Troubleshooting the Batch Vacuum Metallized Part

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ABSTRACT

Troubleshooting coating defects on batch vacuum metallized parts can be frustrating and time consuming. Productivity declines and costs rise as time is spent chasing problems. A systematic approach which identifies metallizing problems and proposes solutions can reduce the time spent troubleshooting.

INTRODUCTION

Over the years, substantial resources have been allocated by batch vacuum metallizers attempting to solve problems with their vacuum metallized products. Time and money which could have been used to produce parts were allocated to pinpoint that elusive problem which made the finished product unacceptable. Although it is unrealistic to believe that a batch metallizer will never produce any scrap or that he will never have to put any time into troubleshooting, much more time and effort is spent on such non-productive activities than is necessary in most cases. Familiarity with the metallizing process and its limitations as well as a systematic approach to troubleshooting can increase the productivity of most batch metallizing operations.

Problems with the batch metallizing operation are usually due to problems in one of the following areas: substrates, applied coatings, equipment operation, fixturing, pumping/firing procedure, and environment. While these groupings are logical, from a troubleshooting point of view, it is usually easier to categorize according to problem, as some metallizing defects can have several different potential causes.

THE METALLIZING ENVIRONMENT

The potential for metallizing defects begins well before parts are being fired in the chamber. Let's begin by examining the environment the metallizing system operates in. The two biggest environmental causes of metallizing defects are humidity and dust. Humidity is trapped on the surface of (absorbed) and is trapped within (adsorbed) substrates [1], chamber walls, fixtures, carriages, and evaporants. In the vacuum chamber this moisture is released from these surfaces into the space being evacuated. It must then be pumped away. Water vapor is one of the most difficult gasses to pump from the chamber. The primary problems created by high humidity are long pumpdown cycles and burned shots. The simplest way to reduce problems from humidity is to air condition or dehumidify the metallizing area.

The other major environmental concern which contributes to metallizing defects is dust. The two most common types of dust that metallizers have to deal with is dust from the outdoors and dust from cardboard. Many metallizers run with all doors open to the outside, particularly during warm weather. Often dust from outdoors simply blows in. It can also be carried in on shoes of employees. As for cardboard, it is used as packaging for finished parts and can be blown through the shop, but the larger problem arises when cardboard is used while transporting parts around the shop. Plastic parts can carry a static charge which will attract dust particles, particularly when humidity is low. Placing parts on cardboard sheets or in cardboard boxes is inviting trouble. Plastic bins or metal cages are usually better for this purpose. To minimize dust, the metallizing area should be located in a separate room which can be positively pressurized with filtered make-up air. This causes air to flow out from, rather than in to the metallizing area, preventing dust from the rest of the building from entering. To remove the dust which does settle on parts, parts can be blown off with a destatic air gun prior to racking. Other possible causes of dust are air makeup systems which draw outside air into the metallizing area, dirt which has not been filtered out of coatings, or unfiltered air in air lines.

PART DESIGN

Another prime consideration when attempting to minimize metallizing defects is part design. Certain parts lend themselves better to metallizing. What are the qualities of a good part for metallizing? First, avoid large flat areas. There is great visual appeal in a mirror-like surface, but in most metallizing operations, such a large, flat area will be a showcase for problems such as dust, coating defects, and surface imperfections [2]. Molding defects such as sink marks will also be more noticeable. Deep cavities or recesses should also be avoided. It is very difficult to coat the sides of them properly. Surfaces perpendicular to the path of the evaporant travel coat better than those parallel to this path. This is because platelets of vapor lay flat on a perpendicular surface, but stand on edge on a parallel surface. As a cavity becomes deeper in relation to its width, the aluminum that gets down deepest into the cavity is traveling in a parallel direction to the side walls of the cavity. The result is a poor dusty gray coating on the side walls deep in the cavity. The solution to this problem is to avoid recesses that are deeper than they are wide, and add more filaments to increase the chances of a more perpendicular deposition path [3]. Where possible, a second surface coating of the opposite side of a deep well coats much better.

