Troubleshooting Coextrusion Film Systems

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Introduction

Coextrusion film structures are being pushed for greater performance every day. This translates into more sophisticated products with increasing numbers of layers and incorporation of functional polymers into a composite structure that frequently improves the overall performance of the film with less total material. The systems to produce these films have likewise advanced and increased in complexity, separate extruders for individual layers, multi-component blending feed systems, advanced feedblock or die technology, higher operating speeds, integrated control systems, automated winding and roll handling systems. Each of these advances brings along a unique set of potential failure modes, which place more demand on the system troubleshooter. This chapter will discuss the typical film system components, the basic troubleshooting method, and outline several specific problems with a method to verify and correct. As few film systems are exactly the same this will not be a comprehensive troubleshooting guide, however, the approach set forth in this chapter should be useable for troubleshooting any machine system.

Coextrusion Film Systems

When troubleshooting a film problem we frequently reduce the source of potential problems to a set of problems we are familiar with from past experience. This may create an approach that never addresses the root cause of the problem. Often times certain adjustments to one sub-system may appear to solve a problem when in reality the adjustments simply masked the fundamental problem in another part of the system. Although it is important to focus on the elements of the film system within your control the troubleshooting process should succeed in identifying root cause problems even if outside of the troubleshooter's immediate control.

Following is a list of typical elements that make up a coextrusion film system today. Although the specific designs are significantly different between cast and blown film systems the fundamental elements exist within each system.

1. Polymeric materials
2. Resin delivery system
3. Resin blending system
4. Material rate control system
5. Film product structure (material layers, sequence, percentage)
6. Extruders (electrical & mechanical drives, screws, heat/cool system)
7. Filtration device
8. Transport pipes
9. Layer combining system (feedback or die)
10. Film shaping system (flat or annular die)

11. Temperature control system
12. Film forming/quenching system
13. Thickness control system
14. Surface treatment system
15. Trimming/slitting system
16. Trim removal and recycle system
17. Continuous winding system
18. Drive control system (DC or AC Vector)
19. Roll removal & shaft reloading system
20. Supervisory control and data acquisition (SCADA) system
21. Packaging and palletizing system

In order to produce a consistent high quality coextrusion film product all of these systems must work in concert. When a quality defect occurs or the machine system goes down it is imperative that the troubleshooter be able to quickly identify and correct the root cause problem. For the highly complex coextrusion systems in operation today a reliable method of consistent problem resolution is required.

Troubleshooting Method

When confronted with a complex coextrusion system today many operators and technicians may feel overwhelmed when challenged to isolate a problem. A typical seven-layer coextrusion system may have six extruders, 3-4 component blenders in each extruder, and gravimetric rate control. These blending systems may draw from 8 or 10 different resin silos or railcars. A cast film combining station may have a feed block with capacity of multiple structures and the ability to compensate for throughput changes or viscosity mis-match. The die may have over a hundred thermally actuated die bolts. The quenching system may include vacuum pinning, air pinning, electrostatic pinning, and air-cooling usable individually or in combination. Forming systems may have multiple cooled or heated rolls with individual temperature controls and drive controls. Web transport rolls may be individually driven. Trim removal systems may include multiple choppers, blowers, grinders, and fluff re-feed machines or re-pelletizing. Continuous winders may be speed, torque, or tension controlled with center or surface drives or combinations. Programmable lay on roll loading, as well as sophisticated transfer logic is typical. Automated handling systems may allow handling of multiple core sizes, spacing between cores, adhesive application, roll doffing, pick and place systems, etc. How does the troubleshooter start?

Whenever confronted with a complex system a consistent method is our most important ally. If we approach a complex system in a haphazard manner we are likely to overlook simple solutions. One of the most powerful tools for troubleshooting was taught to all of us in our early school years, the scientific method. There are four steps involved in this approach and if followed rigorously it will never fail in problem solving. The four steps may be repeated multiple times in solving any problem but persistence and consistency in this approach will assure “root cause” problem solving every time. The scientific method:

1. State the problem
2. Identify a possible solution (The hypothesis)
3. Test the hypothesis
4. Evaluate the results (and repeat as necessary)

Whether we recognize it or not this is the method we all use in problem solving. Most of the time we execute this very informally and vaguely. When it is successful we quickly move on and fail to recognize exactly how we succeeded. When it fails we resort to “experts” or senior and more sophisticated personnel which expand the number of hypotheses. A consensus on how we test and evaluate the hypotheses may also be a stumbling block if this method is not formalized. Let's briefly discuss formal application of the scientific method for troubleshooting.

The Problem Statement

The first benefit of a formal approach in a group environment is everyone recognizes and is working on the same problem. The first step is to write down the problem statement. This is now a visible guide for everyone working on the problem to focus on the same issue. The problem statement must be unbiased. The problem statement should not include the assumed solution.

