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Behaviour of Silver Streaks after Plating on ABS Plastics

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Abstract: Chrome plating on ABS parts have become common and most of the automobile manufactures prefer the chrome plated parts on their vehicle to attract and more premium look for the vehicle. In molding and plating, we have many types of molded defects like sink mark, silver streaks and weld line after plating on plastics. In this experiment, we have focused on all these 3 molded defects and how it is related to mold, molding and plating process and how to avoid it during processing and plating what changes are required to overcome these defects on the final part. We have used Engel 600T injection molding machine and we have utilized ABS (Acrylonitrile Butadiene Styrene) as a raw material for this trial which is widely used on plating of plastics and an automotive components for the study which is plated after molding. Most of the automobile manufacturers prefer chrome plated parts in their vehicles to make it more attractive and look premium. In this experiment, we will have an understanding of behavior of silver streaks after plating. Here, we are focusing on 3 major entity like mold, plating and molding and to find an optimal results to get defect free plated component.

Key words: Plating on plastics, ABS, silver streaks, gate size, injection molding, raw material, streaks

INTRODUCTION

Injection molding has grown leaps and bounds due to high dimensional stability, repeatability, very low cost and lesser cycle time. There has been extensive study on the effect of the molding process parameters on the final quality of the product. ABS, Acrylonitrile-Butadiene Styrene is the Terpolymer thermoplastics which has acrylonitrile-styrene matrix with butadiene rubber which is evenly distributed. The presence of butadiene makes it easy for plating where this will be etched out of the matrix creating porous which are bonded by the electro less plating. Though it looks simple the plating on plastics is a tedious process which has to go through series of chemical treatment on the plastics to make it metallic. The main reason for this study is to lesser rejection on the plated part which can be avoided by the taking care of the molding parameters and the tool design. On a common term plating is a process where the molded defects are magnified after plating, hence, the importance of the mold and parts quality are very important. In order to get a good acceptance after plating we need to get very high quality of molded parts.

In this study, we have taken one automotive parts for analyzing the effect of these defects like silver streaks, sinkmark and weldline by varying the gate sizes, etching temperature, material and molding parameters to optimize the molding parameters which will give better plating results. Most of the molded parts which are sent for plating has been tested visually and thoroughly checked for the presence of these defects on the molded part. Extra care is taken while quality check done on the molded part by using magnifiers and made sure no molded defects are visbile on the top surface of the molded part and checked randomly with stress test immediately by immersing the molded part in acetic acid which is done basically to check whether the molding parameters are under control and to avoid internal stress on the molded part while molding which may cause silver streaks during etching process. The acetic acid stress test is again done after 24 h of molding by this time the molded part will be relieved of all internal pressures. After it is confirmed that the parts are good the molding parameters is noted and varied for 3 sets of parameters to make sure which parameters will suit the requirement of getting good acceptability after plating. The molded part of each set parameter are taken after stabilization of the molded parameter which takes 5-10 shots to stabilize the changes done on the parameters and then 20 shots are taken for our study. The trial which is done basically to check whether the molding parameters are under control and to avoid internal stress on the molded part while molding which may cause silver streaks during etching process. These precaution are taken normally to avoid rejections on plated parts. The plating

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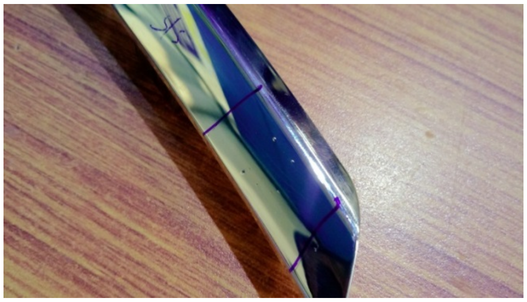

