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RCAR Impacts on Vehicle Air-conditioning System Design practices & guidelines

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Abstract : The integration of RCAR guidelines into automotive design has had a growing impact on the layout, protection, and repairability of vehicle air-conditioning (A/C) systems. RCAR promotes vehicle designs that minimize repair costs following low-speed collisions, leading to significant changes in how A/C components such as condensers, compressors, and refrigerant Pipes are positioned and protected. In this article explores the influence of RCAR defined frontal impacts on the vehicle cooling system, including radiators, condensers, fans, Cooling Pipes and associated structural components.
As a result of these standards, Automakers are increasing incorporate modular front-end structures, detachable mountings, Flexible material integration and protective barriers to reduce the likelihood of A/C system damage in low-speed frontal crash impacts. The study highlights the evolving relationship between safety, cost-effectiveness, and environmental responsibility in the context of A/C system design influenced by RCAR protocols. These adaptations not only enhance repairability and reduce insurance claims but also contribute to more sustainable vehicle designs by minimizing refrigerant leakage and waste.

1. INTRODUCTION

The Research Council for Automobile Repairs (RCAR), established in 1972, comprises a network of international automotive research centers, primarily funded by insurance organizations. Its primary mission is to reduce the cost of motor insurance claims by promoting better vehicle repairability and damageability standards. Through comprehensive testing, including standardized low-speed crash tests (typically at 15 km/h), RCAR has highlighted vulnerabilities in front-end vehicle systems—prompting manufacturers to verify and improve the design and placement of components like the A/C condenser, compressor and Cooling Pipes etc.

RCAR's influence has led to the adoption of design strategies that minimize damage to A/C systems, ensure ease of access for repairs, and promote modular component architecture. These improvements not only reduce repair costs but also contribute to vehicle sustainability by decreasing parts replacement frequency and associated environmental impacts.

This paper explores how RCAR standards have influenced the design, packaging components and reinforced structure to minimize damage and repairability of Air conditioning system of Vehicle.

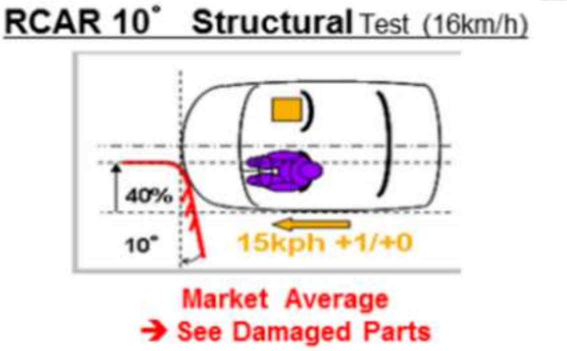


Fig. 1 RCAR Structural Test Overlap and Speed details

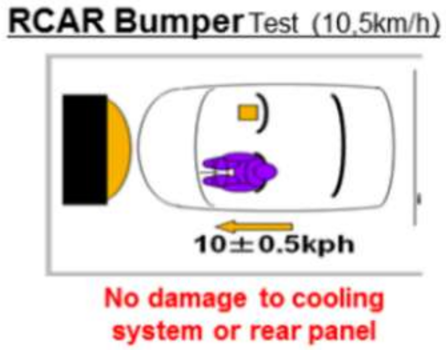


Fig. 2 RCAR Pumper Test Overlap and Speed details

2. OBJECTIVES OF RCAR TEST

The objective of the RCAR test is to Promote standardized, safe, and cost-effective vehicle design to reduce collision repair costs and improve repairability. Here are key objectives of RCAR Test:

- **Assess Damageability and Reparability:** Evaluate how much damage a vehicle sustains during low-speed impacts (typically 10–15 km/h) and how easily and cost-effectively it can be repaired.
- **Promote Repair-Friendly Design:** Encourage manufacturers to design vehicles that are easier and cheaper to repair, such as by making common crash parts more modular or accessible.
- **Reduce Repair Costs for Consumers and Insurers:** Lower long-term ownership costs and insurance premiums by reducing the financial impact of minor accidents.
- **Improve Insurance Group Rating:** The test results often influence vehicle insurance classification, helping insurers assess the risk and potential cost of claims.
- **Encourage Use of Non-Structural Parts:** Promote designs where cosmetic or minor damage doesn't affect structural components, improving vehicle safety post-collision and reducing downtime.

