



Trouble Shooting Guide

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Raw Material Problems:

1. High Prepolymer Viscosity

High prepolymer viscosity can lead to problems in processing and final product quality.

Causes include:

a) Overheated Prepolymer

Because prepolymers are generally heated for processing, it is possible to degrade them by applying too much heat. Normally, the isocyanate (NCO) groups within a prepolymer react with a curative to form an elastomer. When the prepolymer has been overheated, however, these NCO groups react with each other instead, leading to an increase in prepolymer viscosity. In severe cases, the prepolymer can actually gel to a solid mass. If overheated prepolymer is used in processing, soft parts will result—even if the prepolymer has not degraded to the point of gelation.

b) Low Processing Temperature

The viscosity of any liquid is a function of temperature; the higher the temperature, the lower the viscosity. All prepolymers have recommended processing temperatures that differ from one product to another. When the prepolymer is at too low a temperature, it will be difficult or impossible to process. Polyester prepolymers are especially likely to be under-heated because they require higher processing temperatures than do polyether prepolymers of similar hardness.

c) Use of Inappropriate Prepolymer Type

Polyether prepolymers are typically lower in viscosity than polyester prepolymers. Similarly, different prepolymer production methods yield products with different viscosity characteristics.



Solutions include:

a) **Adhere to Melting Guidelines**

To avoid overheating a prepolymer, adhere to the melting time and temperature guidelines provided by the prepolymer supplier. Although prepolymers degrade at different rates upon heating, minimizing heat exposure is always recommended. To monitor this, keep a log of the prepolymer heat history. Use of a band heater is not recommended because heating is too localized. Also, if possible, the prepolymer drum should be rolled while being heated.

b) **Check the Prepolymer Temperature with a Thermocouple**

To avoid low processing temperatures, check the temperature of the prepolymer with a reliable thermocouple to ensure that the preheat oven is working properly. Do not assume that the prepolymer is at the same temperature as the setting of the oven. There may be localized hot or cold spots in the oven, or the prepolymer may not have been in the oven long enough.

2. Prepolymer Difficult to degas

All prepolymers should be degassed prior to being mixed with the curative, and if time permits, the prepolymer/curative mixture should be degassed again prior to being poured into the mold. This will help prevent potential problems caused by small amounts of nitrogen/air that may have become entrained in the prepolymer during production and drum filling.

Causes include:

a) **High Prepolymer Viscosity**

It is more difficult to degas a high-viscosity prepolymer than a low-viscosity prepolymer. High prepolymer viscosity can be a function of the specific prepolymer in use, or it may be because the prepolymer has been degraded. See the [High Prepolymer Viscosity Problem](#) for further details on the causes of high viscosity.



b) Insufficient Vacuum

If degassing seems to be progressing at a slow rate for an extended period of time, the vacuum system may be faulty. With insufficient vacuum, the pressure may not be low enough to allow entrained air to escape. Insufficient vacuum may be caused by a weak or worn vacuum pump or a leak in the vacuum lines.

c) No Degassing Agent

Degassing aids are additives that lower the surface tension of the prepolymer, thereby allowing for easier degassing. Without the use of a degassing aid, degassing problems could be noted.

d) Lower processing temperatures

Prepolymer viscosity increases sharply with decreasing temperature. Ensure resin is at the correct process temperature and that it has not been stored in a cooler position within the melting oven.

Solutions include:

a) Check the Prepolymer Temperature and Heat History

The higher the prepolymer temperature, the easier it is to degas. Ensure that the prepolymer is at the correct processing temperature when degassing. Also check that the prepolymer has not been previously overheated, which will result in increased viscosity. See the [High Prepolymer Viscosity Problem](#) for further details on high prepolymer viscosity.

b) Check the Gauge on the Vacuum Pump

In order to properly degas raw materials, the vacuum gauge on the degassing system should read at least 27 inches mercury (Hg). With less vacuum than this, it will take an excessively long time to degas.

c) Add a Degassing Agent

Use levels are typically recommended at 0.2 parts per hundred parts prepolymer.



