Virtual Simulation of the Engine Hood Misuse Test, Development Practices and Correlation Activities

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Abstract: Misuse analysis of the engine hood is a critical evaluation to verify robustness of vehicles. Major studies are carried out for the recent light commercial vehicle in Tofaş. Virtual simulation of the engine hood misuse test; development practices to improve performance and correlation activities with physical tests are stated on this study. Abaqus/Explicit solver is used for virtual simulations.

Keywords: Engine hood, Misuse, Abaqus/Explicit, Explicit Dynamic Analysis, Topography Optimization, Correlation

1. Introduction

It is very important that no damage occurs on vehicle body or engine hood after misuse by the vehicle user. Misuse test of the engine hood can be defined as releasing the hood free from its full open position.

During the test, the engine hood closes with high speed and results excessive forces on body and lock zones. Performance goals of the test are;

- No collision between engine hood and the components around
- No damage on engine hood and vehicle body that impedes function of the engine hood

The FEM model of the test is composed according to misuse slam physical test norm of the FIAT. Analyses are performed with Abaqus/Explicit.

Some collisions are observed between the engine hood and headlight on initial steps of the project. Following studies are performed to eliminate these negativities.

- Topography optimization has been performed to improve bending behavior of the engine hood.
- Elastic bumpers are added to eliminate collisions between headlight-engine hood and bumper-engine hood.
- The geometry and stiffness of the current snow sealing is improved to dampen collision energy efficiently.

2. Engine Hood Misuse Slam Test

The engine hood is released from full wide-open position to assure drastic conditions for misuse slam test. Performance evaluation criteria of misuse test are stated on Figure 1.

Misuse cofano							
	Presence of bonnet/interfaces contact points (interferences)						
Bonnet drop height from	A	B	C	D	E	F	G
Max. height	✓	✓	✓	✓	✓	✓	✓
TARGET:	Contacts that cause permanent incisions or breaking are not permitted No failure of lock(s) to close (no bonnet rebound) No breakage or malfunction of lock(s)						

Figure 1: Test Conditions

Figure 2: Measuring Points

Minimum distances and contacts are checked on the zones indicated in Figure 2. After the test, there shouldn't be any damage that affects performance of the engine hood and the components around. Also the engine hood lock and striker should function properly.

Additionally while the test is conducted, motions are recorded with high speed camera. The motion behavior of the engine hood is evaluated in detail.

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3. Misuse Slam Simulation

3.1 Finite Elements Details

The finite element model used for misuse analysis is shown in Figure-3. Sectional body model is used to decrease calculation time.

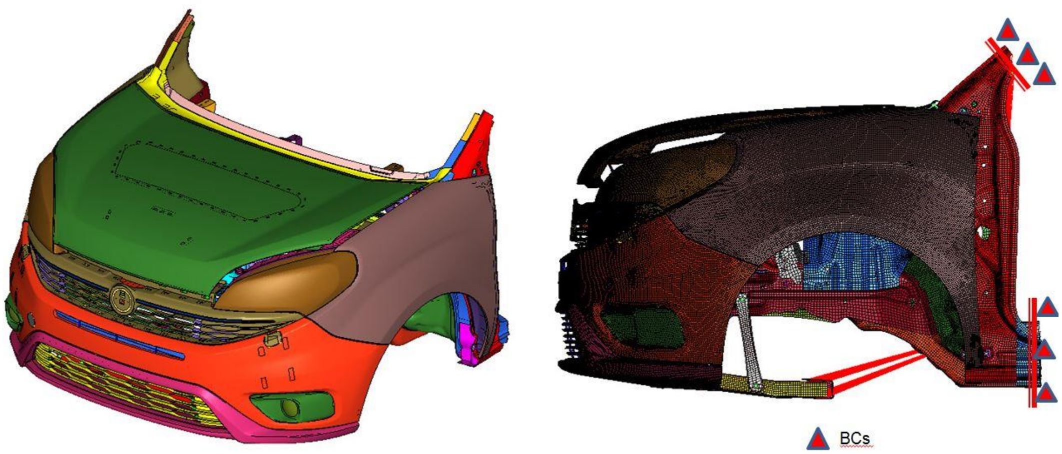


Figure 3: Finite Element Model

The finite element model consists of 830.000 element and 815.000 nodes.