3. TEST FACILITY AND VEHICLE PREPARATION FOR FRONTAL IMPACT

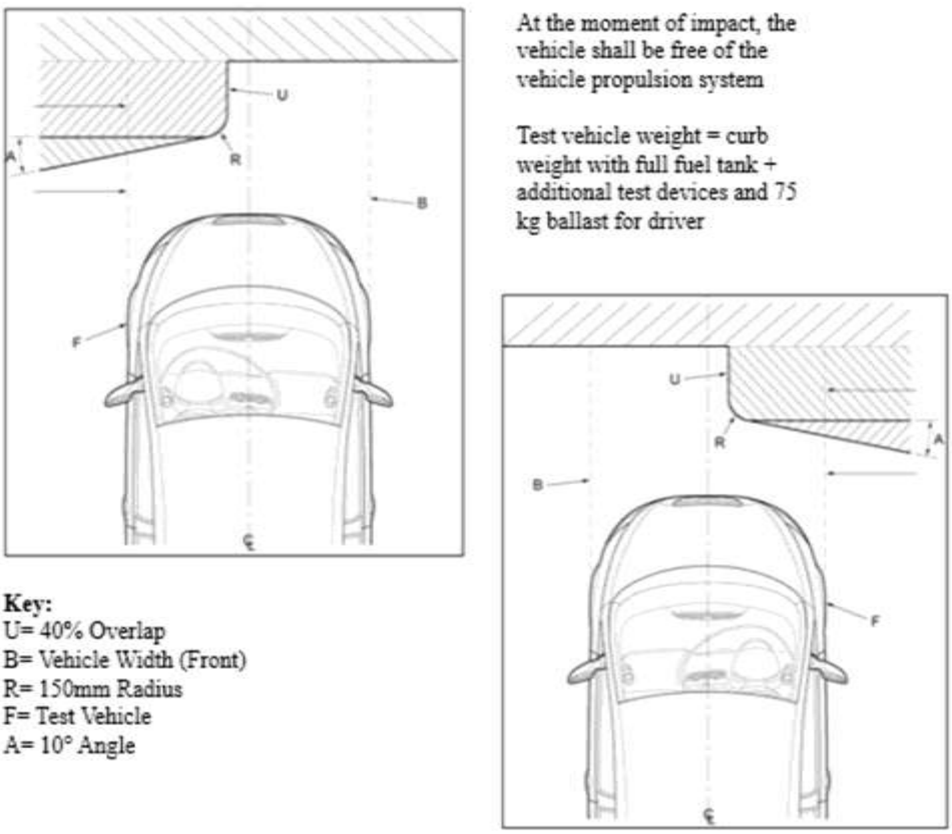
3.1 Test facility

RCAR test area should be large enough to accommodate the acceleration track, barrier and technical installations necessary for the test. The final 5 meters of track adjacent to the barrier should be horizontal, flat and smooth.

3.2 Barrier set up and position

The barrier's dimensions shall conform to those shown in attached Fig. The barrier may be secured to a rigid weight or anchored directly to the floor in such a way that it cannot move during impact. In either case, the front face of the barrier should be vertical to within ±1°.

The barrier should be oriented with its front face 10° (±1°) relative to the perpendicular of the longitudinal axis of the test vehicle. Initial vehicle contact will be on the steering column side, and the front of the vehicle shall overlap the face of the barrier by 40% ± 25 mm. The overlap is measured at initial impact by projecting the edge of the barrier in the vehicle's longitudinal axis onto the test vehicle front end.



3.3 Test vehicle set up

The vehicle setup ensures consistent, repeatable conditions across different vehicle models and test facilities. Defining how the vehicle is prepared and configured before conducting the RCAR low-speed frontal impact test, Here are Key points:

- The test vehicle shall be a standard production model in fully operational condition, representative of vehicles available for sale.
- All standard production parts (front bumper, hood, lamps, grilles, etc.) must be installed — no reinforcements, modifications, or deletions are allowed unless required for instrumentation.
- Fluids such as engine oil, coolant, and brake fluid are filled to manufacturer-specified levels.
- Tire pressures are set according to the manufacturer's recommended cold inflation pressure.

- The vehicle is positioned so that **40% of its front width** overlaps with the **RCAR deformable aluminium honeycomb barrier**.
- The vehicle's **longitudinal axis** is aligned perpendicular to the barrier (0° yaw angle).
- All electrical systems are active, and airbags are connected as in normal operation.
- Instrumentation such as accelerometers, high-speed cameras, and data acquisition systems are installed to record impact speed, deceleration, and deformation.
- Pre-test checks are conducted for alignment, fluid leaks, and brake function.

