Comparing crash behaviours in crash tests – the new biofidelic dummy

Dipl.-Phys. Annika Kortmann

When reconstructing car-to-pedestrian accidents, the damage to the vehicle and the injuries suffered by the pedestrian provide important pointers. The new biofidelic crash test dummy is the first of its kind to allow their realistic simulation.

Owing to the often severe consequences of the injuries suffered by pedestrians, accidents involving these vulnerable road users require a detailed reconstruction of the course of events. For this reason, modern accident reconstructions increasingly employ crash tests using dummies. Amongst other factors, the assessment of the damage to the vehicle plays a particularly critical role in narrowing down the vehicle's collision speed.

The dummies that have hitherto been used for this kind of crash test normally consist of a "bone structure" predominantly made from aluminium and steel. This exceptionally solid dummy construction causes a higher degree of damage to the car than would be the case in real-world pedestrian accidents at the same collision speed. As a result, there are serious questions about how reliably crash tests replicate real accidents.

The biofidelic dummy as a realistic surrogate

Since the beginning of 2017, the German company crashtest-service.com GmbH (CTS), in collaboration with the Dresden University of Applied Sciences (HTW Dresden) and the Technical University of Berlin, has taken on the construction and ongoing development of biofidelic dummies, continuing the work started by Dr. Michael Weyde. CTS have been building the dummies in their own laboratory since July 2017, see fig. 1.

The specialised design of the biofidelic crash test dummy makes it very similar to a real human body. The materials employed were chosen because they possess physical properties that mirror the different parts of the human body as closely as possible. For instance, the dummy’s "bones" are made of epoxy resin and an aluminium powder additive in order to recreate the fracture resistance of human bones as realistically as possible. The biofidelic dummy also features ligaments and tendons made from polypropylene webbing. Soft tissue is replicated using silicone and acrylic.

Since every dummy is assembled by hand in a step-by-step process (see fig. 2), it is also possible to deviate from the dummy's standard specifications of 1.75 m and 79 kg to create customised variants with different heights and weights. A standard biofidelic dummy can be built in about 2 weeks, while customised versions can be made in as little as 4 weeks.
As CTS produce the dummies themselves, they can be supplied with integrated measuring devices which make it possible, for example, to measure collision-related accelerations and the resulting forces acting on the cervical spine. In addition, they can be fitted with special sensors that measure the pressure on areas such as the chest and individual segments of the spinal column during a collision.

Comparing and contrasting crash behaviours

In order to demonstrate the differences in crash behaviour between the traditional dummy made from steel and the biofidelic dummy, a crash test was carried out in which a VW Golf III collided frontally with both dummies simultaneously at a typical speed for built-up areas of 50 kph. Fig. 3 shows the impact configuration with the conventional (NAMI) dummy on the left-hand side when looking at the vehicle front-on and the biofidelic dummy on the right.

The different motion sequences of the dummies during the collision, especially during the mounting phase, were filmed separately and are shown in figures 4 and 5. Fig. 4 shows the motion sequence of the conventional dummy. As soon as the dummy is hit, its legs lift off the ground; the "pull under effect" of the supporting leg typically seen in pedestrian impacts does not occur. Because of its rigid structure, the NAMI dummy does not wrap around the bonnet; instead, the body is stretched out almost completely straight as the head hits the car windscreen. The last frame in fig. 4 shows a clear gap between the NAMI body and the car bonnet during the head impact.

The motion sequences for when the biofidelic dummy is struck by a car (see fig. 5) reveal a much closer similarity to the impact behaviour of a real pedestrian. This is due to the fact that when the impact occurs, the supporting leg is first pulled underneath the car and the dummy then wraps around the car bonnet as the collision progresses. The head impact occurs in a top-down movement while the body is in contact with the bonnet .

Damage to the car

The fact that the accident reconstruction is more realistic when using a biofidelic dummy also becomes apparent when comparing the collision damage on opposite sides of the car. Fig. 6 shows a frontal view of the Golf III after the impact, with the damage caused by the NAMI on the left and the damage caused by the biofidelic dummy on the right. The image clearly shows that the NAMI caused significantly more damage in the contact area. Looking at the fracture pattern in the windscreen, there is a higher degree of shattering on the left-hand side, while the close-up view in fig. 7 shows that, unlike the biofidelic dummy, the head of the NAMI even made a hole in the windscreen.
As a result of the biofidelic dummy's body wrapping around the bonnet during the collision, it is even possible to identify the areas where the hip and shoulder made contact (see fig. 8, rightmost image). The NAMI's impact with the bonnet, on the other hand, caused a single, uniform dent covering a large area, together with a high number of scratches which would not occur in this form in a real-world pedestrian accident (fig.8, leftmost image). In particular at high impact velocities, when the dummy makes contact with the edge of the car's roof, the extremely solid structure of conventional NAMI or Hybrid II dummies causes considerably more damage than a human body striking the same area. This makes it a lot harder to estimate the collision speed when reconstructing an accident.

Injuries suffered by the pedestrian

As well as enabling a comparison of the damage to the car, the use of biofidelic dummies has for the first time also made it possible to simulate the injuries suffered by a pedestrian during a real-world accident.

The addition of aluminium powder to the epoxy resin means that the biofidelic dummy can be X-rayed post collision to reveal any bone fractures resulting from the crash test. The principle is illustrated in fig. 9 which shows a CT image of the previous biofidelic dummy model. In this instance, the dummy was struck at a collision speed of 70 kph. After the crash test, an X-ray examination can be carried out in cooperation with the Telgte veterinary hospital, which has been granted an official licence for these scans by the district government. If required, a "post mortem" can also be carried out on the dummy after the collision. Once the biofidelic dummy has been used in a crash test to reconstruct a car-to-pedestrian accident, it can be repaired by CTS. This means that the cost of using the dummy in a crash test is limited to a hire fee rather than having to pay for the dummy in full.

Conclusion

The biofidelic crash test dummy is a very useful tool in modern accident reconstruction, as it allows a far more accurate estimate of the collision speed based on the damage caused to the car. Thanks to a design that simulates human physical properties as closely as possible, it can even realistically replicate the injuries suffered by the pedestrian.

In addition, the deployment of different measuring devices opens up a range of possibilities for capturing the various forces, accelerations and pressures which the body is subjected to during an impact. The biofidelic dummy is under constant development. Its flexibility, for example, is being continuously improved and it is also due to receive a new face with an epoxy resin bone structure in early 2018.

The use of a biofidelic dummy is a valuable asset in accident reconstructions, as it helps to produce well-founded expert reports based on reliable damage patterns – supported by images – for both car and dummy and on the recorded measurement data.

(1) Dr. Michael Weyde (PhD), Ingenieurbüro Priester & Weyde, Heinrichstraße 5-6, D-12207 Berlin

Dipl.-Phys. Annika Kortmann
has been working at Ingenieurbüro Schimmelpfennig + Becke since 2014, specialising in road traffic accidents.

Fig. 1: The CTS laboratory where the new biofidelic dummies are produced

Fig. 2: The different stages involved in building a biofidelic dummy

Fig .3: Impact configuration – conventional dummy on the left, biofidelic dummy on the right

Fig. 4: Motion sequence of the NAMI dummy during the crash test

Fig. 5: Motion sequence of the biofidelic dummy during the crash test (mirrored)

Fig. 6: Frontal view of the damaged car

Fig. 7: Windscreen fracture pattern

Fig. 8: Contact trace evidence on the bonnet caused by the NAMI (L) and the biofidelic dummy (R)

Fig. 9: CT image of a biofidelic dummy (1)