Problem: Unmelt gets are causing holes in the film

This problem statement will cause the trouble shooting effort to focus on melting as the problem and you may overlook a contamination or crosslink problem.

Problem: Gels are causing holes in the film.

This statement assumes no pre-conceived cause for the gel. This will allow for a more complete consideration of potential causes for the gels in the hypothesis stage.

Taking the effort to formally write down each step in this process will not only provide focus and clarity to the troubleshooting effort but can be maintained as a record for future reference should the problem re-occur. This will reduce the time to correct future problems and improve the troubleshooting capabilities of the entire group.

The Hypothesis

This is often the most important step. Spending a little extra time at this stage in problem solving will often allow considerable time savings in the overall effort. This should be approached very much like a brain storming exercise. The more comprehensive the list of potential causes of the problem the more likely it is that we can isolate the root cause of the specific problem we are experiencing. In the exercise of developing hypotheses that have caused our problem we want to consider the entire coextrusion film system, all elements. Again in "root cause" problem solving ignoring one element as a potential cause may result in your solution masking the actual root cause. Looking at the film system as outlined and the gel problem statement the hypothesis generated might include:

1. High gel count / off spec resin
2. Ingress of contaminants in resin delivery
3. Cross contamination in blending components
4. Incomplete melting in extruder
5. Over shearing / over heating in extruder
6. Over heating in downstream equipment
7. Hang up in melt flow path
8. Cross contamination between layers in combining system
9. Over heating / hang up in die or feedblock
10. Die lip build up
11. Chill roll contamination
12. Inconsistent sizing and re-feed of trim scrap

The objective at this stage should be to generate as many reasonable potential causes to the problem as possible. The next step requires selecting one possible cause and developing a test that will be able to eliminate that root cause as the source of the specific problem we are working on. Some of the potential problems may have a low probability of being the root cause but may be easily tested and eliminated. Some of the potential problems may have a much higher probability of being the root cause however the testing and verification may be more difficult. Selecting the hypothesis to pursue and developing a test that allows unquestioningly identifying that hypothesis as the root cause or eliminating it from the potential cause list is the next step.

Test the Hypothesis

Now we are ready to develop some tests to verify if our hypotheses are true or false. This is a process of elimination until we identify the root cause. It is important to design a test that will truly indicate the validity of the hypothesis.

With the gel problem we have been working on we have developed twelve potential causes. More than one test will be required, although some tests may eliminate more than one hypothesis from consideration. Some hypotheses may not require a specific test but may be eliminated due to available data. For example, hypothesis 1, off spec resin may be eliminated as a potential cause if materials from the same source lot are being processed on another film system without the gel problem. Let's assume that due to our experience and the appearance of the gel we feel that it is likely unmelted resin, hypothesis 4. We can conceive a number of tests to check this hypothesis, as follows:

1. Increase barrel temperatures to promote melting
2. Increase the system pressure to retard the solid bed and promote mixing
3. Change the feedscrew to one that increases the mechanical work input
4. Re-melt a sample gel under observation on a hot stage microscope
5. Reduce the screw speed and increase all system temperature settings

There are almost an unlimited number of tests that we could develop that will indicate if our hypothesis is valid. We would like to proceed with a test that proves conclusively that the hypothesis is true or not. If we look at the 5 tests that we have come up with we see that only number 4 truly eliminates unmelted resin as the potential problem. If we try the other tests and the gel is eliminated we have determined that it was very likely unmelted resin, however if we complete the test and the gel still exists can we conclude that it is not unmelted resin? Since these tests are indicators but will not develop a conclusive answer we will evaluate using a hot stage microscope.

Evaluating the Results

The last step in the troubleshooting process is to evaluate the results of the test and determine if the source of the problem has been found. If we feel we have found the cause we can then move to corrective action. If the test is inconclusive or if it indicates that our hypothesis was not the root cause of the problem then we have to return to our list of hypotheses. Depending on what is learned from the first test additional hypotheses may be generated.

Back to our example, if we find that as we reach the melting point of the film that the gel melts we have unmelted resin. If it does not melt at this temperature we can continue to heat the sample and see if it melts at some other temperature, indicating that our system is contaminated with some foreign polymer or mildly crosslinked resin. If it never melts we may conclude that it is severely crosslinked resin or some other foreign material has entered the system. At the conclusion of this test we clearly know if our problem is unmelted resin or not. If it was discovered that we have unmelted resin we may now pursue a strategy to more completely melt the resin. If it was clearly not unmelted resin we can return to our original list of hypotheses and select another one to evaluate. Since we gained additional data in this process, say the gel never melted and we observed a foreign material in the center of the gel, we would now try to pursue one of the hypotheses that assumed foreign material contaminating the system, hypotheses 2, 3 and 11.

