

## **Expert's opinion**

### **Restraint system for operators of forklift trucks – door handle type „PilotProtector“ by IWS (Ingenieurgesellschaft Weiner & Schröter mbH)**

#### **1. Terms of reference**

IWS handed over their manufactured door handle type „PilotProtector“ in order to find out if this door handle limits the operator's risk according to 3.1.5 of Directive 95/63/EEC to be hit by the operator's protective roof in case of a side dump of a fork-lift truck. IWS is a private enterprise that was co-founded by Diplom-Ingenieur Weiner, a former employee to the special field of Production engineering at the Gerhard-Mercator-University of Duisburg. Within the scope of his occupation, Mr Weiner has dealt with the problems of accidents with forklift trucks and has played a decisive role in the success of the research project mentioned in Point 2. The de-velopment of the tested door handle system has not taken place while working for this faculty.

#### **2. Basis of the assessment**

The following expert's opinion is based in fundamental findings on the final report of the research project „Restraint systems for operators of forklift trucks“ of 30.09.1998 which has been acquired by the production engineering laboratory of the Gerhard-Mercator-University in Duisburg under the direction of the undersigned, on behalf of the Hauptverband der gewerblichen Berufsgenossenschaften (Main association of the industrial trade associations) assisted by some manufacturers of forklift trucks and seats for forklift truck operators. The final report comes to the conclusion that rigid lap-belts, belt systems with a mechanical tilting sensor, lap brackets, side retaining seat-integrated handles and vehicle-integrated door handles are fulfilling the demands of a restraint system for forklift trucks operators, each in different ways.

Within the scope of this research project, experimental test have been realized that comprising driving tests with a front-seat forklift truck (make Linde, type H30D) up to a tipping angle of 15°, as well as tests on a test bench which has especially been developed for these tests by FTL in Duisburg. The following results were reached:

## 2.1 Driving tests up to a tipping angle of 15°

In the driving test „steering into a bend“ the forklift truck was accelerated out of a standstill to 24 kph by driving straight ahead. The operator is steering the vehicle with his left hand clasping the steering wheel knob, while his right arm is laying on his right thigh. The operator now steers the forklift truck into a right-hand bend with a radius of 5 m. The same driving test was made by driving backwards. But in this case the vehicle was steered into a left turn. The difference results from the arrangement of the outrigger (which is installed on the left side of the forklift truck to avoid the vehicle's knock-over) as well as from the construction of the test vehicle. All restraint systems mentioned above, have kept the operator inside the operator's cab, however different well, up to a tipping angle of 15°.

## 2.2 Attempts on the test bench of FTL in Duisburg

On the test bench developed and built by FTL in Duisburg, dynamic and static tipping tests can be realized up to a tipping angle of 90°.

The test platform (fig. 1) is able to accelerate the operator's cab that has to be examined, on adjustable radius and with increasing track speed up to the moment of tipping. At the time of tipping, a lateral acceleration of 0.6g takes effect. While tipping, the operator's movements can be analysed by video recordings which are taped by a camera set up on an experimental carrier. The impact of the operator's cab is absorbed by hydraulic brake cylinders. Therefore it is impossible to give a statement about the risks of injury for the operator during the impact; for reasons of safety it was only possible to use test subjects on the test bench up to a tipping angle of 60°.

The restraint system tested within the scope of the research project, kept the test subject inside the operator's cab that was formed by roof support and protective roof. Afterwards, tipping tests up to a tipping angle of 90° were realized with a dummy (see fig. 2).



Fig. 1: Test bench for static and dynamic tipping tests



Fig. 2: Tipping test with a dummy

### 3. Description of door handle type „PilotProtector“ of IWS

The door handle was set up on the rear roof strut with hinged plates and on the front strut with a trap lock. As a result of this, the door handle forms a shelter between rear and front operator's protective roof strut with a perimeter on the left side of the operator. In addition, it is impossible for the operator to jump off the vehicle while having closed the door handle. However, the operator is not affected in his room to move, especially not by driving backwards. It was easy to open and close the door handle. In addition, the door handle offers the operator within the range of pelvis, hip and shoulder or upper arm respectively, additional protection from injuries and against side slipping out of the shelter that is formed by the door handle. This additional protection is possible because of an upholstery which was assembled at the inner side of the door handle.

