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Crash Test for Seat Belt Anchorage

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Abstract: Over 50% of tractor-related fatalities can be related to tractor rollover, and it is estimated that up to 40% of all farm injuries could be prevented by use of safety equipment, such as ROPS and seat belts. The international standards SAE J2194, ISO 3776 and OECD Codes include a test for determining the strength of seat belt anchorages. These standards recommend the procedure for anchorage in the case of an overturn with a ROPS-equipped tractor. But there happen different kind of accidents such as collision, going off road, hitting to pedestrian etc. In that accidents seat-belt should certainly restrain the occupant from being fully ejected out of the vehicle. In collisions and rollovers, the forces influenced on tractor are transferred to the operator and cause the operator to move in the direction of the impact force. The movement is dependent on speed of tractor, type of accident, the properties of seat belt restraint, the size of operator, and the force and direction of the impact. This study aims a practical approach to the seat belt procedure for current OECD Codes and standards. In order to be able to simulate an accident, a Spring Operated Seat Belt Tester (SOSBET) was constructed. It determines the force acting on the seat belt due to inertia of the occupants or drivers in case of a collision. In different tractor speeds such as 5 km/h, 10 km/h and 15 km/h, the strengths of seat belt were found 1011 N, 2397 N and 3550 N respectively.
Key words: Tractor, safety, seat belt and crash tests

INTRODUCTION

Seat belt is one of the operator restraint system used for securing the driver in motor vehicles (Powers et al, 2000). A seat belt prevents drivers being thrown out of the cab in the case of an overturning or road accidents where the drivers are most likely to be killed or injured. (HSE 2003). Agricultural tractors fitted with a protective structure are often sold with pelvic restraint belts for operators. Pelvic seat belts are lap belts that are latched together across the operator's pelvic region (Figure 1a) (OECD 2003). Pelvic and torso restraint systems like on passenger cars can be seen rarely in some tractors (Figure 1b). Pelvic and torso seat belts are required to help prevent occupant head impact with the steering wheel during a frontal impact. They also help prevent torso motion during side, rear, and rollover accidents.

In the European Community, directive 2003/37/EC, compels manufacturers to fit a ROPS on the tractor, tested according to directives 79/622/EEC, 86/298/EEC and 87/402/EEC or according to the equivalent Organisation for Economic Cooperation and Development (OECD) Codes 4, 6, 7, 8 and 9. EC directives force manufacturers to fit a seat belt anchorage, which is considered a tractor component (Molari and Rondelli, 2007). On the other hand, in OECD ROPS Codes do not compel manufacturers to fit a seat belt but there is an optional test for determining the strengths of seat belt anchorage and its mounting parts. According to scope written in these codes is as follow:

The seat should be in position during the tests and fixed to the mounting point on the tractor using all intermediary fittings such as suspension, slides, etc. specified for the complete tractor. The anchorages should be capable of withstanding the loads applied to the seat belt system using a device as shown in Figure 2.

a b

Figure 1. Seat belt types used in tractors

Forward loading shall be applied in a forward and upward direction at an angle of 45º ± 2º to the horizontal, as shown in Figure 3a.The anchorages shall be capable of withstanding a force of 4450 N. A tensile force in rearward loading shall be applied in a rearward and upward direction at an angle of 45º ± 2º to the horizontal, as shown in Figure 3b. The anchorages shall be capable of withstanding a force of 2225 N. The seat belt anchorages shall be capable of these test loads applied with the seat adjusted in the worst position of the longitudinal adjustment to ensure that the test condition is met. The test loads shall be applied with the seat in the mid-position of the longitudinal adjustment if a worst position among the possible seat adjustments is not recognised by the testing station (OECD, 2011).

