Aspects on the Secondary Safety of Motorcycles

Part 1: Motorcycle impacts on roadside barriers - new solutions based on real-world accident studies and crash tests
Part 2: Motorcycle Airbags - an option?

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Mobility and Safety Conference, Lietuva, Vilnius, 30-06-2013
Aspects on the Secondary Safety of Motorcycles

Structure:

- Introduction
- Motorcycle Impacts on Roadside Barriers
  - Statistics and Real-World Crashes
  - Crash Tests
  - First Prototype of a “Motorcycle Friendly” Barrier
  - Further Developments and Status Quo
- Motorcycle Airbags – an Option?
  - Historical Background and Status Quo
  - Prototype of an Airbag for a Mid-Sized Touring Motorcycle
  - Crash Tests
  - Potential
- Summary
Introduction

Historic Evolutions of MC Fleet and Killed MC Riders in Germany

- 1969: 308 killed MC riders per 100,000 MCs registered in the fleet
- 2011: 18 killed MC riders per 100,000 MCs registered in the fleet

- Since 1992 incl. New Länder of FRG
- Since 2008 without vehicles temporarily out of registration

3.828 million MCs registered in the fleet

- 556 killed motorcycle riders rural
- 152 killed motorcycle riders urban

708 killed MC riders
Introduction
Shares of killed Road Users Urban in Germany

the share of killed motorcycle riders of all killed road users urban increased from 8 % (out of 3,349 fatalities) in 1991 up to 14% (out of 1,115 fatalities in 2011)
Introduction
Shares of killed Road Users Rural in Germany

N = 7,951
N = 2,894

share

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

year (1991 until 2011)

N = 7,951
N = 2,894

- others
- commercial vehicle occupants
- car occupants
- pedestrians
- bicycle riders
- mofa/moped riders
- motorcycle riders

The share of killed motorcycle riders of all killed road users rural increased from 9% (out of 7,951 fatalities) in 1991 to 19% (out of 2,894 fatalities) in 2011.
Motorcycle Impacts on Roadside Barriers
Reports

Heike Bürkle, Alexander Berg
September 2001, BASt V90

Marcus Gärtner, Peter Rücker
Alexander Berg
Juni 2006, BASt 940

Ralf Klöckner, Maike Zedler
April 2010, BASt V 193
Motorcycle Impacts on Roadside Barriers

Barrier Examples

- **Steel-made roadside protection systems (examples)**
  - „Einfache Schutzplanke ESP“
  - „Einfache Distanzschutzplanke EDSP“

- **Concrete Barrier**
  - “New Jersey Profile“
Motorcycle Impacts on Roadside Barriers
Figure of Killed Motorcycle Riders due to Barrier Impacts

- German accident statistics

Estimation Federal Highway Research Institute (BASt, 2002): “Approx. 50 killed motorcycle riders per year involved in single vehicle accidents with crashes into roadside protection systems” seems to be still valid today.
Motorcycle Impacts on Roadside Barriers
Real-World Crash Example 1

Accident
- MC leaves the road in a left-hand curve
- single vehicle accident
- sliding into steel barrier
- einfach Schutzplanke (ESP)
- sigma post (no jacket)
- $v_{MC} = 85 - 95 \text{ km/h}$

MC rider
- $v = 85 - 95 \text{ km/h}$
- neck impact
- AIS 5
- neck fracture below C4
- internal injuries
Motorcycle Impacts on Roadside Barriers
Real-World Crash Example 2

**Accident**
- MC leaves the road due to a tyre defect
- single vehicle accident
- MC impacts upright
- einfach Schutzplanke (ESP)
- sigma post (no jacket)
- $v_{MC} = 50 - 55$ km/h

**MC rider & passenger**
- $v = 50 - 55$ km/h
- impact with left leg
- rider: AIS 3
  - leg and left arm fractured
- passenger: AIS 3
  - leg and left arm fractured

$R = 170m$
$V_k = 50 ... 55$ km/h
$5^\circ$
Motorcycle Impacts on Roadside Barriers
Crash Tests

velocity ≈ 60 km/h

MC impacts upright

Kawasaki ER-5 Twister `98

MC impacts sliding

Hybrid III, 50th percentile male
Motorcycle Impacts on Roadside Barriers
Crash Tests Using Conventional Barriers

MC impacts upright into „Einfache Distanzschutzplanke (EDSP)“
Impact angle 12°, velocity = 60.5 km/h

MC impacts upright into concrete barrier (H = 0.81 m)
Impact angle 12°, velocity 60.5 km/h

MC impacts sliding into „Einfache Schutzplanke (ESP)“
Impact angle 25°, velocity 59.5 km/h

