

Automotive Security: Design and Development of Rear View Camera System

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Abstract— A rear view camera is an automotive technology for preventing a vehicle from collision while reversing and to provide vision to an unobserved area adjacent to rear bumper. These cameras are coupled with Inner Rear View Mirrors with LCD displays. In this study, vehicle data was collected for various types viz., Sedan/ Hatchback/ SUV/ LUV/ MPV and a statistical analysis of bumper height, bumper surface pattern and its inclination with respect to ground was done. Several CAD models for IP67 casing were developed by benchmarking existing OEM models. Geometrical mapping for horizon level was aptly analysed and corresponding camera axis angle was computed. CAD models were subjected to FEM computational analysis for snap calculations and fatigue/ failure conditions.

Key words: Backup Camera, Snap-Fit Joint, Back-up Collision, Automotive Security

I. VEHICLE STUDY & METHODOLOGY

In accordance with Department of Transportation of National Highway Traffic Safety Administration,

- A rearview technology should display a 10-by-20-foot area directly behind the vehicle.
- Systems should show the driver an image of the area no more than 2 seconds after they put the vehicle into reverse.

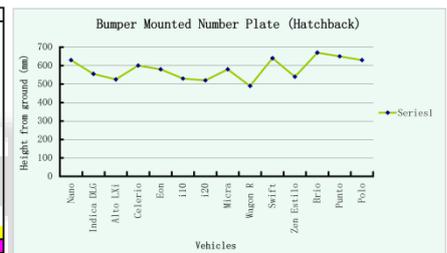
Grouping the vehicles based on mounting height from the ground was done. The groups were categorised based on the mounting height irrespective on the vehicle model.

- Sedans: Dzire, Manza, Xcent, Verna, Etc.
- Hatchback (A type): Nano, Celerio, Eon, I10, I20, Etc.
- Hatchback (B type): Santro, Getz, Spark, Ritz, Figo, Etc.
- SUV: Ecosport, Duster, Terrano, Etc.
- MPV: Scorpio, Safari, Innova, Etc.
- LUV: Ertiga, Mobilio, Etc.



II. VEHICLE DATA COLLECTION TYPE A & JUDGEMENT

Group 1	Ht wrt Gnd	Angle
Nano	630	
Indica DLX	555	
Alto LXI	525	3
Celerio	600	10
Eon	580	12
I10	530	7
I20	520	12
Micra	580	10
Wagon R	490	4
Swift	640	NA
Zen Estilo	540	9
Brio	670	9
Platio	650	12
Polo	630	
Average:	581.4285714	10.125
	580	10



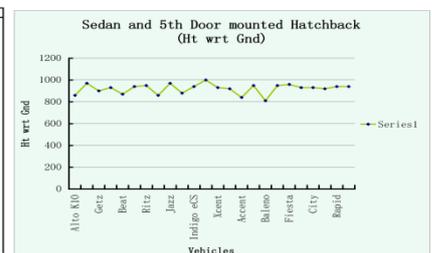
Omit Alto LXI due to small angle and Swift due to pocket on its plane.

A. Type A:

Nominal average height of 580mm and angle of 10° will cover maximum vehicle population. However in order to take care the angle variation, 3 angular shims (3°,5°,8°) were provided for finer adjustability. These shims are common for both type of vehicles.

III. Vehicle data collection type b & judgement

Group 2	Ht wrt Gnd	Angle
Alto K10	860	
Santro	970	
Getz	900	7
Spark	930	3
Beet	870	3
Aveo LS Liva	940	3
Ritz	950	11
Figo	860	8
Jazz	970	2
Fabia	880	5
Indigo eCS	940	-5
Manza	1000	12
Xcent	930	6
Swift Dzire	950	-4
Baleno	810	5
Classic	950	4
Fiesta	960	6
Amaze	930	6
City	930	6
Vento	920	5
Rapid	940	5
Aveo	940	5
Average:	920.166667	4.8117647



Omitting Indigo CS and Swift Dzire due to negative angle. Omitting Ritz, Manza and Accent due to large angles.

