Alongside design and reliability, safety plays a key role in the decision to buy a particular car. As early as 1998, Mazda set itself the goal of extending the safety standards that it had so far applied to its top range of cars to its smaller models too. This ambitious project was given the name MAIDAS (Mazda Advanced Impact Distribution and Absorption System) and was premiered in the Mazda 3.

1 Introduction

The three most important elements in the development process are 1. calculation 2. simulation and 3. early practical testing. These proven principles deliver high standards of quality and safety. The entire safety concept must be correct from the very outset. All subsequent corrections will reduce the quality of the final result. Mazda developers did not just focus on satisfying the legal criteria for vehicle safety, they set their sights far higher. During internal tests based on the crash requirements of various countries, the bodywork survived the full-area frontal impact and the lateral impact at 55 km/h plus the offset crash at 64 km/h and did so with excellent results.

The biggest problem for safety in smaller vehicles is one of space. The smaller the vehicle is, the more refined the technology has to be if it is to protect its occupants. The crumple zones in smaller vehicles are far shorter. Consequently, the deformations required to absorb energy must take place in a shorter total distance than is the case with a large vehicle. What is more, the specific characteristics of the various materials used must be optimised to absorb as much of the impact energy as possible.

How do we maximize the safety of vehicle occupants? We treat them as if they were a raw egg in a tin can. If you place an egg in a tin can and drop it on the ground, the egg will break. Exactly the same happens if you wrap an egg in a thin soft cloth. But if you place the egg in several soft cloths and then place the cloths in the tin can, the egg will remain unharmed. It "survives" the crash like a car occupant in an accident. What is important is to find the correct combination of hard and soft safety elements.

2 Effects of Crashes

To be precise, the car crash needs to be broken down into three individual crashes. Crash 1: The car crashes into a rock, a tree or another vehicle. Crash 2: The occupants impact with the retention systems such as the seat belt, airbag or, in a worst case scenario, the steering wheel or dashboard. Crash 3: The internal organs impact against the bones of the occupant’s skeleton. In order to optimise the occupant’s chances of survival, the primary development goal of manufacturers must be to absorb the maximum amount of impact energy from crash 1 in order to minimize the effects of crashes 2 and 3 on the occupants.
Small and compact vehicles are at a disadvantage in this regard due to their physical parameters. This is because the shorter the front section of the vehicle is, the smaller the energy absorption zone, i.e. the section that absorbs the energy without transferring it to the passenger compartment. In order to give the relatively short Mazda 3 a similar length of absorption zone to that of the longer Mazda 6 or the RX-8, Figure 1 and Figure 2, the impact energy occurring during an accident needs to be absorbed and channelled away, Figure 3. Two components play a key role in this regard. Firstly, the kinetic energy generated during an impact must be transferred precisely along the predefined load paths, Figure 4. Secondly, these load paths must have a structure that is able to dissipate the high level of energy in a defined way. This is where MAIDAS comes in.

### 3 The "Triple-H Principle"

MAIDAS uses the "Triple-H principle" as its key design element. It derives its name from the three basic components, each of which forms an "H" shape. The triple "H", Figure 5, creates a stable passenger cell which, in the event of impact, minimizes the deformations and, in all conceivable accident scenarios, transfers the impact energy to predefined load paths in the bodywork. In the event of a frontal impact, a three-pronged structure at the end of the front side members transfers the energy from the front side members diagonally and outwards into the A-pillars, as well as laterally via the bulkhead cross-piece and downwards into the door sills in order to minimize the deformation of the passenger cell in the foot area of the driver and front passenger, Figure 6. The engine, transmission and front axle move to the rear and maximize the absorption of the impact energy before it can reach the passenger cell, Figure 7. This gives the engine block 15 centimetres to move backwards in the event of a frontal impact before a cross-member prevents it from penetrating the passenger compartment and diverts it underneath the passenger cell, Figure 8. This new front structure is also used in the Ford C-MAX and Volvo S40.

