DESIGN, MANUFACTURING AND QUALITY CONTROL OF THE TOOLS USED IN STAMPING PROCESS OF CAR BODY PARTS IN AUTOMOTIVE INDUSTRY

Gabriel-Daniel STANCA [1], Miron ZAPCIU[2]

Rezumat. *În realizarea unei scule fie ea de ambutisare, fie pentru o operaţie de repriză, trebuie acordată atenţie asupra calităţii proiectării, a calităţii suprafeţelor generate prin modelare, a calităţii prelucrărilor mecanice. În realizarea unei piese de automobil prin deformare plastică la rece, trebuie să se acorde o atenţie deosebită asupra calităţii totale a proceselor de elaborare a sculelor necesare realizării piesei. În procesul de analiză a calităţii este nevoie de experienţă pentru a putea ajunge la o identificare rapidă a defectelor, a posibilelor riscuri, dar şi pentru găsirea imediată de soluţii fezabile. În continuare, la ajustare şi la încercările la care sunt supuse sculele, trebuie să se lucreze inteligent, economic şi să se rezolve cele mai multe probleme imediat ce sunt observate, pentru a micşora timpul total al proiectului.*

Abstract. *In the making of a tool whether it is a stamping machine or for a drawing operation, attention must be paid to the quality of the Design, the quality of the surfaces generated by Modeling, the quality of the machining. When creating a car part by cold plastic deformation, special attention must be paid to the total quality of the processes for the elaboration of the tools to make the part. Thus, attention must be paid to all the tools needed to make the piece. For a quality analysis it is necessary to have experience in order to be able to quickly identify faults, possible risks, but also to find feasible solutions immediately. Further to the adjustment and the tests to which the tools are subjected, they must work intelligently, economically and solve most problems as soon as they are observed, in order to reduce the time required for the project.*

Keywords: Quality, Mold, Manufacturing process, Automotive industry

1. Introduction

The process of manufacturing by cold pressing acquires, in the last period of time, an increasing applicability, due to the important advantages: high productivity, high precision of the parts and low cost [1].

Therefore, the development stage of cold pressing, the extension of this manufacturing process in all branches of the machine building industry represents an indication of the technical progress that characterizes the last years.

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The economy and the needs of the population are constantly growing, and these two trends determine the development of the field of cold pressing. To improve the cold pressing industry, new methods of optimizing [2] are introduced daily:

- the pressing process analysis;
- part design and shaping;
- the tool manufacturing process, etc.

2. Current state

2.1. Performing and interpreting the simulation stamping for the hood panel

To perform the simulation of the stamping operation in *Autoform* software, the active parts of the component elements were created. Thus, given that it's a simple operation, three components are obtained: the punch lower support, the part and the upper support of the mold [3].

The required surfaces necessary to simulate the embossing, for this case study operation, are shown in the Figure 1.

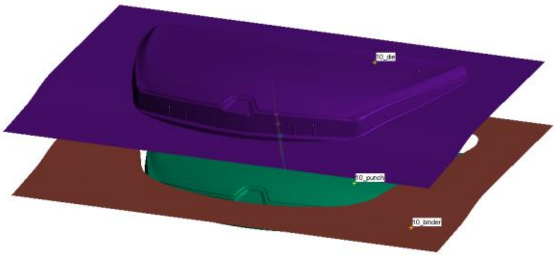


Fig. 1. Active elements required for simulation.

Some other elements are needed to create the simulation. The first element would be the flange, the sheet format that will deform. It can have various forms. Depending on the complexity of the part, a format could be made on universal guillotines or by choosing to make a special cut that will make the sheet formats on the batch size production.

Regarding the simulation and the quality of the embossed part, the cuts are desirable, but these make it difficult for the customer who needs an extra tool over the range. For simple parts, the customers prefer to use the standard guillotine sheet [2].

On the case-study, we used a format that is made on guillotine and is shown in the Figure 2.

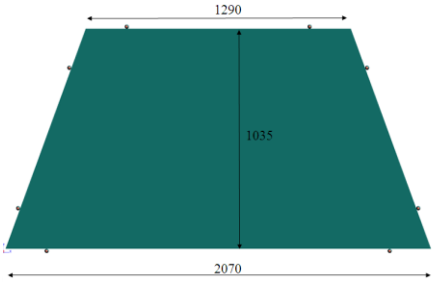


Fig. 2 The dimensions of the sheet format.

The material is another important element. This is important for obtaining the functionality of the part and for having the satisfied mechanical characteristics. In this case for the hood we will use HC220C. The desired thickness for the workpiece is e = 0.65mm.

Regarding the mechanical characteristics taken into account by *Autoform* software, these are included in the Figure 3.