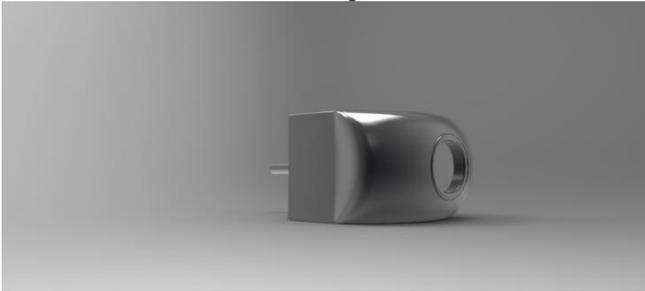
A. Type B:

Nominal average height of 920mm and angle of 5° will cover maximum vehicle population. However in order to take care the angle variation, 3 angular shims (3°,5°,8°) were provided for finer adjustability. These shims are common for both type of vehicles.

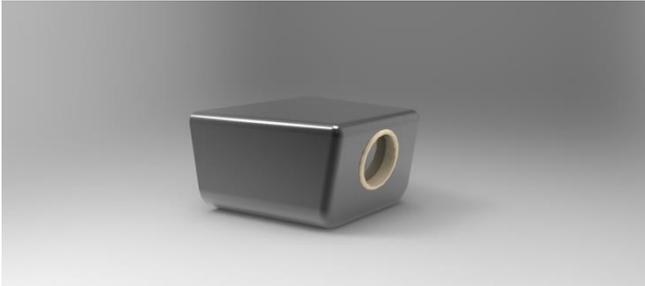
IV. OEM MODELS FOR REFERENCE DESIGN

Minimum mounting Area available on all studied Hatchback and Sedan models is 30mmX45mm.

Few OEM & other camera casing were studied:



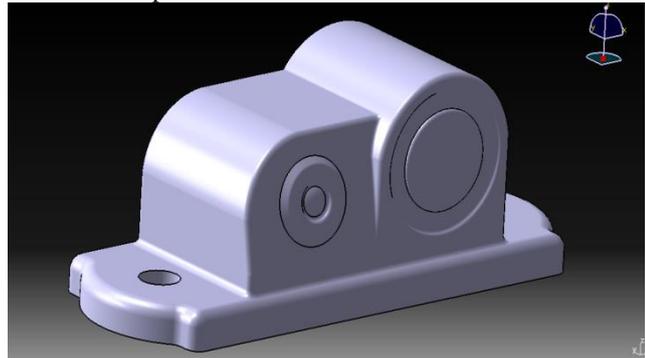
OE fit Honda Accord



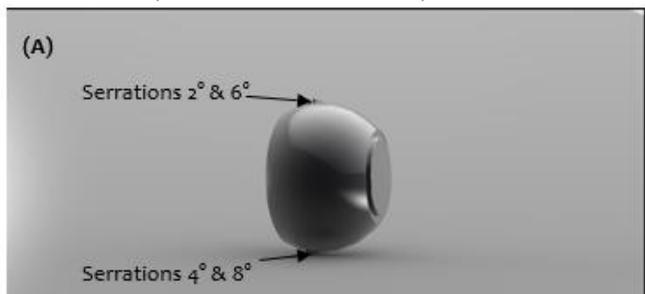
OE fit Hyundai Verna



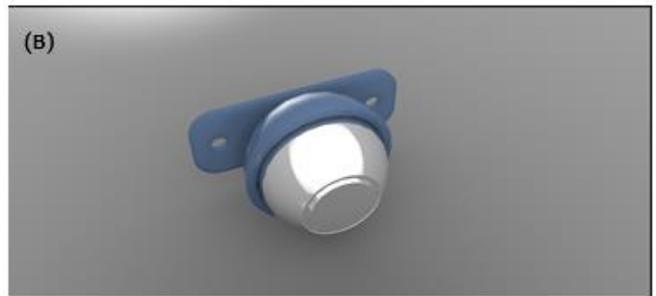
Alternative Option



Golden EYE (Camera + Sensor Model)

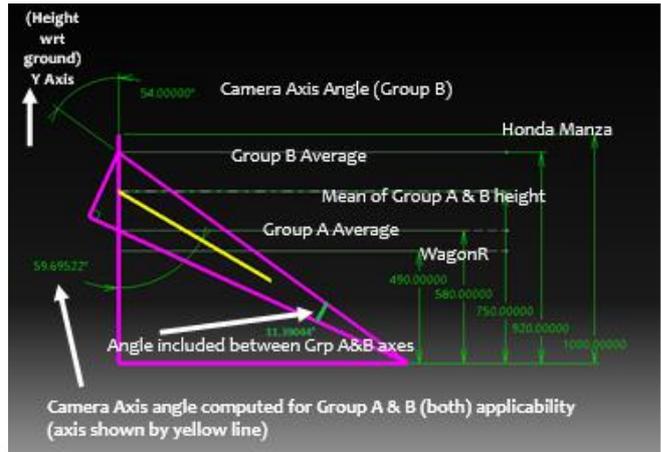


Pivotable Alternative Option (2° - 4° - 6° - 8°)



