EU POSITION PAPER

TEST–CASE ON FUNCTIONAL EQUIVALENCE

PROPOSED METHODOLOGY FOR AUTOMOTIVE REGULATORY EQUIVALENCE

1. EXECUTIVE SUMMARY

As part of the Transatlantic Trade and Investment Partnership (TTIP), a possible approach for assessing equivalence between EU and US motor vehicle regulations has been proposed. While, indeed, it is widely understood that there are differences with regard to individual technical requirements on motor vehicle safety, the overall level of safety in each of the regions can generally be regarded as equivalent.

In an attempt to develop a successful approach to establish such equivalence on safety performance, this document considers, as a test case, the respective US and EU legislation regarding seat belt anchorages. The conclusion of the analysis is that the two sets of requirements, despite their technical differences, provide an equivalent high level of safety for car occupants. Indeed, following a careful assessment, based on literature review and accident analysis, it appears that the two sets of requirements have proven to be working effectively and equally well with respect to the practical performance of seat belt anchorages systems in real world passenger car collisions. In particular, it stems from the analysis that the technical differences in technical requirements and testing conditions do not lead to any meaningful difference in the real-world.

Therefore, the selected test-case is illustrative of a robust methodology that allows concluding on equivalence of certain automotive safety standards, on the basis of their real-world performance.

2. SCOPE OF THE ANALYSIS

A seat belt directs the occupant forces into the structure of the vehicle through seat belt assembly anchorage points and this aspect is regulated separately in the US by standard FMVSS 210 (and to some extent FMVSS 207 on seating systems) and in the EU by UNECE Regulation No 14. FMVSS 208 further clusters specific child restraint fitting requirements that are also addressed in separate regulatory measures in the EU. This latter aspect is not further analysed in this context.

In summary, the seat belt anchorage point prescriptions (FMVSS 210/207 and R14) for passenger cars (EU: M_1 vehicles) between the EU and US are not identical, varying specifically in terms of the ramp-up time and duration of the maximum test force application.

Before entering into the details of the analysis, it should be pointed out that carrying out a compliance test on a test bench poses certain limitations that will cause the strength test not to be completely representative of a real-world crash. Rather, the seat belt anchorage

point prescriptions are based on static pull tests which are subsequently compared in this context and summarised in the sections below.

More realistic tests of the seat belt system using dynamic loading conditions, which account for the forces and their rate of application as observed in real-life accidents, are mandated in the US as part of the full-scale car crash tests under FMVSS 208 and in the EU under UNECE Regulation No 94. These frontal impact tests are not yet reviewed as part of this first assessment.

However, the seat belt anchorage point safety equivalence comparison in this analysis, when assessed following the US or EU provisions, still provides a relevant judgement of real-world performance of the seat belt anchorages.

The following steps in the analysis are provided below:

- Initial comparison of the respective US and EU standards
- Literature review of seat belt anchorage problems in the field
- Accident analysis investigating potential seat belt anchorage problems in the EU
- Experimental assessment of seat belt anchorage forces in US and EU tests
- Conclusions

3. COMPARISON OF TECHNICAL REQUIREMENTS FOR SEAT BELT ANCHORAGE IN FMVSS 210/207 AND UNECE REGULATION NO 14

The strength test requirements for seat belt anchorages applicable for the EU are set out in UNECE Regulation No 14, Sections 6.3 and 6.4. The respective requirements for the US are defined in FMVSS 210, S4.2 and S5.2.

The high forces pulling on the seatbelt systems' anchorage points can only be increased at a rate that the pulling equipment can physically cope with and may last up to 30 seconds according to FMVSS. UNECE Regulation No 14 suggests that the application of the maximum load should be as rapidly as possible, but allows an application time of up to 60 seconds. In the EU, the maximum force is to be withstand for at least 0.2 seconds, whereas the US rules prescribe that the force has to be withstand for at least 10 seconds. The latter is the main difference between the two standards. The force application rates and holding times seen in both tests do not correspond with the reality of an actual car crash pulse in the real-world, as explained above.

For reference, Figure 2-1 provides a simple schematic of the seat belt geometry and anchorage positions. The diagonal (or shoulder) portion of the webbing runs from the D-ring (upper) anchorage and travels across the occupant's chest through the slot in the tongue, which is engaged in the buckle, which is in turn secured by the lower inboard anchorage. The lower inboard anchorage is either attached to the seat or seat mounting or directly secured to the vehicle structure. The webbing travels through the tongue over the occupant's upper thighs and is fixed at the lower outer anchorage. Again, this can be attached to the seat or seat mounting or directly secured to the vehicle structure.

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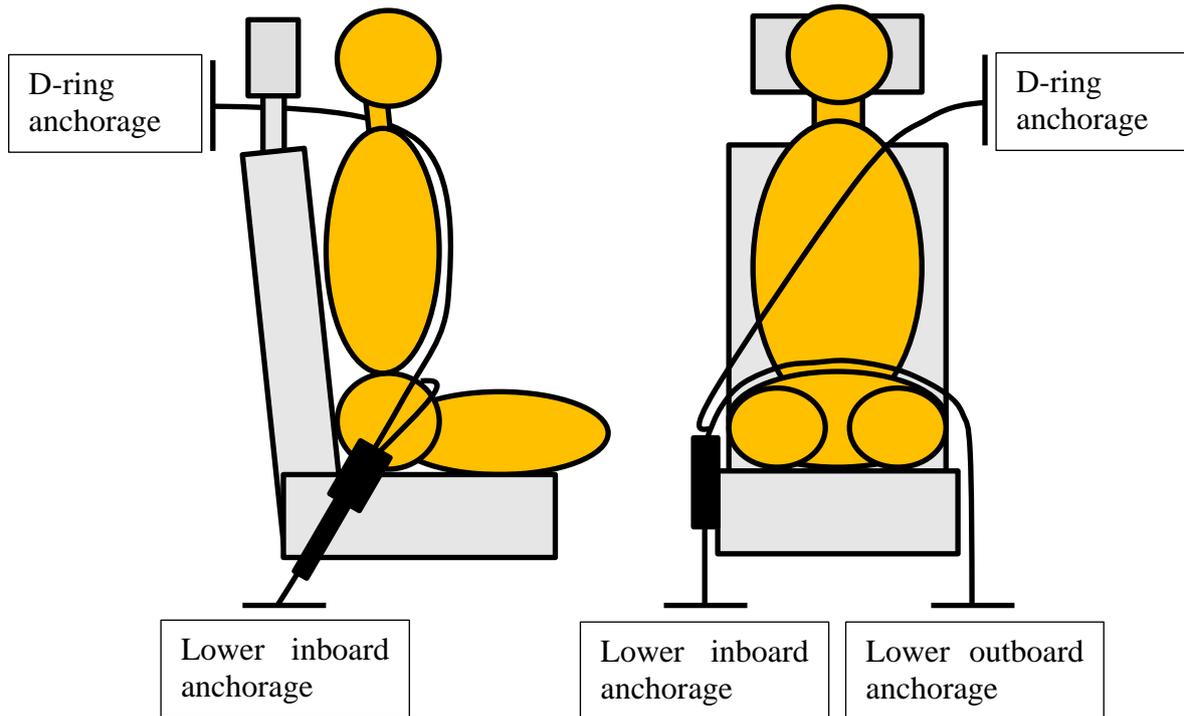
Figure 2-1: Schematic of seat belt geometry and anchorage positions