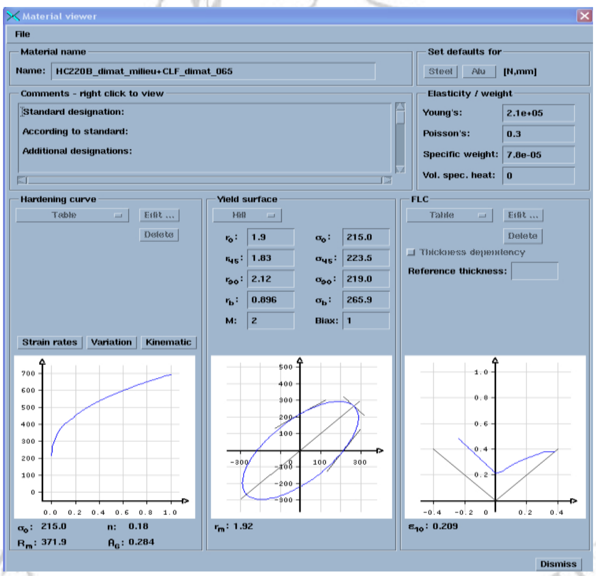


Fig. 3 Material characteristics of HC220C.

Unlike the free stamping in which the part is formed, between the punch and the die during the stamping of the vehicle parts, it is necessary that the sheet format be kept outside the final part, to prevent the creation of corrugations and to ensure the plastic deformation of the piece. For this, it was necessary to use a shelf.

The holding force achieved by tightening the sheet between it and the die, however, is not sufficient. For this purpose, retaining joints are created on the shelf. These are represented in simulation by a closed or open curve, after acting the force (junction) on the board.

The physical representation of the rushes can be done in various forms of baffles or keyboards. In our case, the baffles were used. The retaining joints used for simulation process are presented in the Figure 4.

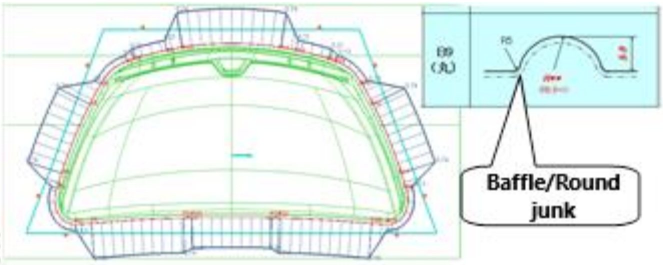


Fig. 4 Retaining joints.

Now, with the corresponding settings required for *Autoform* the simulation can be launched [7]. In results interpreting process, several steps can be taken. A first step would be the formability as shown in the Figure 5, at different steps before closing the tool. The green color shows that the board is deformed from the gray color which means that the deformation is small. The colors of blue and purple show a crowd of material. In the other direction of the color scale, when the yellow color appears, it indicates a thinning of the material, the orange color shows the risk of breaking, and the red color appears at the time of breaking..

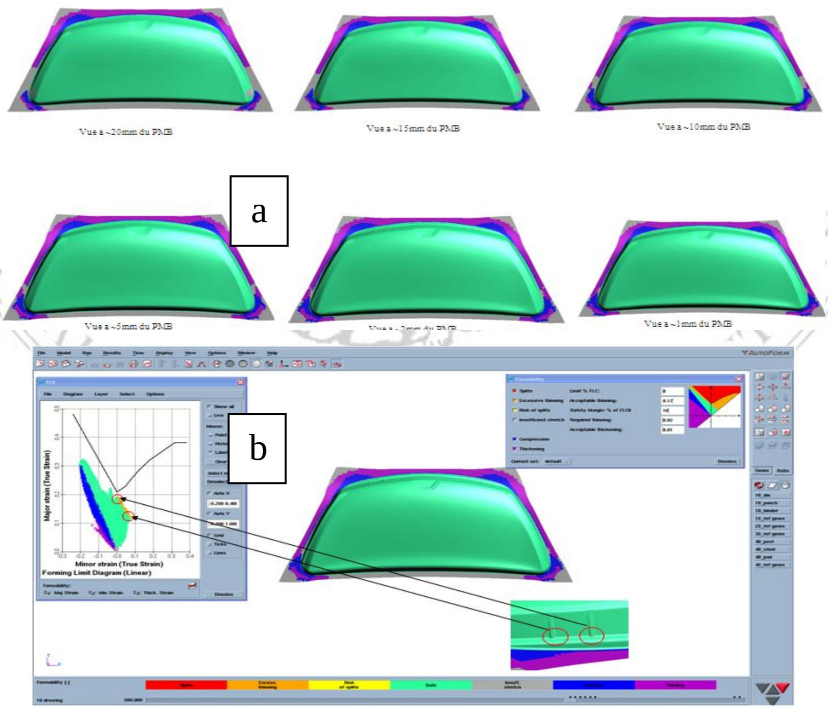


Fig. 5. Formability of the part (a - in steps; b - at the end of the race).

Using the simulation [5], the graph of required forces is obtained in the Figure 6 (from which the force required at the punch and the reaction of the die are depending on the chosen value of the force for holding the shelf).