V. MAPPING STUDY: VIEW COVERAGE GRID

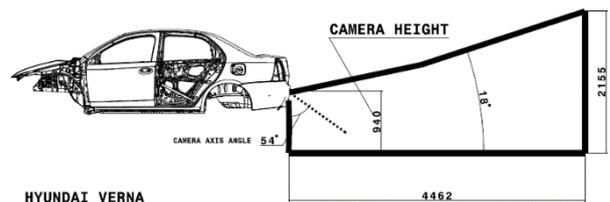
A. For Type A (Bumper Mounted Hatchbacks):



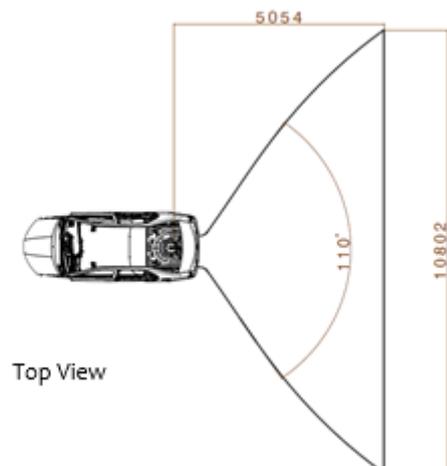
Computed Universal (for Group A & B both)
Camera Axis Angle = 60°

B. For Type B (Boot Lid Mounted Hatchback & All Sedans)

In this stage, study on Hyundai Verna SX was done and the coverage grid was computed. Ground Level is at 920mm from camera axis - vertically downwards. Maximum distinctive object seen in IRVM is at 15m.



Computed Camera Axis Angle = 54°



The height of camera wrt ground of Hyundai Verna is also 920 as well as angle also is +5° which concludes that current coverage grid can be most favourable for Group B, under some restrictions, viz., angle variation amongst others like 3° and 8°.

VI. STUDY FOR HORIZON LEVEL

The horizon level tends to vary till the end of total height of the display as we opt to go on open ground space. It will merely depend on the nearest vertical obstruction in that direction. Eg. 59% in Honda City as opposite wall which acts as pseudo horizon was very near from rear bumper.



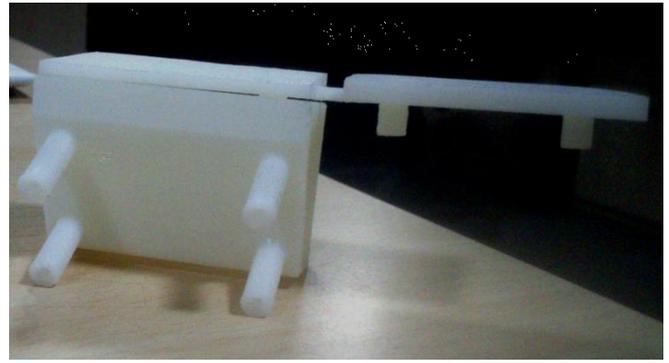
Horizon height of 85% from the bottom of IRVM LCD screen for a distance of about 100m.

The clause by NHTSA explains that it is more important to display the bumper on LCD screen rather the horizon level as total expected area restricts to 18.6m² starting right from the bumper.

In the boot lid mounted category, for current design the bumper surface is satisfactorily seen, also the clear picture of above mentioned area is captured eg. Verna, Swift Dzire. On the contrary, this set up will not be precisely appropriate for bumper mounted as an offset is maintained (eg. Alto) which can hide kids/ small animals in the neighborhood from the display. Yet as the design is a generalized solution for numerous Hatch/ Sedan / SUV, this set up will suffice as a product.

- As Hatchbacks with OE fit rear view camera are uncommon, the equivalent camera axis angle (59.69522°) and the included angle between two axes (11.39044°) of Group A and Group B was computed geometrically as shown in previous slide.
- Equivalent Camera Height for Group A and B was mean of Group A average height and Group B average height i.e., (580+920)/2 = 750mm.
- Camera axis angle at this height was computed as summation of Group B axis angle and half of angle included between two axes i.e., 54+ (11.39044/2)= 59.69522° ≈ 60°.

Considering these mathematical geometry results, a Rapid Prototype was developed using Fused Deposition Modeling technique using ABS material. This model was verified using test PCB.