In the event of a frontal impact the occupant will load the seat belt webbing, which will restrain the thorax by the diagonal (or shoulder) section of the belt and the pelvis by the lap portion. The webbing is attached to the vehicle by three anchorage points.

The basic principle of the anchorage test procedure for three point (lap and diagonal/shoulder) seat belts in passenger cars (M_1 vehicles) is the same in both pieces of legislation. A flexible strap is connected to the anchorage points and pulling forces are applied simultaneously via two traction devices (see figure above). These 'body blocks' pull the lap and the diagonal sections of the seat belt. The anchorages must withstand these forces for a defined duration (permanent deformation does not constitute failure).

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Figure 2-2: Seat belt anchorage test setup showing yellow traction devices.
Source: Dahl Engineering, 2010, Safety Standards & Test Procedures

The test loads are applied over loading devices (body blocks) and transferred by the seat belt to the vehicle structure (Figure 2-3). The body blocks are not fixed to the seat belt webbing or the seat and so contact and slippage between all parts can occur. Therefore, this represents a complex kinematic system and the configuration, including the specific geometry of the webbing relative to the seat and anchorage points, determines the distribution of loads to the anchorage points.
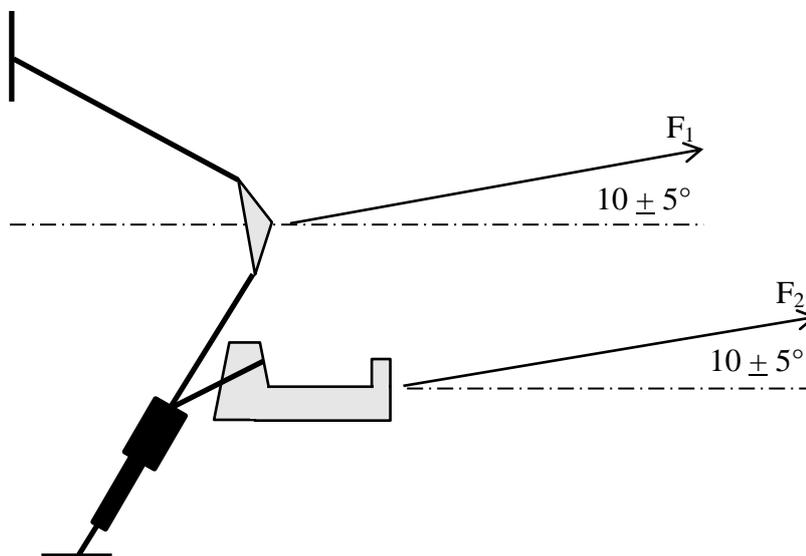
Figure 2-3: Sketch of load application

The force levels applied for R14 and FMVSS 210 are virtually identical; apart from a 1% difference stemming from different unit systems:

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	UNECE Regulation No 14	FMVSS 210
Diagonal section force (F_1)	13,500 N ± 200 N	13,345 N (= 3000 lbs)
Lap section force (F_2)	13,500 N ± 200 N	13,345 N (= 3000 lbs)
Force direction	forward; 5° to 15° above horizontal	forward; 5° to 15° above horizontal

The loading ramp and peak force duration differ between EU and US (for unknown reasons). The US test requires that the peak force is applied for an elongated period of time compared the EU. Both exceed the typical duration of frontal collisions and can be considered static tests, thus the material response is not necessarily influenced by the effects of dynamic load application. Namely, in many cases, the vehicle structure deforms or fails (completely) differently depending on how fast the force is applied.

	UNECE Regulation No 14	FMVSS 210
Loading ramp duration	≤ 60 s (manufacturer can request ≤ 4 s); "as rapidly as possible"	< 30 s
Peak force duration	≥ 0.2 s	= 10 s

According to both UNECE Regulation No 14 and FMVSS 207, the restraining device for a forward-facing seat shall not release or fail when a forward longitudinal force, in Newtons, equal to 20 times the mass of the hinged or folding portion of the seat in kilograms multiplied by 9.8 is applied through the centre of gravity of that portion of the seat.

Whether or not anchorages are attached directly to the seat, FMVSS 210/207 and R14 requirements are the same for categories M_1 and N_1 vehicles in terms of pull forces. However, there are differences possible with respect to the position of the seat during the test. FMVSS 210 requires the seat to be placed in the rearmost position, whereas R14 specifies the seats to be positioned as to give the most adverse conditions with respect to the strength of the system. Generally, EU complaint systems concerning typical front row seats are tested with one seat slightly rearward of the most forward position, and one seat slightly forward of the most rearward position, but in any case the worst case position.

There are some further differences with respect to the seat belt anchorage positions, with R14 permitting an anchorage zone forward to the belt anchorage guide. The effective belt anchorage points for the lower anchorage points are broadly the same. However, the upper anchorage point in FMVSS 210 (where load is transferred to vehicle structure) is considered as the bolt attaching point. For R14 this is the point where the seat belt leaves the guide (D-ring). FMVSS specifies the locations of the physical anchorage points on the vehicle structure. R14 specifies the locations of the points at which a guide ring or

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other vehicles structure and seatbelt webbing come in contact (i.e. the effective anchorage point, which can in some cases be the same as the actual anchorage point).

With regard to the test results, FMVSS 210 and R14 do not consider permanent deformation or rupture of an anchorage or of its surrounding area failure, providing the required force is sustained for the stipulated duration.

4. ABSENCE OF EVIDENCE OF REAL-WORLD ANCHORAGE FAILURES

4.1. INTRODUCTION

A literature review was undertaken to identify the recent evidence base about seat belt anchorage failure.

