Improving the laser engraving quality of pad-painted and spray-painted mechatronic devices

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Abstract. Considering the cost reduction in automotive processes, in the case of mechatronic devices that use 2-3 colours for symbols, a solution is to replace the multi-component molding injection with the painting of a white component substrate in different colours. However, combined painting techniques, namely pad-painting and spray-painting, can lead to many risks, especially when those symbols are obtained by laser etching, so removing the final paint layer to let only the first coloured layer be visible. The paper's aim is to present the analysis and reduction of the variation due to the different thickness of the coating layers as well as their drying level by using the ultrasonic measuring techniques and the optical microscopy cross-section to reduce the over-adjusting of the engraving parameters and to improve the final quality of the symbols.

1 Introduction

The process of pad-printing was invented more than 200 years ago being used to print out the Chinese plates.

The principle of the pad-printing is based on the indirect process of photogravure. Therefore, an image is engraved on a flat plate then an ink cup is moved on the surface causing the ink to remain by flooding in the etching areas. A printing silicone pad is pressed onto etching areas and picks up the ink. Due to evaporation of the solvent from the ink, this becomes sticky and the image can be easily transferred onto the product to be printed as a small film [1].

The process is repeated, and the ink cup will be moved again to transfer the ink in the etching area, then the printing silicone pad will transfer a new image on the next product (Figure 1).

This application is used in the production of the mechatronic devices when the symbols are two or three color based and the manufacturing cost must be reduced (instead of using three-component injection molding machine).

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Fig. 1. Schematic principle of the pad-printing

2 Case study

The case study was conducted in an automotive mechatronic devices manufacturer and the product studied was a ring that is made by two-component injection molding, one component being transparent, a polycarbonate combination from one part Alcom and three parts Lexan, and another component a polycarbonate (PC) plus Acrylonitrile butadiene styrene (ABS).

The transparent material will lead the light from the LED of the printed circuit board assembled and blue and red colours using pad-printing process (Figure 2 and Figure 3) will cover these parts.

Fig. 2. Two component injected ring – areas to be covered by the paint in pad-printing process

Fig. 3. Two component injected ring – areas covered with blue/red ink by pad-printing

Afterward, the rings are spray-painted with black paint, a laser etching process will remove the black paint from the red, and blue pad-printed areas, eventually the rings will show as in Figure 4.

Fig. 4. Two component injected ring – final product after spray-painting and laser etching process

2.1 Measurement analysis

The thickness of the pad-printing results, as the thickness of the black spray painting results as well are performed by using some metal plate and measuring the printed pads or the paint by with the portable instruments FMP 10 for measuring coating thickness (Figure 5). This device is using a magnetic inductive test method on ferrous substrates (DELTASCOPE) and is periodical calibrated using some specific calibration foils [2].

Fig. 5. FM10 coating thickness measurement device

Therefore, at the beginning of each measurement, the technician calibrated the device based on the specified method in order to assure reliable measurements. The foil with specific thickness, in the presented case, 24,1 microns, was measured by putting this over a metallic plate as presented in Figure 6. More, as the measurements were conducted on each shift for more than four weeks, a gage R&R study (GRR) has been performed prior to this. The study was examined with Minitab R17 [4] and is the result shows us that the measurements are reliable as soon as the GRR is lower than 20%. The graphs and the result can be seen in Figure 7.

Fig. 6. Foil for calibrating the FM10 before the measuring process

Fig. 7. Gage R&R study result using Minitab R17

In order to evaluate the pad-printed and spray-painted parts, for each experiment, have been used the metallic plates to allow the thickness measurements. It means, for each experiment have been produced 30 plastic rings in pad-printing and spray-painting and used 4 pcs. metallic plate. Those plates were printed twice and measured by the technician in three different points for each colour of the ink, therefore the measured values were transposed in the table result (only the minimum value measured, as the average between these two measurements and similarly for the maximum value). After the spray-painting process [5], the plates were measured again over the areas where pad-printing was – see Figure 8a) and 8b).

Fig. 8. a) Measurement of the metallic plate after pad-printing; b) Measurement of the metallic plate after spray-painting

As the process of pad-printing plus spray-painting is performed over the molding injected plastic parts and the measurements have been done by using metallic plates, some tests have been made in the laboratory to check the thickness of the ink and the thickness of the paint directly on the part. The rings were inserted in dedicated plastic cups and the resin

was used to keep the parts in order to allow the cross-section of these parts and measuring on microscope (the scale 0,08 MM was magnified in the figure below to be seen) – Figure 9.

Fig. 9. Cross-section of the pad-printing over the molded injected plastic part

2.2 Design of experiments

The following experiments have been performed in order to understand the variation of the pad-printing for each colour, red and blue, as for the black spray painting as well: a total number of 150 pieces have been used for 5 viscosity levels of the pad-printing ink, for each viscosity level used 30 pieces. Out of these 30 pieces, 10 pieces have been used to evaluate the result of the laser etching process immediately after the black painting (before to pass 30 minutes after the painting, the paint not dry). Then, 10 pieces have been used to evaluate the result after black painting at 6 hours (not more than 6,5 hours, the black paint almost dry) and the rest of 10 pieces were used to evaluate the same process after 24 hours (when the black paint was dry). Those 10 pieces have been engraved as following: 5 pieces with standard parameters (current intensity and speed the laser fascicle) and 5 pieces with changed parameters (based on the tests with different values of the current intensity and speed of the laser fascicle) – see Table 1 and Table 2.