Common Problems, Hypotheses, and Tests

This powerful method of diagnosing and solving problems may be applied formally or informally. It is indeed applied informally by all problem solvers, occasionally steps are omitted, or decisions are made based on ambiguous results but progress is made and the problem is solved. Recognizing the method and formally documenting it will result not only in quicker resolution to problems but a record of the behavior of your particular system and trends that may allow you to recognize potential problems before they result in lost production. The remainder of this chapter contains a tale listing common coextrusion film system problems, potential causes (hypotheses), and verifying tests. Until the tests are conducted results cannot be analyzed.

Proble	Potential Cause (Hypothesis)	Test
1 Gels in film	1 High gel count/off spec resin	Run same lot of resin on other film line
	2 Ingress of contaminants in resin delivery	Feed material direct to extruder manually
	3 Cross contamination in blending system	Bypass blending system
	4 Incomplete melting in the extruder	Analyze on hot stage microscope
	5 Over shearing / over heating in extruder	Run at reduced speed
	6 Over heating in downstream equipment	Run at significantly reduced downstream temps
	7 Hang up in melt flow path	Disassemble, clean and re-run
	8 Cross contamination in combining system	Add color to layer, run, disassemble, inspect
	9 Overheating in die or feedback	Run at significantly reduced temps
	10 Hang up in die or feedblock	Disassemble, clean, and re-run
	11 Die lip build up	Clean die lips, run with video observation
	12 Chill roll contamination	Clean chill roll, re-run
	13 Inconsistent sizing and re-feed of trim scrap	Divert trim scrap
2 Poor clarity	1 Extrusion temperature too low	Raise run temperature
	2 Coextrusion interface instability	Adjust relative extruder outputs
	3 Quenching temperature too high	Reduce quenching temperature
	4 Poor finish on chill roll	Evaluate alternate finishes
	5 Inappropriate polymer for application	a.Evaluate alternate materials
		b.Blend in clarifying agent
3 Wrinkling	1 Poor gauge control	Measure samples with alternate gauge (off-line)
	2 Non-uniform quenching	Monitor web temperatures by CD position
	3 Non-uniform melting (shear history)	Monitor melt temperatures by CD position
	4 Transport rolls mis-aligned	Check level and tram
	5 Poor tension control	Adjust and observe
	6 Non-uniform pinning	Clean and align pinning device
	7 Web not centered on spreading rolls	Adjust deckles to center web in machine
4 Unable to reach output	1 Resin supply systems unable to keep up	Disconnect feed from extruder and verify max rate
	2 Restriction in feed	Inspect feed throat and supply lines for obstruction.
	3 Improper feedscrew design	Conduct rate checks at various speeds

		and pressure, confer with screw designer
	4 Restriction in downstream system	Conduct rate checks with and without downstream components connected
5 Poor mixing of melt	1 Resins incompatible	Confirm compatibility, run in alternate systems
	2 Mis-match of masterbatch rheology	Compare rheology at processing conditions
	3 Inconsistent dosing from blenders	Monitor dosing size and frequency, check random sample consistency
	4 Improper feedscrew design	Conduct rate checks at various speeds and pressures, confer with screw designer
	5 Operating temperature improper for optimum mixing	Adjust set points to increase shear input
	6 Specific residence time inadequate for optimum mixing	Increase head pressure / specific residence time
	7 Stratification of melt components in flow path	Add stationary mixing device
6 Melt temperature too low	1 Wide melt temperature variation	Check temperature uniformity across flow with exposed junction melt T/C – see item 5
	2 Improper barrel set temperature	Adjust to higher set temperatures
	3 Specific residence time inadequate for temperature development	Increase head pressure / specific residence time
	4 Improper feedscrew design	Conduct rate checks at various speeds and pressures, confer with screw designer
7 Melt temperature too high	1 Improper barrel set temperatures	Adjust to lower set temperatures
	2 Specific residence time excessive for temperature development	Reduce head pressure/specific residence time
	3 Improper feedscrew design	Conduct rate checks at various speeds and pressures, confer with screw designer
8 Extruder power insufficient	1 Drive not developing design power	Verify drive power inputs
	2 Barrel set points too low	Adjust to higher set temperatures
	3 Improper feedscrew design	Review application with feedscrew design
9 Streaks or lines in film	1 Die is dirty	Clean die (shim) in location of streak, re-run, or split and clean die
	2 Imperfections in die	Split die & inspect
	3 Die lip out of adjustment	Check die gap, check bolt powers and backlash