3. Changes in Pot life or Gel time

All prepolymer/curative combinations have a specific pot life and gel time. Pot life is generally defined as the amount of time available after mixing to work with the system before it becomes too thick to pour. Gel time is typically defined as the time it takes for the system to cease exhibiting any liquid-like characteristics. Generally, the higher the percent NCO of the prepolymer, the shorter the pot life and gel time. Pot life and gel time are also both influenced by temperature.

Causes include:

a) **Degraded Prepolymer**

A degraded prepolymer will usually exhibit a reduction in percent NCO. This reduction will shorten the apparent pot life and possibly lengthen the demold time.

b) **Degraded Curative**

Some curatives, such as Mboca, can be degraded with exposure to too much heat. When Mboca begins to decompose, a significantly faster reaction with the prepolymer results.

c) **Improper Catalyst Addition**

Catalysts are often added to decrease the pot life and gel time of a system to achieve increased productivity. Typical catalysts used for this purpose are amine, acid or tin based. Catalysts are added at very small use levels, and it can be very difficult to monitor an exact amount. In addition, since they are used at such low levels, a small amount of catalyst will last a long time. Some catalysts, especially tin-based products, can become less active over time and can lose their effectiveness.

d) **Incorrect Temperatures**

Higher reactant temperatures will cause an increased reactivity rate between the prepolymer and curative, thereby reducing the system pot life and gel time. The converse is also true. With smaller parts, mold temperatures that are significantly different from the mix temperature can cause reactivity problems by quickly adding or removing too much heat from the system.



Solutions include:

a) **Minimize the System Heat History Before Processing**

To eliminate degradation of the prepolymer and/or curative due to excessive exposure to heat, follow the supplier's processing temperature guidelines for each product.

b) **Check the Catalyst Addition**

Catalysts, if they are used, can have a significant effect on the reactivity of the system. Some catalysts, especially tin-based products, can become less active over time. If reduced catalyst activity is suspected, a new lot of catalyst should be tried. To assist in monitoring catalyst addition amounts, consider mixing the catalyst in a curative or plasticiser, such as Benzoflex.

c) **Try a New Lot of Catalyst**

d) **Monitor Batch Temperatures Closely**

Changes in batch temperature and mold temperature will affect reactivity. Monitor these temperatures carefully. Also, do not rely solely on oven temperature gauges—always have a secondary method to determine temperatures.

Appearance Problems

1. Large Voids In Parts

Upon demolding, there may be large voids either within the part or on the surface of the part. These voids are visible with the naked eye, and they usually occur at thin-walled sections, corners and other transition areas.

Causes include:

a) **Air Entrapment During Pour**

As the batch is poured into the mold, it displaces air from the mold. If the air becomes trapped within various cavities and has no mechanism to escape, it will form a void. This can happen in thin-walled areas if the prepolymer viscosity is too high.



b) Short Pot Life

As the batch is poured into the mold and it displaces the air in the mold, some air will become trapped there temporarily. This air will then begin to work its way to the upper surface of the part. This process takes a finite amount of time, and if the pot life of the system is too short, the air bubbles will not have a sufficient amount of time to escape.

c) Leaking Mold

If some of the material poured into the mold leaks out, a void will form at the leaking area. Leaking is more likely to occur in systems with a long pot life and low viscosity.

Solutions include:

a) Redesign the Mold/Vents

A proper mold design with adequate venting will generally prevent problems with large voids.

b) Use Lower Viscosity Prepolymers

Using a lower viscosity prepolymer will make it easier for the air to escape from the mold. Using a polyether prepolymer instead of a polyester prepolymer will also decrease voids, if the application allows for this substitution. In addition, using a system with a lower viscosity and longer pot life will help reduce void formation.

c) Tilt Mold and Pour Down Its Side to Minimize Splashing

Often, tilting the mold upon filling, especially in the case of large rollers, will allow air to escape more easily. Also, pouring down the side of the mold will decrease splashing, another source for air bubbles in the system.

d) Add a Degassing Agent

The addition of a degassing aid will reduce the surface tension of the system. With higher viscosity materials, this is often enough additional help to reduce the formation of voids. Use levels are typically recommended at 0.2 parts per hundred parts prepolymer.