GATHERING INFORMATION

Now that we've discussed how to avoid problems before metallizing, let's discuss what to do about metallizing problems that occur during metallizing. The most important rule in troubleshooting the batch vacuum metallized part is troubleshoot while parts are still on the carriage. This cannot be stressed strongly enough. Some of the most valuable information about the cause of a metallizing defect is tied to its location in the chamber. Far too often, some poor soul sits in a room with a lone part trying to figure out what's gone wrong in his metallizing department. This is futile. Train shop personnel to leave bad parts on the carriage, or to note their specific location before removing them. If you remember nothing else from this paper, remember this. The second rule of troubleshooting is to have histories available. Keep records on pumpdown times, cleaning schedules, oil changes, number of rejected parts, weather, substrate lot, or any variable you can think of which affects your metallizing operation. The reason for this is simple. When you start making bad parts, you need to know what you are doing differently than you were doing before. The more information you have about your operation, the easier it will be to pinpoint potential causes. Realize that this information comes at a cost. It takes time and effort and therefore money to collect this information. But gathering information on a regular basis soon becomes habit and is almost always cheaper than trying to make up for the lack of it. Third, be systematic in your approach to troubleshooting. Follow a set of guidelines such as the ones which will be shown in this paper. This keeps you from overlooking a possible solution and gives you and others working with you a frame of reference. When a possibility is eliminated, everyone can be confident that it has been thoroughly considered and everyone can move forward together. Time and efforts will not be lost chasing down blind alleys and dead ends, or in disagreement over what the next step should be. As many people as possible should be trained in this process. It is better for an operator to solve a problem than for him to have to call his supervisor over and have the two of them working on it together.

BURNED PARTS

The first problem we will deal with is the problem of burned parts. This is probably the single biggest cause of rejected parts for the batch vacuum metallizer. Burned parts have a straw, blue, or black tint to them instead of the usual bright silver. The dark shot is caused by an interaction between the evaporant and a contaminant. In the batch vacuum metallizer, such contaminants come from leaks, volatiles in plastic parts or coatings, or lubricants [4]. Troubleshooting the burned part will show the importance of leaving reject parts on the carriage to troubleshoot.

If the burned parts are always located near the front of the chamber, the problem is a leak or source of outgassing near the front of the chamber. Check for a dirty, over-greased, or cut door seal. A dirty seal may be preventing proper seating of the door gasket. An over-greased gasket will attract dirt and excess grease may be a source of outgassing. Use only vacuum grease. A cut in the door gasket may be allowing air to enter the chamber. Correct any of these conditions. If the discoloration persists, check the porthole for leaks. Some chambers have gas feedthroughs or emergency vacuum breaks in or around the door, check these next.

If the burned parts are near the rear of the chamber, the cause is usually found within the pumping system. Check for significant amounts of oil at the back of the chamber. If found, wipe clean. Check periodically for return of oil. If oil returns, check valves for correct operation. Also check valve seals for dirt which may have been drawn in and is preventing valves from completely closing. Make certain oil is not fouled with water. This will reduce its effectiveness. Check to see if pumpdown times have risen. Check that diffusion pump is operating at recommended temperature. Lower than normal temperature may indicate a burned out heater or improper coolant flow. Higher than normal temperature may indicate inadequate coolant flow or blocked coolant line. Also check planetary drive feedthrough for leaks.

If discoloration is on all surfaces of all parts, check vacuum pressure to be sure it is in the proper range. If discoloration is dark black, has the chamber or carriage recently been stripped with caustic? A failure to properly rinse and dry after caustic cleaning often results in a chamber full of black parts. If discoloration is randomly distributed about the chamber, check these possibilities. The chamber and fixtures may need to be stripped clean. Vacuum levels may be higher than is normal (lower pressure). This can draw volatiles from chambers walls, carriages, and parts which may not outgas at higher pressures. These volatiles react with the depositing aluminum and cause it to discolor. Has the basecoat been properly cured? Undercured basecoats are often a cause of discoloration. Oven temperatures and bake times should be closely monitored. Also check that coating has not been applied more heavily than is usual. If so, it may have failed to cure adequately. If the burned part seems to consistently occur in one area of the chamber, check the filaments near that area. Are they properly connected? Do they burn brighter or more dimly than others in the chamber? Many burned parts are the result of poor current distribution throughout the chamber. Filaments should light as evenly as possible across the carriage. Here is the reason. If some filaments burn more brightly than others, it will be difficult or impossible to determine the proper firing point which should be used. If one uses the brightest filaments as a determiner, then filaments which are not getting as hot will not fire off all of their evaporant, or might drip evaporant off the filament onto parts. Chances are that the coating will be inadequate and the filaments which are lighting improperly will have a diminished life. If the decision is made to use the dimmer filaments as a guideline, by the time they have gotten hot enough, long enough for them to evaporate their charge, the hotter filaments will have already fired and will have been pouring excess heat into the chamber, probably resulting in burned parts. As you can see, even lighting of filaments is a prerequisite for good coatings. Also, if a filament burns out during a firing cycle, it will sometimes cause a dark area. If the burn always appears on the same area of the part, check the fixturing. Does the burned area pass close to the filaments at any point during the rotation? As a rule, parts should never pass closer than six inches from the filaments.