3.4 Vehicle test weight

The vehicle test weight is the curb weight plus a 75 ± 5 kg test dummy or equivalent ballast on the driver's seat secured with the standard 3-point seat belt. If this weight cannot be achieved for any reason, the vehicle may be tested at a lower weight with the mutual agreement of the vehicle manufacturer and the test facility. This agreement must be included in the test report.

The weight of any on-board test equipment shall be offset by removing ballast or components which have no effect on the test results. The resulting change in weight caused by the addition of ballast or on-board test equipment, or the removal of components, should not change the vehicle's front-to-rear weight ratio by more than 5%.

By mutual agreement between the vehicle manufacturer and the test facility, the vehicle may be tested at a weight higher than the determined test weight. This agreement must be included in the test report along with the final test weight of the vehicle

3.5 Vehicle test condition

The vehicle test condition defines the physical and operational state of the car before the frontal RCAR low-speed impact test. These conditions ensure that the test results accurately represent how a real production vehicle would behave in a low-speed collision and that all tests are consistent and repeatable.

- The test is conducted under **controlled environmental conditions**:
    - Ambient temperature: **20 ± 5°C**
    - Relative humidity: **30–70%**
    - Wind speed: **< 5 m/s** (for outdoor tests)
- The **test surface** is flat, clean, dry, and made of concrete or asphalt.
- The **RCAR aluminium honeycomb barrier** is inspected and verified to conform to dimensional and material specifications before each test.
- The vehicle must be **in new or undamaged condition**, with no previous impact exposure or repair.
- All electrical and safety systems, including airbags and sensors, remain active.
- The vehicle is pre-conditioned to normal operating temperature prior to the test (engine idling and fluids stabilized).

3.6 Propulsion of test vehicle

The vehicle must reach the specified impact speed (15 km/h ± 1 km/h) smoothly and accurately before colliding with the RCAR deformable barrier.

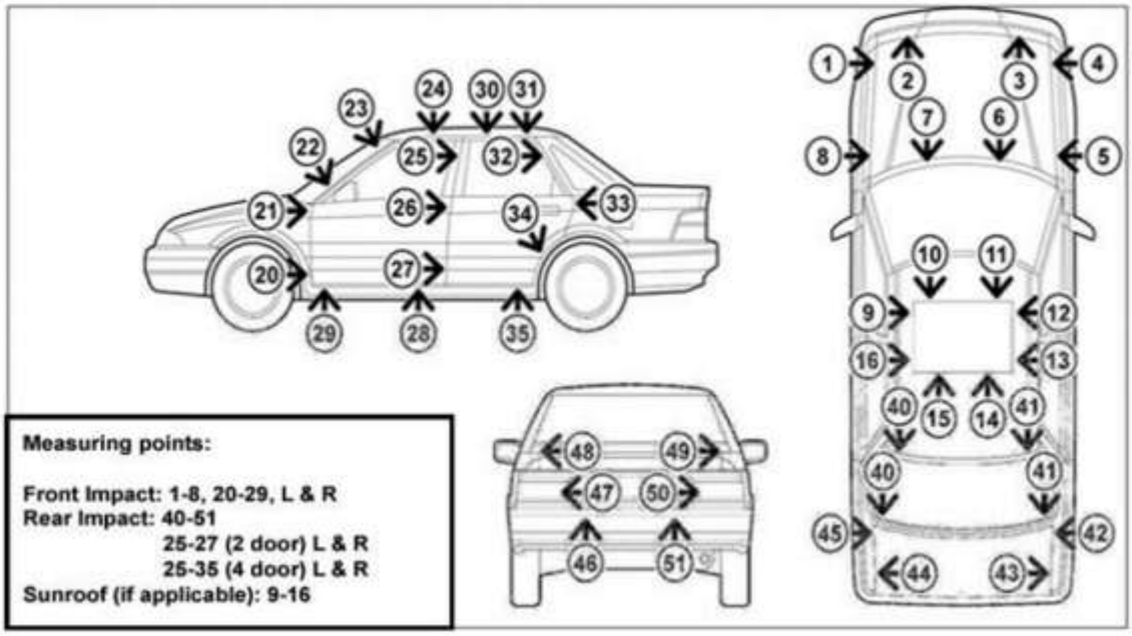
Propulsion methods commonly used:

- **Towing system (most common):**
    - The vehicle is towed using a **towing cable or belt** connected to a **propulsion system** (electric winch or hydraulic drive).
    - The towing device releases the vehicle just before impact to ensure **free-flight** contact with the barrier.
    - Ensures consistent acceleration and minimal interference at impact.
- **Self-propelled mode:**
    - The vehicle's own **engine and drivetrain** propel it to test speed.
    - The driver (or remote control) accelerates the vehicle to 15 km/h and disengages propulsion just before impact.
    - Used primarily when precise control systems are available.

