Dynisco

From lab to production, providing a window into the process

Defects and Defect Determination

DEFECT DETERMINATION

Defect determination is a procedure used to determine the origin of a defect. Such a procedure should be logical and systematic if defects are to be eliminated. This procedure is based upon one suggested by John Brown in his book "Injection Molding of Plastic Components" published by McGraw Hill 1979. Defects should be clearly described and all the possible causes for their occurrence should be examined. When the cause has been identified the necessary steps should be taken to eliminate the defect and to prevent its recurrence. Those defects that cause the most rejects should be identified, using Pareto analysis, and eliminated first.

Equipment Required

Before a defect determination exercise is performed the person concerned must be equipped with the appropriate equipment. These include:

- A pen, notebook and sample marker
- Bags or containers to hold the samples
- Weighing scales accurate to 0.01 g
- A knife and small saw
- A magnifying glass
- A portable pyrometer
- Gauges or jigs for sample measurement
- A stopwatch
- Samples of the product, that have been approved as being of the correct quality
- A light-box to check the color of the product under standardized conditions

Name the Defect

Many defects are given more than one name. Ensure that the terms used to name a defect are unambiguous and are known to all concerned. The alternative names for a defect should be listed and components that exhibit that defect should be available for inspection and comparison.

Describe the Defect

Describe all common defects in the simplest possible terms. A possible cause may be revealed by this description. For example, voids in the extrudate from the presence of moisture may be described as "foaming" or "out-gassing".

Defect Percentage

The defects, or rejects, from an extrusion run may be named by such terms as: voids in extrudate, contamination, degradation, granules/nibs in the output, gassing, color distribution or poor surface finish on the output. The total (100%) defects, or rejects, are sorted into their named fault categories. The quantity, in each fault category, is then expressed as a percentage of the total rejects (Pareto analysis) in a three column "league table". The most frequently seen defect is placed at the top of the table (1st column) followed by the remaining defects in descending order of their frequency. The percentage of each defect is entered in the second column with the cumulative percentage total shown in the third column.

	% of Total	**Cumulative %**
1. Voids	35	35
2. Contamination	25	60
3. Degradation	15	75
4. Granules/nibs	10	85
5. Gassing	8	93
6. Poor color distribution	5	98
7. Poor surface finish	2	100

A Pareto diagram may then be drawn of cumulative percentage (vertical axis) against the type of defect (horizontal axis). The major defect is placed on the left-hand side and the least common on the right. Such a diagram often shows that the bulk of the defects are of three or four types. This type of analysis indicates where efforts should be concentrated to eliminate the most defects in the shortest time.

Procedure

Make a complete record of the machine settings before making any change. Adjust only one setting at a time, choosing the easiest one first. If this change does not eliminate the defect, go back to the original settings after making notes of what was done and taking marked samples of what was produced. Allow sufficient time for the machine to respond to the changes and to come to equilibrium with each change before samples are taken.

Defect Cause

Finding the cause of the defect may be a lengthy process since it requires consideration of material, machine, die and process. Observe the effect of regrind addition on component properties and on the processing characteristics (compared to the virgin material). If the defect is apparent with different lots of the same manufacturer’s resin or with material from a different supplier, this indicates the material is not at fault. If the defect disappears when the production is shifted to another machine, the source of the problem is most likely the processing conditions used and/or the consistency of production on the original machine. If the defect disappears when a different person operates the machine, then the fault may be due to the operator involved in the process.

Effect of the Defect

If the defect renders the component unusable or non-salable it must be rectified. If it is only of minor significance, then it may be unnecessary to try to eliminate it entirely. However, clearance to continue production with the minor tfault must be obtained in writing.

Defect Responsibility
Determine where the responsibility for the defect lies. This may only be of academic interest, but if the defect recurs, the operator – as well as the material, machine, die and process – needs to be checked.

Avoidance Action
Take immediate, and appropriate action to avoid the defect. If this is not done, then the reasons for continuing production with the defect should be entered on the production record sheet.

Prevent Recurrence
Take steps to prevent a recurrence of the defect. Make full records of the conditions used when the defect was present and of the conditions used when it was eliminated. Note any repairs and alterations that were made to the die or the machine and any variations in type, grade or quality of material. If rework is used, note the proportion used and the quality. Keep labeled samples of what is being produced – both with and without the defect. No defect-determination exercise is complete unless all of the above points have been considered. Making defective products, even though they can all be recovered, re-ground and the material used again, is uneconomic and non-productive.

MINIMIZING DEFECTS
In many cases, the production of a product that contains defects can be minimized if the operator makes some basic checks before, and/or during, production. For example, he must check that the extruder appears to be functioning correctly and that the machine is set correctly. The material fed to the machine must be carefully checked.