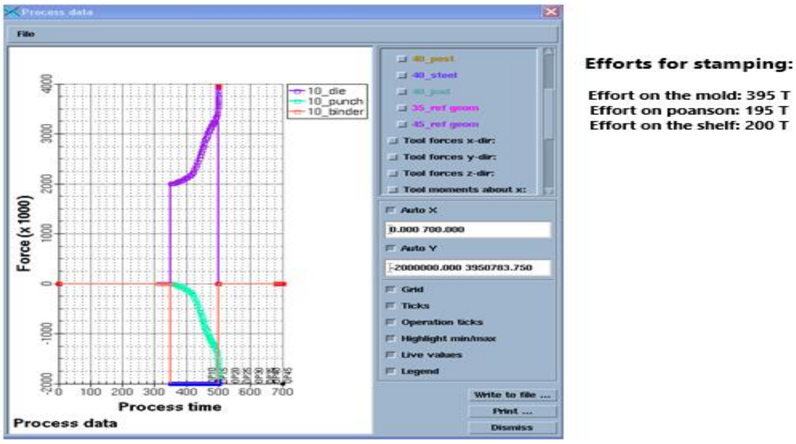


Fig. 6 Simulation result on required forces.

Other performed analysis are done on material thinning, plasticity and the risk of defects appearance. The thinning of the material is considered as the percentage of the initial thickness that is lost as a result of the deformation. In our case, the maximum permissible thinning is 17%, and after the simulation a 1.6% thinning is obtained (Figure 7). In this case-study is desirable for the part to be in plastic deformed areas, in order to have resistance in operation and for the preservation of form during subsequent stages, in assembly and in operation. An elastic deformation of the part causes defects in appearance, as a result of subsequent operations, a poor operating resistance that leads to the deformation of the part. The plastic deformation analysis on the hood panel is illustrated in the Figure 8. The black color shows the area where the deformation is in the plastic areas.

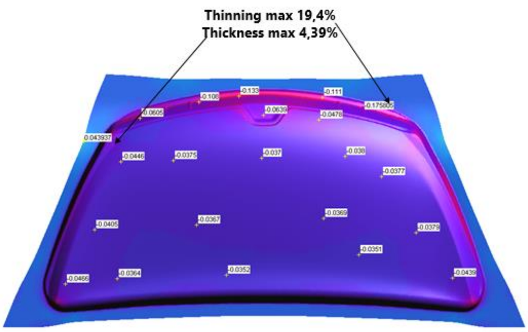


Fig. 7. Thinning material.

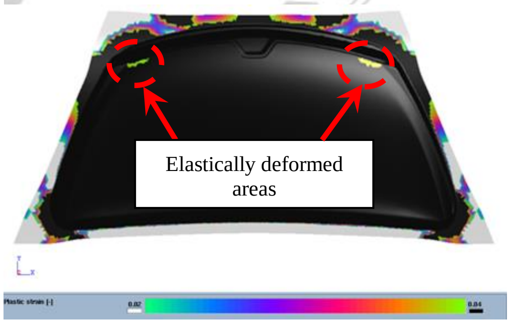


Fig. 8. Plasticity of the piece.

The risk of appearance defects calculated by *Autoform* is shown in the Figure 9. Two areas with risk of appearance defects appear in operation 10, but they will be analyzed if they will appear on the piece. The final part according to the manufacturing sheet is presented in the Figure 10.

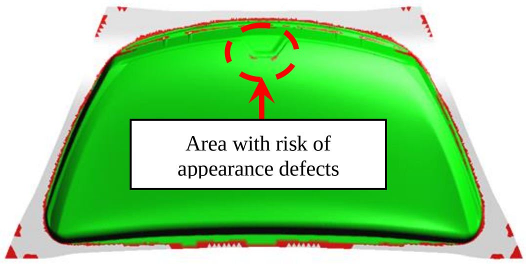


Fig. 9 Risk of defects appearance.

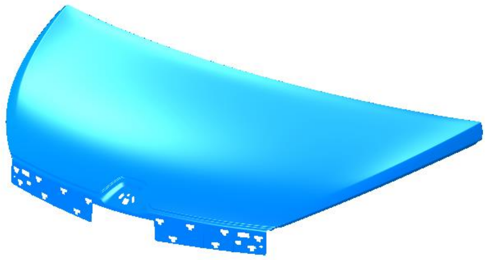


Fig. 10 Final part of bonnet panel

2.2. Manufacturing record analysis

In order to obtaining the manufacturing sheet [7], it is necessary to receive a preorder from the client. This is summarized in the number of operations to be performed in each stage, as well as the balance of the part in the tool. Balance means the rotations and translations that the part undergoes in order to bring it from the machine axis to the tool axis. These apply to the part at the starting point that is considered the origin of the piece [6].

The axis system of the machine is shown in the Figure 11, detailing the coordinates of the part origin (departure point).

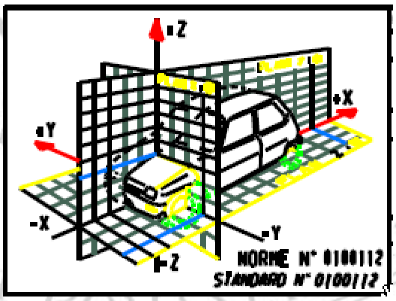


Fig. 11 Machine axis system.

In the execution of the tools, starting from the Manufacturing Sheet, the following steps exist:

- realization of the 3D project (the design of the tools for each operation in the manufacturing file);

- obtaining the polystyrene models, according to the 3D project, in order to make the molded supports;
- sending the polystyrene models to the collaborating foundries;
- reception of molds;
- development of CNC programs for machining and manufacturing of the components;
- measuring the supports with the mounted components;
- adjusting the active elements before entering the tools in MAP (tests, checks and production of parts on presses);
- the entry of the parts in the MAP and the execution of the first piece of tools (the IOD piece).