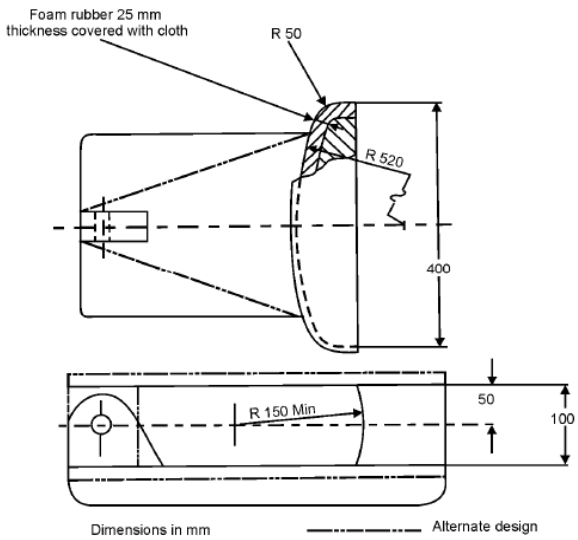
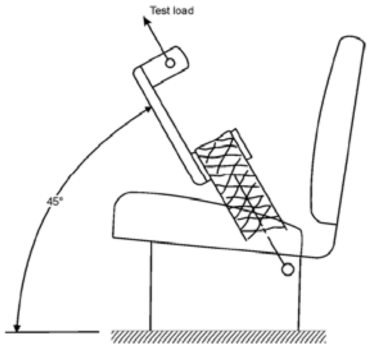
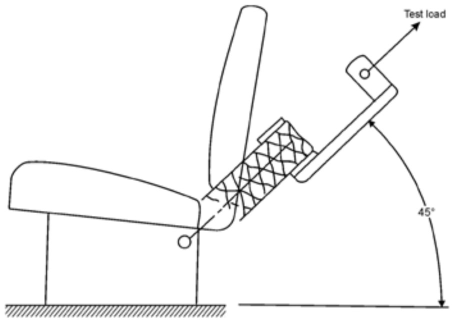


Figure 2. The load application device



(a)



(b)

Figure 3. Load applications in the forward and rearward direction

According to test procedure written in the code, tests for anchorages are only applied statically for simulating an overturning accident. This test does not cover collisions such as going off road, hitting to pedestrian, on highway collisions etc.

From the data available with definite rollover accident it has been established that this type of accident happens very often and the number of seriously injured occupants can be high. Frontal accidents don’t happen very often but there is a high possibility between farm road and farm. In urban road, there happen a lot of accidents between the cars and tractors. The rear-end collision is a common type of farm equipment vs. motor vehicle collision on public roads. Most of the accidents occur after the hill due to the tractors which move slowly. Other accidents occur by falling off tractor, on highway collisions and collision with objects such as trees, water channel etc. in the field because of the wrong manoeuvre. Table 1 shows the accidents related to tractor in Turkey in 2007 (TUİK, 2007).

Table 1. Accidents for tractors

	Number of total vehicles involved in accidents	Number of vehicles involved in accidents with death	Number of Vehicles involved in injured accidents	Number of Vehicles involved in accidents with material loss only	Number of drivers killed	Number of drivers injured
Total	3544	63	1029	2452	27	377
Inhabited area	2752	30	643	2079	18	194
Uninhabited area	792	33	386	373	9	183

Table 2. Accidents happened in Isparta Province (Akbolat et al., 2007)

Type of accident	Number	Proportion (%)	Death
Collision	53	57.6	14
Overturn	33	35.6	18
Going off the road	4	4.4	2
Hitting a pedestrian	1	1.1	1
Falling off moving vehicle	1	1.1	0
Total	92	100	35

In the study carried out University of Suleyman Demirel (Akbolat et al, 2007) the reasons of tractor accidents have been investigated in Isparta Province between the years 1995 and 2003. According to results, most of the tractor accidents had happened as single and multiple vehicle accident in state roads or close to Isparta province. Additionally, the type of accident has been reported as collision (57.6%), overturn crashes (35.6%), going off the road (4.4%), hitting a pedestrian (1.1%) and falling off moving vehicle (1.1%) (Table 2).

In the report prepared by, The Committee on Agricultural Safety and Health Research and Extension, Feb. 2009 (Agricultural Equipment on Public Roads) (USDA, 2009); recently reviewed characteristics of crashes between farm equipment and motor vehicles from previous studies and it has been listed as:

- Crash fatality rates in the most rural counties are almost double the rate in urban counties
- Rural crashes are more frequent, more severe, and more likely to result in death than urban crashes
- Certain types of crashes, such as those between motor vehicles and farm vehicles, are unique to rural environments and usually involve slow moving tractors with trailing equipment and higher speed motor vehicles
- The environment of the rural road contributes to increased crashes and more severe injury outcomes
- In crashes involving farm vehicles, the farm vehicle occupant is killed nearly twice as often as occupants of the other vehicle

The international standards SAE J2194, ISO 3776 and OECD Codes include a test for determining the strength of seat belt anchorages. These standards recommend the procedure for anchorage in the case of an overturn with a ROPS-equipped tractor. But there happen different kind of accidents such as collision, going off road, hitting to pedestrian etc. In that accidents seat-belt should certainly restrain the occupant from being fully ejected out of the vehicle. In collisions and rollovers, the forces influenced on tractor are transferred to the operator and cause the operator to move in the direction of the impact force. The movement is dependent on speed of tractor, type of accident, the properties of seat belt restraint, the size of operator, and the force and direction of the impact. This study aims a practical approach to the seat belt procedure for current OECD Codes and standards. Crashing and releasing test without any damage will give us data to form a new procedure for the collisions happen in the road.

