Improvements in Motorcycle Safety (1)

Spoiler for Crash Barriers

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Introduction

I have used TRIZ and SIM [1] to come up with new products and developments which can significantly reduce the number of accidents and casualties amongst motorcyclists. The first of these developments is a spoiler for crash barriers.

Problem Definition

10 to 15% of all casualties in motorcycle accidents are caused by a crash barrier. If I were a motorcycle manufacturer, that would worry me. As a motorcyclist, I just don't understand. But complaining never did anybody any good, so let's look at where all this is coming from. A typical crash barrier construction is a horizontal beam, bolted onto vertical support beams. This construction has been designed and calculated to stop a motor vehicle (car or truck) from exiting the road and thereby preventing collisions with large objects like trees, buildings, sign posts or preventing that the vehicle falls into a creek, river or ravine. In short, it is an object that will cause a small controled collision to prevent a larger uncontroled one. Pretty smart.

However, the crash barriers have not been designed for motorcycles. During an accident, a motorcyclist will fall off his or her bike and slide toward the crash barrier. At this point, two things can happen when dealing with a traditional crash barrier design:

1. The person hits a vertical support beam. These support beams are most often metal I-beams, C-beams or sigma-beams which will cut off limbs upon impact. The person will then usually bleed to death. If the support beam is being impacted dead-center (no fun intended), then the resistance is high enough to cause death upon impact.
2. The person does not hit a vertical support beam. Here we have multiple possibilities.
    a. The person slides underneith the barrier. With some luck, he will not hit the object for which the crash barrier was erected in the first place.
    b. The person slides into the void between the horizontal beam and the ground. Depending on the space available, he may get stuck and/or lose body parts.
    c. The person bounces off the horizontal beam because it's very close to the ground. This would be a hard and damaging impact, given the fact that the beam was designed to withstand the impact of cars and trucks.

The sliding before impact will take away some of the speed, but speed is only one of several factors that will cause injuries.

Given that motorcyclists and vehicles require two completely different approaches to design a crash barrier, a choice was made to favour the vehicles for obvious statistical and safety reasons. There are clearly contradictions to besolved here and that is well known territory to a TRIZ enthousiast.

Contradictions

	Vehicles	Motorcyclists
Material	Hard	Soft
Flexibility	Flexible under heavy load	Flexible under light load
Design	High center of impact	Low center of impact

Solving these contradictions will result in a better crash barrier, but that is not where it stops. SIM also suggests to look at the Trends of Evolution of objects. By challenging the current design and analyzing in what direction it can still evolve, I came up with several other features which can be incorporated.

Looking at the supersystem would lead away from the crash barrier and towards more fundamental road design requirements. That is a hard nut to crack for an outsider. Besides, in the end, the ideal crash barrier is no crash barrier.

Results

The final result is a spoiler which is integrated into the horizontal beam (Fig.1a) or a spoiler which is mounted onto the horizontal beam (Fig.1b). In both cases, the spoiler is not connected to the vertical support beams. The sharp bend between the upper part and the lower spoiler acts as a living hinge for the spoiler.

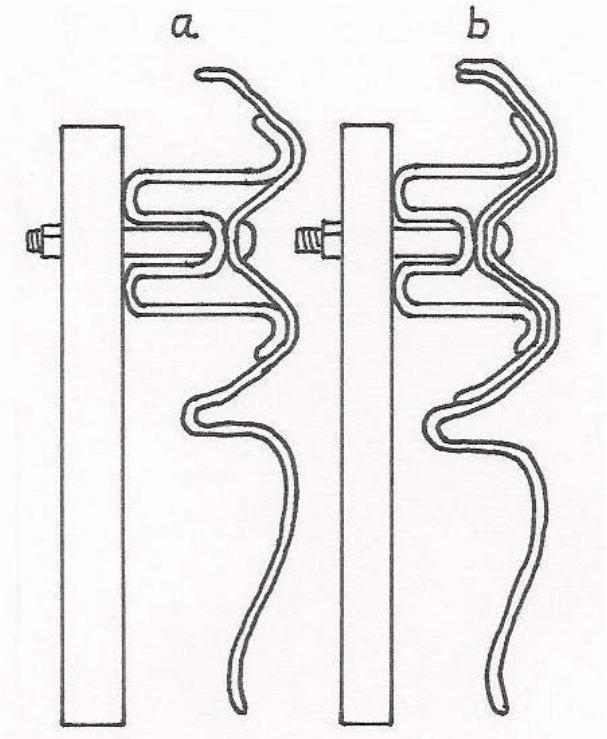


Figure 1: Cross section of an integrated (a) and mounted (b) spoiler.