2.3. Measurement of parts

After the first final piece has been obtained, it must be measured. For this, a control model is required, on which the final piece is placed. Once the layout is measured and it is ok you can measure pieces on it.

As part measurements, there are 2 types:

- Capacity measurements in which the serial points are measured on 5 pieces (the serial points are defined in the Geometry File);
- Piece encryption, in which the landing areas of the Part Drawing with a certain tolerance and the rest of the volume are measured on a piece.

For ease of measurement, measuring ranges are created for the machine to measure itself.

Part capability

The Capability measurements measure 5 pieces at certain points defined in the Geometry File (Figure 12), And the measured values are passed in the Green Sheet, which is an Excel document.

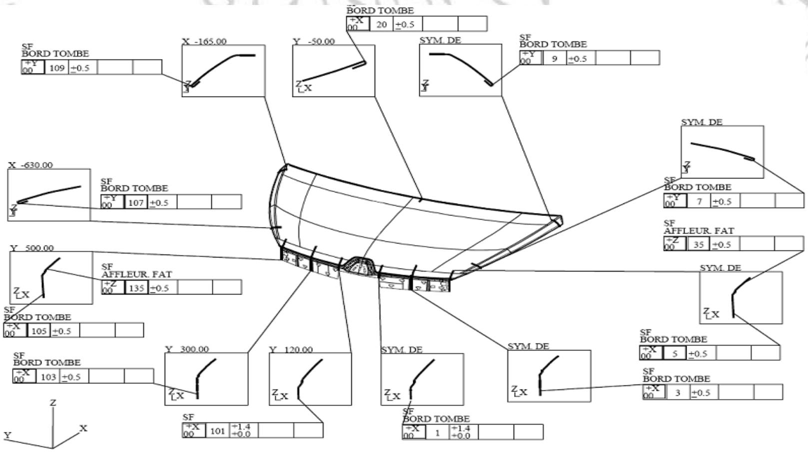


Fig. 12. The geometry file of the hood panel.

Part encryption

For encryption measurements, the piece is measured starting from the part drawing. In the Drawing from the figure 13, are presented the tolerances for the important areas of the part and the rest of the tolerances of the part for perforations, trimming contour and part volume.

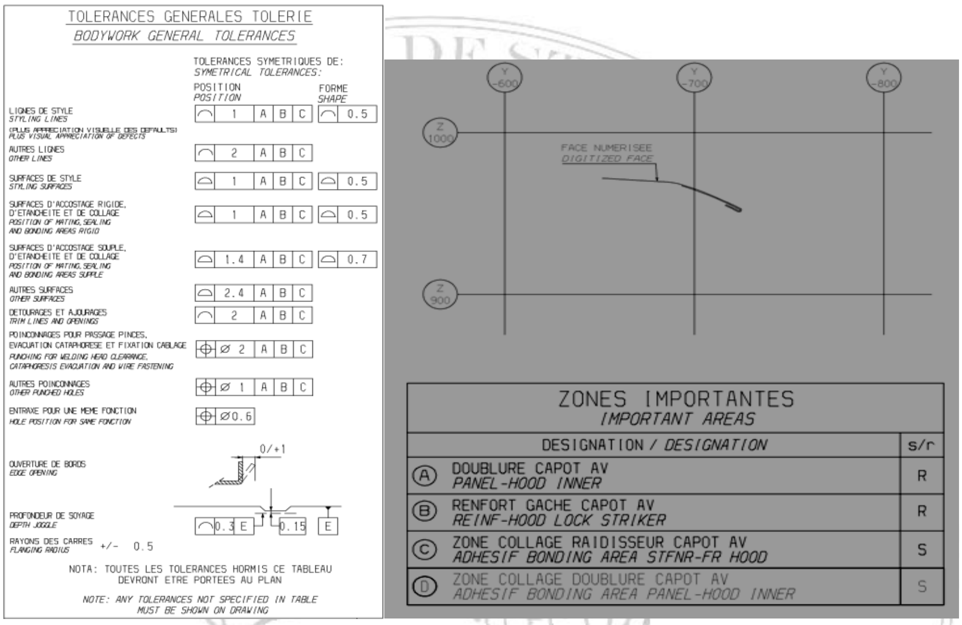


Fig. 13. Front hood panel drawing part.

In order to have a better image on the quality of the piece, VTS scanning using a laser beam is used [4]. This is processed and for the IOD piece the scan of the final part is shown in the Figure 14.

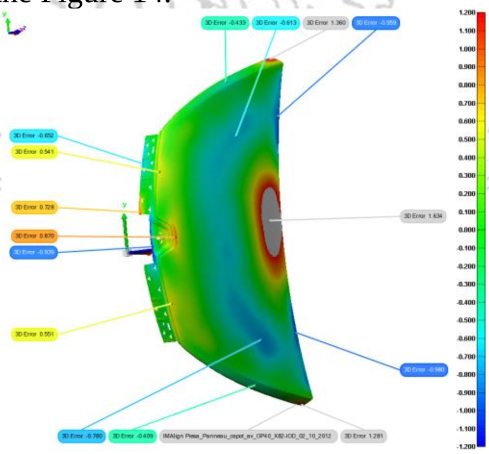


Fig. 14 Scanning of the IOD part.