2. Small Bubbles In Parts

Sometimes small bubbles are apparent throughout parts. These bubbles may or may not be localized.

Causes include:

a) **Moisture Contamination of Components**

Moisture (H_2O) will react with the isocyanate group in a prepolymer to produce carbon dioxide gas (CO_2). CO_2 bubbles will manifest themselves as small bubbles in the part. Moisture can come from many sources, including the prepolymer, curative, catalyst, adhesive, primer or additional additives. Of primary concern are polyol curatives (such as 1,4-butanediol, or BDO) and pigments that are hygroscopic, meaning they readily absorb atmospheric moisture. With moisture contamination of the raw materials, the bubbles are seen throughout the part, and when you have moisture contamination of the adhesive or primer, the bubbles are generally seen only at the bond line.

b) **Moisture Contamination of the Mold**

Molds that have not been heated for a sufficient time above the boiling point of water could have atmospheric moisture on their surface. Molds may also have water condensation in humid environments if they are allowed to cool down and are not completely reheated. Also, the improper application of water-based mold release agents can lead to water being on the mold. With water contamination of the mold, bubbles usually appear on the surface of the part, especially on the lower horizontal surfaces.

c) **Inadequate Degassing**

If the prepolymer is not degassed prior to mixing, and the batch is not degassed prior to pouring, small entrapped bubbles will be the result.

d) **Poor Pouring Technique**

Considerable splashing during pouring will introduce bubbles into the batch. This is especially an issue with low-viscosity systems where splashing is more pronounced.



e) **Failed Seal in the Processing Machine**

When using a meter-mix dispensing machine, degassing usually occurs in the component storage tanks. With this system, materials are pumped from the storage tanks directly to the mixing head, where they are mixed, so there is little opportunity for incorporation of air into the mixture. However, seals in the mix head can fail, which can introduce air into the stream, and thereby negate the effect of the original degassing.

Solutions include:

a) **Store All Products Under Dry Nitrogen**

Storing as many materials under dry nitrogen as possible will reduce the likelihood of the absorption of atmospheric moisture. With some products, there is also the added benefit of potentially reducing oxidation due to the presence of air.

b) **Degas All Components Before and After Mixing**

Degassing all components prior to and after mixing will remove any entrained air in the components and the mixed system. Also, degassing raw materials will distil out any water in the material, which will negate the NCO/H₂O reaction that forms CO₂.

c) **Ensure that the Mold is Properly Heated**

Heating the mold above the boiling point of water [212°F (100°C)] will remove moisture that has condensed on the mold, as well as any remnants of water-based mold release left on the mold.

d) **Maintain the Mix Head Seals**

A regular maintenance program for machinery is always a wise practice. Consult your machine supplier for their maintenance recommendations.



3. Excessive Shrinkage, Cracking or Warping In Parts

Molds usually allow for the shrinkage that occurs in an elastomer when the prepolymer and curative react. Typical shrinkage rates are 1-2% under normal processing conditions. Excessive shrinkage, however, will cause warping or unnatural stresses in the part. Cracking, which can also result, will vary from small internal cracks, to more obvious surface cracks.

Causes include:

a) Incompatible Resin and Mold Temperatures

As a prepolymer/curative mixture begins to react, it generates heat that increases the temperature of the mixture. If there is a substantial difference between the reaction temperature and the mold temperature, there will be stresses placed on the system as it tries to shrink or expand during the reaction. The critical time for these two temperatures to be approximately in balance is when the mixture goes through its "green stage," which is when it changes from a liquid to a solid. Too low of a mold temperature relative to the mixture temperature will cause the gelling reactants to shrink excessively, sometimes to the point of cracking. Too high of a mold temperature is generally less of an issue, though this could lead to excessive warping.

b) Localized Temperature Variation in the Mold

Localized hot and cold spots within a mold can also cause internal stresses that may lead to shrinkage, cracking and warping.

c) Low Stoichiometry

Low stoichiometry leaves unreacted isocyanate that will increase crosslinking of the system. This additional crosslinking will tighten the elastomer and lead to increased cracking and shrinkage.