4.2. SEARCHING OF PUBLISHED LITERATURE

Published literature was searched using the following methods:

- Searches using databases available for analysis;
- Web-based search tools (e.g. Google Scholar);

The following databases were interrogated:

- TRID – Transport Research International Documentation is an integrated database that combines the records from TRB's Transportation Research Information Services (TRIS) Database and the OECD's Joint Transport Research Centre's International Transport Research Documentation (ITRD) Database. TRID provides access to more than one million records of transportation research worldwide; and
- ScienceDirect - an online resource focussing on scientific, technical and medical information with almost 9 million articles.

The search terms used in the study are shown in the table.

Literature Search Terms
Seat belt failure
Anchorage points vehicle belts
Seat belt failure anchorage statistics
Failure of seat belt anchorage
Seat belt anchorage strength
Anchorage failure safety belts
Failure of anchorage components safety belts

The results did not produce any relevant literature of seat belts failing as a result of the anchorage. The main literature relating to the failure of seat belt systems is associated with the buckle mechanism or tearing of webbing in very unusual and rare incidents. The literature identified which discussed seat belt anchorages was in relation to tractors and securing wheelchairs in vehicles.

> **The lack of literature on relevant failings of seat belt anchorages suggests that an appropriate level of safety is provided.**

5. IN-DEPTH ACCIDENT DATA ANALYSIS

5.1. CO-OPERATIVE CRASH INJURY STUDY (PASSIVE SAFETY)

Data from the Co-operative Crash Injury Study (CCIS) were analysed to help inform and support the project's investigation with respect to quantifying the frequency of seat belt anchorage failure in real world scenarios.

The UK's Co-operative Crash Injury Study (CCIS) is one of Europe's largest car occupant injury causation studies. The data is held within the UK government's Road Accident Investigation Studies (RAIDS) programme, which in 2012 superseded CCIS.

CCIS started collecting data in 1983 and under RAIDS the same high level methodology is applied and investigations of real-life car accidents continue.

CCIS investigated and interpreted real-world car occupant injury crashes retrospectively. Police reported injury road traffic crashes from defined geographical areas of England were reviewed to establish if they met the sample criteria. Multi-disciplinary investigation teams examined crashed vehicles and correlated their findings with the injuries the victims suffered to determine how car occupants were injured. One of the objectives of the study was to improve car crash performance by continuing to develop a scientific knowledge base to identify the future priorities for vehicle safety design as changes take place.

The basic selection criteria used for the accidents presented in this analysis were:

The accident must have occurred within the investigating teams' geographical area

- The vehicle must be a car or car derivative

- At least one vehicle in the accident must have been less than 7 years old at the time of the accident <u>and</u> this car must have had at least one occupant who was injured (according to the police)

- The vehicles must have been towed from the scene of the accident.

Accidents were investigated according to a stratified sampling procedure, which favoured cars that met the age criteria and contained a fatal or seriously injured occupant as defined by the British Government definitions of fatal, serious and slight. The crashes that met the criteria and involved a CCIS classified fatal or seriously injured occupant

were investigated. Random selections of accidents involving slight injury were also investigated, up to a target maximum.

Vehicle examinations were undertaken at recovery garages several days after the collision. An extensive investigation of the cars' residual damage and structural loading along with detailed descriptions of the restraint system characteristics and any occupant contact evidence was recorded using the CCIS data collection protocols. This process allows the nature and severity of the impact(s) and/ or rollover damage to be precisely documented so different crash types can be compared.

Where practical the investigation teams visited the scenes of the crashes a day or two after the collision and gathered evidence with respect to the highway and environmental factors.

Car occupant injury information was collected from hospital records, coroners' reports and questionnaires sent to survivors. The casualties' injuries were coded using the Abbreviated Injury Scale (AIS; 1990 and 2005). AIS is a threat-to-life scale and every injury is assigned a score, ranging from 1 (minor, e.g. bruise) to 6 (currently untreatable). The Maximum AIS injury a casualty sustains is termed MAIS. The scale is not linear; for example, an AIS 4 is much more severe than two AIS scores of 2.

The casualties' characteristics (age, gender, seat belt use) and injury information were correlated with the vehicle investigation evidence. This methodology allows the causes and mechanisms of the injuries to be documented.

Accidents investigated between June 1998 and December 2009 were included in the analysis (CCIS Phases 6, 7 and 8).

5.2. RESULTS - CASUALTIES

There were 13,121 car occupants who were known to have used their three-point, lap and diagonal seat belts. The car users were differentiated by whether or not their vehicle rolled over. For the majority of casualties whose vehicle did not experience a rollover, their type of collisions is summarised in the table below. There were 6,488 people who experienced a single frontal impact.

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Type of collision	Car occupant injury severity				Total
	Fatal	Serious	Slight	Uninjured	
No rollover					
Front	239	1878	3424	947	6488
Right[1]	119	425	1006	254	1804
Left	106	280	614	198	1198
Back	13	65	407	92	577
Multi-impact	93	330	530	133	1086
Other	11	16	17	12	56
Involved rollover					
	120	524	1068	200	1912
Total	701	3518	7066	1836	13121

Distribution of car occupant injury by crash typology

Part of the CCIS investigation involved a forensic non-destructive examination of seat belts. If the investigator identified any failures associated with the seat belt, the associated anchorages, buckles or other components, this was recorded in the database. There were 18 people who experienced a variety of seat belt failure events.

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[1] Right is the driver's side in the UK – sometimes referred to as 'offside'

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Type of collision	Car occupant injury severity				Total
	Fatal	Serious	Slight	Uninjured	
No rollover					
Front	1	1	0	0	2
Right	3	0	2	0	5
Left	3	0	2	0	5
Back	0	0	0	0	0
Multi-impact	1	0	1	0	2
Other	2	0	0	0	2
Involved rollover					
	0	1	1	0	2
Total	10	2	6	0	18

Distribution of car occupant injury by crash typology for those who experienced 'seat belt failure'

Seating position	Car occupant injury severity				Total
	Fatal	Serious	Slight	Uninjured	
Driver	7	2	4	0	13
Front passenger	3	0	1	0	4
Rear right passenger[2]	0	0	1	0	1
Total	10	1	5	0	18

Seating position of occupants who experienced 'seat belt failure'

Only two cases of seat belt failure were associated with frontal impacts, the remaining failures occurred in side and other impacts or rollovers.

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[2] Rear right or offside passenger is seated directly behind the driver in the UK.