	4 Air knife out of adjustment	Check air knife gap adjustments
	5 Vacuum box out of adjustment	Check vacuum box for leaks in seals and high air velocities
10 Melt appearance defects Applesauce Sharkskin Orangepeel Interface instability	1 Poor mixing	See item 5
	2 Extrusion temperature too low or too high	See items 6 & 7
	3 Poor melt temperature uniformity	See item 5
	4 Mis-matched velocities / shear stress at interface	a adjust relative extruder outputs b adjust relative manifold shape at combining point (requires adjustable feedblock or die) c Adjust relative viscosities through material selection or temperature adjustment
	5 Poor purging technique	Dis-assemble, clean and re-run
	6 Resin contamination	See item 1
11 Thickness Variation – CD	1 Die lines or gauge bands	See item 9
	2 Improper operation of automatic gauge	Run in manual mode
	3 Interlayer non-uniformity	Introduce color in alternate layers, check uniformity (note: typical gauges will not compensate for layer density variations)
12 Thickness variation – MD	1 Unstable extruder outputs	See item 16
	2 Poor tension control	Verify drive speed uniformity and control
	3 Unstable vacuum box or air knife pressure	Monitor frost line position stability during steady state
13 Poor wound roll appearance See TAPPI	1 Non-uniform gauge	See items 9 & 11
	2 Poor tension control, improper tension	Monitor drive loads, adjust tension or taper tension
	3 Excessive slip additive in resin	Wind film without slip additives
	4 Blocking	Add anti-block
	5 Inadequate cooling before wind up	Reduce cooling roll temps, reduce line speed
	6 Over treatment	Reduce treat levels
	7 Winder or idler alignment	Check roll level and tram
14 Edge tear – unstable edge	1 Inadequate resin draw strength	Use alternate material, use edge encapsulation
	2 Improper setting of edge pinners	Adjust pinning, die, chill roll relation
	3 Material too cold	Adjust to higher melt temperatures
	4 Deckles set too narrow (too wide)	Adjust deckles
	5 Leakage (weapage) around deckles	Adjust deckles or die bolts
15 Pin holes	1 Gels	See item 1

	2 Abrasive roll surface	Inspect and modify rolls
	3 Air (or volatiles) entrained in polymer melt	Check drying, check temperature settings, review screw design
	4 Die is dirty	Clean die (shim) in location of streak, re-run, or split and clean die
16 Extruder surging	1 Inconsistent material feeding	Monitor resin supply to feed throat
	2 Over heating in feed throat	Monitor feed jacket temperature, adjust cooling supply
	3 Overheating on screw root	Monitor root cooling temperature, adjust cooling supply
	4 Improper feedscrew design	Conduct rate checks at various speeds and pressures, confer with screw designer
17 Draw resonance	1 Improper air gap	Increase air gap
	2 Improper melt temperature	Adjust melt temperature
	3 Inconsistent polymer release from die surface	Add polymer processing aid
	4 Improper die gap	Adjust die gap
	5 Balance of extensional response with rate of cooling	Adjust air impingement draw resonance eliminator
18 Discoloration of film	1 Melt temperature too high	Reduce melt temperature, screw speed
	2 Resin contamination	See item 1
	3 Degraded material from improper shut down	Purge or dis-assemble and clean
19 Poor heatseal	1 Inappropriate resin	Use alternate resin
	2 High melt temperature	See item 7
	3 Excessive corona treatment	Reduce treat levels
	4 Improper additive levels	Use alternate resin or additive
	5 Contamination with air borne silicone	Discontinue use of silicone sprays
20 Odor-flavor scalping	1 Improper resin	Use alternate resin
	2 High melt temperature	See item 7
21 Poor Strength	1 Inappropriate processing temperature	Adjust processing temperature
	2 Poor gauge control	See items 11 & 12
	3 Inappropriate resin	Use alternate resin
	4 Excessive pressures or temperatures at nip rolls	Adjust nip pressures and temperatures
22 Film blocking	1 Inadequate cooling	Reduce cooling roll temps, reduce line speed
	2 Winding tension too high	Reduce winding tension
	3 Static build up	Add static elimination

	4 Over treatment	Reduce treat levels
	5 Inadequate levels of anti-lock	Adjust anti-block levels
23 Poor printability	1 Non-uniform treatment	Check treater gap, corona appearance
	2 inadequate treat levels	Increase treat levels, reduce line speed
	3 non-uniform gauge	See items 11 & 12
24 Camber	1 Inadequate quenching	Reduce cooling roll temps, reduce line speed
	2 Non-uniform stress/thermal history	Review die designs
	3 Non-uniform transport forces	Reduce unsupported web spans, pre-trim edge beads
25 Scratches	1 Idler rolls not turning at web speed	Check all roller speeds
	2 Abrasive roll surface	Inspect and modify rolls