Fig. 1: Silver streaks on plated part

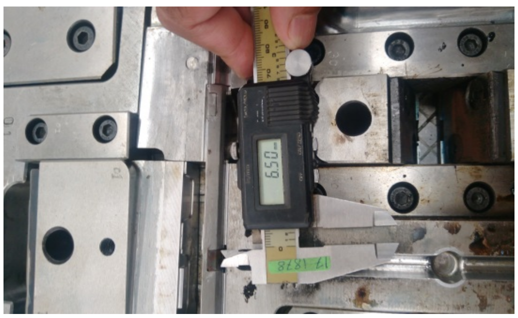

Fig. 2: Gate size 6.5 mm

process normally takes 4 h to complete one batch. The batch quantities are normally designed based on the parts size and the bath size. The molded parts are normally fixed on the jigs where the current is passed through the rectifiers in each bath apart from etching bath where the butadiene is etched out to create space for metallizing the plastics. We have gone through the plating process by varying the etching temperature from 63-70°C and we have analysed the same with the end plated part.

We have gone through the CAD DATA of the mold and we have gone through the gate positioning and size as per mold flow and we have tried to vary the gate sizes so that we can optimize the silver streaks and also varied some of the important parameters in mold processing. What we have observed theoretically is we have seen the silver streaks near the gate areas which is shown in Fig. 1 and 2, hence, we varied the hot runner temperature by 3 stages of 5° from 230-220° and also increased the preheating temperature of the ABS by 3° varying from 85-91° to see the effect of the silver streaks after plating.

In plating as earlier explained the defects are magnified and hence, the defects are more prominent. Silver streaks are the splash appearance of moisture, air or charred plastic particles on the surface of a molded part which are fanned out in a direction emanating from the gate location. Nasir *et al.* (2013) conclude that using RSM it is good to optimize the molding parameters to reduce warpage of optical mouse to 0.0043% on the top part. In this experiment, mould temperature plays a major role in affecting warpage and the other two parameters which play significant roles are packing pressure and packing time.

Nasir *et al.* (2015) have studied that the warpage is a quite normal problem in the injection molded parts to minimize the cost and to avoid the rework process, the optimized parameter of injection molding process can be accomplished through optimization method one of the optimization method that used from previous researchers is a Response Surface Methodology (RSM) and Particle Swarm Optimization (PSO).

Gupta has utilized RSM and PSO method to optimize the machining parameters by reducing the lubrication environment of titanium alloy and the results have found that PSO gave a closer value than the desirability approach. Kadirgama *et al.* (2010) has done the study on how to optimize cutting force and tool life by optimizing the machining parameters in this study RSM was used to reduce number of experiments and PSO was used to optimize the parameters like cutting speed, feed rate and axial depth. Sundareswaran *et al.* (2014) has done the experiment on electrical field and analysed the maximum power point tracking in partially shaded photovoltaic systems using PSO and RSM technique. The conclusion was the results shows that the different output of tracking efficiency using PSO and RSM method is not a big different. The different between RSM and PSO method of tracking efficiency of shading pattern number 1, 2, 3 and 3 are 0.09, 0, 0.92 and 0%, respectively. The researchers agreed that using RSM method is enough to maximize the power point of tracking.

Azlan *et al.* (2016) his research is on maximizing the strength of molded parts using simulation software and to optimize the injection molding parameters the material used for this study is Acrylonitrile-Butadiene-Styrene (ABS) whereas mould temperature, melt temperature, packing pressure and packing time were selected as variable process parameters. The polynomial model obtained using Design of Experiment (DOE) was integrated with the Response Surface Methodology (RSM) and Centre Composite Design (CCD). Genetic algorithm was used for RSM to find out the optimum values of the process using the process parameters and it was found the strength has gone up by 2.2%.

Miza *et al.* (2017) has done his experiments on optimizing of warpage on molded part. Thin shell plastic parts was considered for this experiment and design of experiments with Finite Element Analysis (FEA), moldflow analysis and Response Surface Methodology (RSM) these are some of the techniques used to lessen the warpage on X-Z on the thin part. Four process parameters were considered to minimize warpage from occurring they are packing pressure, cooling time, melt temperature and mold temperature.