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The mechanisms of seat belt failure for the 16 cases that were not frontal, were mainly as a result of vehicle intrusion and direct loading and distortion of the anchorage points and/or subsequent tearing of the seat belt webbing. Although damage was observed to the seat belt anchorages in some of these cases, failure was not a result of overloading due to occupant-induced seat belt webbing forces, but the 'normal' crushing of vehicle structure as a result of an accident.

For the two frontal impact cases:

One resulted in a driver sustaining serious injury and damage to her seat belt assembly because of an unrestrained rear seat passenger impacting her seat back. This therefore does not relate to the anchorage testing under discussion

One driver was killed and there were concerns over the performance of the seat belt buckle. The lower and upper anchorages did not fail. As the seat belt buckle is in turn mounted to the actual seatbelt anchorage point in the vehicle, this does also not relate to the anchorage testing under discussion.

From the analysis of the CCIS data, there is no evidence of seat belt anchorage failures.

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6. EXPERIMENTAL ASSESSMENT OF SEAT BELT ANCHORAGE FORCES

This section compares the static seat belt webbing forces that could typically be expected in FMVSS 210 and R14 and the dynamic seat belt webbing forces experienced in real world accidents and crash tests

6.1. STATIC LOADING OF SEAT BELTS DURING FMVSS 210 AND R14

Wu et al (2009) undertook some experimental tests using a force application device, which loaded the lap and diagonal portions of the seat belt in a very similar way to the mechanism employed by the body blocks shown in point 2 above. The multiple tests involved the application of approximately 13.35 KN (3,000 lbs) both to the diagonal and to the lap portion of the seat belt. The test set-up incorporated a rigid seat and high-strength webbing and reported average diagonal (shoulder) seat belt webbing forces of 8.56 KN (1,923.4 lbs); and average lap belt webbing forces of 6.58 KN (1,479.3 lbs). The full results are provided in Appendix 1.

6.2. DYNAMIC LOADING OF SEAT BELTS DURING AN IMPACT

In the event of a frontal impact a seat belted vehicle occupant will be restrained by its belt webbing. Unlike in the static condition, the loading rate will be rapid and duration of the forces will be small, i.e. less than 150 milliseconds (ms). The magnitude of force experienced by the webbing and in turn the seat belt anchorages will be determined by the effective mass of the occupant and the acceleration experienced. A simplified model is shown in Figure 5-1.

$$F_1 = m_1a$$

$$F_2 = m_2a$$
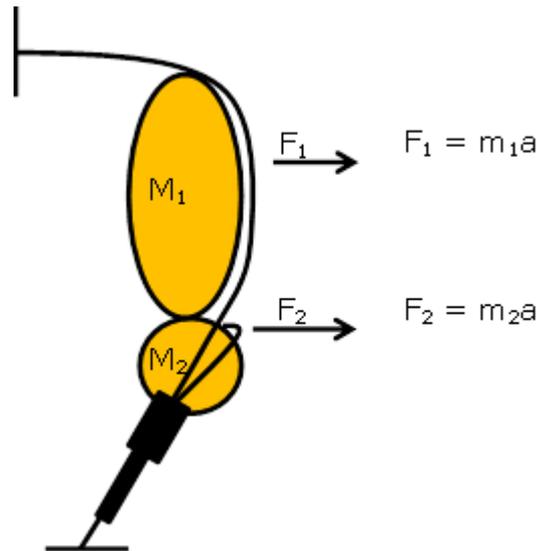
Figure 5-1: Forces applying to diagonal (shoulder) and lap seat belt portions

Hynd *et al.* (2001) undertook a study investigating the potential benefits that could be realised if modern car restraint systems were optimised to protect a more diverse range of car users. A part of this research programme involved sled testing with different size dummies and measurements of the seat belt webbing forces. A key element of the programme investigated the effect of different load limiters. Three different load limiter behaviours were simulated in the testing.

The first was a default 4 KN load limiter. This type of limiter started at a force of 2 to 2.5 KN and rose up to 4 KN at which point no further increase in force was allowed. The second was a 2.5 KN load limiter and finally a progressive load limiter was used (LLP). The latter (LLP) worked with a load limit starting at 2 KN and it increased, according to the amount of belt paid out, up to about 7 KN.

The behaviour of the load limiters used in this test work was characterised by measuring the belt forces close to the diagonal (shoulder) belt anchorage and on the same side (outboard) close to the lap belt anchorage point. The measured force levels give an indication of typical belt forces experienced in frontal crashes (similar to full-scale crash tests according to UNECE R94 and FMVSS 208). This shall give a benchmark for the force levels applied in static anchorage tests.

The function of the diagonal belt load limiter is described by the shoulder belt forces as shown in Figure 5.2-1 below for the offset barrier pulse tests with hybrid III 50th percentile dummy. It can be seen that the measured forces are very similar in the first 20 ms of the impact after which differences develop. From this point the 4 KN load limiter 56 km/h tests continue to increase in force until a plateau is developed at about 4 KN, after 80 to 85 ms. Alternatively the 2.5 KN load limiter and LLP responses stay at around 2 KN until about 60 ms, when pay-out on the LLP is enough for the force to start increasing rapidly up to a peak value of over 5 KN. In the 56 km/h test, the 2.5 KN load limiter does eventually rise up to about 2.5 KN, whereas in the 40 km/h test it stays close to 2 KN for most of the impact event. In the 40 km/h test with the 40 KN load limiter, the shoulder belt force never reaches 4 KN.

