TROUBLESHOOTING THE FOAM/SKIN INSULATION EXTRUSION PROCESS

R.L. Silverman, Equistar Chemicals, LP
D.E. Roberts, Equistar Chemicals, LP

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BACKGROUND

There are two layers in high density polyethylene (HDPE) foam/skin insulation for telephone singles, an inner layer of foamed polymer and a thin outer layer of solid polymer (Fig. 1). The thin solid outer layer, or skin, provides the mechanical properties and protects the foam. The inner foam layer decreases the electrical capacitance of the overall insulation, which allows closer spacing of the insulated conductors in the telephone cable. Air in the voids of the HDPE has a dielectric constant of 1.00 compared to the dielectric constant of approximately 2.32 for HDPE.

Fig. 1. Foam/Skin Construction

The foam and skin layers are applied to telephone singles in a high speed co-extrusion process (Fig. 2). Each layer is extruded through its own extruder using processing temperatures appropriate for the polymer (Fig. 3). The two layers meet in the crosshead.

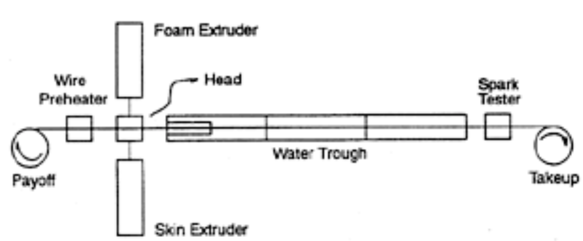

Fig. 2. Schematic of the Foam/Skin Extrusion Line.

Zone	Foam (°C)		Skin (°)
Feed	149		149
2	177		177
3	204		204
4+	210		238
Adaptor	210		246
Die		246	
Note: This figure is an illustration of profiles used on a 2½ in. 20:1 extruder. Profiles may need modification for any particular combination of extruder and screw.			

Fig. 3. Typical HDPE Foam/Skin Extrusion Conditions.

For each layer, it is important to achieve complete melting and homogenization at high screw speeds (much the same as in a single layer extrusion). Additionally, in extruding the foam layer, it is important to control the chemical reactions that produce the HDPE foam. Finally, it is important to control the cooling rate of the foam/skin insulation after it exits from the coextrusion head.

Computers automatically adjust variables of both extruders to keep the coextruded structure's capacitance and diameter within the specified ranges. However, problems can occur and an engineer or operator may need to adjust the extrusion conditions.

TROUBLESHOOTING

Troubleshooting the HDPE foam/skin insulation extrusion process starts with recognizing symptoms and, then, relating them to possible causes. The troubleshooting techniques discussed below are based on a combination of technology and experience. The figures accompanying the text form a short guide for the process engineer or operator.

Rough surface (Fig. 4). A rough surface most often is caused by poor melt quality of the outer layer: Incomplete melting or a nonhomogeneous melt. To solve this problem effectively, improve the melt quality by imparting additional energy to the polymer melt. The most common ways of doing this are using a finer screenpack, increasing the screw speed, or increasing the temperature profile.

Problem: Rough Surface	
Possible Causes	**Possible Solutions**
1. Poor Melt Quality	• Adjust Temperature Profile • Adjust Screw Speed • User Finer Screenpack • Check if Screw is OK
2. Improper Cooling Techniques	• Decrease Wire Preheat • Reduce Splashing from Water Trough
3. Gum Space Too Small	• Increase Gum Space
4. Moisture in Compound	• Dry Compound in a Dessicant Hopper Dryer

Fig. 4. HDPE Foam/Skin Troubleshooting

A rough surface also can be caused by problems in the cooling step, which can be solved by decreasing the conductor preheat temperature or reducing splashing in the water trough. Other causes for a rough surface are excessive moisture in the resin prior to extrusion (solved by drying in a hopper dryer) and/or inadequate gum space, the distance between the guider tip and the die exit (solved by increasing the space slightly).

Poor mechanical properties (Fig. 5). Poor mechanical properties--in particular, low ultimate elongation--are generally caused by cooling that occurs too rapidly or by poor melt quality. In the case of rapid cooling, excess strains are retained in the polymer. These residual strains could cause the polymer to behave in a brittle manner. Effective troubleshooting techniques keep the polymer hotter for a longer time so the strains have the opportunity to relax. In order to keep the polymer hotter for a longer time, decrease the cooling rate in the water trough, adjust the melt temperature of the skin, or adjust the conductor preheat temperature.

Problem: Poor Mechanical Properties	
Possible Causes	**Possible Solutions**
1. Cooling Too Rapid	• Decrease Cooling Rate in Water Trough (warm water in first zone[s]) • Adjust Skin Melt Temperature • Adjust Conductor Preheat
2. Poor Melt Quality (Skin)	• Adjust Temperature Profile • Adjust Screw Speed • User Finer Screenpack • Check if Screw is OK
3. Excessive Color Concentration	• Decrease Addition Rate

Fig. 5. HDPE Foam/Skin Troubleshooting

Poor melt quality can result from either incomplete (nonhomogeneous) melting or degrading of the polymer. If the cause is incomplete melting, the best solutions are those that increase the energy imparted to the resin, i.e., increasing the conductive heat transfer (by increasing the temperature profile or the polymer's residence time) or increasing the shear imparted by the screw (by increasing the screw speed). If the problem is degradation, the opposite adjustments will be more effective.