As shown in Figure 4, all sheet parts in the model are modelled with S3, S4 shell elements. Components like sealing, adhesives are modelled with C3D8 solid elements. Spot welds are modelled with fastener elements.

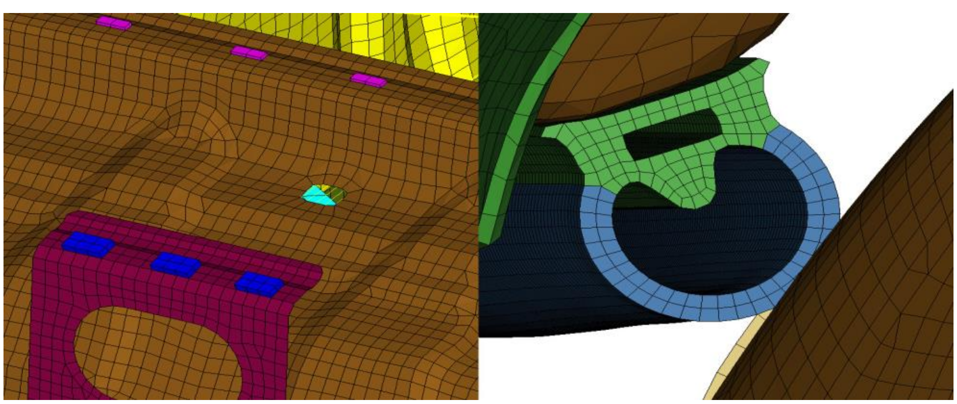


Figure 4: Shell and Solid Elements

3.2 Finite Elements Details

*GENERAL CONTACT is used to model contact behavior between engine hood and body components.

*TIE Contact is used between adhesives and sheet parts as shown in Figure 5.

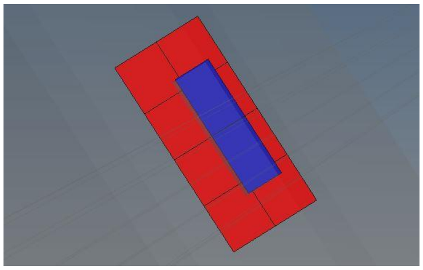


Figure 5: Tie Contact

```
*TIE, NAME = Tie:S:Motore_Cofano:19 S:COLLANTE_OSSATURA:35, ADJUST=NO,
TYPE=SURFACE TO SURFACE
S:Motore_Cofano:19, S:COLLANTE_OSSATURA:35
```

Elastic bumpers on body are modelled with connector elements as shown in Figure 6.