Solutions include:

a) Balance the Exotherm and Mold Temperatures

Every polyurethane system will have a different peak exotherm, which is the highest reaction temperature reached by the mixture. For a given system, this is a function of the individual components as well as the reaction mass. Larger mass mixtures will have a higher peak exotherm than smaller masses. The ideal case is to balance the mold temperature to within $\pm 5^{\circ}\text{C}$ of the peak exotherm.



b) Heat the Mold Adequately

Ensure that the oven is circulating air properly, so that there is a uniform temperature throughout the oven. Also, the mold should stay in the oven long enough to come to a constant, uniform temperature.

c) Monitor Raw Material Temperatures

Raw materials can lose heat as they are degassed and mixed, or while they sit before mixing, and therefore, they may need to be reheated in order to maintain the proper temperature. If the temperature of the system is too high, cracking may result. Lower system temperatures and higher mold temperatures are generally recommended.

4. Poor Surface Quality

Several processing conditions can cause surface irregularities in cast parts. This is a concern since many applications for polyurethane parts require aesthetically pleasing surfaces.

Causes include:

a) Improper Mold Release Application

Using either too much or not enough mold release will lead to poor part surface characteristics. Many processors try to push their release agent to get several releases with one application. This will eventually result in parts sticking in the mold and ruined part surfaces. It may also be tempting to try to use a heavy coat of mold release to get several turns from the mold. However, this too can lead to surface quality problems. Not all mold releases work with all systems; wax-based mold releases, for example, may work for MDI systems, but not for TDI systems.

b) Dirty Mold

Build-up of elastomer material on the mold will cause poor surface quality on the molded parts. This build-up generally occurs because of inadequate mold release, which in turn continues to allow elastomer material to build up on the mold surface. The molded parts subsequently take the shape of the mold, which now has deposits of polyurethane on it.



c) **Excessively Cold Mold**

Cold molds can lead to shrink marks on the surface of parts. This is particularly true with MDI prepolymer systems. The long "green state" of these systems, combined with excessively cold molds, will lead to shrinkage marks.

Solutions include:

a) **Apply the Proper Amount of Mold Release Evenly**

Following the manufacturer's directions for mold release application will solve most surface quality problems. Also make sure that the mold release is applied after the appropriate number of turns.

b) **Clean Molds Regularly**

Sandblasting the mold is one method of cleaning molds whenever a build-up is noticed and part surface imperfections have begun to appear.

c) **Heat the Mold Thoroughly**

Thorough heating of the mold will reduce the likelihood of cold mold marks and will help avoid several other potential problems. The mold should also be removed from the oven as close to pour time as possible.

d) **Choose the Best Mold Material**

Steel molds retain heat better than aluminium; therefore, it is easier to keep the temperature of steel molds uniform versus aluminium molds.



5. Swirls / Streaks In Parts

Occasionally, swirls and streaks will show up in a finished part. This generally manifests itself as multicoloured swirls throughout the part in a fairly random pattern.

Causes include:

a) **Improper Mixing**

Even without pigment, the prepolymer and curative are generally different colours, or different shades of the same colour. If these two (or more) materials are not completely mixed together, prepolymer-rich or curative-rich pockets will remain in the elastomer. This will lead to poor physical properties since the pockets will alter the stoichiometry of the elastomer. This phenomenon is usually fairly easy to spot when a pigment is in one stream of the mixture. The drastic difference between the colours in the streams is an excellent indicator of poor mixing.

b) **Unevenly Dispersed Filler**

Many softer polyurethane formulations contain fillers that in some instances can be very difficult to mix into the formulation. Insufficient mixing of fillers will cause swirls and streaks in the resulting part.

c) **Knit Lines**

In the production of some parts, most notably vertically cast rollers, one can observe knit lines. These lines occur when material flows around a core or insert and the material is partially cured when it meets at the opposite side of the insert. Depending upon the degree of cure at the point of contact, this knit line area can be a weak point in the elastomer.