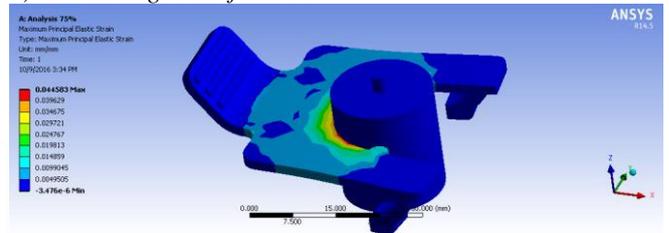


VII. COMPUTATIONAL FEM ANALYSIS

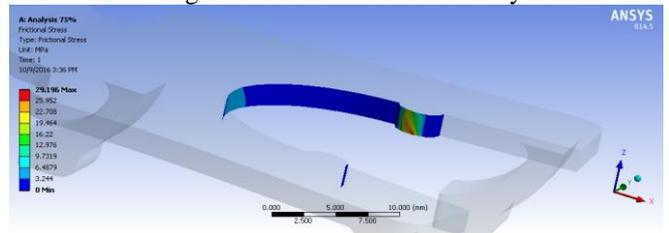
The assembly to be fit on vehicle bumper was adhered strongly with plastic retainer clip and annular metallic snap clips. The FEM analysis was done stage-wise on retainer annular snap (between camera slot and retainer for different percentage snap overlap), retainer leg snaps and camera metallic annular snaps.

A. Retainer annular snap (camera slot and retainer clip interface):

1) Percentage interface: 75

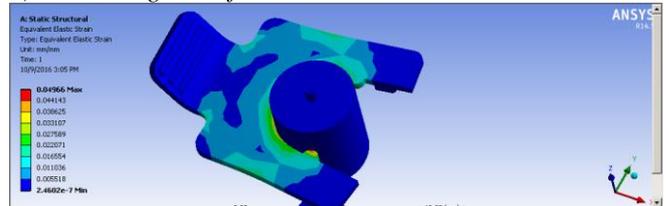


In this scenario, the Maximum Elastic Principle Strain for the retainer clip of material ABS or PP at interference snap area was greater than 4.45% which was greater than allowable principle strain of that material. Hence this configuration is flawed for assembly fitment.



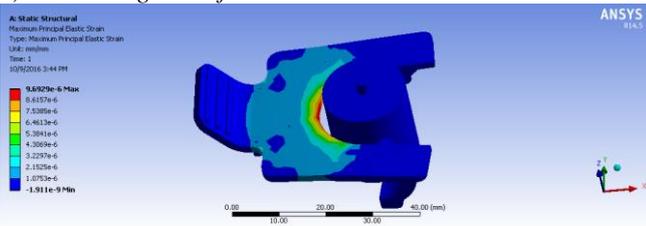
Also, contact frictional stresses at snap was computed greater than 29 MPa which also contributed negatively for assembly adherence.

2) Percentage interface: 80:



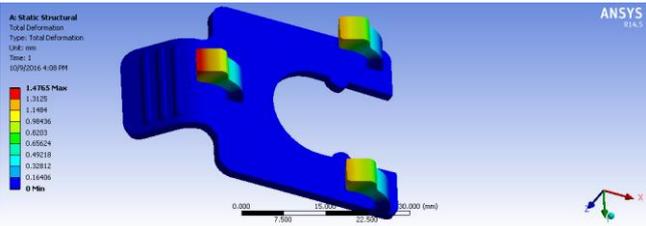
The equivalent elastic strain for this scenario in retainer clip again exceeded 4.9% which is greater than allowable strain value.

3) Percentage interface: 90:

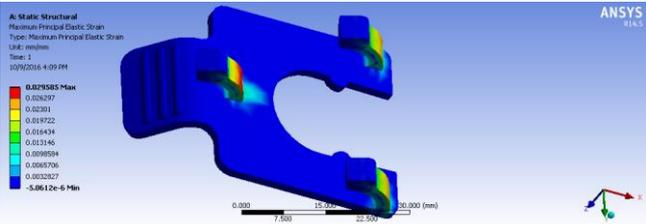


This scenario showed equivalent strain of $9.6 \times 10^{-4}\%$ which is far lesser than allowable strain, hence this was considered the safest assumption for further design stages.