The assembling height of the door handle was chosen corresponding to the VDI Directive 2198 accordingly seating height  $h_7$ . Corresponding to DIN 33402 Part II, we assumed a thigh height of 165 mm (95th percentile, male, age 26 to 40). Accordingly, the centre line of the lower door handle's carrier shall pass in a height of approx. 80 to 90 mm above the seating height of the operator's test cab (original operator's cab of front-seat forklift truck of Linde AG, type E16).



Fig. 3: tested door handle

**The indicated measures have to be altered according to type of forklift truck and manufacturer. In this connection, the divergent spring distance of the operator's seat has to be taken into consideration if necessary. Only in that case, a special restraint effect of the door handle caused by ergonomics can be reached.**

### 4. Description of the realized tests

We have tested the bow system in different dynamic series of experiments with a dummy up to a tipping angle of  $90^\circ$ . At the maximum angle of  $90^\circ$ , the operator's cab stumbles on hydraulic brake cylinders and is slowed down with a constant delay within the next  $10^\circ$ .

The speed of the test platform moving on a circular path was increased from outside up to the attainment of the point of tipping. In principle, this is equivalent to a drive with a forklift truck that increases its speed in a turn with a constant radius up to the tipping limiting speed.



Fig. 4: used dummy

During every driving test speed, tipping angle and acceleration taking effect, were measured in three axis. These measurements are mainly for checking the given test parameters which have to be observed. From the track radius of the cab measuring 2.57 m (outer curve wheel) and the height of the total centre of the gravity of cab and dummy results a tipping limiting speed of approx. 3.9 m/sec. This value is approximate to a lateral acceleration (also on the outer curve wheel) of approx. 0.6g. At a tipping angle of  $7.5^\circ$ , the process of slowing down is initiated in order to approximate the speed course of the platform to the speed course of a forklift truck in a real tipping accident. (These speed courses have been ascertained mathematically and simulative during the research project). Fig. 5 shows the course of tipping angle and accelerations crossways or vertical to the seat respectively. The acceleration sensor is located right from the operator's seat near the control levers for the lifting device (approx. 0.9 m off the outer tipping edge).

