Session H3.6

PREDICTION OF E-COAT VOIDS AND PUDDLES DURING AUTOMOTIVE PAINTING USING ANSA

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KEYWORDS - V.Traps, e-Coat void, e-Coat puddle, automotive paint, corrosion resistance

ABSTRACT - In automotive painting, Electro-Coat (e-coat) is applied to the car body sheet metal to increase its corrosion resistance. After e-coat application another three coatings of paint materials, namely prime, basecoat and clearcoat, are applied to provide the final paint finish. E-coat voids and puddles are common issues occurred during e-coat application and this study uses ANSA to identify the potential problem areas.

After the car body is coated with e-coat it is sent through a baking oven for curing. Two of the most common issues that occur during this process are voids and puddles. A void occurs when air is trapped in vehicle cavities. This prevents contact of the e-coat bath with the metal and thereby prevents paint deposition. A puddle occurs when excess e-coat liquid is trapped in the vehicle cavities due to incomplete drainage. This excess e-coat liquid reaches its boiling point while in the oven and can cause poor appearance on the vehicle exterior surface.

ANSA's built-in feature, V.Traps, was utilized in this study to detect the formation of voids and puddles. Combined with ANSA's localized meshing and hole creation features, it is easy to study the effectiveness of drainage hole locations on voids and puddles. Results of the case study are presented along with recommendations to enhance V.Traps features. A comparison between the traditional method for void and puddle prediction and ANSA's V.Traps feature is also included.

TECHNICAL PAPER -

1. INTRODUCTION

Modern automotive painting is a highly complex process that provides corrosion resistance, color, and a glossy finish to the vehicle body. The shell of the vehicle enters the paint shop from the body shop and goes through a pretreatment process. In the pretreatment process, oil and debris are washed off of the vehicle body and phosphate is deposited on the metallic surface. Phosphate is an important part of the paint corrosion protection system and increases the adhesion of e-coat to metallic surfaces. The vehicle body then goes through the e-coat process. E-coat is an epoxy paint layer which is applied using electro-deposition. This paint layer is cured in an e-coat oven to ensure the performance characteristics of the coating. Following e-coat, prime is applied to exterior surfaces and cured, followed by enamel application and cure. The purpose of primer is for chip resistance, protection of the e-coat from UV light, and improved surface smoothness. Two layers of coating are applied in the enamel process, basecoat and clearcoat. Basecoat provides the color, while clearcoat provides the glossy appearance and scratch resistance to the finished vehicle body.

The main purpose of e-coating is for corrosion resistance. The vehicle body is hung from an overhead conveyer with chains and dipped into a tank that is filled with e-coat paint (see Figure 1). Electrodeposition occurs in the tank and builds a layer of e-coat film on interior and exterior surfaces of the vehicle body. E-coat must cover all sheet metal surfaces, including recessed locations such as rocker panels, in order to protect these regions from corrosion. That is part of the reason why e-coat is applied using an immersion process, whereas prime and enamel paint are applied only on exterior surfaces using a spray process.