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The maximum shoulder belt force measured in each of the configurations is above 5 kN; the duration of peak force is short compared to the 0.2 seconds static anchorage test.
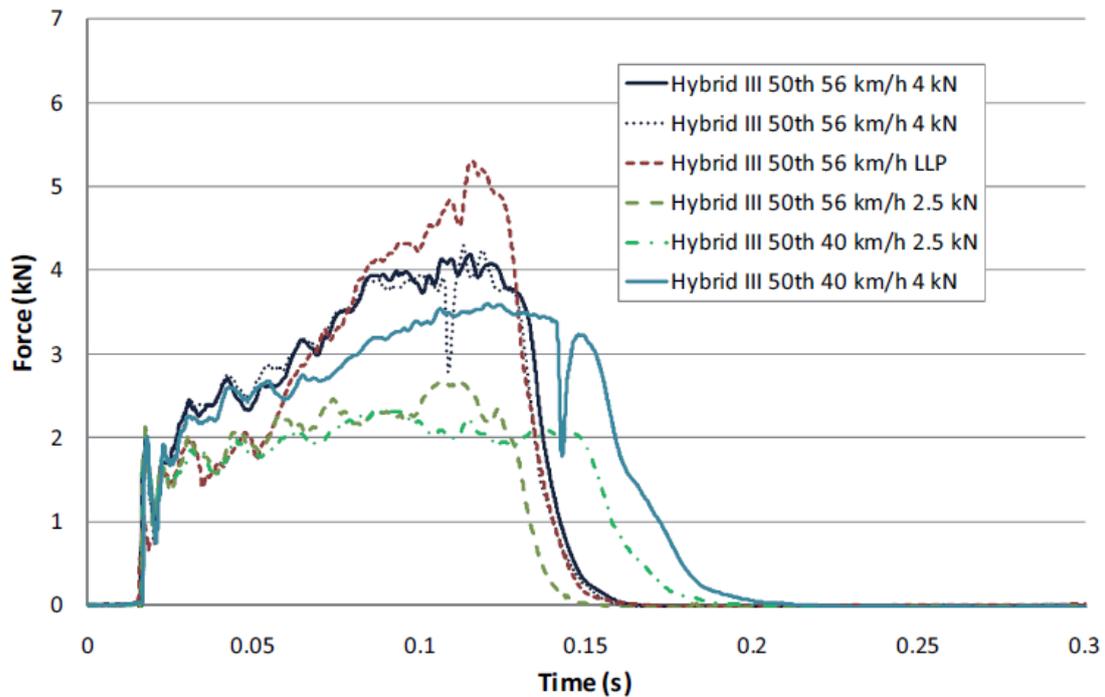
Figure 5.2-1: Hybrid III 50th percentile male shoulder belt forces (Hynd et al. 2011)

Figure 5.2-2 below shows the lap belt forces in the same test configuration. The maximum level is approximately 8 kN (experienced again for a short duration). The dummies were additionally restrained by airbags during these tests. The femur loads showed no sign of direct contact and were well within regulatory limit.

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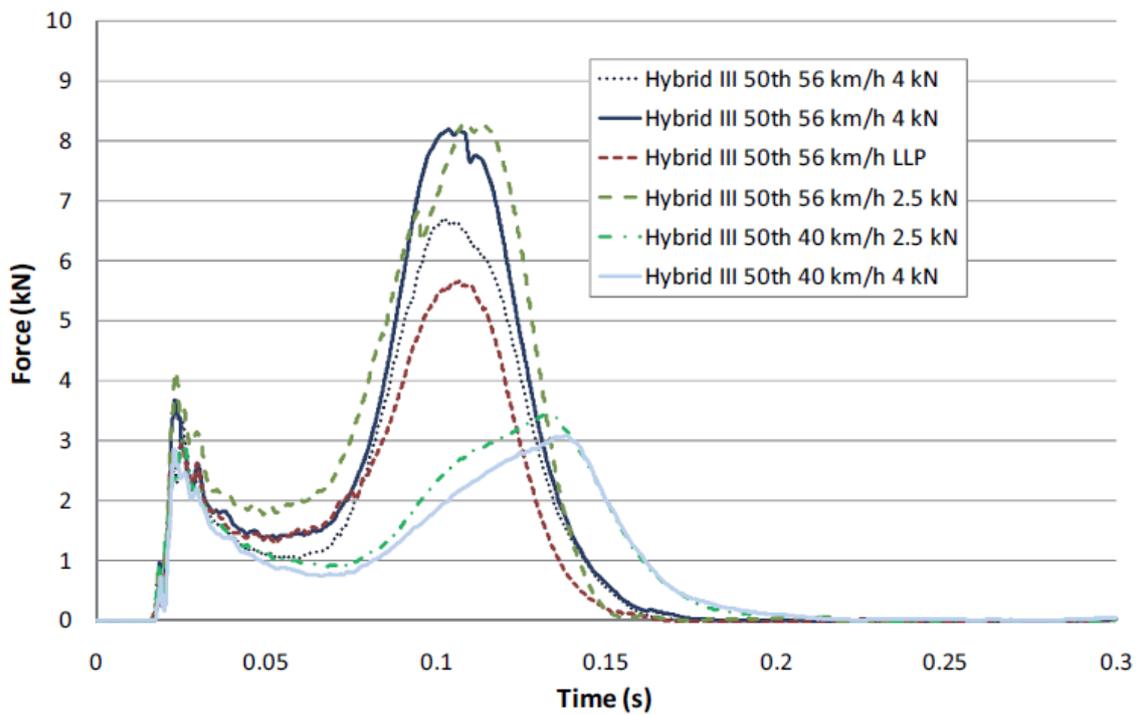
Figure 5.2-2: Hybrid III 50th percentile male lap belt forces (Hynd et al. 2011)

The forces measured on the shoulder portion of the seat belt during the 95th percentile male dummy tests with an offset pulse are shown in Figure 5.2-3 below. The function of the load limiters is being used fully with the larger dummy.
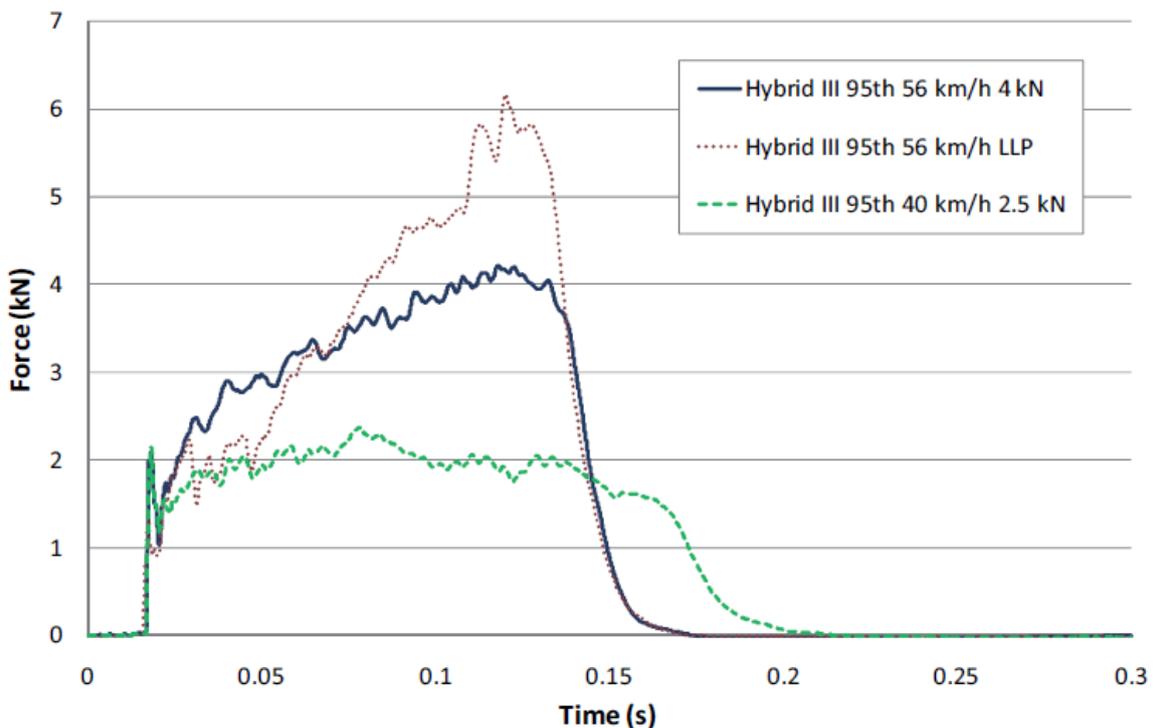
Figure 5.2-3: Hybrid III 95th percentile shoulder belt forces (Hynd et al. (2011)