### 4 Zone System

The front structure of the bodywork of the Mazda 3 is subdivided into several zones, each of which performs a different task in the deformation process. The outer zones have the task of absorbing the majority of the deformation. It is important that the closer the collision forces come to the passenger compartment, the less deformation is experienced by the materials. The aim of this design is to ensure that the passenger compartment remains intact in most collisions. In order to ensure that the required characteristics are in place around each zone, four different types of steel and, consequently, four different strengths of steel have been used in the various sections. Applying this zone system in this way means that the collision forces can be absorbed intelligently and efficiently.

The front bumper contains an extremely rigid cross-member made of boron steel. The link to the side members of the bodywork create what is known as crush boxes that absorb the collision forces generated during a low-speed impact without damaging the rest of the bodywork structure. The crush boxes can be replaced easily and inexpensively.

The straight section of the side members consists of high-strength steel, a material that can be shaped easily and enables high energy absorption. This zone must absorb most of the deformation in a collision. In addition, upper side members have also been integrated into the compact Mazda 3. These provide an important protective function in a collision with, for example, a truck loading platform.

The area of the cross-member, which links to the A-pillar along the outside, is made of extremely high-strength steel and is particularly rigid. It serves as a barrier to protect the occupants and as a safety zone against deformation. This high-strength construction also minimizes the risk of the front wheels being pressed into the passenger compartment. Instead, the wheels themselves absorb part of the collision forces.

Thanks to the very efficient arrangement, the engines in the new Mazda 3 are narrower and shorter than in its predecessor, the Mazda 323. If a collision occurs, the engine can be pushed backwards before the crankcase impacts on the cross-member near the bulkhead. A rigid cross-member connects the A-pillars and the lower side members. They are designed as particularly strong three-point reinforcements on both sides. This in turn protects the passenger compartment from deformation.

### 5 The MAIDAS Components

In the event of a frontal impact, a three-pronged structure transfers the energy from the front side members diagonally and outwards into the A-pillars, as well as laterally via the bulkhead cross-piece and downwards into the door sills in order to minimize the deformation of the passenger cell in the foot area of the driver and front passenger.

In order to further reinforce the passenger cell, a stable cross-piece is used to link the side members. This prevents the A-pillars from bending outwards in the event of a frontal collision. If a frontal impact occurs at high speed, the engine, transmission and front axle move backwards to absorb the maximum amount of impact energy before it reaches the passenger cell.

A rigid cross-member connects the A-pillars and the lower side members. They are designed as particularly strong three-point reinforcements on both sides. This in turn protects the passenger compartment from deformation.

The roof of the Mazda 3 consists of three stable cross-members that contribute to the extremely high stability and rigidity of the entire bodywork. In the event of a lateral impact, large central struts, cross-members and side struts distribute the energy to the entire bodywork. The lateral impact protective struts overlap with the door frame and transfer the energy into the floor structure. This significantly reduces the extent of penetration into the passenger cell.

Extremely strong steel in the doors, the A-pillar, the C-pillar and the roof ensures the basic stability of the vehicle. Airbags, seats and headrests are designed in such a way that the occupants are surrounded by as much soft material as possible and do not impact with hard objects in the event of a collision.

### 6 Choosing the Correct Material

Particular attention is paid to the steel components in order to dissipate and channel away the impact energy effectively. High-strength and very high-strength steels improve the torsional rigidity of the bodywork and possess a high capacity for energy absorption, a very positive factor in the event of a crash. It is for this reason that Mazda has selected a combination of high-strength steels, tailored blanks, steel sandwich plates and high-pressure moulded hollow profiles. The components are designed in such a way that they are not stretched to the limits of their stability, but rather always have a residual elasticity capable of absorbing deformation energy in the event of an accident. In addition, high-strength steels with tensile strengths of up to 980 N/mm² possess particular material characteristics. Some of these grades of steel become harder under deformation, since the latter results in structural changes to the material. The situation is similar to the example of a paper clip. If you move