Solutions include:

a) **Ensure Sufficient Mixing of All Components**

Use of a pigment will help highlight areas where materials are mixed inadequately.

b) **Disperse Fillers in Plasticiser**

It is often more effective to dissolve or suspend fillers in a plasticiser before adding to the prepolymer.



c) Use Smaller Size Particles for Fillers

Smaller particles are generally more difficult to disperse in the mixture. However, if the problem appears to be particles settling out of the mixture, then going to a smaller particle may help.

d) Use Materials with High Viscosity

Again, if settling appears to be the issue, the use of prepolymers with higher viscosities could solve the problem.

e) Use Systems with Increased Pot Life

The general way to minimize knit lines is to either pour material into the mold at a higher flow rate or to use a system that has a longer pot life.

Processing Problems

1. Poor Physical Properties

Inferior elastomer physical properties will generally show up in field performance, though testing is possible to confirm abnormal behaviour before the part gets to a customer. Repetitive errors, such as incorrect stoichiometry and incomplete cure, are easy to determine through testing. Random errors, such as an overheated drum of prepolymer, are more difficult to spot.

Causes include:

a) Incorrect Stoichiometry

Maintaining the correct ratio of prepolymer to curative, which is called stoichiometry, is critical in producing consistent, high-quality elastomers. The typical ratio used to obtain the best combination of properties is 95%. A table can be requested from Notedome that outlines the effect of stoichiometry on elastomer physical properties.

b) Overheated Prepolymer

Use of an overheated prepolymer will have the same ultimate effect on the elastomer as processing at an incorrect stoichiometry. You will be able to tell that a prepolymer has become overheated because it will have a lower percent NCO than what is indicated on the prepolymer container.



c) **Incomplete Cure**

Post-curing is used to relieve internal stresses and to allow proper alignment of the polymer chains.

Solutions include:

a) **Calibrate Balances Regularly**

Balances must be calibrated regularly. In a production environment, balances can become covered with prepolymer, curative and other materials. If these materials are on the weighing pan, they can force the balance out of calibration.

b) **Calculate the Amount of Curative Based on the NCO of Each Lot of Prepolymer**

Many processors will use an average percent NCO for determining the amount of curative to use with a prepolymer. However, with some prepolymers, this can amount to a stoichiometry error of up to 5%, which can affect properties significantly.

Each drum of prepolymer has a specific percent NCO. It is important to use the percent NCO of the particular prepolymer lot that you are using. The amount of curative to use can then be determined with the following equation:

$$\frac{(\% \text{ NCO})(\text{Stoichiometry})(\text{Curative Equivalent Weight})(\text{Amount of Prepolymer})}{42.02}$$

c) **Minimize the System Heat History**

Follow the manufacturer's guidelines for exposure of prepolymer and curative to heat.

d) **Follow Supplier Curing Guidelines**

Prepolymer suppliers have standard recommendations for the curing of their materials. A typical guideline is to cure the prepolymer for 16 hours at 100°C, though please verify this recommendation for each system. Some prepolymer/curative combinations require different conditions.



e) **Use an Elemental Analyser During Production**

For Mboca, Lonzacure® MCDEA curative or Ethacure® 300 curative-based elastomers, an analyser with an X-ray source can be used to determine the stoichiometry during production.

2. Low Hardness

Hardness measurements are considered statistically the same if they are ± 3 points from the average of several measurements. If the hardness is outside this range, then there could be a hardness variation concern.

Causes include:

- a) **Overheated Prepolymer**
- b) **Incomplete Cure**
- c) **Incorrect Stoichiometry**

With gross errors in stoichiometry, the hardness of the elastomer may decrease.

d) **Inadequate Mixing**

Inadequate mixing will leave areas in the elastomer that are rich in prepolymer or curative, which will lead to incorrect stoichiometry, and in turn, will result in problems with part physical properties.

Solutions include:

- a) **Minimize the Heat History**
- b) **Follow the Supplier Curing Guidelines**
- c) **Calculate the Amount of Curative Based on the NCO of Each Lot of Prepolymer**
- d) **Ensure Sufficient Mixing of All Components**

Use of a pigment will help highlight areas where materials are mixed inadequately. See [Swirls/Streaks in Parts](#) for further detail.