3. Development of corrections to improve the quality of the piece

The first encrypted piece - TB piece (TB engineer's required piece)

Given the low level of quality of the piece it was decided to improve the quality of the piece before delivering parts to the customer.

If at the IOD piece the tools were not fully equipped and the quality of the tools (the foundation) was low, for this part they improved.

According to the measurements, an improvement in the level of *Aptitude* in the *Green Card* reaches a percentage of 65% (Figure 15).

TNC OBJECTIF		Measurement results
POURCENTAGE D'ACCEPTATION SERIE		
Mesurées	100%	100%
Moy. < 2IT	100%	100%
Disp. OK	100%	90%
Moy. OK	88%	75%
Aptitude	65%	60%

INDICATEURS D'AVANCEMENT DE LA GEOMETRIE DES PIECES NUES *Evolution of single part dimensional accuracy*			
Jalon / *Trial Time*	1ère Pièce Chiffrée / *T001*		
Désignation / *Part Name*	PANNEAU EXT CAPOT AV		
N° Pièce / *Part N°*	651123403R	Traçabilité / *Traceability*	
Ind. D Géo/ *Change Level Dgeo*	D01	Date / *Date*	23.10.2012
Nb de cotes / *Total Points*	40	Véhicule / *Vehicle*	X52
Matière / *Material*	HX220BD	Epaisseur / *Thickness*	0.65

Moyenne *Average*	Etendue *Range*	Ecart type σ	Ecart type Limite *σ limit*	Mesurées	Moy. < 2IT	Dispersion	Moyenne	Aptitude	Commentaire *Comment*	Classe	Point n° *Pt N°*	Ti *LSL*	Ts *USL*	Pièce n°1 *Part N°1*	Pièce n°2 *Part N°2*	Pièce n°3 *Part N°3*	Pièce n°4 *Part N°4*	Pièce n°5 *Part N°5*	Type de cote *Type quotation*
-0.03	0.46	0.19	0.26						V.G BORD TOMBE	3	1	-0.5	0.5	-0.175	-0.11	0.031	0.27	-0.109	SERIE
0.37	0.27	0.11	0.26						V.G BORD TOMBE	3	3	-0.5	0.5	0.435	0.35	0.203	0.476	0.395	SERIE
0.00	0.39	0.16	0.26						V.G BORD TOMBE	3	5	-0.5	0.5	0.239	0.077	-0.036	-0.123	-0.152	SERIE
0.26	0.37	0.14	0.26						V.G BORD TOMBE	3	7	-0.5	0.5	0.443	0.073	0.324	0.293	0.176	SERIE
0.31	0.10	0.04	0.26						V.G BORD TOMBE	3	9	-0.5	0.5	0.272	0.374	0.327	0.293	0.299	SERIE
-0.03	0.11	0.05	0.37						V.G DETOURAGE	3	16	0	1.4	0.007	-0.095	0.016	-0.016	-0.046	SERIE
0.07	0.15	0.05	0.26						V.G BORD TOMBE	3	20	-0.5	0.5	0.044	0.093	0.068	0.145	-0.001	SERIE
0.46	0.02	0.01	0.26						V.G ACCOSTAGE LOGO	3	30	-0.5	0.5	0.471	0.468	0.474	0.476	0.482	SERIE
0.00	0.46	0.18	0.26						V.G ACCOSTAGE LOGO	3	31	-0.5	0.5	-0.312	0.077	-0.004	0.145	0.081	SERIE
0.10	0.54	0.21	0.26						Y FIX BANDEAU LOGO	3	32	-0.5	0.5	-0.205	0.336	0.006	0.129	0.247	SERIE
-0.06	0.10	0.04	0.26						Z FIX BANDEAU LOGO	3	32	-0.5	0.5	-0.08	-0.009	-0.107	-0.064	-0.057	SERIE
0.37	0.38	0.16	0.26						Y FIX BANDEAU LOGO	3	33	-0.5	0.5	0.301	0.513	0.391	0.137	0.511	SERIE
-0.08	0.07	0.03	0.26						Z FIX BANDEAU LOGO	3	33	-0.5	0.5	-0.104	-0.048	-0.066	-0.114	-0.084	SERIE
0.04	0.02	0.01	0.26						V.G AFFLEUR. FAT	3	35	-0.5	0.5	0.041	0.048	0.028	0.044	0.045	SERIE
0.18	0.28	0.12	0.13						DF ENTRE PTS 7-8-9	3	50	0	0.5	0.323	0.301	0.129	0.036	0.123	SERIE
-0.21	0.12	0.05	0.26						V.G	3	101	-0.5	0.5	-0.269	-0.146	-0.197	-0.257	-0.179	SERIE

Fig. 15. Green sheet for the TB encrypted part.

For this TB piece the scan of the final part is illustrated on the Figure 16.