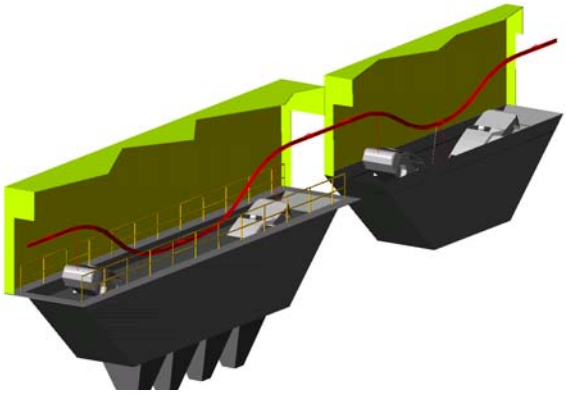


Figure 1: Schematics of a typical e-coat process

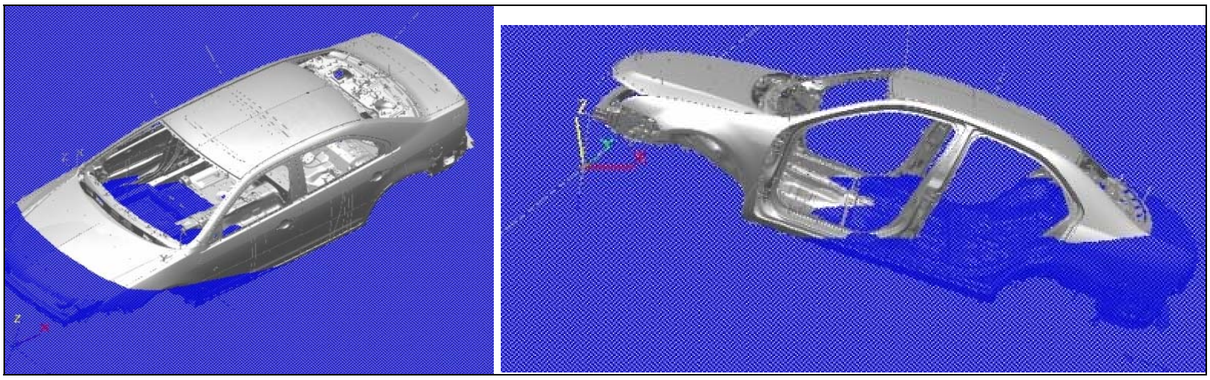
Common defects of e-coat include areas of no paint and runout. No paint usually is because of air bubbles trapped under a concave surface where the sheet metal did not have a contact with the e-coat bath and therefore no material was deposited. Runout usually happens when the e-coat liquid stays in a convex surface and forms a puddle. The liquid in the puddle boils during baking and drips on the sheet metal. The drip is usually sanded to provide a smooth surface for further painting. However, sanding results in thin or no e-coat film protection at that location and hence a potential problematic site for corrosion performance. The dust generated during sanding also creates dirt problems in the paint process.

The purpose of this paper is to discuss the techniques used to detect voids and puddles during the e-coat process from the perspective of vehicle body design. A comparison between the traditional processes and the V.TRAPS functionality of ANSA is included. Case studies of sheet metal parts were used to verify the capability of the new tool, followed by an attempt to define and apply the process for a full-vehicle analysis. At the end, a summary of the case studies and recommended next steps are included.

2. TRADITIONAL PROCESSES

Traditionally, in order to identify problem areas of e-coat voids and puddles, prototype vehicles are used. These prototype vehicles are e-coated to observe no-paint and runout problems. Enclosed areas of the vehicle are cut apart and film builds are measured manually to identify regions of no paint or thin paint problems (see Figure 2). This process is very expensive and time consuming. Automotive manufacturers can only afford a limited number of prototypes for each vehicle program using this destructive method.

Figure 2: A prototype is cut open to measure e-coat film build inside the rocker.



(a) (b)

Figure 3: Using visualization software to find air bubbles and e-coat puddles; (a) when the vehicle enters the tank and (b) when the vehicle leaving the tank.

Thanks to the fast progress of computer technology, engineers can now detect problem using CAD data in the virtual world. This is much cheaper and can be performed earlier in the vehicle development process than the aforementioned destructive method. It also provides engineers the opportunity to improve the design and iterate before physical vehicles are launched. Visualization software is used for the analysis. The analyst tilts the vehicle according to the entrance and exit angle of the e-coat tank, creates a horizontal surface to represent the e-coat liquid surface (see Figure 3), and moves this surface vertically throughout the vehicle to simulate the process of vehicle entering/exiting the tank. The analyst looks for areas of the liquid surface that are isolated by sheet metal, and then look for drainage holes (air escape holes) on the sheet metal. If there is no hole for the liquid/air to escape, it is potentially a problem area for a puddle/void. However, this is a manual process. The accuracy and efficiency totally depends on the experience level of the analyst. An experienced analyst can finish the analysis for a full vehicle body in one working day. This approach can only provide the information of where the potential problem areas are, but cannot predict the size of the e-coat voids or puddles.

3. ANSA V.TRAPS

The V.TRAPS tool of ANSA identifies the regions of resting liquid or air bubble enclosures formed when a complete body-in-white (BIW) or a few parts are positioned to represent the entrance, horizontal and exit positions with respect to the virtual bath. This process is fully automatic and calculates the location as well as volume of air bubbles and e-cost puddles. It also allows the engineers to quickly open holes in the model and evaluate their effectiveness.