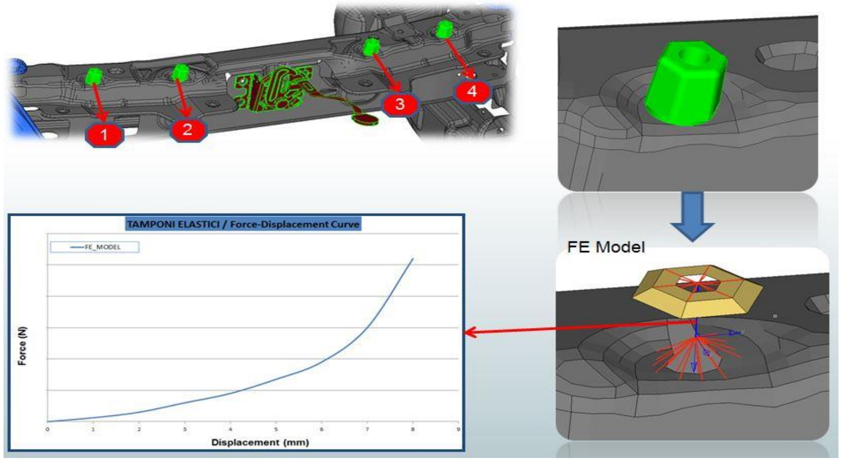


Figure 6: Elastic Bumpers Modeling

Also engine hood lock system is modeled with connector elements as shown in Figure 7.

```
*ELEMENT,TYPE=CONN3D2,ELSET=CON_LOCK
*ELEMENT,TYPE=CONN3D2,ELSET=CON_STOP
*CONNECTOR SECTION, ELSET = CON_LOCK, BEHAVIOR = LEGGE_LOCK
*CONNECTOR SECTION, ELSET = CON_STOP, BEHAVIOR = LEGGE_STOP
*CONNECTOR BEHAVIOR, NAME = LEGGE_LOCK
```

```
*CONNECTOR LOCK, COMPONENT = 1, LOCK = ALL
*CONNECTOR BEHAVIOR, NAME = LEGGE_STOP
*CONNECTOR ELASTICITY, COMPONENT = 1, NONLINEAR
*CONNECTOR STOP, COMPONENT = 1
```

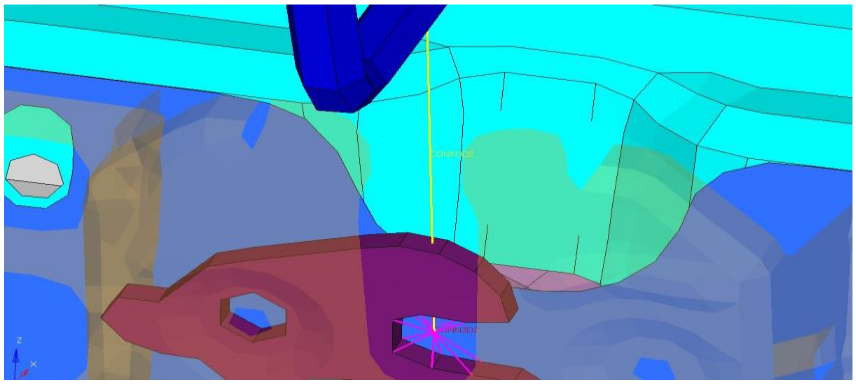


Figure 7: Lock Modeling

3.3 Boundary Conditions

Analysis begins from the moment that engine hood is approximately 6 degrees above the lock instead of full open position to decrease explicit calculation time. The angular velocity of the engine hood on that moment is defined as initial condition of the analysis which is derived by the simulation with MBD model. (Figure 8)

Sectional body model is fixed on all DOFs at the zones as shown in Figure 3. Analyses are performed with these boundary conditions.

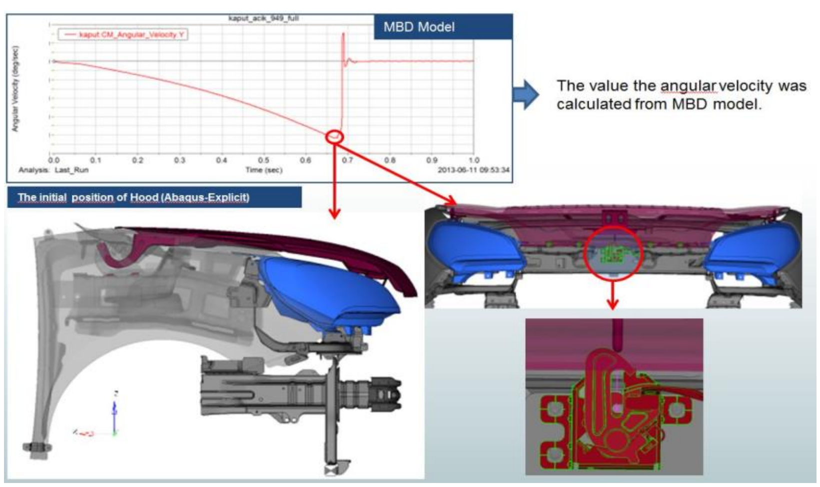


Figure 8: Initial Velocity

3.4 Explicit Dynamic Analysis

Engine hood misuse slam test is a dynamic test; therefore finite element analysis is performed with Abaqus/Explicit solver as explicit dynamic.