POOR ADHESION

The next most common problem in batch vacuum metallizing is poor adhesion. Poor adhesion can be divided into three areas and it is important to know which phenomenon you are dealing with. Adhesion loss can be between basecoat and substrate, aluminum and basecoat and topcoat and aluminum [5]. Each has different causes.

Loss of adhesion between basecoat and substrate is usually due to a problem with the substrate. Check these things. Does the material have an internal lubricant? Was a mold release of any kind used during molding? Often adhesion problems caused by a mold release will show up in the same isolated area again and again. Is the plastic filled with fillers or reinforcing materials? Was reground or recycled material used? If not, check that no surface contamination has occurred. Is there any possibility that the surface of the part has become contaminated? Wash several parts to verify. Use the strongest solvent available that will not damage the substrate. Metallize again and check results.

Loss of adhesion between aluminum and basecoat is sometimes also called delamination. This is the most common of the three types of adhesion problems. As above, the cause could be with the substrate. The same tests apply here too. The coating may be contaminated. Try a different batch of coating. Sometimes mold release will wash off parts and build up in a flow coating system. Try applying the coating by spraying it. The basecoat may be undercured. If so, adjust baking parameters or check for proper film thickness. Sometimes the metallizing process itself is the cause. Was this part double fired to salvage it from a previous rejection? This will sometimes be problematic. If so, consider the part scrap. Dirty racks and fixtures can sometimes leach out contaminants to parts under vacuum. The contaminant film will deposit on the parts and prevent proper adhesion. A more subtle problem can arise from the prevaporization of aluminum. If preheat stage is too hot or too long, a thin film of aluminum can deposit prior to the regular evaporation. This thin film will ruin the adhesion of the heavier layer which is then deposited over it. Give consideration to how the part was handled prior to metallizing. Are all personnel wearing clean cotton gloves when handling parts? Oils from the hands can prevent proper adhesion. Also check for backstreaming in the metallizer. This is especially likely if the problem occurs in one chamber and not in another. Check pumps for proper oil levels, for correct operation of the valves, water in pump oil, and proper pump operating temperature [6].

Finally, we have the adhesion of the topcoat to the metallized layer. This can be a result of an undercured topcoat, an improper coating for the job, overexposure to atmosphere prior to topcoating or subsequent finishing. Most people can troubleshoot the coating problems quickly using techniques discussed earlier in relation to basecoats. It is usually more difficult to trace defects which are a result of atmospheric exposure. Parts which are not immediately topcoated can be exposed to oil vapor, humidity, or dust. The farther that uncoated parts travel through the plant, or the longer they remain uncoated, the greater the chances of this problem. To prevent problems of this type, utilize the shortest route and the shortest exposure time for metallized parts to be topcoated. To troubleshoot this problem, trace the route the parts travel looking for potential sources of contamination. Remember that some contaminants, such as silicone sprays can travel throughout a plant.

IRIDESCENCE

The next problem encountered by batch metallizers is iridescence. A similar phenomenon, known as Newton fringe, is often confused with iridescence. The distinction is an important one. Newton fringe is composed of colors such as pink, green, and purple. It is sometimes said that Newton fringe has the same colors as are seen in the Aurora Borealis. Newton fringe has only two causes. First, the topcoat could be too thin. Correct this by reducing the coating less to raise the viscosity, or by applying the topcoat more heavily (for spray operations). The second cause could be too thin of an aluminum shot. This is corrected by depositing more aluminum or altering fixturing for better coverage [7].