MATERIALS and METHOD

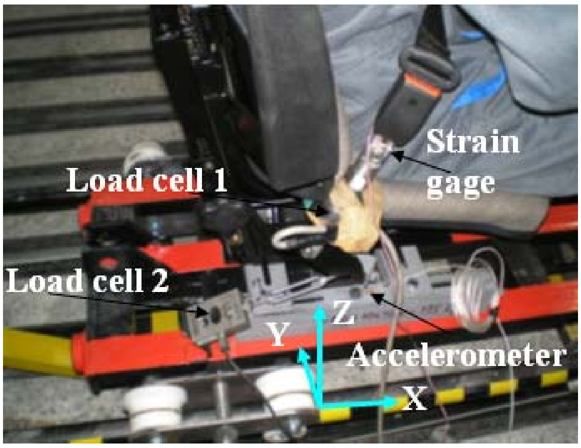
In this study in order to be able to simulate a collision, a Spring Operated Seat Belt Tester (SOSBET) was constructed. It determines the force acting on the seat belt due to inertia of occupants or drivers in the case of a frontal accident (Figure 4) (OECD 2010). SOSBET give us to carry out repeatable tests. In these controlled tests can be applied complete vehicles, partial vehicles and seat restraint systems attached to various platforms. SOSBET is a platform developed to simulate the effects of frontal accidents. A cost efficient mannequin or dummy same as H-III 50th percentile male Hybrid used in crash tests was utilized to assess the force on the seat belt, anchorages and the seat. It was 78 kg weight and 1 m 75 cm height. It is known that several centimetres of vertical, lateral, and forward torso motion in the accidents can expose the operator to impacts with the ROPS or wheel, or worse, allow the head and upper torso to move outside the ROPS canopy. Therefore this study will give an idea how much restraint is provided during a frontal collision.

Impact tests were performed by two different methods. In the first method, sled was hit to the reinforced wall with hard foam and loads and accelerations were measured (Figure 4a). Once the test system was set up or drawn back by hydraulic system to ensure the energy to speed up the test platform with dummy. Then the SOSBET was released and allowed to hit the wall. All tests were recorded by two cameras in two angles. Data was collected by a data logger (eDAQ). In the tests, 2 load cells (2000 kg and 750 kg), 1 single strain gage, two accelerometers (inductive and MEMS) (Figure 5a) and a gyroscope (XSENS) were used (Figure 5b).

(a)

(b)

Figure 4. Test bench for the crash test (SOSBET)



(a)

(b)

Figure 5. Instruments used for measuring the data and directions

In the second method, sled was placed reversely on the SOSBET and it was released equal to acceleration which happens at the crashing test. Sled did not hit to the any object and it did not damage. Tests were performed while the speeds at 5, 10 and 15 km/h. During the tests, loads on the seatbelt and acceleration on the dummy was measured (Figure 4b).

RESULTS and DISCUSSION

In crash test, six tests were carried out, two of them were unsuccessfully. In these two tests seats ejected from their sled. Other four tests were successfully. During the tests, crashes happened at about 13-14 km/h. This speed was not so fast but it was close to the highest speed for the farm works such as fertilizing, transport etc. The cinematically viewing of crash test is given in fig 6.

Figure 6. The moment of collision as cinematically

In the study one crash test result is given in fig 7. The results are the load exposed to seatbelt, acceleration of platform, acceleration of dummy chest at three directions and angular velocity of dummy chest. The seat belt has loaded during the initial 200 ms of the crash. After 200 ms the load decreased. The maximum belt load is 801N. This load is not high for the seat and it covers the OECD seat belt anchorages test. Figure 7b shows the acceleration on the platform at x (longitudinal) direction. The maximum acceleration is 8g. It is not dangerous for the driver. The acceleration on dummy's chest is 1.5g at z direction. It is also not high; the acceptable acceleration on the chest is 30g (Huang, 2002) (Figure 7c). Figure 7d shows the rolling speed during the impact. It explains the moving direction of dummy (see fig. 5b). According to this movement there is no motion to the rearward and upward direction. Roll angle was found 15-20 deg on y axis due to restriction of seat belt.