MC impacts sliding into concrete barrier (H = 0.81 m)
Impact angle 25°, velocity 59.3 km/h
Motorcycle Impacts on Roadside Barriers
Crash Tests Using Conventional Barriers

MC impacts upright into „Einfache Distanzschutzplanke EDSP“

Distance 1st impact to final rest position
MC: 28.0 m
Dummy: 20.5 m
Motorcycle Impacts on Roadside Barriers
Crash Tests Using Conventional Barriers

MC impacts upright into concrete barrier

Movements shown until $t = 1.75$ s after first impact

Distance 1st impact to final rest position
MC: 38.0 m
Dummy: 25.5 m
Motorcycle Impacts on Roadside Barriers
Crash Tests Using Conventional Barriers

MC impacts sliding
into „Einfache Distanzschutzplanke ESP“

Distance 1st impact to final rest position
MC: 1.9 m
Dummy: 4.8 m
MC impacts sliding into a concrete barrier

Distance 1st impact to final rest position
MC: 13.6 m
Dummy: 13.6 m
Motorcycle Impacts on Roadside Barriers
Crash Tests Using Improved First Prototype Barrier

„Swiss box-type“ profile

Sigma post

Lower rail

Ground

MC impacts upright and sliding
Motorcycle Impacts on Roadside Barriers
Crash Tests Using Improved First Prototype Barrier

MC impacts upright

Movements shown until $t = 2.30$ s after first impact

Distance 1st impact to final rest position
MC: 23.0 m
Dummy: 21.7 m
Motorcycle Impacts on Roadside Barriers
Crash Tests Using Improved First Prototype Barrier

MC impacts sliding

Distance 1st impact to final rest position
MC: 1.0 m
Dummy: 7.1 m
## Motorcycle Impacts on Roadside Barriers
### Assessment Results for the Improved First Prototype Barrier

<table>
<thead>
<tr>
<th>MC impacts upright</th>
<th>MC sliding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages:</strong></td>
<td><strong>Advantages:</strong></td>
</tr>
<tr>
<td>▪ Sliding along the barrier after first impact (may also be a disadvantage) smaller delta-v of dummy</td>
<td>▪ Separation of dummy and MC</td>
</tr>
<tr>
<td>▪ No snagging of the dummy</td>
<td>▪ No snagging of the dummy</td>
</tr>
<tr>
<td>▪ Separation of dummy and MC</td>
<td>▪ Short distances from first impact to final rest position of MC and dummy</td>
</tr>
<tr>
<td>▪ No rebound of MC</td>
<td>▪ Impact damping effect by lower rail</td>
</tr>
<tr>
<td>▪ Absorption of energy resulting from deformation</td>
<td>▪ absorption of energy resulting from deformation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Disadvantages:</strong></th>
<th><strong>Disadvantages:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Possible movement of dummy over protection system into other traffic</td>
<td>▪ The fastening of the lower rail failed (should be reinforced)</td>
</tr>
</tbody>
</table>
Motorcycle Impacts on Roadside Barriers
Assessment Results for the Improved First Prototype Barrier

MC upright

Advantages:
• Sliding along the barrier after first impact (may also be a disadvantage)
  slow delta-v of dummy
• No snagging of the dummy
• Separation of dummy and MC
• No rebound of MC
• Absorption of energy resulting from deformation

Disadvantages:
• Possible movement of dummy over protection system into other traffic

MC sliding

Advantages:
• Separation of dummy and MC
• No snagging of the dummy
• Short distances from first impact to final rest position of MC and dummy
• Impact damping effect by lower rail
• Absorption of energy resulting from deformation

Disadvantages:
• The fastening of the lower rail failed (should be reinforced)
Motorcycle Impacts on Roadside Barriers
Follow-up-improvements on Barriers and Current Status

Problem of Propagation:
The installation of a new barrier is much more expensive than the retro fitment of an already installed conventional barrier (ESP or EDSP).