3.7 Panel Gap Measurement Guide

The following table used to record gap measures, in mm, before and after the impact. The reference points are shown in the figure below. Separate forms should be used for front and rear impacts

Test ID			
Part	**Before**	**After**	**Difference**



Note: Air Conditioning System related measuring points to be checked under Frontal Impact 1-8

4. Key Component of Vehicle Air-Conditioning System

Following Key Component must be protected from Low-Speed Frontal Crash Impact

Compressor:
This is the "backbone" of the system. It takes low-pressure, low-temperature refrigerant vapor and compresses it into a high-pressure, high-temperature gas.

Condenser:
A car condenser is a component of the vehicle's air conditioning system that dissipates heat from the high-pressure refrigerant gas coming from the compressor, causing it to condense into a liquid before it moves to the expansion valve or evaporator.

Expansion Valve:
An expansion valve in a car air conditioning system is a device that controls the flow of refrigerant into the evaporator and reduces its pressure and temperature, allowing it to absorb heat from the cabin air

Evaporator:
Evaporator is a key part of the air conditioning system whose function is to absorb heat from the air inside the vehicle. As warm cabin air passes over the evaporator's cold surface, the refrigerant inside evaporates, cooling and dehumidifying the air before it enters the cabin.

Air Condition Pipe:
Air conditioning pipes (or AC lines) in a car are tubes that carry refrigerant between the components of the air conditioning system — such as the compressor, condenser, expansion valve, and evaporator.

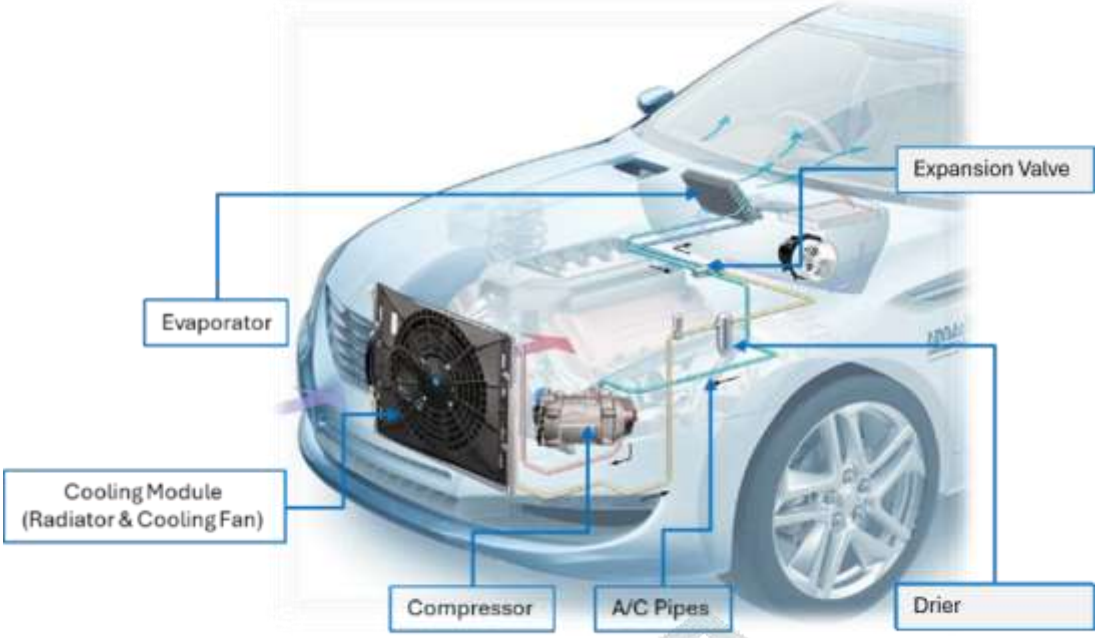


Fig. Key Component of Vehicle Air-Conditioning System

5. Design Practice and Guideline to minimize Impact

Minimizing RCAR (Research Council for Automobile Repairs) impact on the Vehicle Air-Conditioning (A/C) System involves careful design practices and guidelines aimed at reducing damage during low-speed collisions, primarily frontal impacts. RCAR focuses on repairability, parts damageability, and repair costs in standardized crash tests (e.g., 15 km/h offset barrier).