Feedstock Checks
With regard to the feedstock, the operator must check that the:
- Correct types of material are being used
- Correct grade of materials are being used
- Correct level of materials (such as masterbatch and regrind) are being used
- Material is free of contamination
- Material is dry and free from an excessive concentration of fines

Temperature-Related Settings
Temperature-related settings or parameters cause many problems. The operator must check that the:
- Thermocouples are not loose in their mounting holes
- Thermocouples are of the correct type
- The feed throat is at the correct temperature
- The hopper is at the correct temperature
- The barrel and die are at the correct temperatures

• The melt is at the correct temperatures (in order to be accurate the melt temperature must be measured with an immersion thermocouple)
• The specified volumes of water are circulating through the feed throat and rolls so they are at the required temperatures

Speed Settings

Check that the rotational speed of the screw (in rpm) is being correctly measured and displayed, and that the draw down, or haul off, speed of the rolls (in rpm) is being correctly measured and displayed.

Die and Ancillary Equipment Checks

With regard to the die, the operator must check that:
• The die lips are clean and polished
• The die is properly set
• Any adjustable parts of the die function smoothly and correctly
• The correct screen pack has been fitted
• The ancillary equipment is properly set and that all the parts function smoothly and correctly
• All parts of the die and the ancillary equipment are at the correct temperature

Consult the Setting Sheet

The operator must also check that the machine is set as specified by the setting sheet and/or, by the supplier of the material. The operator must also check that the pressures, temperatures and speeds are achieved in production and that accurate records are kept. Samples of product must be taken at approved intervals and submitted to quality control.

EXTRUSION DEFECTS AND CAUSES

Process Problem (Location or Cause)	**Problem or Type of Defect**																		
Hopper Throat	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Bridged	*	*																	
Cooling faulty		*																*	
Barrel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Feed zone temp too high																			*
Feed zone temp too low	*														*				
Barrel temps too high						*						*	*				*		
Barrel temps too low	*	*											*		*			*	
Temp profile wrong	*		*			*					*	*		*			*	*	
Temps fluctuating			*			*													
Cooling required																*			
Venting required				*				*											
Worn	*	*	*			*													

Process Problem (Location or Cause)	Problem or Type of Defect																		
Die	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Temps too high						*						*	*				*		
Temps too low	*	*											*		*			*	
Temps fluctuating			*			*													
Incorrect design	*		*		*	*		*		*	*	*	*	*	*				
Requires adjustment	*													*	*				
Requires cleaning	*	*				*				*			*	*	*				
Screen Pack	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Blocked	*	*										*			*	*			
Wrong rating used	*		*	*						*	*		*	*					
Screw	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Worn	*	*	*			*													
Cooling required											*	*			*		*		
Incorrect design		*					*			*	*	*			*			*	
Insufficient mixing											*	*	*						
Requires cleaning	*	*					*							*					
Drive System	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
RPM varying		*	*																
Drive belts slipping	*	*																	
Gearbox oil level low																			*
Gearing incorrect																			*
Gearbox worn																			*
Plastic Material	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Requires drying	*		*				*												
Polymer quality poor	*	*	*	*		*	*	*	*			*							
Wrong grade used	*		*		*	*	*					*							
Extrusion Rate	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Too high				*		*	*		*	*	*								
Too low						*		*			*							*	
Additives	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Colorant not premixed											*	*							
Colorant incompatible				*							*	*	*						
Reclaim contaminated	*				*	*							*	*					

Problem or Type of Defect

1. Low output
2. Erratic or intermittent output
3. Surging output
4. Voids in extrudate

11. Color distribution poor
12. Color variation
13. Poor surface finish on the output
14. Streaks in the output

5. Contamination
6. Degradation
7. Varying viscosity
8. Granules/nibs in the output
9. Gassing
10. Uneven flow
15. Excessive barrel pressure
16. Temperature over-shoot
17. Material leakage
18. High motor amperage
19. Material adheres to screw

PRODUCTION PROBLEMS AND FLOW BEHAVIOR

Since most processes for plastics involve flow, one might expect that rheological concepts would be understood and widely used. In practice, however, quantitative application of rheology is still somewhat limited. This is because of the complex nature of the flow behavior of polymer melts, the complicated flow patterns involved in many shaping operations (for example, the filling of a profile die), and the fact that melt cooling occurs while the melt is still flowing. Nevertheless, an understanding of flow behavior can often help to overcome processing problems. The use of computer programs, which combine rheological and thermal data, is very important in computer-aided design and engineering.