Shi *et al*. (2013), this optimization process is performed by a Parametric Sampling Evaluation (PSE) function. PSE is an infilling sampling criterion. Although, the design of experiment size is small this criterion can take the relatively unexpected space into consideration to improve the accuracy of the ANN Model and quickly tend to the global optimization solution in the design space.

Kusic *et al*. (2013) has taken six process parameters to find out the impact of six process parameters for shrinkage and warpage after molding and cooling. Everything was done through quantification of Acoustic Emission (AE) signals and in-cavity pressure by using taguchi method he has found the optimal parameters to reduce warpage and shrinkage. ANOVA was used to get the most influential parameter. The intensity of the measured AE signals resulted in determination and catego-rization of acceptable or non-acceptable parts, through a strong correlation with shrinkage and warpage of the specimens. Oktem *et al*. (2007) utilized orthogonal arrays to determine the influence of the process parameters on warpage and shrinkage of thin-shell plastic components. This was achieved through the Signal-to Noise (S/N) and ANOVA in which an improvement of 2.17 and 0.7% in warpage and shrinkage, respectively.

RSM and GA are integrated by Sun *et al*. (2010) in order to get the optimal parameter to reduce warpage on the molded part. The optimal parameter was mold temperature was 66.5°C melt at 276.3°C, packing pressure when it 100% and lastly injection velocity is 0.44's. This experiment has improved the warpage by 30% from30 % from 0.4886-0.3446 mm. Chen *et al*. (2010) has done a study on DOE, BPNN and GA to optimize MIMO warpage and length. In this the researcher has used DOE, RSM and GA technique in order to get an optimal process parameters settings of multiple-quality characteristics.

By Chen *et al*. (2012) initial parameter setting is done based on DOE. MINITAB has been used along with RSM and ANOVA to get the regression equation and significant factor. Then regression model of length and warpage are combined with GA. Acrylonitrile Butadiene Styrene (ABS) plastic material was used for making wireless communication product's case body the part and optimal parameters for process are melt temperature at 203°C, injection velocity at 34 mm/sec, injection pressure at 69 MPa, packing pressure of 60 MPa and packing time of 2.2 sec give the experimental results 123.96 mm for length and 0.2 mm for warpage.

In this experiment, we have used 4 sizes of gate (6.5, 6.9, 7.5 and 8 mm) to avoid the silver streaks on the molded parts. The gate size plays a major role in elimination of silver streaks in plated parts after molding.

We have kept all the parameters like injection pressure, Injection speed, refilling time same apart from the gate sizes which are changed after 4 batch quantity of the part. One batch quantity is 12 nos for a bath, we have scrapped first 20 shots for consistency and then, we have produced 60 nos good parts on each gate sizes and identified has T1, T2 and T3 and each batch is marked has T1A, T1B, T1C and T1D similarly for other trials are marked as T2A, T2B, T2C and T2D, T3A, T3B, T3C and T3D and T4A,T4B,T4C and T4D:

MATERIALS AND METHODS

Countermeasures related to molds:

- Cleaning and enhancing the air vents
- Increase the gate size
- Cold slug well to be made bigger

Countermeasures related to the injection molding conditions:

- Injection speed to be less and cavity to be filled slowly
- Barrel temperature to be lower
- Refilling to be slow so that material is homogenized
- Cushion stroke to be monitored
- Drying and melting temperature to be monitored

Countermeasures related to the molded product design:

- The wall thickness should be equal as much as possible
- Sharp edges to be avoided

Countermeasures related to the plating process:

- Should be free off flash
- Molded parts should be free of weld line
- "SINK"marks should be avoided

