figure 5. Fiber Orientation in Weld Line

Adapted from Robert A. Malloy, Plastic Part Design for Injection Molding (1994)

KEPITAL(POM Copolymer)'s Weld Properties

Type	Grade	MI(g/10min)	Retention factor of tensile strength (%)	Retention factor of tensile elongation (%)
Standard (Non-reinforced)	F10-03H	3	99	**32**
	F20-03	9	99	**40**
	F30-03	27	99	**37**
	F40-03	50	97	**33**
Impact strength	TE-24	6	81	**5**
	FU2020R (for weld)	2.5	99	**65**
G/F-reinforced	FG2025	7	26	**57**

Footnote) 1. FU2020R : Weld elongation improved grade

[Standard Products/Non-reinforced Products]

Non-reinforced products have lower retention factors of tensile strength and elongation compared to a non-weld product, although it differs from viscosity at the weld line.

[Effect of impact resistance agents or glass fiber]

When material includes impact resistance agents or is glass fiber-reinforced, the POM also has a lower retention factor of tensile strength and elongation compared to a non-reinforced product at the weld line.

KEPAMID(PA6, PA66)'s Weld Properties

Type	Grade		Retention factor of tensile strength (%)	Retention factor of tensile elongation (%)
PA6	1300CRH	Non-reinforced	92	24
	1533GFU	G/F 30%-reinforced	40	29
PA66	2300MR	Non-reinforced	80	53
	2330GFH	G/F 30%-reinforced	29	26

Glass fiber 30%-reinforced of PA6 and PA66 has lower retention factor of tensile strength and elongation compared to the non-reinforced product at the weld line.

KEPEX(PBT)'s Weld Properties

Grade		Retention factor of tensile strength (%)	Retention factor of tensile elongation (%)	Note
1200M	Non-reinforced	99	57	
3330GF	G/F 30%-reinforced	20	13	

Glass fiber 30%-reinforced PBT like PA6 and PA66 also has lower retention factors of tensile strength and elongation compared to the non-reinforced product at the weld line.

7. Troubleshooting

(1) In case the resin temperature is too low at the weld line

1) Increase the temperature of the cylinder, nozzle, and mold. Alternatively, increase the temperature of the resin at the weld line by generating shear heat when resin flows to the weld line. (Change of injection speed and product thickness)
2) Installation of cold slug well or increase of its size.
3) Increase the number of gates.
4) Change the placement of gates.

(2) If it occurs by gas

1) To prevent gas, inject at a lower temperature, if possible. Strengthen gas vents.
2) Increase the size, as a lot of gas is produced because of strong friction at the gate, runner, and sprue.
3) Control the speed by proceeding step by step to ventilate gas

4) Reduce the space time of resin within a cylinder of the injection machine. (Reduction of gas generation)
5) Check dryness of resin
6) Install ejector pin near weld line (The function of gas vent)

(3) If the combination imperfect as a resin gets less pressure at the weld line
1) Increase pressure
2) Check wear and tear of screw and check ring: pressure drop

(4) Avoid using mold release agents if possible. If necessary, use stearic acid, not silicone.

(5) Install boss, prominent pin, and tap at the position of weld line to move the weld line to the boss or prominent pin and tap. Remove them after injection.

(6) It is impossible to expand thickness near the weld line. However, it is possible to expand thickness near the hole. This can increase weld line impact and decrease width.

(7) Weld lines or bubbles will form at the center of thin part, when thickness variation of a product is great, because resin flows to thick parts first and thin parts after.
In this case, control the flow of resin by decreasing the thickness variation or installing a flow leader to control the flow of the resin.

(8) Check mix for other material or foreign substances

(9) Move the position of the weld line to make it invisible through the flow leader installation or change product thickness and gate position.
(10) Embossing finishing process or putting a logo near weld line

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