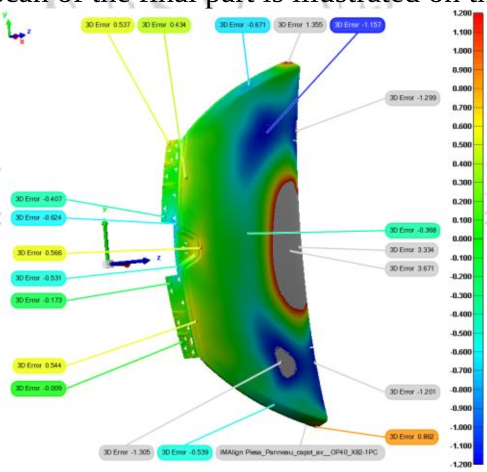


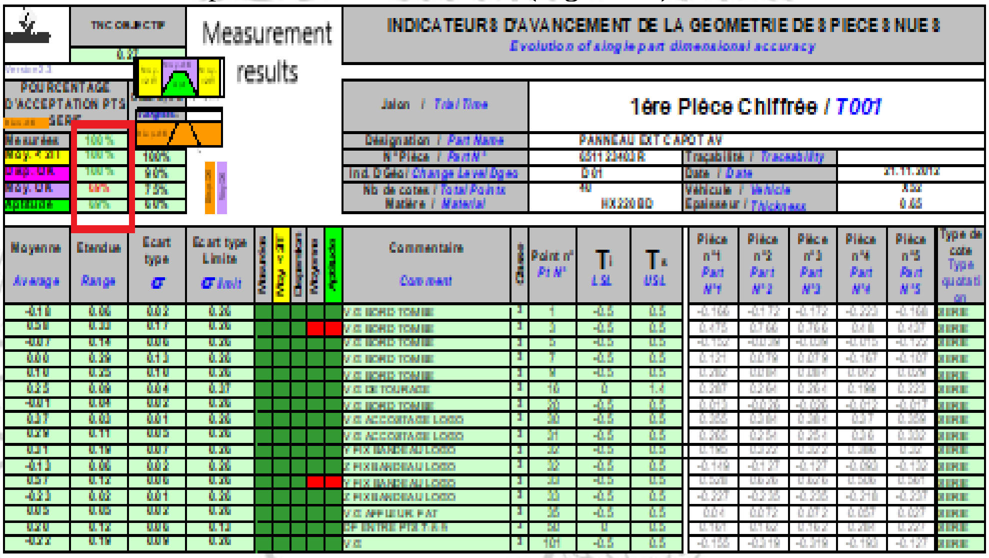
Fig. 16. Scanning the TB track.

First encrypted piece (1PC)

Considering the improvement of the level of Aptitude towards the piece IOD it was decided that it is sufficient to send parts for the client.

After the execution of the batch of parts in optimal conditions, 5 pieces were measured for Capability (Green Sheet) and one piece for encryption (measurements) completely.

As a level of aptitude there has been progress towards the previous milestone. Thus the level of *Aptitude* at 1PC was 69% (Figure 17).



INDICATEURS D'AVANCEMENT DE LA GEOMETRIE DES PIECES NUES
Evolution of single part dimensional accuracy

1ère Pièce Chiffrée / *T001*

Désignation / *Part Name*	PANNEAU EXT CAPOT AV
N° Pièce / *Part N°*	6511 23403 R
Ind. D Géo / *Change Level Dgeo*	D01
Nb de cotes / *Total Points*	40
Matière / *Material*	HX220BD
Traçabilité / *Traceability*	
Date / *Date*	21.11.2012
Véhicule / *Vehicle*	X52
Epaisseur / *Thickness*	0.65

POURCENTAGE D'ACCEPTATION PTS		
Mesurées	100 %	
Moy. < 2IT	100 %	100%
Disp. OK	100 %	90%
Moy. OK	69%	75%
Aptitude	69%	60%