Silver streaks: Silver streaks are the splash appearance of moisture, air or charred plastic particles on the surface of a molded part which are fanned out in a direction emanating from the gate location. In this experiment, we have used 4 sizes of gate (6.5 6.92, 7.5 and 7.6 mm) these are shown in Fig. 3 and 4, to avoid the silver streaks on the molded parts. The gate size plays a major role in elimination of silver streaks in plated parts after molding. We have kept all the parameters like injection pressure, injection speed, refilling time same apart from the gate

Table 1: Process parameters for experimental analysis

Denoted	Process parameter	Stage1	Stage 2	Stage 3	Stage 4
IT	Injection pressure	110.0	110.00	110.00	110
IS	Injection speed	32.0	32.00	32.00	32
RT	Refilling time (sec)	28.0	28.00	28.00	28
Gate	Gate size	6.5	6.92	7.51	7.6

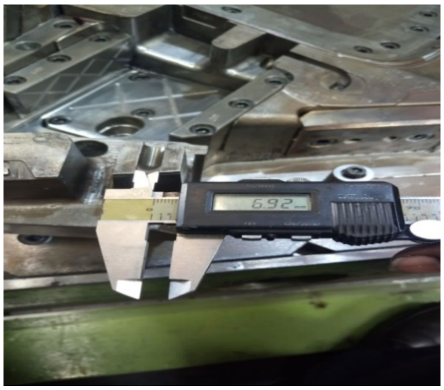

Fig. 3: Gate size: 6.92 mm

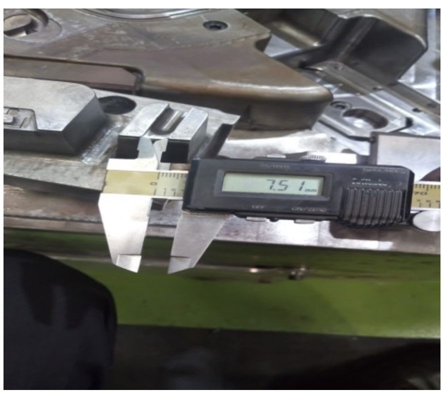

Fig. 4: Gate size 7.51 mm

sizes which are changed after 4 batch quantity of the part these parameters are shown in Table 1. One batch quantity is 12 nos for a bath, we have scrapped first 20 shots for consistency during molding and then, we have produced 60 nos good parts on each gate sizes and identified has T1-T3 and each batch is marked has T1A, T1B, T1C and T1D similarly for other trials are marked as T2A, T2B, T2C and T2D, T3A, T3B, T3C and T3D and T4A, T4B, T4C and T4D.

RESULTS AND DISCUSSION

In this experiment, we have kept all the parameters constant apart from changing the gate size for which we have made 4 sizes in order to find the actual cause of silver streaks in the plated parts. The logic is when the gate is bigger the flow is smoother and the pressure

Table 2: Gate size 6.5 mm

Batches	Batch quantity	Accepted	Rejected	Silver streaks	Plating defects
T1A	12	5	7	5	2
T1B	12	6	6	6	0
T1C	12	4	8	6	2
T1D	12	5	7	6	1

Table 3: Gate size 6.92 mm

Batches	Batch quantity	Accepted	Rejected	Silver streaks	Plating defects
T2A	12	7	5	4	1
T2B	12	6	6	5	1
T2C	12	7	5	4	2
T2D	12	7	5	4	1

required will be lesser. To conduct this experiment, we have kept the injection speed and the pressure has constant and less. For plating on plastics the molded part quality has to be very good in order to get better results after plating. When the flow is uniform with minimal increase in gate sizes will play a big role in reduction of plating rejection. The gate size has to be clearly done through trial and error method in order to get an acceptable plated parts from the plating. This will also, help in avoiding the molding related problems such as weldline and flow mark.