The spoiler does not reduce the effectiveness of the rest of the crash barrier system. The living hinge may give some added stiffness, but the minimum values for crash resistance will definitely be maintained.

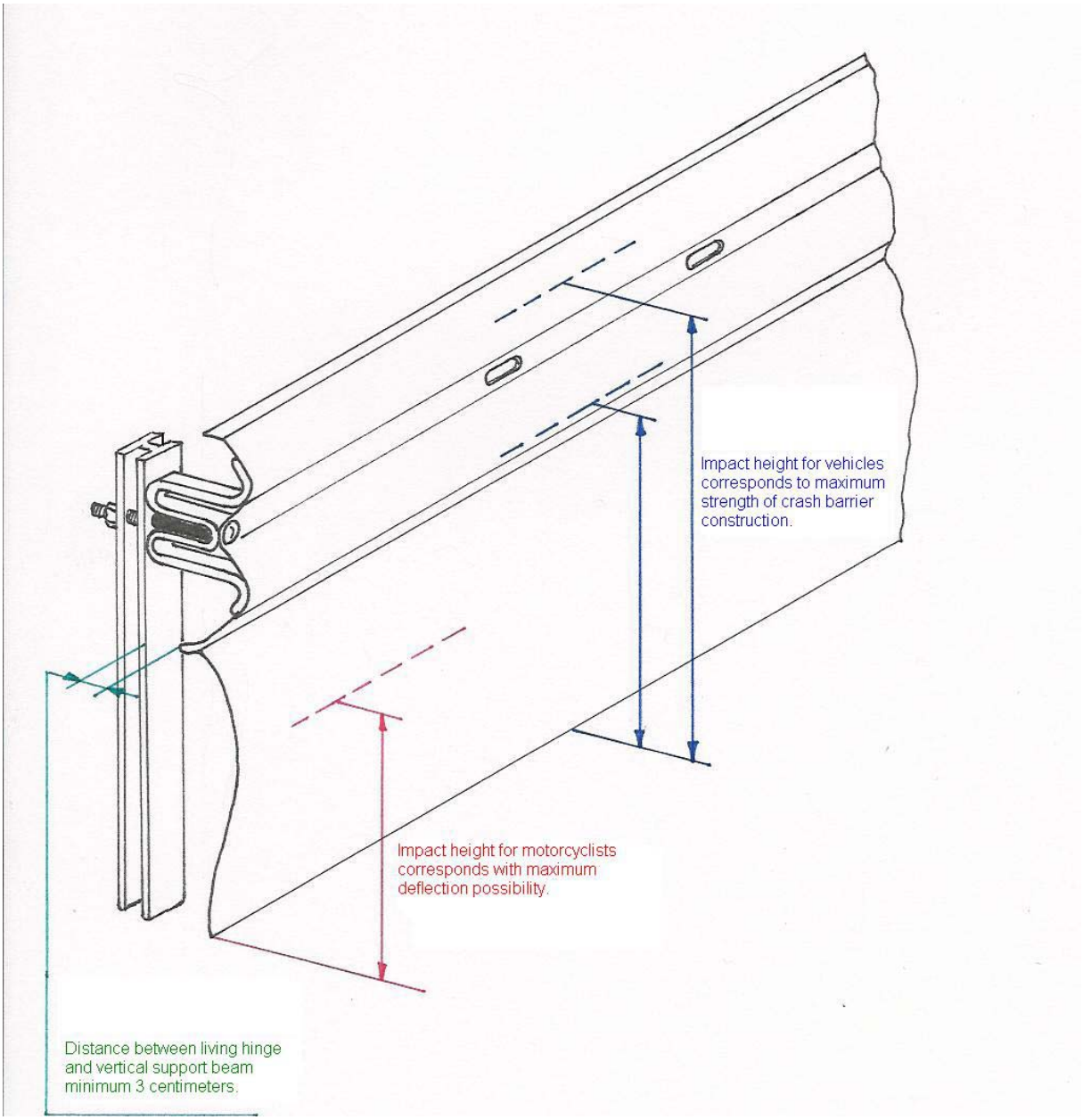
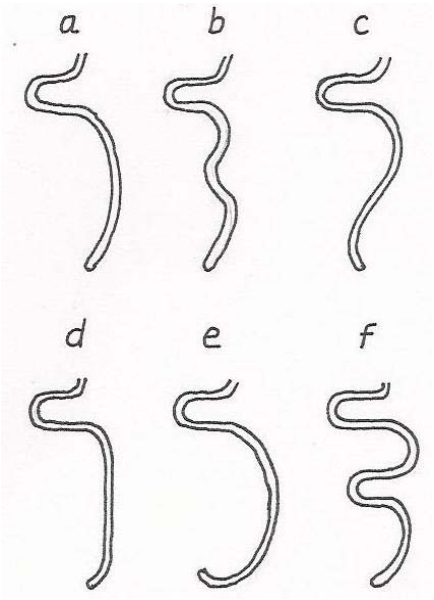