True iridescence contains the colors of the rainbow. Iridescence is usually the result of a physical shift of the 3 layers (basecoat, metallizing, topcoat) in relation to one another. This shift results in a prism-type effect and thus the colors. What can cause coating layers to shift? Very often the answer is improper thickness or improper curing of one of the coating layers. Let's deal with the basecoat first. Check to see that basecoat is properly cured. If it is not, raise bake time or temperature as required. Check for temperature variation and inadequate airflow in ovens. The basecoat film thickness may be excessive or inadequate. Measure basecoat thickness if possible, and check with coating supplier for recommended thickness. If your basecoat was cured at a low temperature and your topcoat at a high temperature, you may get iridescence. This results from the basecoat moving as it finishes curing during the topcoat bakeout. If your basecoat is thin and your topcoat is thick, the underlying coatings will move as the topcoat cures. This can also happen if your basecoat is normal but the topcoat is excessive. The important lesson here is watch your film thickness. Also, if the part is not allowed adequate air dry time before baking, the coating may shrink rapidly as it dries and again cause iridescence. Also watch baking temperatures in regard to the substrate. High baking temperatures can distort plastic substrates and cause iridescence or even severe part warping. Some lesser causes of iridescence are backstreaming of pump oil and water absorbtion by parts. Nylon absorbs a high amount of water. Check with your resin supplier if you are unsure about the water affinity of your substrate material. Backstreaming very small amount of oil will cause iridescence. Look for the problem to be most severe toward the rear of the chamber. Large amounts of oil backstreaming will cause a dark shot or poor adhesion.

SHADOWING

Shadowing is a problem which results from not all surfaces being metallized in an even manner. Causes include improper fixturing of parts, poor filament positioning, firing time/carriage rotation mismatches, or poor part design for metallizing. All surfaces to be metallized need to be in a direct line of sight with one or more filaments during the firing cycle in order to achieve proper coverage. Problems occur when something obstructs that direct line of sight or when a part is not designed or positioned properly to achieve the proper exposure. Be aware that standoff posts can have a shadowing effect if they are too large or are too close together. The carriage needs to complete a minimum of one complete rotation during the actual firing of the filaments. Several rotations are best. Parts that have recesses which are deeper than they are wide will be metallized with difficulty. Fixture oblong cavities for maximum exposure time. Sometimes the only way to address this issue is to fire longer, add more filaments, or increase evaporant charge.

SPATTERS

Spatters of aluminum sometimes show up on parts. There are two primary causes of this. The first is spitting. When firing, aluminum will pop or spit off the filament and land on parts, usually causing a small burn mark and perhaps sticking on to the part, or perhaps bouncing off. Spitting usually occurs in direct fire operations or when preheat is too short or temperature is increased too rapidly. The cause of the actual spitting is oxygen trapped in the aluminum expanding rapidly, like water in hot grease, or it is because the aluminum itself becomes vapor so rapidly that it projects some molten aluminum. By incorporating an appropriately timed preheat the spitting can largely be eliminated. The second cause of aluminum drops on parts is molten aluminum dripping off of filaments. If preheats are too long or too hot, molten aluminum will run down a filament and collect on the last turn. If enough collects, it will drip off. The jarring action of the carriage planetary drive can worsen this problem. A drip trough placed six inches or so below the filament can help to reduce this problem. Be cautious. The closer the drip trough is to the filaments, the more it will shadow the evaporant from the parts. Sometimes molten metal will bounce out of the trough and land on parts anyway. It is important to keep the trough clean to prevent outgassing from the buildup. The best way to combat the spatter problem is to eliminate it by adjusting preheat and firing cycles.

OTHER DEFECTS

There are, of course, other causes of metallizing defects. Many of them have to do with the coatings applied. Although coating problems are not the primary focus of this paper, here are some of the more common coating problems and some proposed solutions. Blistering of finishes can be caused by trapped organics in either substrate or coatings. Make certain parts are clean and dry before coating and that coatings are completely cured. Moisture in coatings can cause blushing of the coatings. Common sources of moisture are water in air lines, high absolute humidity in atmosphere, water in solvent-based coatings, or water in reducing agents. Fisheyes are coating defects that look like little eyes or rings. They can be caused by surface contaminants, particularly silicones. Keep all silicones away from the painting and metallizing areas. Crazing of the finish is usually caused by coating soaking in to low density areas of a part or from coatings which have very strong solvents in them. If a coating is excessively thick or insufficiently atomized when sprayed, this can cause crazing as well. These same factors can sometimes cause a similar phenomenon which looks like cobwebs. A dull finish can be caused by inadequate basecoating, by harsh solvents, or by low density areas of the substrate. Many problems such as orange peel, runs, wrinkles, or bubbles in the finish are caused by improper use of thinners and solvents, or by improper application of coatings [8]. It is best to contact your coating supplier for these types of problems.

CONCLUSION

No metallizing operation can hope to completely avoid metallizing defects. A systematic approach to troubleshooting combined with good historical data on the metallizing operation can significantly reduce the cost and aggravation such defects will cause.

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