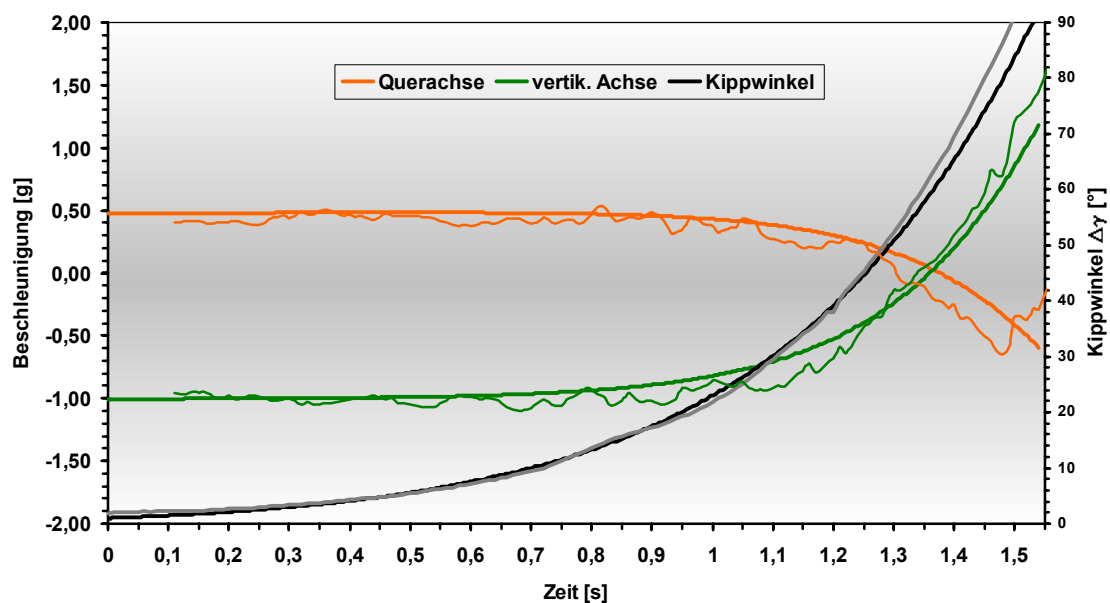


Fig.5: measured values during dynamic tipping test

There are two lines for every acceleration value. The regular lines are the measured values and the plane lines are the calculated courses. For the course of the tipping angle the grey lines show the measured value and the black line the calculated value. The tipping device with cab and dummy has its balance point at approx.  $27^\circ$ . From tilting ( $1^\circ$ ) to the attainment of this value point passes approx. 1 sec. Up until that point, the acceleration values hardly change. The negative acceleration due to gravity ( $-1g$ ) is registered on the vertical axis whereas the effecting lateral acceleration of 0.6g is registered on the transverse axis. With a further increase of the tipping angle, the tipping dynamics are clearly perceptible. The remaining tipping time of the balance point ( $27^\circ$ ) until the impact at  $90^\circ$  (2/3 of the total way) is only 0.5 sec. Between the tipping angle of  $50^\circ$  and  $55^\circ$  the influence of the vertical acceleration due to gravity is zero (concerning the sensor position).

## 5. Results of the dynamic tipping tests

**Remark:** The described tests present the final tests in which the maximum speed and therefore the maximum strain for dummy and restraint system was simulated.

Schon vor Kippbeginn wird der Dummy leicht an den Türbügel herangeschoben. Bei einem Kippwinkel von etwa 45° bis 50° (Bild 6) verliert der Dummy den Halt auf dem Sitz, wird jedoch nicht stärker an den Türbügel gedrückt.

The dummy is moved towards the door handle even before the tipping is started. At a tipping angle of approx. 45° to 50° (fig. 6) the dummy loses its hold on the seat but is not strongly pressed against the door handle. We have realized this test several times under the same circumstances. The test body has never perceptibly touched the door handle during the tipping in one of these tests. This is clearly perceptible in fig. 7 which shows the dummy's position during the second phase of the tipping process exemplary for all tests. At a tipping angle of 75° the dummy still remains completely inside the shelter divided by the door handle, but without perceptibly touching it. Even immediately before the impact (fig. 9) the dummy is not touching the door handle.



Fig. 6: dynamic tipping at an angle of about 45°

The dummy is hurled onto the door handle not until the impact of the operator's cab. As we had to use shock absorbing hydraulic cylinders, we are not able to give valid statements about the forces appearing during the process.

## 6. Static tipping test

In the static tipping test, the operator's cab is lifted with a fixed testing platform until the tipping point is reached. At this point, the test subject slides against the door handle at first. At the following tipping process, clearly lower forces are mathematically taking effect on the test body as in the dynamic tipping test. At this point, the door handle is fulfilling a helpful function for cushioning the operator who, as a result of this, cannot fall out of the shelter built by the protective roof struts and the door handle.

## 7. Strength and stability test

We have statically stressed the delivered door handle in another test in a horizontal position with a force of 200dN. The door handle was not permanently deformed.





**Fig. 7:** dynamic tipping tst with a moving camera

operators protective  
roof (fops)

restraint bowl



**Fig. 8:** dynamic tipping test at approx. 76°

steering wheel

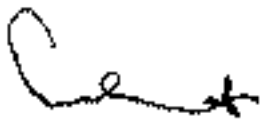


**Fig. 9:** dynamic tipping test – impact

## 8. Summary

The tested door handle type „PilotProtector“ is suitable for forming an additional shelter, if it is assembled on both sides of the vehicle on the rear struts and locking at the front struts of the operator's protective roof. It is stable enough to absorb side forces up to 200dN without permanent deformations. According to its ergonomic construction, it can certainly protect the operator from being hurled out of the forklift truck in case of unexpectedly appearing centrifugal accelerations as they are typical while driving along tight bends. While side tipping (e.g. as a result of operating errors while lifting load) the operator is kept inside the formed shelter because of the ergonomic construction of the door handle.

Besides this, the tested bow system prevents the operator of the forklift truck from jumping off the vehicle in case of a sudden unexpected tipping process. The operator's risk to be hit by the struts of the protective roof in case of such a side dump is, as a result of this, additionally limited by the tested door handle.



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