Figure 2: 3D impression of the spoiler concept without add-ons or perforations.

The **energy absorption** is mainly determined by

1. The thickness of the material
2. The choice of material
3. The geometry of the spoiler

Flexibility or rigidity of the spoiler can be tailored by changing the geometry of the spoiler.



There is a virtually unlimited range of possible geometries which can be applied for the spoiler. The geometry in Fig. 3f contains a second hinge and will be somewhat more rigid in the lateral direction (along the length of the spoiler). Material choice evidently plays a significant role in this matter.

The geometry in Fig. 3a and Fig. 3d are clearly more flexible in the lateral direction.

The final design and geometry can easily be determined by performing a Finite Element Analysis (FEA) on the suggested solutions.

Figure 3: Various spoiler geometries

Along the whole length of the crash barrier, there is no point where the spoiler is attached to the vertical support beams and therefore, the motorcyclist does not have any "hard areas" anymore. Every point of impact will give the same amount of cushioning.

Attaching a spoiler onto an existing horizontal beam, permits to change the choice of material. One logical choice may be PDCPD (polydicyclopentadiene) which is known for its high impact resistance properties – even at low temperatures - and perfect resistance to environmental corrosion.

Figure 4 shows an insert or a bolted-on adapter to connect fixed or flexible piping to the construction. This might be used for several functions: transporting electricity, transporting herbicides or antifreeze, and so on.

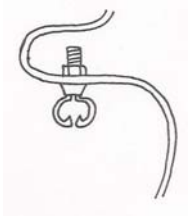


Figure 4: Connection for piping

Some other features which can be integrated in the spoiler are

1. Stripes of thermosensitive paint which change color around freezing point, warning road users for the possibility of freezing.
2. Strain gauges which measure a certain amount of deflection and/or break and which can transmit a signal to a central computer to indicate that a crash barrier has been impacted or broken at a certain location.
3. Signage for road signs or advertising

As you can see in figure 2, the crash barrier has now become a closed construction from top to bottom, except for some possible perforations. This brings an added benefit which animal lovers will like: *it prevents small animals from crossing the road*. Not that this makes the animals any happier, but at least they can cross the road in a more concentrated area, which allows to erect signage and warnings to make their passage safer.

How does it work?

The spoiler acts in four steps (see figure 5).

1. The convex curves of the spoiler are deformed and absorb the first energy upon impact. For small impacts, this deformation – which is reversible – will be sufficient to absorb all the energy.
2. The living hinge will then act as a second resistor. Because it has a higher thickness then the spoiler, it will resist more and will only act after the spoiler has deflected. The hinge itself will absorb energy in this step.
3. An shock absorbing block of material placed around the vertical support beams will absorb the shock of the spoiler hitting the vertical support beams.
4. Once the vertical support beams are reached, the spoiler should further deform without cracking. This requires flexibility and rules out the used of cheap glass fiber reinforced polyesters, because they would break and might get sharp edges. Shock absorbing padding on the back of the spoiler would also absorb some additional energy.
5. The next step is the vertical support beam who resists to the remaining impact energy. This is not an action by the spoiler although the spoiler prevents contact with the sharp edges of the beams.