In preparation for the use of the V.TRAPS tool, the CAE model must be meshed with triangular elements free from intersections and duplicate elements as shown in the Figure 4. Upon activating the V.TRAPS tool, the model becomes transparent as shown in Figure 5. Using the positioning tool, the model is oriented to match the entrance and exit angles of the actual e-coat tank that the new vehicle will be launched.

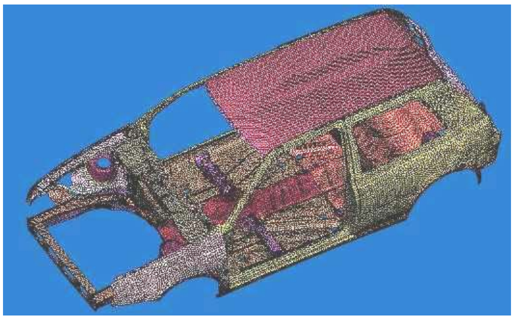


Figure 4: An example of mesh ready for V.TRAPS analysis.

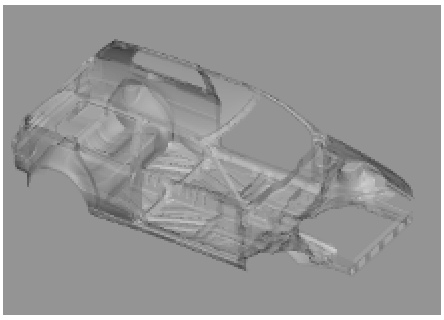


Figure 5: Vehicle model in transparent form after V.TRAPS is activated.

Check for Voids or Bubbles

After the mesh is ready, the vehicle body is first positioned to match the entrance angle of the actual e-coat bath as shown in Figure 6, then the bubble check button is activated and step size is specified. ANSA identifies the air trapped in vehicle cavities and displays the total volume, total metal wetted area, positioning and the step size used for the analysis as shown in Figure 7. The user has an option to specify a minimum significant volume below which the traps are ignored and not shown on the screen. The user also has the option to traverse through all traps to evaluate their significance.

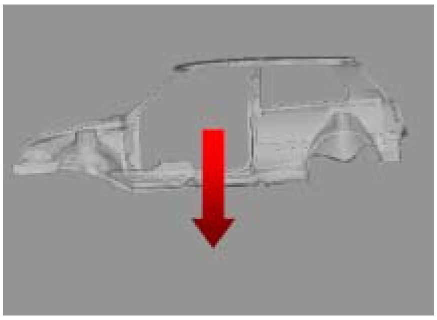


Figure 6: Bubble check in progress

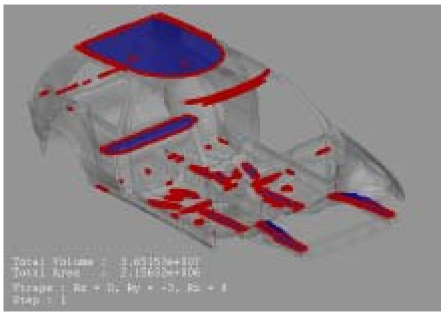


Figure 7: Results of bubble check.

Check for Puddles or Ponds

Regions of excess e-coat liquid trapped in the vehicle cavities due to incomplete drainage are identified using the “Ponds Check” function. The BIW is positioned horizontally or at an angle representing the exit of the vehicle of the e-coat tank as shown in Figure 8 and the pond check button is activated. ANSA identifies the puddles in the model and displays them on the screen along with the total volume, wetted area, positioning and the step size used in the analysis as shown in Figure 9.

After completion of the analysis, ANSA automatically saves the simulation results as shell elements with a separate part and PID for easy filtering and viewing.

