Reducing the cost of repairs after road accidents is an important development objective which must already be considered in the design process of a vehicle. In the case of low-speed collisions, as little damage as possible should be caused to the bumper or to the crossmembers and side members. To achieve this aim, component crash tests using reversible impact absorbers were carried out jointly by KTI – Kraftfahrzeugtechnisches Institut und Karosseriewerkstätte GmbH & Co. KG and ZF Boge GmbH.

1 Introduction

Crash tests carried out in recent years have greatly increased the level of knowledge of passive safety in cars. The application of this knowledge has led to an improvement in the crash performance of modern vehicles. This, combined with effective restraint systems such as seat belt pretensioners, belt force limiters and air bags adjusted precisely to the particular vehicle, has drastically reduced the loads exerted on the occupants in accidents.

Every year, roughly 10% of the 40 million or so licensed vehicles in Germany are repaired after accidents.

The frontal collision, representing approximately 55% to 65%, is the road traffic accident which occurs most frequently. With this type of accident, the majority of the energy to be absorbed by the front end of the body is converted into deformation energy by the vehicle side member. Modern vehicle side members achieve maximum energy absorption through the mechanism of crumpling. This process is initiated by creating defined deformation locations so that the stiffness of the side members increases uniformly from the front to the rear. The increase in stiffness, which is influenced by the changes in the thickness of the sheet metal as well as the shape and the extent of the profile, produces a deformation process which progresses from the front to the rear. The described measures must prevent a sudden collapse in which only a quarter of the energy absorption of the crumpling process is obtained.

The function of the crossmember in the front area of a vehicle is to ensure that the forces applied in a frontal crash are distributed as evenly as possible over the structure of the vehicle. In most cases, the crossmember is the first frame component which makes contact with the other vehicle or object involved in the accident. In or-
order to avoid frame damage in minor collisions, crossmembers nowadays have an integral crash box. This ensures that the energy is absorbed by the deformation of the crash box.

However, since the space available for a crossmember is very limited, the crash box cannot always be designed so as to ensure complete avoidance of frame damage at the side members. In most cases, sectional side member repairs are inevitable.

For this reason, various impact absorber systems capable of dissipating higher levels of energy in a given space are available on the market today. These are divided into reversible impact absorber systems, which are designed for impacts at up to 8 km/h, and irreversible impact absorber systems designed for impacts at up to 15 km/h.

In order to reduce the high cost of vehicle crash testing and at the same time obtain detailed knowledge of the deformation characteristics and stiffness of individual vehicle components, KTI have been carrying out component crash tests.

For the component crash tests described in the following, the side members and crossmembers were bolted directly to a moving crash test barrier and crashed into a rigid stationary barrier. In these tests, deformable crossmembers and rigid crossmembers with progressive impact absorbers were tested at different speeds.

The object of these component crash tests conducted jointly by KTI and Mannesmann Boge was to develop an impact absorber system which operates reversibly at up to 15 km/h and avoids damage to frame components. The problem which has to be resolved is the conflict between the construction, i.e. the required space, and the wishes of the designer.

2 Test Structure and Overview

The crash tests were carried out using the side members of the Volkswagen A platform as the basic structure. Table 1. These were cut off at a length of 529 mm and welded to a mounting plate. Then, the mounting of each side member on the plate was stiffened with four braces. The braces were also welded in place. The crossmember and impact absorbers were then bolted in front of the side members according to the test specification.

2.1 Crossmember and Impact Absorbers for Tests SH-0087 and SH-0088

A rigid crossmember and Mannesmann Boge impact absorbers with a stroke of 110 mm were used for this test. The impact absorbers were welded to the crossmember to ensure a firm connection between the crossmember and the impact absorbers. The original bolted joint was omitted.

2.2 Crossmember with Integral Crash Box for Test SH-0090

A deformable crossmember was bolted to the side members for this test.

2.3 Crossmember and Impact Absorbers for Tests SH-0094 and SH-0095

Rigid crossmembers with Mannesmann Boge impact absorbers with a length of 45 mm were used for these tests. The impact absorbers were secured with the original bolts to ensure a firm joint between the crossmember and impact absorbers.

The front end crossmember assemblies were bolted to a moving crash test barrier weighing 1014 kg and crashed against a rigid non-deformable barrier. The moving barrier was driven by means of a cable. The acceleration loadings on the moving barrier were recorded by means of two triaxial acceleration sensors.

The crash tests were filmed from above and from the left with two high-speed video cameras. Tests SH-0087, SH-0088 and SH-0090 in test series 1 were carried out in accordance with the modified RCAR standard at speeds of 8.5 km/h to 15.5 km/h, Table 1.

Test SH-0094 in test series 2 was carried out at approximately 8.1 km/h with a 100 % overlap against the flat non-deformable barrier, Table 1.

Test SH-0095 in test series 2 was carried out at a speed of 8.2 km/h against a non-deformable barrier turned through 30°.

3 Depth of Deformation

In order to determine the static deformation, the depth of the front end side member and crossmember assemblies was measured before and after the crash tests. The measurements were taken on the left-hand and right-hand sides. The dynamic deformation values were calculated on the basis of the acceleration measurements, the mass of the moving barrier and the sampling frequency.

3.1 Static Depth of Deformation

Table 2 shows the measured static deformation on the left-hand side and the right-hand side as a reference prior to the crash test. In addition, the impact speed, the mass of the moving barrier and the impact energy are also listed.

Figure 1 shows the length of the assemblies after the crash test compared to the length prior to the crash test.

Test SH-0087 (at 8.5 km/h) with the first pair of impact absorbers produced no permanent intrusion. Both absorbers returned to their initial position.

In test SH-0088 (at 15.5 km/h) with the first pair of impact absorbers, both impact absorbers returned to their initial position. The crossmember was slightly deformed, finishing 10 mm shorter on the left-hand side.

Test SH-0090 (at 15.5 km/h) with the original deformable crossmember produced a compression of 170 mm on the left-hand side. The right-hand side was not measurably shortened. The crossmember was squashed completely on the left-hand side.

Test SH-0094 (at 8.1 km/h) with the pair of short impact absorbers against the flat barrier with a 100 % overlap produced no static deformation.

Test SH-0095 (at 8.3 km/h) also with the short impact absorbers against the barrier angled at 30° also produced no static deformation.

3.2 Dynamic Depth of Deformation

The dynamic depth of deformation is shown in Table 3 and Figure 2.

The greatest differences between the static and dynamic depth of deformation were to be seen in the tests with reversible impact absorbers.

These tests showed their progressive nature, particularly clearly, i.e. that the strength characteristic of the impact absorbers was dependent on the impact speed. The higher the impact speed, the higher the strength characteristic, tests SH-0087 and SH-0088.

In addition, reversible impact absorbers were able to dissipate deformation energy without permanent deformation on the right-hand side (in the right-hand impact absorber) as this had a lower strength characteristic due to the lower speed. This is not possible with front end structures with a crash box. This is illustrated in particular by tests SH-0088 and SH-0090.

In test SH-0087 (at 8.5 km/h with a 40 % overlap) with the first pair of long impact absorbers, the left-hand impact absorber had a stroke of 87 mm and the right-hand impact absorber a stroke of 64 mm.

In test SH-0088 (at 15.5 km/h with a 40 % overlap) with the first pair of long impact absorbers, the stroke of the left-hand impact absorber was 110 mm and that of the right-hand impact absorber was 69 mm, Figure 3.

In test SH-0090 (at 15.5 km/h with a 40 % overlap), the left-hand side was compressed by 170 mm. There was no measur-