Moyenne *Average*	Etendue *Range*	Ecart type σ	Ecart type Limite *σ limit*	Commentaire *Comment*	Chap.	Point n° *Pt N°*	Ti *LSL*	Ts *USL*	Pièce n°1 *Part N°1*	Pièce n°2 *Part N°2*	Pièce n°3 *Part N°3*	Pièce n°4 *Part N°4*	Pièce n°5 *Part N°5*	Type de cote
-0.18	0.06	0.02	0.26	V.G BORD TOMBE	3	1	-0.5	0.5	-0.166	-0.172	-0.172	-0.223	-0.168	SERIE
0.58	0.33	0.17	0.26	V.G BORD TOMBE	3	3	-0.5	0.5	0.475	0.766	0.766	0.48	0.437	SERIE
-0.07	0.14	0.06	0.26	V.G BORD TOMBE	3	5	-0.5	0.5	-0.152	-0.036	-0.036	-0.015	-0.122	SERIE
0.00	0.29	0.13	0.26	V.G BORD TOMBE	3	7	-0.5	0.5	0.121	0.079	0.079	-0.167	-0.107	SERIE
0.10	0.25	0.10	0.26	V.G BORD TOMBE	3	9	-0.5	0.5	0.262	0.084	0.084	0.042	0.029	SERIE
0.25	0.09	0.04	0.37	V.G DETOURAGE	3	16	0	1.4	0.287	0.264	0.264	0.199	0.233	SERIE
-0.01	0.04	0.02	0.26	V.G BORD TOMBE	3	20	-0.5	0.5	0.013	-0.026	-0.026	-0.012	-0.017	SERIE
0.37	0.03	0.01	0.26	V.G ACCOSTAGE LOGO	3	30	-0.5	0.5	0.365	0.384	0.384	0.37	0.359	SERIE
0.29	0.11	0.05	0.26	V.G ACCOSTAGE LOGO	3	31	-0.5	0.5	0.265	0.254	0.254	0.36	0.302	SERIE
0.31	0.19	0.07	0.26	Y FIX BANDEAU LOGO	3	32	-0.5	0.5	0.195	0.322	0.322	0.386	0.32	SERIE
-0.13	0.06	0.02	0.26	Z FIX BANDEAU LOGO	3	32	-0.5	0.5	-0.149	-0.127	-0.127	-0.093	-0.132	SERIE
0.57	0.12	0.06	0.26	Y FIX BANDEAU LOGO	3	33	-0.5	0.5	0.528	0.626	0.626	0.506	0.561	SERIE
-0.23	0.02	0.01	0.26	Z FIX BANDEAU LOGO	3	33	-0.5	0.5	-0.227	-0.235	-0.235	-0.218	-0.237	SERIE
0.05	0.05	0.02	0.26	V.G APPUI LUR FAT	3	35	-0.5	0.5	0.04	0.072	0.072	0.057	0.027	SERIE
0.20	0.12	0.06	0.13	JF ENTRE PTS T & R	3	50	0	0.5	0.161	0.162	0.162	0.281	0.227	SERIE
-0.22	0.19	0.09	0.26	V.G	3	101	-0.5	0.5	-0.155	-0.319	-0.319	-0.193	-0.127	SERIE

Fig. 17. Green sheet for piece 1PC.

The scan of the final part at this milestone (1PC) is shown in the Figure 18.

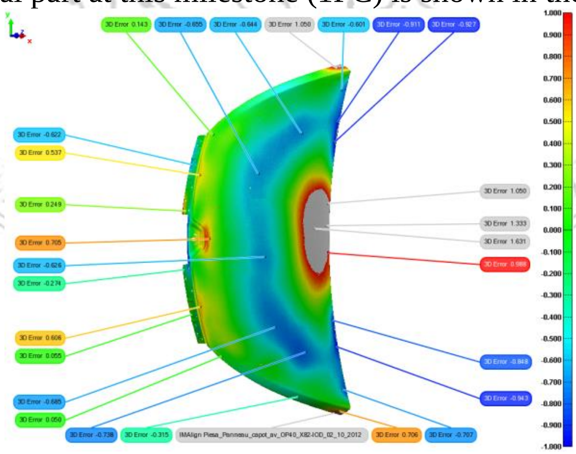


Fig. 18. Scanning the 1PC piece.

3.1. Remediation instruction 1

The first reshuffle instruction consisted of detaching the control layout (MC) on the side area. From the project phase there was an over-constraint of the part that was placed on the control model on Ø12 supports, with a thickness of 5 mm, but also on an area of 10 mm of resin (Figure 19). Basically the resin area deforms the piece.

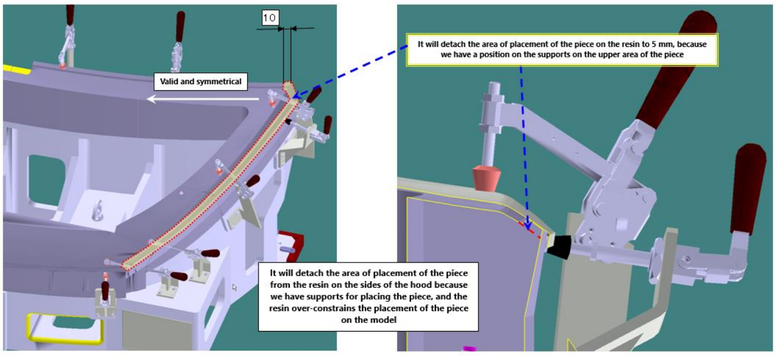


Fig. 19. Remedy instruction IR1 - MC land relief.

3.2. Remediation instruction 2

In this instruction I indicated the correction of the trimming contour in OP 20, because having a Flux in OP 10 to counteract the elastic return of the piece and another one in OP 20 for a better placement of the piece, it came out smaller on the back area on Figure 20.

Fig. 20. Remedy instruction IR2 - trimming contour change.

3.3. Remediation instruction 3

The most important modification of the hood was made during this phase, when is decided to modify the bend line of the hood on the left side. Thus, the increase of the volume on the collapsed board area is corrected, but also the position of the perforations on the front of the hood (Figure 21).