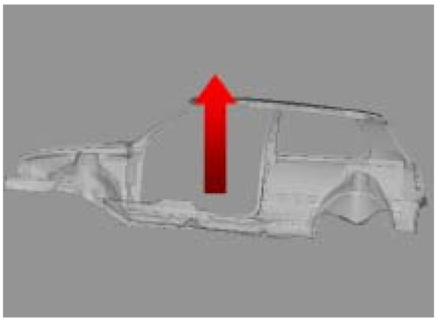


Figure 8: Pond check in progress

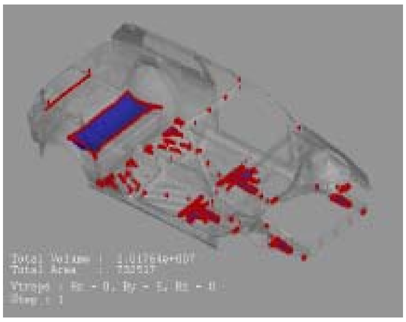


Figure 9: Results of pond

V.TRAPS CAPABILITY VERIFICATION

Two case studies were performed to verify the capability of V.TRAPS. The purpose of these studies was to demonstrate the void/puddle detection capability of V.TRAPS and compare the results with the traditional method using visualization software as well as experiences during vehicle launch.

Case Study 1 – Rear Floor Pan

The traditional method predicted that there would be e-coat accumulation in the highlighted regions of the rear floor pan as shown in Figure 10. But the process could not determine the extent of accumulation.

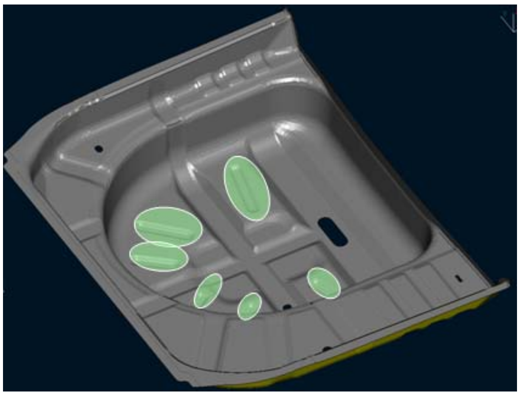


Figure 10: The traditional method predicted e-coat puddles in the indentations.

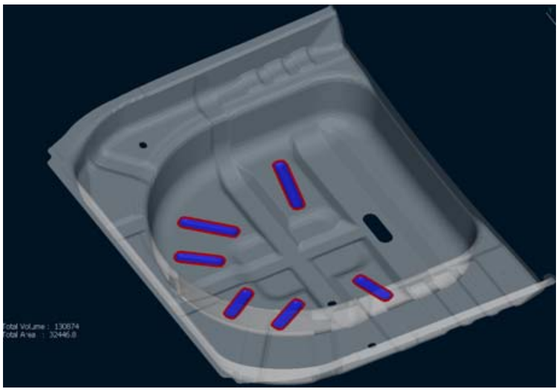


Figure 11: Results of V.TRAPS analysis on the same part.

The same model was prepared and meshed in ANSA and then analyzed using V.TRAPS as shown in Figure 11. The results were verified to match the results obtained by the traditional process. The tool also calculated the total volume of these puddles to be about 1 cc (1083 mm3). This small amount of e-coat accumulation would flatten over the surface of the sheet metal thus increasing the e-coat thickness by just a few microns. Such small volume of accumulation would not pose a big problem when the unit goes through the curing oven. Hence, a design change is not necessary. This case study demonstrated the value of V.TRAPS capability of calculating bubble/puddle volume. The ability of V.TRAPS to quantify the bubble or puddle volume helps in deciding if any design changes are required. Without the knowledge of the volume, unnecessary design changes would be performed and extra cost and time delay would occur.

Case Study 2 – Rear Quarter Panel

In the original study using the traditional process, a problem in the rear quarter panel was undetected and resulting in a significant accumulation of e-coat. This was observed later during physical launch. In order to solve the problem engineers added a hole to drain the accumulation. The same model was prepared and meshed in ANSA and then analyzed using V-TRAPS. The V-TRAPS tool was able to detect the e-coat accumulation and also calculated the volume to be 32 cc (10 oz) as shown by Figure 12.

Figure 12: E-coat accumulation was identified by V.TRAPS.

Figure 13: The capability of evaluating effectiveness of drainage holes was demonstrated

With ANSA's mesh editing features, an opening was created to represent a drainage hole in the sheet metal. The analysis was re-run and it was observed that the e-coat accumulation reduced to minimal (Figure 13). Hence, ANSA could have detected the issues that the traditional process overlooks early in the design phase. This case study also demonstrated the value of ANSA's mesh editing feature which enables simulation of a drainage hole and evaluate its effectiveness.