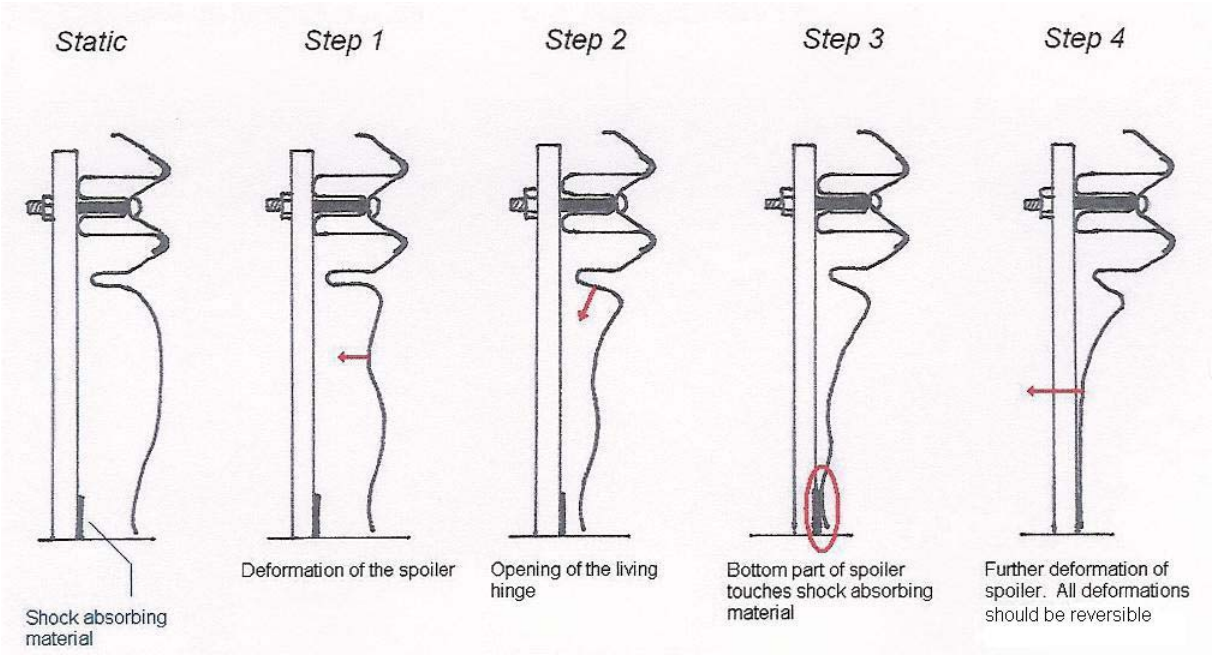


Figure 5: Working principle of the spoiler

The spoiler has to be designed so that in most cases, only steps 1 to 3 are needed. In these steps, there is one more degree of freedom than in the following steps, namely the displacement in the direction of the impact.

An FEA would allow to put numbers behind these steps in order to show which contribution each step has in the total energy dissipation. This will also be the basis for the development and optimization of this type of spoiler.

Inventive Principles

In this particular case, it is clear that TRIZ would have solved the contradictions, but with less possible features than SIM. The final result has used the following 13 inventive principles based on the contradiction matrix.

3. **Local Quality**: Low area is soft and flexible; high area is hard and more rigid. Looking at the broader perspective, one can choose to place these spoilers only in "black spots" on the road or in high risk areas for motorcyclists.
4. **Asymmetry:** The profile of the horizontal beam has changed from a symmetrical W-shape to an irregular shape.
5. **Merging**: Both energy absorbing functions have been combined into one construction.
6. **Universality:** One construction contains a restraint for vehicles, motorcyclists, a spraying system, a temperature indicator, a carrier for signage and a barrier for animals that cross the road.
7. **Nested doll**: The spray system which is integrated into the spoiler, while the spoiler is integrated into the crash barrier.
11. **Beforehand cushioning**: At high velocities, the energy of the motorcyclist is first being absorbed by the spoiler and then by the vertical support beams which will stop the spoiler from deflecting.
14. **Curve**: Curving the spoiler determines its flexibility. In Fig. 3, "profile a" is more flexible than "profile f".
20. **Continuity of useful action**: The flexibility of the spoiler makes it bend back into position after normal – foreseeable- impacts.
24. **Intermediary:** An additional shock absorbing block of material can be placed around the vertical support posts, to reduce the impact when the spoiler is fully deflected.
25. **Self service**: The system keeps itself free from weeds. The surface of the spoiler can be made self cleaning by adapting the surface structure.
31. **Hole**: Perforations in the lower side of the spoiler can reduce the weight and also allow air and wind to flow through, which will reduce the buildup of snow and dust near the spoiler.
32. **Color change**: Fitting the spoiler with stripes of thermosensitive paint allows to create a visual indication of the possibility of freezing.
40. **Composite**: The spoiler can be made out of steel (as an extention of the horizontal beam), but it can also be made out of a more flexible and better suited material.