Explicit dynamic analysis procedure executes large number of small time increments efficiently. An explicit central-difference time integration rule is used; each increment is relatively inexpensive (compared to the direct-integration dynamic analysis procedure available in Abaqus/Standard) because there is no solution for a set of simultaneous equations. The explicit central-difference operator satisfies the dynamic equilibrium equations at the beginning of the increment, *t*; the accelerations calculated at time *t* are used to advance the velocity solution to time $t + \Delta t / 2$ and the displacement solution to time $t + \Delta t$.

4. Results

Highest stresses occur when the engine hood hits the lock and locking takes place during misuse analysis.

The step which highest stresses occur on engine hood and environmental components is shown in Figure 9.

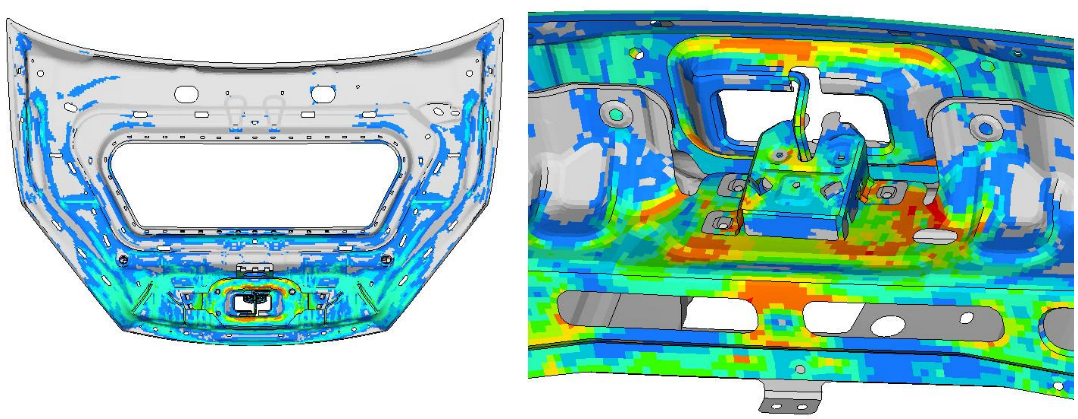


Figure 9: Stress Distribution on the Hood

The velocity curves, energy curves and the forces on lock system and elastic bumpers are shown in Figure 10-11-12.