5.1 Strategic Placement of A/C Components

- Avoid locating critical A/C components (e.g., condenser, compressor, receiver-drier) directly in front of the bumper or within typical low-speed crash zones. Recommendation to use detachable fixation instead for rigid fixation for Cooling module, So during frontal impact Cooling module can move/rotate towards back to minimize damage.

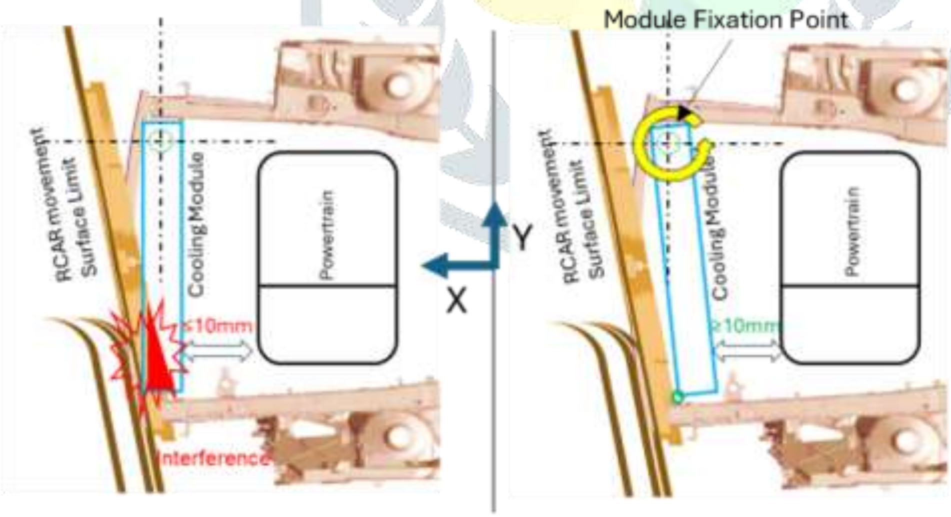


Fig. Cooling Module packaging out of RCAR Surface Limit to minimize Frontal collisions

5.2 Use of Energy-Absorber

- Integrate crash boxes and energy-absorbing materials in the front-end module to absorb Frontal crash forces before It reach to Air-conditioning System components.

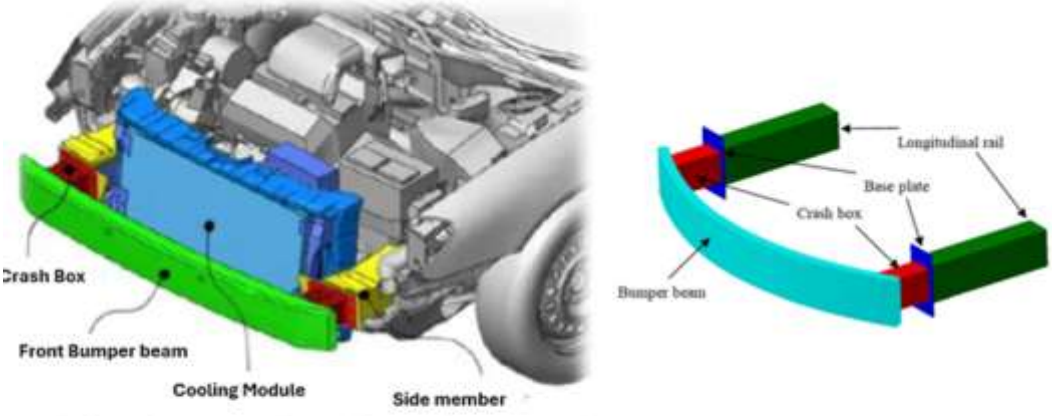


Fig. Crash Box addition in Front of Cooling Module to absorb Crash Impact energy and minimize damage

- Recommendation to Use deformable or detachable brackets to mount cooling module and Air-conditioning system parts to allow for controlled movement during an Frontal Low-Speed crash impact, minimizing component damage and reduce repairability.