B. Retainer Leg snaps:

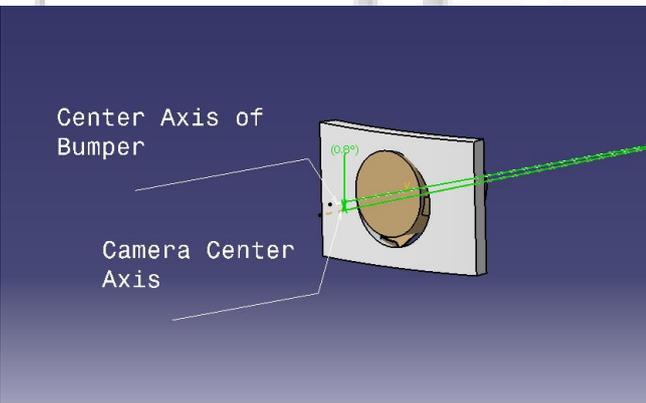


Retainer legs showed maximum deformation of 1.47 mm which was sufficient distance for camera fitment.

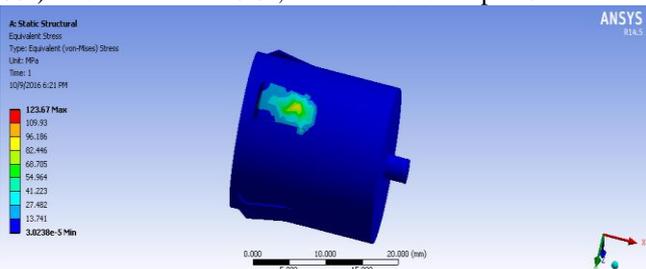


The strain computed for slip legs was 2.9%, lesser than allowable strain and safe design consideration for retainer assembly without failure.

C. Camera metallic annular clips:



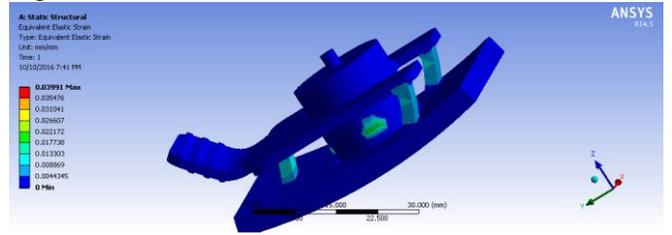
When camera was snap fit with bumper when hole of $\Phi 18\text{mm}$, with metallic snaps alone (without plastic retainer), central axis misalignment (against camera axis 60°) was observed of 0.8° , which was not as per OE norms.



Also, Von Mises Stress of 123 MPa were accumulated at the contact edge of metallic snaps of Steel.

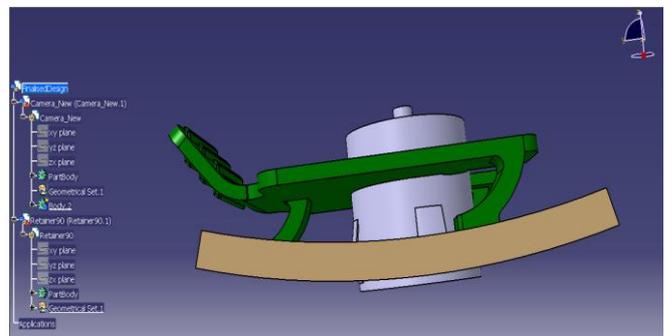
D. Final Design:

Considering FEA results for various configuration, assembly was finalised with metallic annular clips and plastic retainer clips both



The assembly showed strain value lesser than allowable value at both retainer-camera snap interface and retainer-bumper snap interface with minimum deformation for failure free design. The camera axis misalignment was reduced to less than 0.1° .

VIII. CONCLUSION



The robust Rear View Camera system was designed, suitable for range of automobile types ranging from Hatchback to SUV. The variety of number plate height with respect to ground was overcome with average height CAD-geometry analysis. The multiple camera axis inclination values for considered sample space was finalised to apt angle value and also few shims were designed for proper fitment of vehicles with irregular bumper design and surface pattern. Further, the FEM analysis was conducted in order to confirm the robustness of the assembly together against the dynamic vehicle road conditions viz., bump, acceleration, vibration etc.

IX. SCOPE FOR FUTURE WORK

This study can further be developed as an optimum solution in Aftermarket Automotive Accessories. The current study data can be extrapolated and tested for numerous automobiles and a powerful product of Rear View Camera along with Inner Rear View Mirror with LCD Display can be developed with cheaper price as compared to expensive automotive OEM solutions.

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