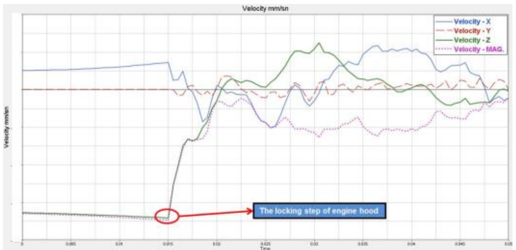


Figure 1: Velocity Curves

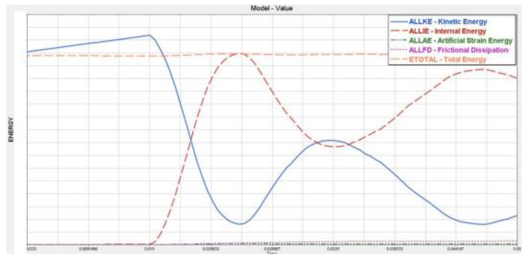


Figure 11: Energy Balances

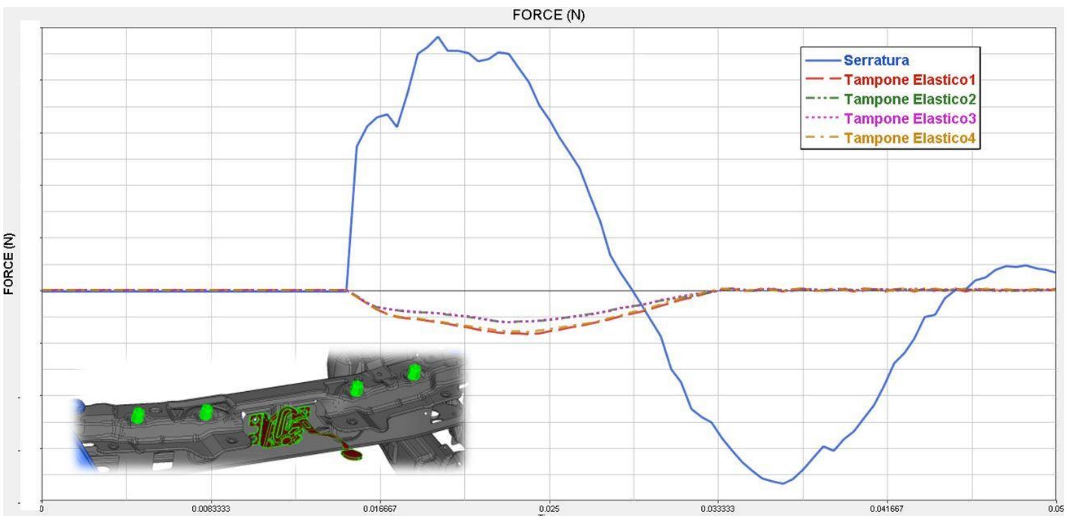


Figure 12: Reaction Forces of Lock System and Elastic Bumpers

On the analyses performed initially, penetrations were seen between engine hood, bumper and headlight zones as shown in Figure 13 and Figure 14. (The general contact interaction between the engine hood and the bumper is cancelled due to monitor the scale of penetration. Other contact relations are still intact in the model.)

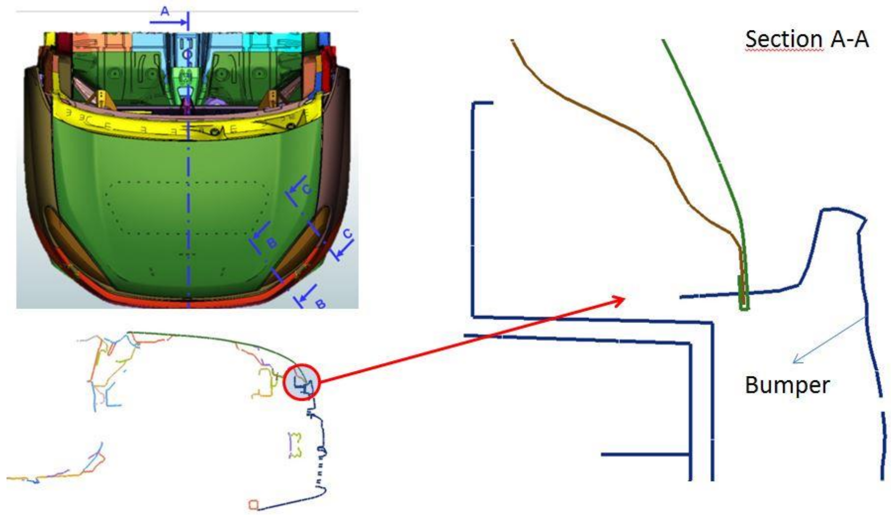


Figure 13: Section A-A

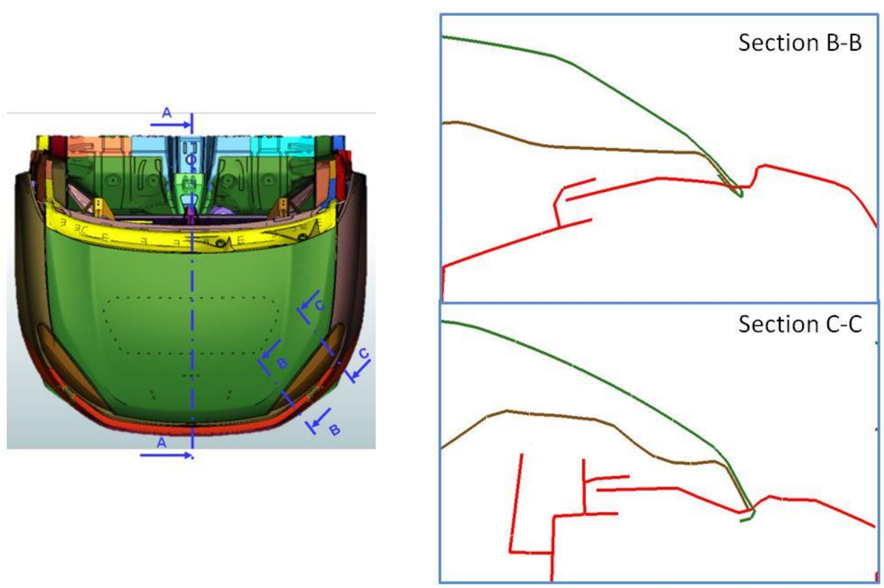
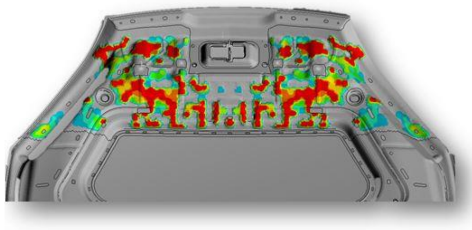