4. FULL VEHICLE ANALYSIS

After the bubble/puddle detecting capability of V.TRAPS was verified by the above two case studies on sheet metal parts, the next step was to define the process of analyzing a full vehicle body using V.TRAPS. Model preparation was identified as a potential problem. A full vehicle body consists of a large number of sheet metal parts. These parts are put together in the body shop by seam welding, bonding, or fastening. Sealers are applied to seal off gaps between parts. However, in the virtual world, all parts are separate and gaps exist between them. V.TRAPS sees these gaps as escape channels for air/liquid and no bubble/puddle will be formed. It is necessary to seal the parts at the mesh or CAD level to represent the welds or sealers. Two approaches were evaluated, one begins with raw CAD (IGES, IDEAS, or CATIA format), and the other begins with an existing mesh.

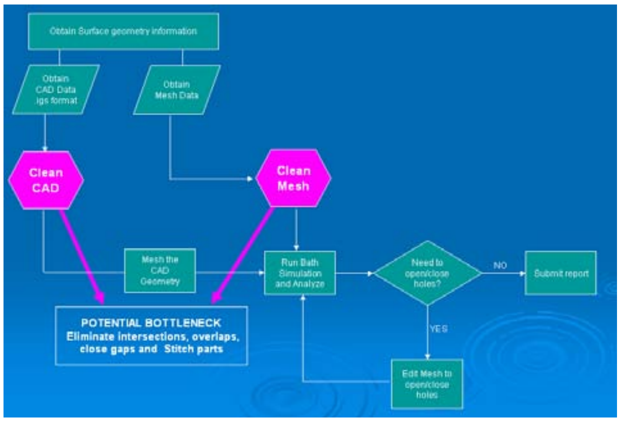


Figure 14: Process of full vehicle analysis

Model Preparation – Raw CAD

To prepare a V.TRAPS model for paint bath analysis, the CAD model of the BIW in the form of IDEAS, CATIA or IGES is used. This CAD is then translated into ANSA either using the CATIA translator or using the IGES reader available within ANSA. The translated CAD is then cleaned using tools available in ANSA under the TOPO menu.

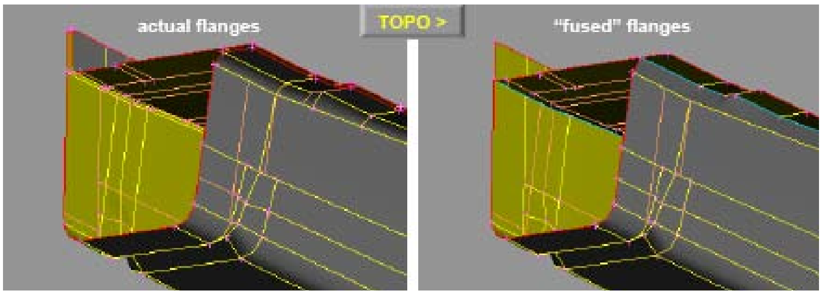


Figure 15: Model preparation for V.TRAPS analysis.

The next step is to stitch/fuse the parts together at the welded flange as shown in the figure 15. To represent the actual welding the flanges has to be "fused" together, otherwise the V.TRAPS detects these as openings and allows air/fluid to leak through the gaps. Fusing is performed preferably at TOPO level using CAD functions, Alternatively, the user can also create shell elements and close the gaps using other function in the MESH menu. Red and Cyan representing free and multiple edges respectively and pose no problem for the V.TRAPS analysis.

Once the stitching of the parts is done, the model is meshed using triangular elements. Any duplicate elements in the model are identified and deleted. The final step in model preparation is to eliminate intersections in the model. ANSA automatically identifies the intersecting parts and highlights them on the screen. The user then offsets the nearby parts or moves the nearby nodes to clear the penetrations. The model is now ready to be analyzed using V.TRAPS tool. After the analysis, if there is more than acceptable amount of voids and puddles the user can add drainage holes and re-run the analysis to study their effectiveness.