Finally, the addition of too much color concentrate can contribute to poor mechanical properties.

Excessive shrinkback (Fig. 6). Excessive shrinkback is caused by residual strains in the foam/skin insulation. Most often, these strains are caused by either overly rapid cooling or excessive orientation (drawdown). In addition, conductor properties can affect the adhesion of the foam to the conductor and, therefore, the resistance to shrinkback.

Problem: Excessive Shrinkback	
Possible Causes	**Possible Solutions**
1. Cooling Too Rapid	• Decrease Cooling Rate • Increase Wire Preheat • Increase Skin Melt Temperature
2. Excessive Drawdown	Reduce Drawdown (extrude close to size)
3. Conductor Problems	• Remove Contamination • Replace Wipes • Reduce Tension (pull-down, stretch)

Fig. 6. HDPE Foam/Skin Troubleshooting

If the cause is overly rapid cooling, the best strategy is to keep the polymer hotter longer. This is done by decreasing the cooling rate in the water trough, increasing the conductor preheat temperature, or decreasing the melt temperature of the skin polymer.

Often, shrinkback can be reduced by decreasing the drawdown. When the HDPE is drawn down, strain is induced. When using pressure tooling, it can be helpful to extrude "on size" or slightly under size. When using tube-on tooling, the drawdown ratio should be minimized as much as possible.

The surface condition or stretching of the conductor can affect shrinkback. Oils or contaminants on the surface of the conductor limit the adhesion of the HDPE foam to the conductor and, thus, the ability of the construction to resist shrinkback. Much the same way, wire stretch or pulldown can break the adhesion between the foam and the conductor.

Excessive spark failures (Fig. 7). The spark tester provides a good method to test the continuity of the insulation. A fault is recorded if a spot in the insulation provides a conductive path.

Problem: Excessive Spark failures	
Possible Causes	**Possible Solutions**
1. Contamination	• Change Screenpack • Locate Source of Contamination and Correct Situation • Check Color Concentrate Addition Rate, Adjust as Needed
2. Rough Surface	• Correct Rough Surface, refer to Fig. 4
3. Spark Tester Operation	• Calibrate Voltage • Adjust Air Wipe • CheckCircuits, Correct Deficiency
4. Damage to Insulation	• Eliminate Obstruction in Wire Path

Fig. 7. HDPE Foam/Skin Troubleshooting

Contaminants in the foam/skin can cause spark tester failures. Changing the screenpack can help, but the best solution is to find and eliminate the source of the contamination. In some cases, an excessive level of color concentrate can cause spark failures, similar to contamination.

A rough skin surface can cause spark failures due to thin spots or holes (skips). Thin spots can fail under the electrical stress applied by the spark tester. In addition, a rough surface can hold water which will cause a spark failure.

Spark tester failures also can be caused by faulty operation of the spark detector, ineffective air wipe operation, or damage to the insulation due to interference in the wire path.

Poor cell structure (Fig. 8). Poor cell structure in the foam can be caused by several factors, but most often is caused by extrusion conditions. The rates of the chemical reactions, which cause the chemical blowing agent to decompose and produce the gas that results in foaming the melt, are controlled by the melt temperature. Moisture in the foam compound also is a possible cause for poor cell structure.

Problem: Poor Cell Structure	
Possible Causes	**Possible Solutions**
1. Compound Too Hot	• Reduce Temperature Profile • Reduce Screw Speed
2. Head too Hot	• Reduce Head Temperature
3. Premature Blowing	• Reduce Temperature in First Zone(s) of the Extruder
4. Blowing in Dead Spot in Head	• Reduce Head Temperature
5. Head Volume too Great	• Reduce Head Temperature • Streamline Head • Install Smaller Head
6. Back Pressure too Low	• Lengthen Die Landor Die • Reduce Gum Space
7. Incomplete Decomposition of Chemical Blowing Agent	• Increase Melt Temperature • Adjust Temperature Profile
8. Moisture inCompound	• Dry Material in Desiccant Hopper Dryer

Fig. 8. HDPE Foam/Skin Troubleshooting

When viewed through a microscope, the cells of the foam should appear round and located next to each other, each being separated by a thin wall of polymer. If the cells appear large and merged with other cells, the foam has been overexpanded. The most effective solutions are to either reduce the melt temperature, especially in the first zones, or reduce the residence time of the compound in the extruder. If the cells appear very small and separated, the foam has not been expanded sufficiently. In this case, process adjustments that cause the melt temperature to increase are the most effective solutions.

CONCLUSION

HDPE foam/skin insulation for telephone singles offers many design and performance benefits. The coextrusion process is more complicated than the standard single layer extrusion process, but problems encountered generally can be solved by making basic changes in the process conditions and/or equipment. This brief troubleshooting guide provides process engineers and operators with possible solutions to the most common problems encountered with the coextrusion of foam/skin insulation.

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LyondellBasell Industries
P.O. Box 3646
Houston, TX 77252-3646
United States

www.LYB.com