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In the tests most of the available space was used and the dummy chest excursion was close to the expected maximum based on pre-test quasi-static measurements. However, the pelvis was constrained by the pre-tensioning to move less than 100 mm. This resulted in higher lap belt loads than for the other two dummies (Figure 5.2-4), particularly in the 56 km/h test with the 4 KN load limiter.
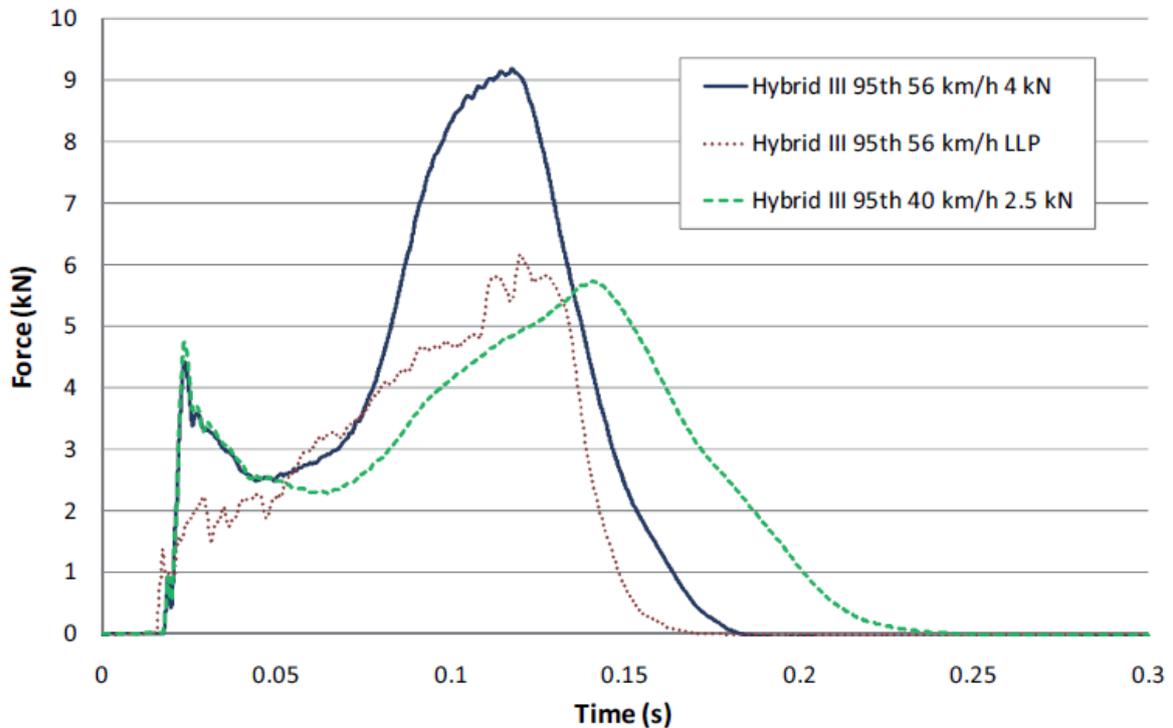
Figure 5.2-4 Hybrid III 95th percentile lap belt forces (Hynd et al. 2011)

The 50th percentile male hybrid III shoulder belt forces from the tests with a full-width pulse are shown in Figure 5.2-5. The notable differences in shoulder belt loading between these tests and those with an offset deformable barrier pulse (previously shown Figure 5.2-1) are a quicker rise to the force level as set by the load limiter and a shorter duration (of about 100 ms instead of about 150 ms).

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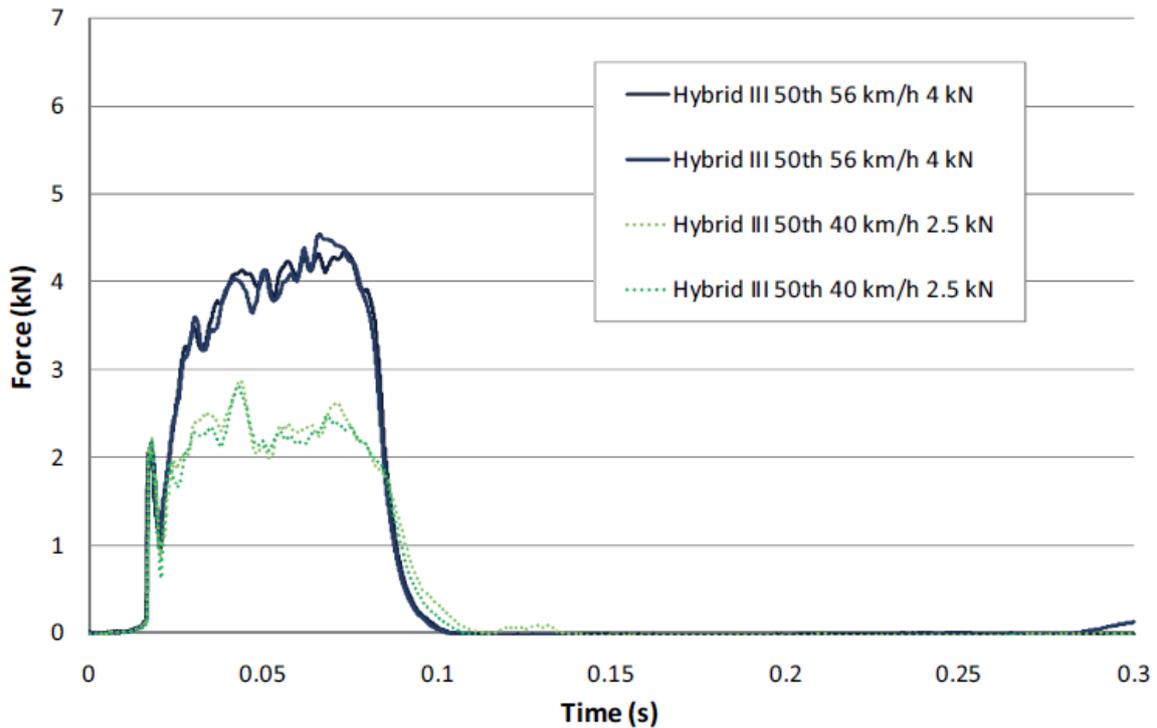
Figure 5.2-5: Hybrid III 50th percentile shoulder belt forces (Hynd et al. 2011)