In this experiment it is proved that the gate size plays a major role in reducing the silver streaks on molded parts after plating. We can see from Table 2 and Fig. 2 when the gate size is at 6.5 mm the appearance of silver streaks is more due to pressure of filling will be high which can create gas or bubble due to restricted flow into the mold which in turn can cause silver streaks. As shown in Table 3 with gate size 6.92 mm shows the results are better but still the flow of material is not smooth which causes the gases to form which in turn is getting reflected like silver streaks after plating but to be clear these silver streaks will not be visible after molding which will open only etching in plating where the etching temperature is at 60° on the plating bath. We have removed the parts after etching and we analyzed the part which was showing signs of silver streaks and this was near the gate points, hence, we thought we will make one more gate block with 7.5 mm gate which is shown in Fig. 4 and 5, the results are shown in Table 4 where the results are far better and under acceptable limits and we went on to increase still further to 7.6 mm which is shown in Table 5 and Fig. 6 to ensure whether the results are superior what we got on 7.5 mm gate size but the results are negative which is showing more parts are having silver streaks and the parting line flashes has started which will also affect the plating acceptance and quality, hence, we stopped the trials at 6.5 mm gate size where the results are good and consistent. Restriction in flow due to sprue, runner, gate

Table 4: Gate size 7.51 mm

Batches	Batch quantity	Accepted	Rejected	Silver streaks	Plating defects
T3A	12	10	2	1	1
T3B	12	9	3	2	1
T3C	12	10	2	1	1
T3D	12	11	1	0	1

Table 5: Gate size 7.6mm

Batches	Batch quantity	Accepted	Rejected	Silver streaks	Plating defects
T4A	12	6	6	2	4
T4B	12	7	5	2	3
T4C	12	6	6	3	3
T4D	12	5	7	4	3

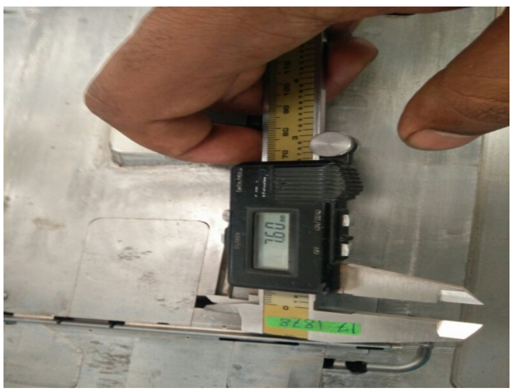

Fig. 5: Gate size 7.6 mm

and even part design can create heat and which can cause degrading of raw material at the gate area. Increasing the back pressure can also improve the blending of the material inside the injection molding machine which can release unnecessary air or gas which are trapped in the material. The other important things which has to be followed for avoiding the silver streaks is we need to clean the airvents regularly in order to allow gas to escape easily entrapped gas can cause silver streaks on the parts after plating.

It is also clear the gate size has to be optimal and it should be in checked for parting line flash as well. If the gate size are little bigger the parting line flashes will increase which will create in reworking the molded part which is not good for plating where you will get lot of molded part under cut issues which will add to molded part rejection if sent for plating the defect will be more visible leading to additional problem so it is always better to have gate sizes increased based on the surface area of the plated part.

Silver streaks can be avoided by taking of the all the basic requirement listed above the more important feature is gate size which can drastically reduce the silver streaks on the plated parts but we need to careful in doing, so, we can go step by step in increasing the gate sizes. The larger the gate size can also cause flashing which will increase the flashing leading to higher rejection. In this experiment, we have found 7.51 mm gate size decreases the rejection due to silver streaks:

CONCLUSION

The tool design also plays a big role in getting good plated parts the following points should be taken care when we design a mold for plated parts:

- Avoid sharp edges
- For plating on plastics (ABS) the gate size should be 50% more than the normal ABS moldings
- Space between the gate should be >25 cm apart in order to avoid other molding issues like weldline
- Ribs and bosses should be less as much as possible in order to avoid the sinkmark
- The cavity surface should be highly polished which will give a good surface finish to the molded parts

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