Figure 14: Section B-B / Section C-C

5. Improvement Studies

5.1 Topography Optimization

After misuse analyses are performed, too much deflection is observed on engine hood during locking stage. Therefore a linear-static analysis is performed with loads on engine hood similar the loads occur on misuse analysis. An optimization problem was built upon that linear analysis which aims to minimize displacements at the ends of the engine hood. The stiffness of the engine hood is increased with topography optimization. The definition of optimization problem and design variables are shown in Figure 15.



Bead Parameters and Manufacturing Constraints	
Bead Width	18
Bead Heigth	4
Draw Angle°	60-70
Symmetry Condition	1/Plane Symmetry

- ✓ Design Variable : Geometry of Beads
- ✓ Objective Function: Max. Stiffness

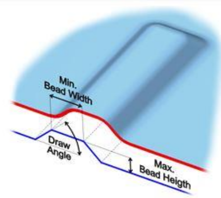


Figure 15: Topography Optimization

5.2 Adding Elastic Bumper

2 new elastic bumpers are added to the zones which shown in Figure 16.

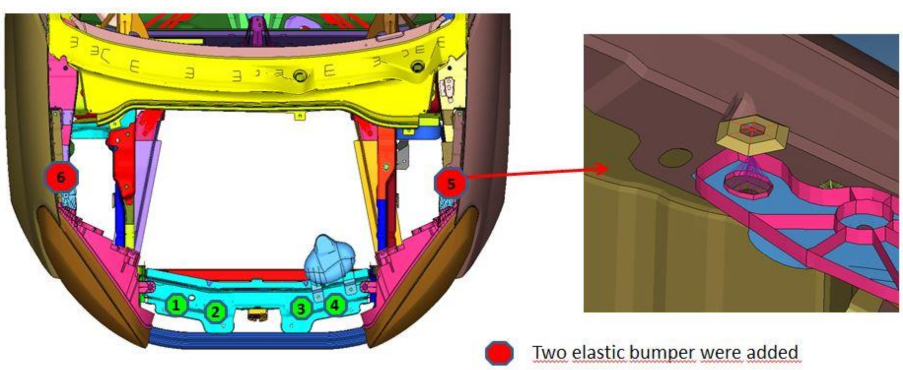


Figure 16: Elastic Bumpers

5.3 New Snow Sealing Design

Snow sealing is used to prevent leaking snow from the gap between bumper and engine hood as the name suggests.

While the engine hood is on closed position, snow sealing is somewhat compressed. But the force between the engine hood and sealing should be as small as possible. If this force is high when the engine hood is on closed position, the gap between engine hood and bumper will increase.

The snow sealing design is modified as shown in Figure 17 to dampen the energy of collision when the hood contacts to bumper surface on misuse analysis.