The maximum lap belt load was observed with the THOR dummy, tested at 56 km/h with the full-width pulse and a 4 KN load limiter (Figure 5.2-6). At almost 12 KN peak force, one must assume that this level of lap belt force is heading towards an injurious level.
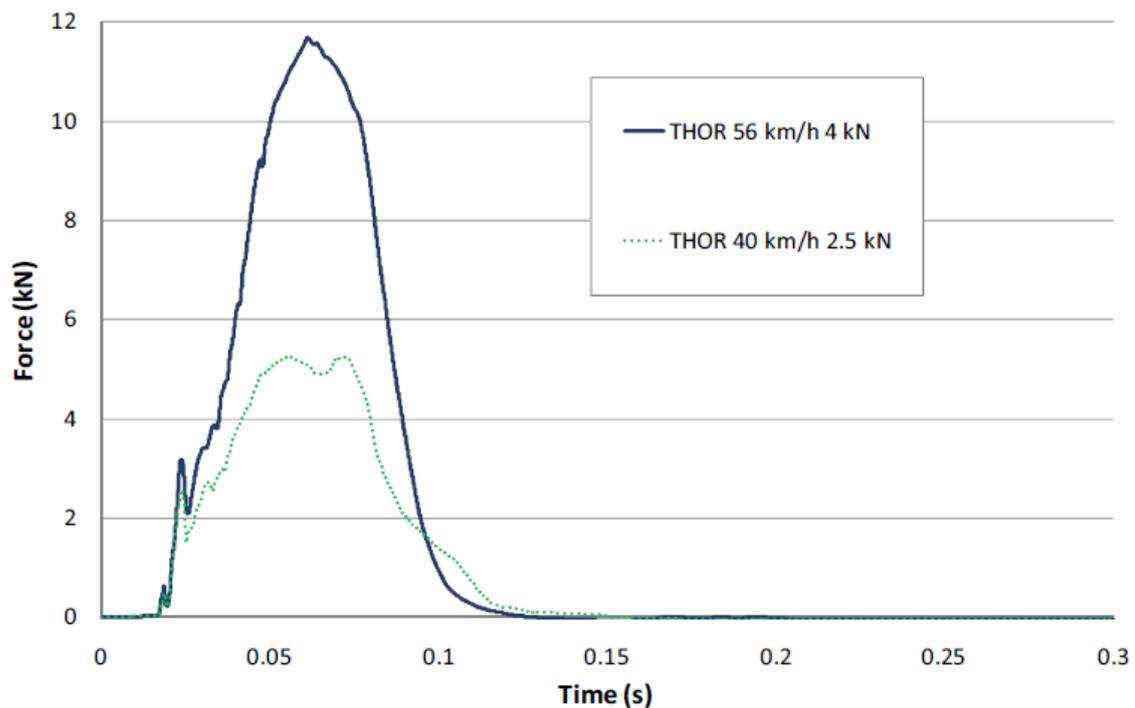
Figure 5.2-6: THOR lap belt forces from full-width pulse tests (Hynd et al. 2011)

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6.3. COMPARISON OF STATIC AND DYNAMIC SEAT BELT FORCES

In summary, for the offset and full width testing undertaken by Hynd *et al*. (2011), the diagonal (shoulder) seat belt webbing forces were all below 8.56 KN, which was the maximum measured in the static pull test by Wu *et al*. (2009). The maximum shoulder webbing force recorded in the dynamic tests was about 6 KN. However, the maximum lap belt webbing force observed in the sled tests was nearly 12 KN, compared with 6.58 KN experienced in the static test.

As the above charts shows, the belt loading duration in all configurations was well below the 0.2 seconds used in static EU anchorage tests.

7. CONCLUSION

Stemming from the comparison between FMVSS 210/207 and UNECE Regulation No 14 as contained in this document, both FMVSS 210/207 and UNECE Regulation No 14 have proven to be working well with respect to the practical performance of seat belt anchorage systems in real world passenger car collisions. This is supported by the literature research under item 4 providing no evidence of real-world cases, the item 5 in-depth analysis of EU accidents and the assumption that there is no US in-depth accident data that would point in the direction that there is a potential problem with seat belt anchorages that were certified according to FMVSS 210/207.

 In particular, the following was observed:

- There were some minor differences noted between FMVSS 210/207 and R14 with negligible effects on performance parameters.

- FMVSS 210/207 and UNECE R14 use an identical test setup (two body blocks load lap and diagonal (shoulder) belt respectively) and the tests apply the same peak force to the seat belt anchorages (and to the seat structure if applicable).

- Whilst the loading ramp and peak force duration differ between EU and US (the US test requires that the peak force is applied for an elongated period of time compared to the EU) it does not appear to have practical consequences. Comparing seat belt webbing forces observed during static anchorage pull tests, that can be deemed representative of both EU and US provisions, with dynamic sled test conditions (representing typical frontal full-scale crash test configurations), it was found that:

    - The shoulder (diagonal) belt forces in the static anchorage test condition were higher than in the dynamic tests;

    - For some dynamic tests, the lap belt webbing forces significantly exceeded those measured in the static anchorage tests; and

    - The duration of force application in both EU and US static anchorage test configurations exceeds the required duration observed in the dynamic tests.

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The three points above therefore also indicate that the behaviour under dynamic conditions further supports an integrated approach that does not only assess the level of safety on an item-by-item basis, but rather also as a whole, with aspects clustered in the relevant context (i.e. with different vehicle systems interacting with each other).