Problem of Compatibility:
Improvements on barriers regarding increased safety for motorcycle riders could lead to reduced safety for car occupants (test according to DIN EN 1317)

Therefore:

- System “Euskirchen” was assembled for retro fitment of an ESP using the lower rail only for sliding impact protection (not the “Swiss box type profile” on the top for upright impact protection) – but crash tests (DIN EN 1317) have shown degradations of the safety for occupants in impacting cars
- Improved system “EuskirchenPlus” was developed using retrofitting components for ESP and EDSP to improve the safety of an impacting motorcycle rider in both upright and sliding impact situation
- Advanced systems “ESP Motorrad” and “EDSP Motorrad” are now available to replace conventional steel barriers ESP and EDSP on all roads that are relevant with high regard to motorcycle accidents
Motorcycle Impacts on Roadside Barriers
Follow-up-improvements on Barriers and Current Status

BASt application release for roadside barriers in Germany

WEBSITE:

- Long term: Supplement for DIN EN 1317 to describe additional demands for impacting motorcycles (and riders)
Motorcycle Airbags – An Option?
Historical Background

- **First proposals to equip motorcycles with airbags go back to the 70’s**
  
  *Bothwell P, Hirsch A E: Airbag Crash Protection for Motorcycle Application*
  
  NHTSA, ASME-Paper, 1973

- **Further proposals followed in the 80’s**
  
  *Chinn B P, Donne G L, Hopes P D: Motorcycle Rider Protection in Frontal Collisions.*
  
  10th ESV-Conference, Oxford, 1985

  
  10th ESV-Conference, Oxford, 1985

  
Motorcycle Airbags – An Option?

Historical Background

1987: HUK-organisation (now GDV), DEKRA and Winterthur-insurance conducted a joint crash-test project in Wildhaus (Switzerland) – a moving motorcycle (equipped with kneepads and airbag) crashed into the side of a moving passenger car.
Motorcycle Airbags – An Option?
Historical Background

1994: Motorcycle-airbag feasibility study carried out by the motorcycle industry and various research institutes

14th ESV-Conference, Munich, 1994

1996: Motorcycle-airbag study was developed and tested in Great Britain (Triumph/Lotus Engineering/TRL)

XXVI FISITA-Congress, Prague, 1996
15th ESV-Conference, Melbourne, 1996
Motorcycle Airbags – An Option?

Historical Background

1999: BMW pointed out the airbag as an option for further development to improve the passive safety of the C1

1990 … 2004: Honda developed an airbag for a large touring motorcycle (Gold Wing)

16th ESV-Conference, Windsor 1998

17th ESV-Conference, Amsterdam, 2001
Motorcycle Airbags – An Option?

Recent and Future Projects
Motorcycle Airbags – An Option?
Prototype of an Airbag for a Mid-Sized Touring Motorcycle

Volume and geometry

Definition of requirements:
DEKRA Accident Research

Design and production:
hs-Technik + Design

1. Volume determination
   (60 litre)
2. Design of bag geometry
   when undeployed
3. Assessment of Bag-Geometry
   when deployed
Motorcycle Airbags – An Option?
Prototype of an Airbag for a Mid-Sized Touring Motorcycle

Side view to airbag in 1st inflation test

Time to deploy: 40 ms
Motorcycle Airbags – An Option?
Prototype of an Airbag for a Mid-Sized Touring Motorcycle

Stationary Test
To check geometry and inflation on the motorcycle relative to the rider
Motorcycle Airbags – An Option?
Crash Tests

Since 1996: ISO 13232 is the worldwide standard for motorcycle crash tests
Purpose: Investigate the effects of passive safety elements fitted to motorcycles

\[ \mathbf{v}_{\text{Motorcycle}} = 0 \text{ kph} \]
\[ \mathbf{v}_{\text{Motorcycle}} = 48 \text{ kph} \]
\[ \mathbf{v}_{\text{Car}} = 0 \text{ kph} \]
\[ \mathbf{v}_{\text{Car}} = 24 \text{ kph} \]
\[ \mathbf{v}_{\text{Car}} = 35 \text{ kph} \]
Motorcycle Airbags – An Option?
Crash Tests

**Test configuration:**
- Impact configuration 413 (ISO 13232)
- 1\textsuperscript{st} step: „moving/stationary“
- 2\textsuperscript{nd} step: “moving moving

**Protective effects:**
- Cushioning of the rider's impact in the early phase of the collision and reduction of the rider's velocity
- Avoidance of severe contact with the roof rail of the car
- Influence of the rider's cinematic in a later phase of the collision (movement of rider into upward direction) due to a “airbag ramp”
- Sliding onto the roof of a car
- No negative influence to the free movement of the rider
- No negative influence to the rider's injury risk
Motorcycle Airbags – An Option?
Crash Tests

Test configuration:

- $v_{\text{Motorcycle}} = 48 \text{ kph}$
- $v_{\text{Car}} = 0 \text{ kph}$
- Dummy: Hybrid III
- No airbag
Motorcycle Airbags – An Option?
Crash Tests

Test configuration:
- $v_{\text{Motorcycle}} = 48$ kph
- $v_{\text{Car}} = 24$ kph
- Dummy: Hybrid III
- Airbag
Motorcycle Airbags – An Option?
Crash Tests