Model Preparation – Existing FE Mesh

Alternatively, an existing finite element mesh can be obtained from other CAE groups for analysis. If the obtained mesh has any quad elements in it they are converted to triangular elements. The mesh is checked for any intersections and fixed if required. The parts are stitched at the welded flanges as described above to represent welds and sealers.

Case Study 3 – Floor Pan

A study was performed to estimate the approximate time needed to clean a finite element mesh before a full vehicle body can be analyzed using V.TRAPS. A previously generated mesh was utilized for this study. The cleanup started with the floor pan. The mesh was converted to triangular elements and the edges were stitched to represent welds and sealers. It took approximately an hour to prepare this module for ANSA's V-TRAPS analysis (as shown in Figure 16).

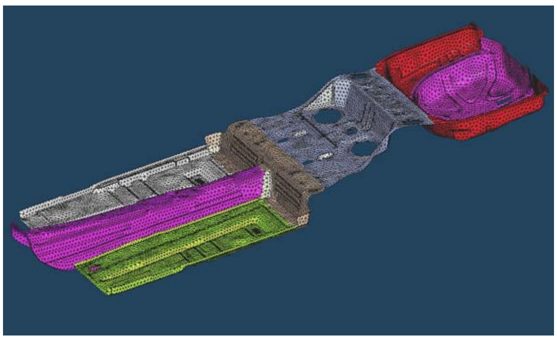


Figure 16: It took one hour to prepare a floor pan with 8 parts. It is estimated to take hundreds of man-hour to prepare a full vehicle model.

At this stage it was estimated that it would take hundreds of man-hours to fix a mesh of a full vehicle body including all the closure panels. The amount of time needed depends on the complexity of the model and the quality of the base mesh. Due to the time limit on this study it is not practical to continue the process to prepare the full vehicle model for V.TRAPS analysis.

5. SUMMARY

ANSA's V.TRAPS functionality of identifying e-coat voids and puddles was evaluated. It is superior to the existing traditional process in several areas. V.TRAPS is an automatic process that eliminates the human factor in the traditional method. It also has the ability to calculate the volume of the bubble/puddle. ANSA is capable of creating a drainage hole in the mesh and evaluate the effectiveness of the hole. It is also useful to evaluate an effective drainage hole design if the void or puddle is above the acceptable size. However, the mesh requirement for V.TRAPS is too strict. The time needed to clean up the geometry for a full vehicle analysis is unacceptable. The use of this tool is recommended only to perform analysis on a single sheet metal part or an isolated module. It is not practical to use this tool for the analysis of a full vehicle body unless there's a dramatic improvement of the geometry data quality or if there are improvements on V.TRAPS functionality that takes into consideration that small gaps between sheet metals to be ignored.

6. NEXT STEPS

Based on the results of the study, following opportunities for improvement of the V.TRAPS tool are identified:

1. The ability to save the results of the V.TRAPS analyses was unavailable in ANSA v12.0.3 used for the study. This capability is currently added in ANSA version 12.1.0. However, the user should be able to save results in the V.TRAPS menu similar to cross section tool.
2. The bubbles and puddles/ponds identified in the analysis should be displayed in different colors for easy identification.
3. There should be a capability to add the drainage hole within the V.TRAPS menu that would avoid going back into the MESH menu every time the user creates a hole.
4. The capability to consider a welded flange (welded using traditional RBE2 elements) as “sealed” should be added in the future versions of ANSA. Currently, all the welded flanges need to be fused in order to prevent the fluid from passing through.
5. Fluid dynamics should be incorporated to further enhance the tool. For instance, the user should be able to calculate the time required to drain a puddle based on the volume of fluid, viscosity and other parameters. This time required to drain will help engineers to decide on the severity of the puddle and to design a drainage that is large enough to drain the liquid in time without jeopardizing structure integrity of the vehicle body.
6. ANSA V.TRAPS does not take into account the dynamic movement of the BIW through the bath. For example, the user can see the puddles created when the BIW comes out at an angle of 15 degrees. However, the BIW will come back to horizontal position after it comes out of the bath which results in the drainage of some of those puddles identified earlier. The above dynamics is not captured by the V.TRAPS tool and is a potential opportunity for improvement.