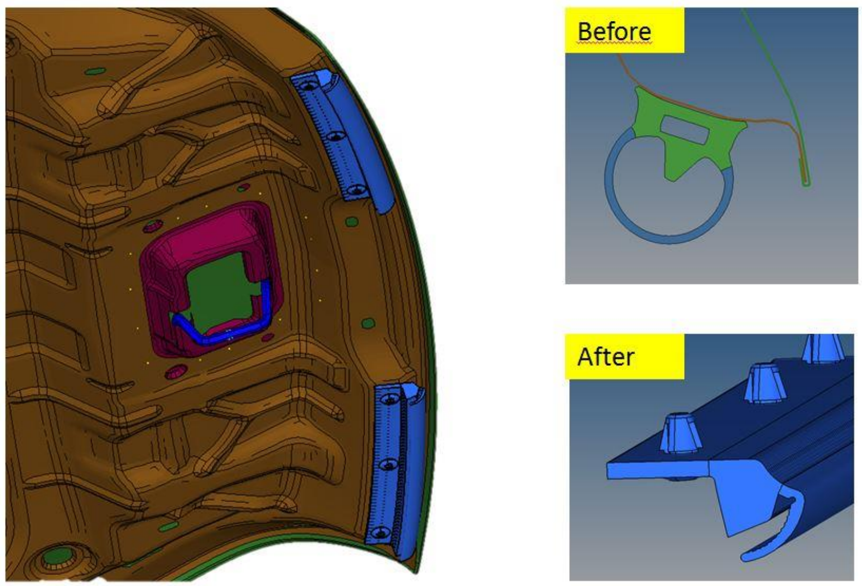


Figure 17: New Snow sealing Design

5.4 Improved Design Results

After all these improvements, penetration problems between engine hood, bumper and headlights are eliminated. The analysis results before and after the improvements are shown in Figure 18 and 19. (The general contact interaction between the engine hood and the bumper is cancelled due to monitor the scale of penetration. Other contact relations are still intact in the model.)

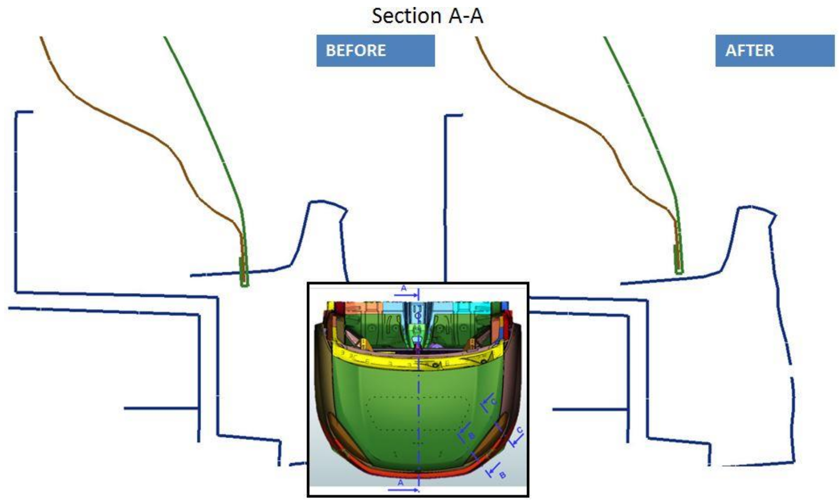


Figure 18: Before-After Section A-A

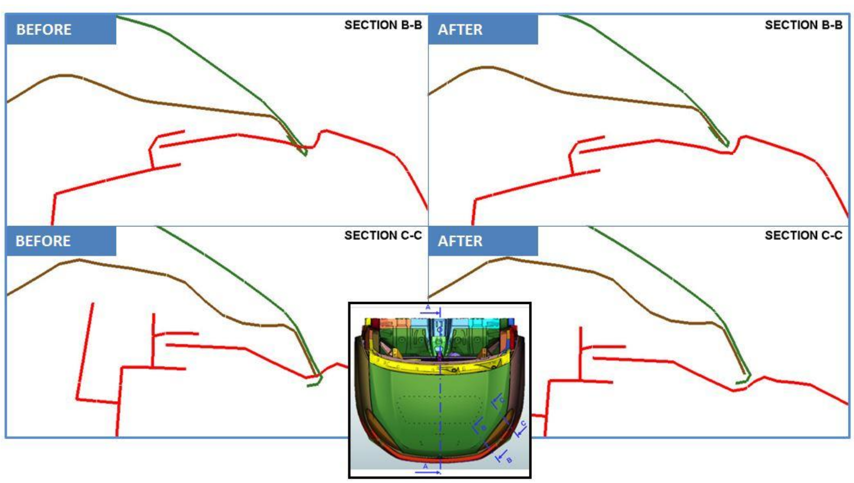


Figure 19: Before-After Section B-B and C-C

6. Comparison between Physical Test and Simulation

No negative results are observed on physical tests with the engine hood developed with mentioned improvements.