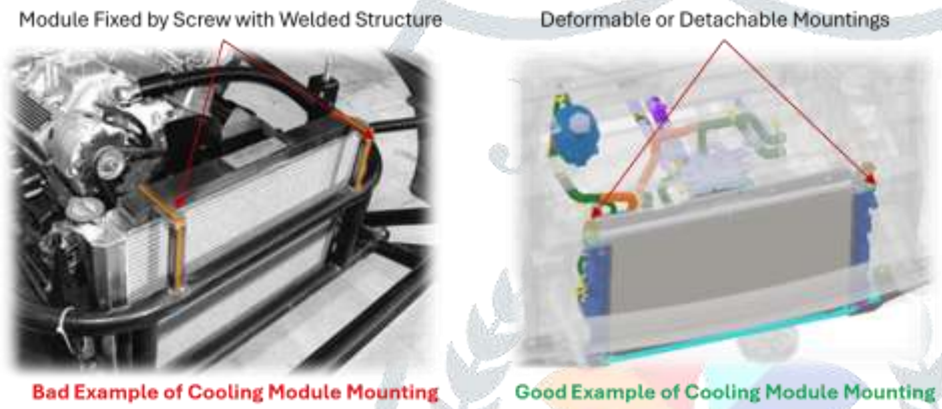


Fig. Deformable or Detachable Mountings to protect damage on Module during Frontal Impact

5.3 Component Flexibility

- Avoid rigid A/C Pipes to place in Frontal zone, there is Risk of Pipe deformation and refrigerant leakage during Low Speed Crash Impact.
- Use isolated mounting brackets or Integrate Flexible Material in Pipe that allow to move slightly/detach and absorb energy in a controlled way during impact

Fig. Flexible Hose integration in AC Pipe to absorb Frontal low -speed Crash Impact energy

5.4 Modular and Service-Friendly Design

- Design A/C components to be individually replaceable without requiring the removal of the entire front-end module
- Use quick-connect couplings for refrigerant lines to simplify replacement and reduce labour costs.
- Allow easy access to damaged parts without requiring bumper or fender removal.