- A literature review found no evidence of seat belt anchorage failures (in both EU and the US) supporting that such failures are not an issue when it comes to passenger car safety in the real-world.

- From the analysis of in-depth collision data from Great Britain (CCIS), there is no evidence of failures of seat belt anchorages type-approved under UNECE R14 following an analysis of 13121 accidents investigated between June 1998 and December 2009.

8. REFERENCES

Analysis carried out by TRL on behalf of the European Commission

Hynd, D., Carroll, J., Richards, D., Wood, R, & Goodacre, O. (2011). Restraint system safety diversity in frontal impact accidents. TRL Published Project Report PPR577

Wu, J. & Saunders, J. (2009). Repeatability analysis of the forces applied to seat belt anchors using the force application device. NHTSA Technical Report: DOT HS 811 139.

FMVSS 210:
http://www.gpo.gov/fdsys/pkg/CFR-2013-title49-vol6/pdf/CFR-2013-title49-vol6-sec571-210.pdf

UNECE R14:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:109:0001:0054:EN:PDF

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Appendix 1
FMVSS 210/207 and UNECE Regulation No 14
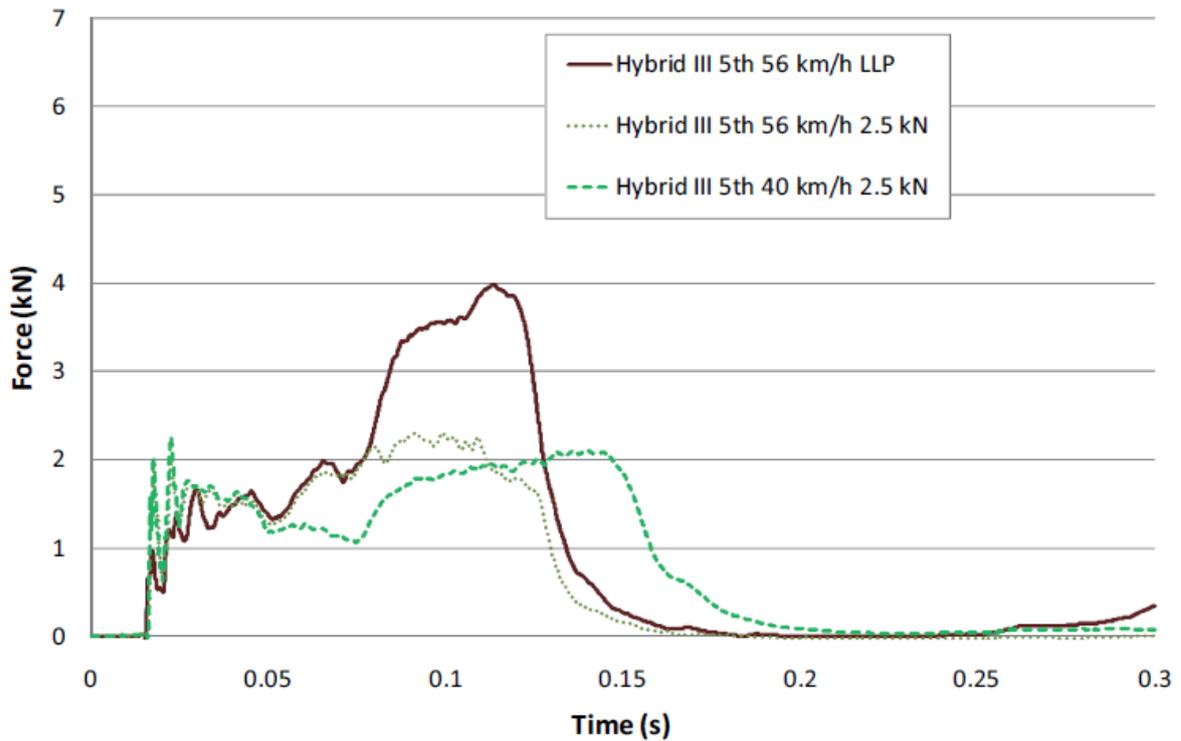
Figure Ap-1: Hybrid III 5th percentile female shoulder belt forces (Hynd et al. 2011)

EU-US TTIP Negotiations

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Figure Ap-2: Hybrid III 5th percentile female lap belt forces (Hynd et al. 2011)

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Mean, overall deviation and CV for all data channels
[NHTSA Report No. DOT HS 811 139]:

Channel	Test 1 (force at Time 1) (lbs)	Test 2 (force at Time 2) (lbs)	Test 3 (force at Time 3) (lbs)	Test 4 (force at Time 4) (lbs)	Overall Mean (lbs)	Overall Deviation (lbs)	CV	Rating
Outboard Lap X	890.4	899.9	924.9	900.3	903.9	12.8	1.0%	excellent
Outboard Lap Y	334.6	352.2	368.7	368.6	356.0	14.1	4.0%	excellent
Inboard Lap Z	2222.1	2213.5	2186.4	2190.6	2203.2	15.8	0.7%	excellent
Inboard Lap X	1849.8	1836.4	1824.1	1808.8	1829.8	15.5	0.8%	excellent
Inboard Lap Y	579.4	602.9	591.5	596.9	592.6	9.0	1.5%	excellent
Outboard Lap Z	1092.9	1131.9	1150.1	1158.3	1133.3	25.2	2.0%	excellent
D-ring X	1707.9	1725.3	1741.3	1744.5	1729.8	14.8	0.8%	excellent
D-ring Y	995.7	1017.9	1061.7	1048.6	1031.0	26.1	2.5%	excellent
D-ring Z	-1938.8	-1970.2	-2195.9	-2008.0	-2028.0	99.6	4.9%	excellent
Retractor X	104.2	104.9	112.1	106.4	106.9	3.1	3.0%	excellent
Retractor Y	-147.1	-152.5	-181.7	-157.5	-159.7	13.3	8.3%	acceptable
Retractor Z	1409.3	1418.0	1615.3	1432.0	1468.7	85.1	6.0%	good
Shoulder Belt RAM	3004.0	3005.4	3005.9	2997.4	3003.2	5.0	0.2%	excellent
Lap Belt RAM	3009.2	3008.9	3008.7	3007.2	3008.5	0.8	0.0%	excellent
Lap Belt Webbing	1440.2	1472.6	1508.1	1496.4	1479.3	26.0	2.0%	excellent
Shoulder Belt Webbing	1907.5	1919.4	1937.8	1928.8	1923.4	11.6	0.6%	excellent

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