Body region | Limit | Value [100 %]
--- | --- | ---
Head | HIC | 1000
Head | $a_{3\text{ms}}$ | 80 g
Neck | $F_{x,\text{max}}$ | 3.1 kN
Neck | $F_{z,\text{max}}$ | 4.0 kN
Neck | $M_{y,\text{min}}$ | -57 Nm
Chest | $a_{3\text{ms}}$ | 60 g
Pelvis | $a_{3\text{ms}}$ | 60 g
Femur left | $F_z$ | 10 kN
Femur right | $F_z$ | 10 kN
Motorcycle Airbags – An Option?
Crash Tests

Test configuration:
- \( v_{\text{Motorcycle}} = 48 \text{ kph} \)
- \( v_{\text{Car}} = 0 \text{ kph} \)
- Dummy: MATD
- No airbag
Motorcycle Airbags – An Option?
Crash Tests

Test configuration:
- $v_{\text{Motorcycle}} = 48$ kph
- $v_{\text{Car}} = 24$ kph
- Dummy: MATD
- No airbag
Motorcycle Airbags – An Option?
Crash Tests

### Body region

<table>
<thead>
<tr>
<th>Body region</th>
<th>Limit</th>
<th>Value [100 %]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>HIC</td>
<td>1000</td>
</tr>
<tr>
<td>Head</td>
<td>(a_{3ms})</td>
<td>80 g</td>
</tr>
<tr>
<td>Neck</td>
<td>(F_{x,,\text{max}})</td>
<td>3.1 kN</td>
</tr>
<tr>
<td>Neck</td>
<td>(F_{z,,\text{max}})</td>
<td>4.0 kN</td>
</tr>
<tr>
<td>Neck</td>
<td>(M_{y,,\text{min}})</td>
<td>-57 Nm</td>
</tr>
<tr>
<td>Chest</td>
<td>(a_{3ms})</td>
<td>60 g</td>
</tr>
<tr>
<td>Pelvis</td>
<td>(a_{3ms})</td>
<td>60 g</td>
</tr>
<tr>
<td>Femur left</td>
<td>(F_z)</td>
<td>10 kN</td>
</tr>
<tr>
<td>Femur right</td>
<td>(F_z)</td>
<td>10 kN</td>
</tr>
</tbody>
</table>

### Graph

- **Head HIC**
- **Head a 3ms**
- **Neck Fx**
- **Neck Fz**
- **Neck My**
- **Chest a (3ms)**
- **Pelvis a (3ms)**
- **Femur Fz (right)**
- **Femur Fz (left)**

**with airbag**

**without airbag**

**% of limit**

- 0
- 20
- 40
- 60
- 80
- 100
- 120
- 140
Motorcycle Airbags – An Option?
Crash Tests

broken femur (test without airbag)
Motorcycle Airbags – An Option?
ADAC Crash Test with Honda Gold Wing

Honda
Gold Wing
Config. 413
ISO 13232, “moving stationary”, v = 72 km/h
Dummy: MATD

<table>
<thead>
<tr>
<th>Body Part</th>
<th>With Airbag</th>
<th>Without Airbag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Neck</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Chest</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Femur</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Knee</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lower Leg</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

injury risk
- very low
- low
- medium to high
- very high

source: www.adac.de
**Motorcycle Airbags – An Option?**
Findings from Real-World Accidents

DEKRA study on 97 real-world motorcycle crashes

Result:
In 11% of the real-world crashes analysed an MC airbag may reduce rider’s injury severity
Motorcycle Airbags – An Option?

Conclusions

- A motorcycle airbag is a real option - especially for the passive safety of touring bikes
- The development of an airbag by DEKRA Accident Research is an additional contribution to corresponding research
- The damping of the impact by the airbag plays an important role especially for large-sized touring motorcycles
- A combination of damping the impact (by reducing the rider's velocity) and influencing the passenger's movement is more target-oriented for smaller-sized touring motorcycles
- Additional crash tests (all 7 full scale test as per ISO 13232) and numerical simulations (200 impact scenarios) are necessary
- Protection clothing may contribute to solve remaining problems, also during secondary impacts on the road (system-approach)
- Accident research can deliver more knowledge on the performance of motorcycle airbags in real-world crashes
Safety of Motorcycles

[Bar graph showing the absolute frequency of motorcycle safety incidents from 1956 to 2010. The x-axis represents the years, and the y-axis represents the absolute frequency. The graph shows a general increase in incidents over the years.]

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Thank you for your attention

Thank you  Takk  Cám ón  Ngiyabonga
Mahalo  Shukran  Jag tackar
Kiitoksi  Efcharisto
Gracias
Merci
Danke schön