Legislation

Legislation poses a tough contradiction by itself: it is installed as an improvement to protect us, but it often puts constraints on further developments and improvements. The legal requirements for road restraint systems can be found in EN1317. In this norm, no mention is made of motorcycles. Compliance to this norm is still under investigation.
In France for instance, standard homologation tests for cars take into account a speed of 110km/h, an angle of impact of 20° and a vehicle weight of 1500kg. For motorcycle-friendly road restraints, they catapult dummies with an impact speed of 60km/h and a 30° angle.

Somewhere someone needs to take a decision and put down some numbers on paper to get a test standard implemented. Fair enough, but motorcyclists usually don't drive at about half the speed of cars. When was the last time you overtook a racing bike on the highway?

The angle of impact is also quite conservative. Imagine the following situation: you want to overtake a car, but misjudged its speed and hit the corner of its bumper with the corner of your bumper. This can also happen when the car in front of you stops and you want to pull along side of it, but just aren't fast enough. Upon contact, the corner of your bumper becomes a pivoting point for your car[2]. The physics of motorcyclists in this situation are somewhat different, because they can pivot around their steering axle. Nevertheless, an angle of impact of 30° is not a worst case scenario and don't we all want safety devices to be built based on worst case scenarios?

In the larger perspective (super system) of crash barrier implementation, you can often see roundabouts where a pavement is constructed on which the crash barriers are installed. This allows the motorcyclist to break his neck before losing a limb. Must be less painful...

All in all, I cannot give you any objective reason why the legislation is the way it is, but I have the impression that it crawls along, just behind the technical developments and that improvements to the test standards, as well as European harmonization is feasible and would be much appreciated.

Conclusion

1. The spoiler concept for crash barriers is a life saver which can drastically reduce the number of fatalities, the seriousness of injuries and the medical and insurance costs involved.
2. Crash barrier constructions contain several contradictions which can be solved using TRIZ and/or SIM. For improved motorcycle safety, the spoiler concept is easy to implement and can be retrofitted onto old crash barriers and onto crash barriers with various horizontal beam geometries.
3. There are several contradictions in the practical implementation and erection (super system) of crash barriers. These can be solved by optimizing the test standards and the legislation.
4. Although TRIZ makes you think in specific directions to solve your contradictions, SIM helps you to develop a more complete product by going beyond the contradictions and making you think about the trends of evolution, the evolutionary potential of the current products and the super system.

Notes

[1] SIM: Systematic Innovation Methodology. This is a method which complements TRIZ with various other tools to create inventive solutions. Following references to this methodology can be found in the TRIZ-Journal archives:

- June 2002: Evolutionary-Potential™ in Technical and Business Systems
- March 2002: Software review: CreaTRIZ™ 2.2

  Comment: I have used the updated version called *Creax Innovation Suite 3.1*

[2] If you have kids, then you can probably do this test with one of their toys: a remote control car. Give the car some speed. Aim for an obstacle with the corner of the car bumper and see what happens upon impact. The physics involved are the same as for vehicles and compared to video footage of real life accidents, the results are also similar.
[3] Patent Pending
[4] The picture below shows the real life assembly of the horizontal beams with a vertical support beam of a crash barrier construction. This might clarify the drawings in the article.

About the author

Dirk Vervacke is a Chemical Engineer with a 10 year working experience in polymers. The majority of this time has been spent in R&D environments where he has mainly worked with detergents, polyurethanes and dicyclopentadiene (DCPD) resins. TRIZ helps him in defining new markets through solution marketing, i.e. identifying which contradictions are resolved by using Principle 40 (Composite materials). However, he mainly uses TRIZ and SIM in his spare time, to enhance practical and innovative solutions for various everyday situations and/or products. Just for fun ... for now.