Table 1. Process parameters and result of the measurements (min-max)

Process			Pad-printing		Spray-painting			
Type of ink/ paint			Thickness RED (microns)	Thickness BLUE (microns)	Thickness RED (microns)	Thickness BLUE (microns)	Thickness BLACK (microns)	
Experiments		Samples	Measurements on metal plates, evaluation on the plastic ring parts					
1	Plastic rings (10 pcs. x each experiment)	Out of upper limit - 1	1 to 30	6,2 - 8,4	6,4 - 8,5	39,4 - 42,3	37,9 - 43,1	31,5 - 34,7
2		Upper limit - 2	31 to 60	5,8 - 7,8	5,9 - 7,7	39,0 - 43,1	38,6 - 41,6	32,3 - 34,9
3		Nominal - 3	61 to 90	5,8 - 7,6	5,8 - 7,8	38,2 - 41,2	38,3 - 41,4	31,5 - 33,6
4		Lower limit - 4	91 to 120	5,6 - 7,2	5,6 - 7,4	38,3 - 40,8	38,7 - 41,2	31,7 - 34,6
5		Out of lower limit - 5	121 to 150	4,1 - 4,9	4,3 - 5,2	37,3 - 39,5	37,6 - 39,8	32,3 - 34,8

Table 2. Process parameters and result of the measurements (min-max)

Experiments	Laser etching																											
	Immediately after spray-painting (less than 30 minutes)								After 6 hours from spray-painting (not more than 6,5 hours)								After 24 hours from spray-painting											
	Standard parameters (current intensity/speed) ok/nok				Changed parameters (current intensity/speed) ok/nok				Standard parameters (current intensity/speed) ok/nok				Changed parameters (current intensity/speed) ok/nok				Standard parameters (current intensity/speed) ok/nok				Changed parameters (current intensity/speed) ok/nok				Standard parameters (current intensity/speed) ok/nok			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
2	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
3	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
4	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
5	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok

The level of the viscosity for the pad-printing is given by the producer and based on the recommendation was used the following combination: out of the mixing of ink, hardener, and thinner, the ratio was 100 parts ink, 10 parts hardener, and 16 parts thinner for the blue ink, also 100 parts ink, 10 parts hardener, and 10 parts thinner for the red ink. The tolerances have been chosen at 2% for each material.

Therefore, in the presented study, the limits to perform the tests in order to catch the influence of the variation given by the thickness of the pad-printing process is presented in Table 3.

Table 3. Process parameters and result of the measurements (min-max)

Quantities (grams)	Red ink	Hardener	Thinner
Out of upper limit - 1	50	5	2,5
Upper limit - 2	50	5	3,5
Nominal - 3	50	5	5
Lower limit - 4	50	5	6,3
Out of lower limit - 5	50	5	10,5

Quantities (grams)	Blue ink	Hardener	Thinner
Out of upper limit - 1	50	5	4
Upper limit - 2	50	5	6
Nominal - 3	50	5	8
Lower limit - 4	50	5	9,8
Out of lower limit - 5	50	5	14

Laser etching parameters	Standard parameters	Changed parameters
Current intensity	26 A	25,1 A
Speed	450 mm/s	850 mm/s

The result of the experiments based on the measurements of the pad-printing, spray-painting, drying levels of the paint and the laser etching parameters as can be seen in the Table 2 shows all good parts for the mixing ration within the tolerances only for the drying level of the paint after 6 hours or more and using the laser etching parameters with lowest current intensity, but the higher speed of the laser fascicle. Consequently, the process of the pad-printing and the laser etching based on the established thickness of the ink and changed laser etching parameters have been monitored for a period of time, 8 weeks, and the capability was examined and evaluated using Minitab 17. As can be seen in Figure 10 and Figure 11, were examined the moving range (MR) charts to see if the process variation is in control. Being this variation in control, were interpreted also the individual (I) charts. Neither moving range charts nor individual charts show the point out of the limits nor 9 points in a row on one side of the centerline, therefore the process is stable and capable.

Fig. 10. I-MR chart of RED pad thickness

Fig. 11. I-MR chart of BLUE pad thickness

Conclusion and next steps

The study shows the low influence of the pad-printing thickness, but the high influence of the dry level of the spray-painting process, as the parameters of the laser etching as well. Take into consideration the drying time of the pad-printed and spray-painted parts, two programs could be created in the laser etching machine to be used for the engraving of these parts: one for the case when the parts are wet (less than 6 hours after the spray-painting) and the other one when the parts are dry, therefore, the quality of the engraved parts will be increased, and the defective parts will decrease.

As this study did not analyse the other variables from the pad-printing as the combination of the velocity of the pad lift-off motion [6], [7] and the dry level of the ink or the temperature/ the humidity of the external environment near the pad-printing machine, in link with the possible defects that could be occurred, for instance, ink filaments at borders (see Figure 12) a new study is designed to measure the following parameters and to evaluate the final result of the pad-printing and laser etching process: the environment temperature and humidity, the velocity of the pad lift-off motion, the evaporating level of the thinner from the ink and the laser etching parameters.

Fig. 12. Ink filaments at borders for pad-printing of plastic part

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