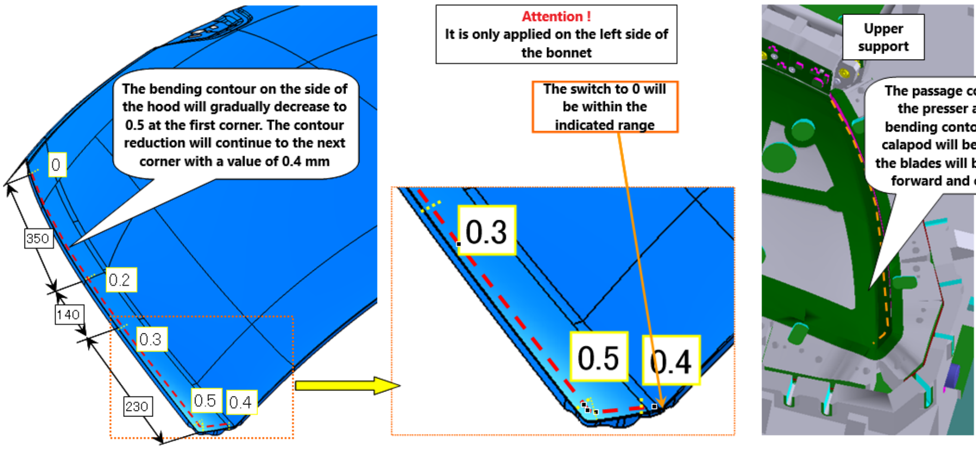
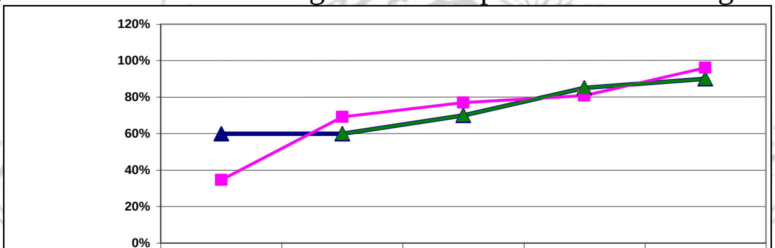


Fig. 21. Remedy instruction IR3 - bending contour modification.

4. Customer receipt of tools (ATLO)

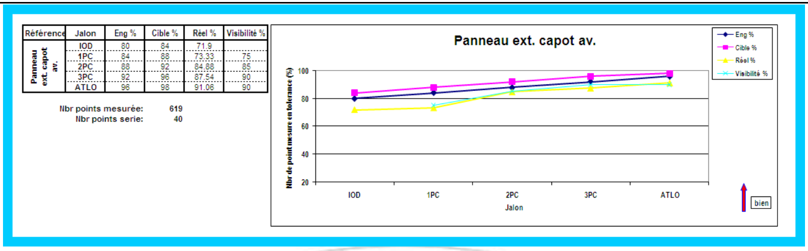
After applying the IR 3 Remodeling Instruction and raising the quality of the tools in order to visit the client for the reception of the tools, the last pieces to be delivered with the tools were made.
Along with the dynamic ATLO of the tools on presses, the lots of pieces for the expedition were executed. From this batch made under optimal conditions were measured 5 pieces for Capability and one piece for complete encryption.
As a level of aptitude there has been progress towards the previous milestone. Thus the ATLO Aptitude level was 96%.
A summary of the evolution of the green card is presented in the Figure 22.



	1ère IOD/ First IOD	1ère Pièce Chiffrée / T001	2ème Pièce Chiffrée / T002	3ème Pièce Chiffrée / T003	ATLO / DIES SHIPPING
Obiectiv Aptitude	60%	60%	70%	85%	90%
Realizat Aptitude	35%	69%	77%	81%	96%
Vizibilitate		60%	70%	85%	90%

Fig. 22. Green card evolution.

As the chart shows, the track aptitude at ATLO, 96%, was above the target which was 90%.
As a level of Geometry (full encryption), there was a progress towards 3 PCs reaching a level of 91% (Figure 23).



Référence	Jalon	Eng %	Cible %	Réel %	Visibilité %
Panneau ext. capot av.	IOD	80	84	71.9	
	1PC	84	88	73.33	75
	2PC	88	92	84.88	85
	3PC	92	96	87.54	90
	ATLO	96	98	91.06	90

Nbr points mesurée: 619
Nbr points serie: 40

Fig. 23. Geometry level of the ATLO part.

Given that the piece is good in terms of Aptitude and Geometry Level, the tools were delivered to the manufacturing site. Compared to the hoods made so far, this was practically the top in terms of quality.

5. Conclusions and contributions

When creating a car part by cold plastic deformation, special attention must be paid to the total quality of the processes for the elaboration of the tools to make the part. Thus, attention must be paid to all the tools needed to make the piece.

In order to certify the quality of the parts it is necessary that the measurements be made under optimum measurement conditions, at a temperature of 20°C ± 2°C and a humidity of around 55% ± 20%. In addition, it is very important that the measuring machines are in normal parameters, are maintained daily and the revisions according to the books of the machines are carried out.

The same problems may also occur with the quality analyst who, besides having to pay attention to all the tools in a project, may have several projects in the process.

If as many of the quality requirements are met then the projects can certainly be carried out according to the planning.

It is very important also the operator who can have a negative influence on the results. That's why he has to be very careful and think twice before making a decision.

Personal contributions:

- identification of the non-conformities in the design and proposal of solutions for their elimination;

- improvements to the geometry of the piece, by changing the trimming contour;

- active parts analysis of the tools after machining and indication of the adjustment areas.

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