Effect of Flow Channel Shape

For a flow channel of a fixed cross-sectional area, greater flow rates occur when the channel is circular than when it is in the form of a slit. It can be shown that the narrower the slit, even though the crosssectional area is the same, the lower the flow rate (under a constant delivery pressure). This difference is relevant in the extrusion of complex shapes, where the extruded crosssection is made up of components of different thickness and shape. The extrudate cross-section may be in the form of a dumbbell with two almost spherical parts being bridged by a slit. In this case, flow will tend to be faster in the round sections and slower in the bridging slit, leading to undue stretching, and possible tearing, of the central parts of the extrudate. Even worse defects may occur when the extrudate cross-section is like a half dumbbell, or key cross-section, with one circular section attached to a slit. In this case the extrudate will tend to curl up as it leaves the die. While such designs are best avoided, the problem may be solved by reducing the parallel portion of the die in those regions where the flow is slowest (in the above examples, in the slit zones). Alternatively, one may throttle the flow in the regions where flow is fastest by the use of a pin or mandrel, inserted in the flow channel at the entrance to the die parallel.

Unbalanced Flow in Tubular Extrusion

Tubing is made by extruding polymers through the annular gap between a circular die and a pin or mandrel. It is sometimes found that the inside wall of the tube has a number of transverse ripples that arise from variations in radial flow velocity through the die. To understand this phenomenon, consider the following. In a simple rod die the flow rates is greatest in the center of the die and zero, or almost zero, at the wall (with simple Newtonian liquids, such as water, the velocity profile is parabolic in shape. The viscoelastic behavior of polymer melts usually makes this profile somewhat flatter). If one extrudes over a very thin pin (of a thickness approximating to that of a thin piece of wire) the velocity profile will be little affected. The flow rate a short distance from the thin pin will be much greater than the flow rate the same distance from the die wall. As the diameter of the pin is increased the difference becomes less. However, the flow rates will be higher nearer to the pin than to the die wall. Since the melt is coming out faster on the inside of the tube this tends to cause buckling and hence rippling on the inside of the tube. One way of reducing this is to fit a restrictor bulge or ring around the pin to slow the flow in this region.

Uneven Die Swell

As a general rule, die swell will increase with shear rate and decrease with the length of the die parallel. If a complex section with varying cross-sections is being extruded, then different shear rates will exist at the walls of the different crosssections. The shear rates are the highest where the cross-section is least. It may be possible to compensate for these differences when carrying out die sizing (See Sizing of Die Components). However, if it is found that at one point the swell is lower than elsewhere, then the die parallel at that crosssection may be reduced to compensate. If this is done, then one should machine the back end of the die parallel and ensure that all changes in crosssection are gradual.

Die Swell and Parison Sag

In extrusion blow molding, it is common to extrude a parison vertically downward. The wall thickness, and thus the tube diameters, will tend to increase, due to die swell, while at the same time they will also tend to decrease as the parison sags under its own weight. While the swell effect will be independent of parison length, the sag will increase as the tube length increases. It is possible to compensate for this by using a tapered die and pin that can be made to move axially, with respect to each other, to open the die gap during the extrusion of the parison. The parison movement may be programmed either as the result of trial and error experiments, or by use of theoretical data.

Melt Fracture and Sharkskin

It is often found that surface defects on an extrudate will show a regular pattern on the surface. With large diameter extrudates, this is likely to be in the form of roughness transverse to the direction of flow, called sharkskin. With smaller diameter products, it is a helical form called melt fracture. If the problem appears to be melt fracture, then the following possibilities should be considered:

1. Reduce output rate (not usually commercially desirable)
2. Increase the melt temperature (which will increase cooling times)
3. Taper the die entry further
4. Taper the 'die parallel' by up to 1˚
5. Use a polymer of lower molecular weight

If the problem is identified as sharkskin, then the following possibilities should be considered:

1. Reduce output rate
2. Vary the die temperatures. Either raising or lowering of the die body temperature may help, while extra heating of the die exit may be particularly beneficial

Steady State Operation

Unlike injection molding, extrusion is a continuous operation that requires keeping the materials used, and the operating conditions, constant over very long periods. Changes to machine settings or controls should be made only after due consideration. If changes in settings (such as speed or temperature) are considered necessary, then they should be altered one at a time. After each change, a reasonable time should be allowed for the system to equilibrate. The operator must appreciate that the reaction time of the extruder to changes differs significantly, depending upon what is being altered. For example, a change in pressure will cause a rapid change in extrudate output and power input. However, a change in a barrel temperature setting will take longer to come to equilibrium, because of the thermal mass of the machine, together with associated output and power input variations. Screw speed changes will also cause a rapid change in extrudate output and power input. It will, however, cause a much slower change in the melt and machine temperatures.