To inquire the correlation between physical tests and virtual analysis, some physical tests are also performed with the engine hood on the initial levels of the project. Similar negative results acquired on virtual analyses are also observed on physical tests. The comparison is shown in Figure 20 and 21.

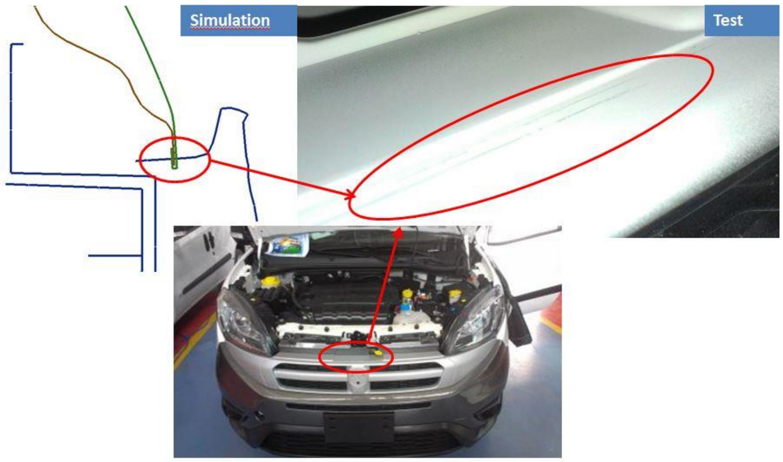


Figure 20: Contact between engine hood and bumper

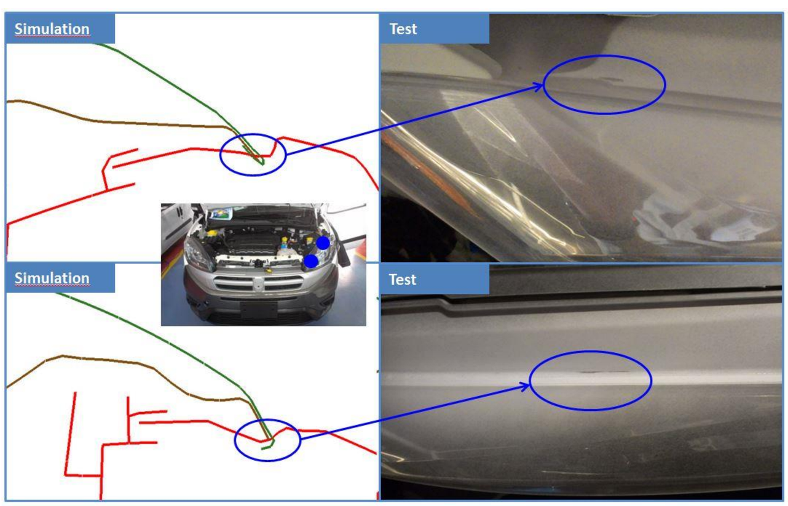


Figure 21: Contacts between engine hood and headlight

7. Conclusion

Collisions between engine hood, bumper and headlights are noticed on virtual misuse analysis at the initial steps of the project. These collisions are eliminated by the development activities carried out with virtual analysis methods. Likewise, physical misuse tests are carried out with the improved design and the results are affirmed as positive. To inquire the correlation between physical tests and virtual analysis; physical tests are also performed with the engine hood on the initial levels of the project. Similar results are monitored on physical and virtual tests.

The correlation between the physical and virtual tests is fulfilled with a good margin. Henceforth, misuse of the engine hood is evaluated only with virtual tests. The costs of physical tests and prototyping are reduced substantially.

8. References

1. Abaqus Version 6.10 Documentation
2. Related Fiat Specifications.