VEHICLE CRASHWORTHINESS AND OCCUPANT PROTECTION

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Motor Vehicle Safety

- The first motor vehicle fatality occurred in 1889 in New York City.
- An early period of safety from the turn of the century to 1935 - period of genesis, growth, and development to understanding the extremely complex process of vehicle collisions.
- The second period from 1936 to 1965 - intermediate safety period with crash avoidance devices.
- The third period starts in 1966- the creation of the National Highway Traffic Safety Administration (NHTSA).

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The Automobile Structure

- Current car body structures and light trucks
  - body-over-frame structure
  - unit-body structure (including space-frame)
- Vehicle body
  - External to minimize drag
  - Interiors for adequate space to comfortably accommodate its occupants
  - Vehicle body with the suspension to minimize road vibrations and aerodynamic noise transfer
  - Vehicle structure to maintain its integrity and provide adequate protection in survivable crashes

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The Automobile Structure

Body on Frame

Body in white of a Unibody construction

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Materials

- The majority of mass-produced vehicle bodies over the last six decades were manufactured from stamped steel components.
- Until the 1920’s, automakers built vehicle bodies from a composite of wood panels joined with steel brackets.
- As metallurgists improved the formability of sheet steel and toolmakers built durable dies capable of stamping millions of parts and spot weld technology allowed for joining large body shells.
- Dodge built an all-steel vehicle body in 1924.

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Crashworthiness

- “Crashworthiness”-measure of the ability of a structure and any of its components to protect the occupants in survivable crashes. (aerospace industry)
- Crashworthiness connotes a measure of the vehicle’s structural ability to plastically deform and yet maintain a sufficient survival space for its occupants in crashes involving reasonable deceleration loads.
- Restraint systems and occupant packaging provide additional protection to reduce severe injuries and fatalities.

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Crashworthiness Goals

- The body structures include progressive crush zones to absorb part of the crash kinetic energy.
- Vehicles maintain integrity of the passenger compartment and simultaneously control the crash deceleration pulse.
- Accident reconstruction and analysis of vehicle crashes provide information regarding the safety performance.
- Currently, vehicle crashworthiness is evaluated in four distinct modes: frontal, side, rear and rollover crashes.

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Crashworthiness Requirements 1/2

- Sufficiently stiff in bending and torsion for proper ride and handling.
- Minimize high frequency fore-aft vibrations that give rise to harshness.
- Accommodate for a range of occupant sizes, ages, and crash speeds for both genders.

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Crashworthiness Requirements 2/2

- Characteristics:
  - Deformable, yet stiff, front structure with crumple zones to absorb the crash kinetic energy.
  - Deformable rear structure to maintain integrity.
  - Properly designed side structures and doors to minimize intrusion.
  - Strong roof structure for rollover protection.
  - Properly designed restraint systems that work in harmony with the vehicle structure.
  - Accommodate various chassis designs for different power train locations and drive configurations

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Achieving Crashworthiness 1/2

- Unique work of automotive structural crashworthiness engineer :
  - must meet all service load requirement and it must deform plastically in a short period of time (milliseconds) to absorb the crash energy in a controllable manner.
  - must be light and be economically mass-produced.
  - The structural stiffness must be tuned for ride and handling, NVH and must be compatible with other vehicles on the road, so it is not too soft or too aggressive.

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Achieving Crashworthiness 2/2

- Automotive Safety engineer:
  - packaging the occupants for decelerations transmitted to the occupants are manageable by the interior restraints to fall within the range of human tolerance.
  - The ultimate goal of the safety engineer is to reduce occupant harm.
  - Typically, designers accomplish this goal using a combination of crash avoidance and crashworthiness measures.

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Crashworthiness Tests 1/4

- In spite of the tremendous progress achieved in crashworthiness simulations, vehicle certification relies on laboratory tests.
- Three categories of tests:
  - – Component tests
  - – Sled tests
  - – Full-scale barrier impacts

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Crashworthiness Tests 2/4

Component Tests:

- Dynamic and/or quasi-static response to loading of an isolated component.
- Crucial in identifying
  - Crush mode
  - Energy absorption capacity
- Understanding performance is essential to the development of mathematical models and prototypes.

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Crashworthiness Tests 3/4

Sled test :

- Vehicle buck - passenger compartment
- Anthropomorphic test devices or cadavers – drivers or passenger.
- Dynamic load-vehicle deceleration-time pulse
- Primary objective – to evaluate restraints
- Sensors on dummy, high speed photography for data.

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Crashworthiness Tests 4/4

Full-scale barrier test:

- Collision of a guided vehicle, propelled into a barrier at a predetermined initial velocity and angle.
- A barrier test uses a complete vehicle.
- ex. Regulations - FMVSS 208
  - Frontal impact with barrier zero , $\pm 30°$
  - Unrestrained dummies in the driver and right front passenger
- NCAP – higher speed impact with restrained dummy

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Crashworthiness Models Requirements

- <u>Accuracy</u> – the model should be able to yield reasonably accurate predictions of the essential features being sought
- <u>Speed</u> – the model should be executable with a reasonable turnaround time, not to exceed 12 hours regardless of its size, to allow for iterations and parameter studies.
- <u>Robustness</u> – small variations in model parameters should not yield large model responses.
- <u>Development time</u> – the model could be built in a reasonably short period of time, not to exceed two weeks