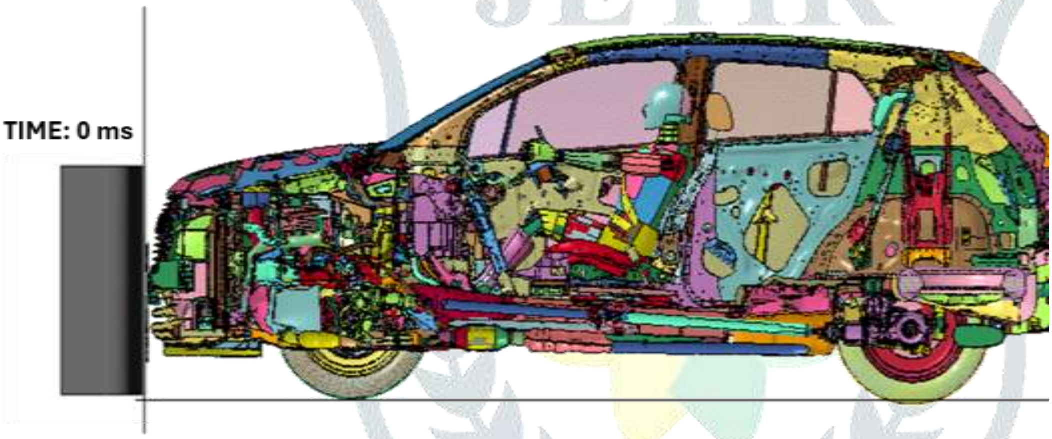
5.5 Protective Shields and Guards

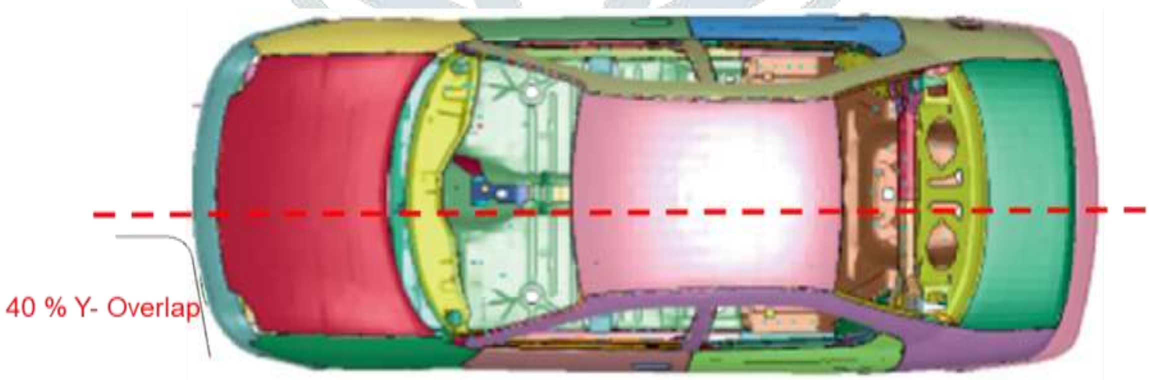
- Install protective shields or grills in front of the condenser and other vulnerable parts.
- Use plastic shields to deflect debris or dissipate impact energy from low-speed collisions.

5.6 Crash Simulation and Validation

- Perform RCAR-specific crash simulations (e.g., 15 km/h offset barrier and pole tests) during vehicle development.
- Validate design changes using crash Simulation report focusing on:
  - Cooling module and Compressor damage
  - Condenser Fins deformation
  - AC Pipe deformation or damage

- **Crash Simulation configuration:**
  - Crash Type: RCAR_FRONT_STRUCTURAL
  - Crash Side: LH
  - Barrier: Fixed Rigid Barrier 40 % overlap
  - Speed: 15.5 km/h
  - Veh weight: 2606.0 kg
  - Ballasting: 25 kg (instrumentation mass)





Note: After frontal collision Strain should be less than 2% on aluminum AC Pipe to avoid repairability, If Strain exceeding more that 2% then modification on Pipe must be taken into account

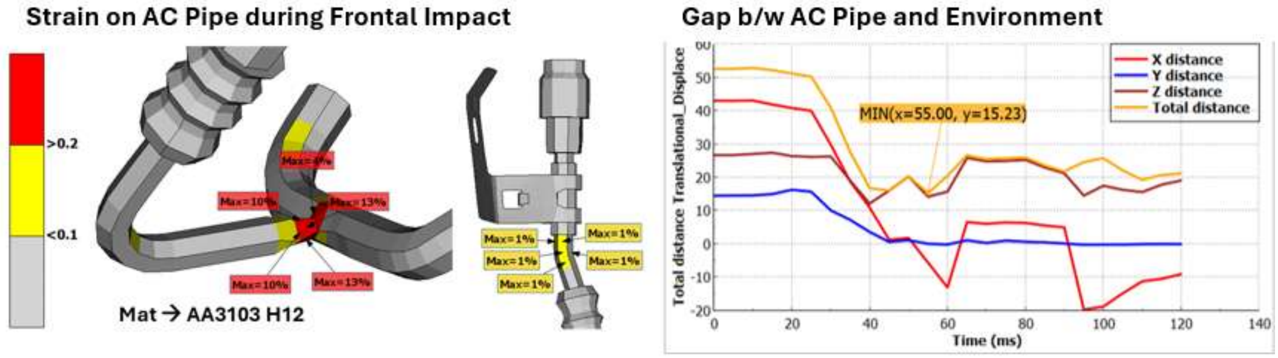


Fig. Frontal Low-speed Crash impact on AC Pipes- Deformation strain and Gap with environment after impact

5.7 Front-End Packaging Optimization

- Consider front-end packaging strategies to reduce RCAR exposure:
  - Move vulnerable A/C components inward or rearward relative to the crash beam.
  - Reduce the stack height (condenser + radiator + fan) exposed to the front bumper area.

6. Conclusion

The implementation of RCAR (Research Council for Automobile Repairs) standards has significantly influenced the design and engineering of modern vehicle air conditioning (A/C) systems. By emphasizing repairability, cost efficiency, and sustainability, RCAR guidelines encourage manufacturers to design A/C components that are modular, accessible, and less prone to collision damage. This shift not only reduces repair costs and vehicle downtime but also supports environmental goals by minimizing refrigerant leakage and waste.

Adopting RCAR-aligned design practices promotes a balanced approach between performance, safety, and reparability. Engineers are now integrating protective structural designs, standardized component placement, and simplified service procedures without compromising thermal comfort or system efficiency.

Ultimately, RCAR's influence fosters a more sustainable and economically responsible automotive industry, driving innovation in A/C system design that benefits manufacturers, repairers, and consumers.

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