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).
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
The Automobile Structure

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Body on Frame

Body in white of a Unibody construction
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.
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.
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.
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.
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
• 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.
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.
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
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.
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.
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, ± 30°
  - Unrestrained dummies in the driver and right front passenger
- NCAP – higher speed impact with restrained dummy
Crashworthiness Models

Requirements

• **Accuracy** – the model should be able to yield reasonably accurate predictions of the essential features being sought.

• **Speed** – 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.

• **Robustness** – small variations in model parameters should not yield large model responses.

• **Development time** – the model could be built in a reasonably short period of time, not to exceed two weeks.