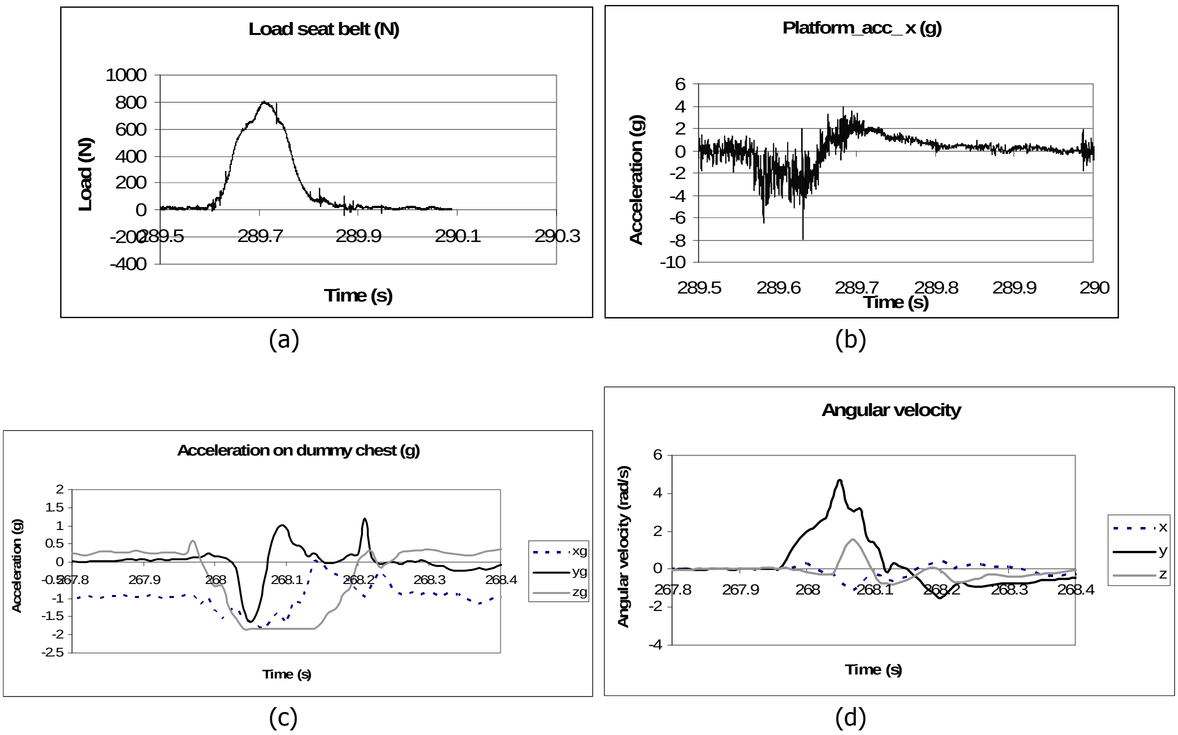
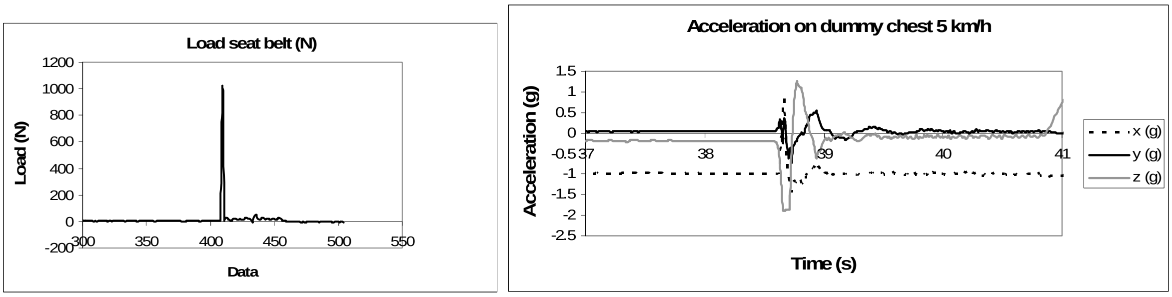


Figure 7. Crashing test results a) Belt force vs. time, s; b) Platform acceleration; c) Acceleration on the dummy chest; d) Angular velocities of dummy during the collision

Undamaged sled test has been applied at 3 different speeds. Test results can be seen in Figure 8. In different tractor speeds such as 5 km/h, 10 km/h and 15 km/h, the strengths of seat belt has been found 1011 N, 2397 N and 3550 N respectively. When figure 8 is examined depending on the launch speed the load exposed to seat belt has increased. The highest value, as expected, has been obtained at about 15 km/h speed as 3550 N. This force is not higher than the force applied at OECD Codes. However, in some tests seats ejected from their sled during test. Such a result shows that driver seats and its components connected to tractor should be considered and an extra loading test should be applied in lower angles than 45 degrees. During the tests acceleration of dummy chest has not been found more than serious impact. The maximum acceleration has been measured as 2g at 15 km/h.



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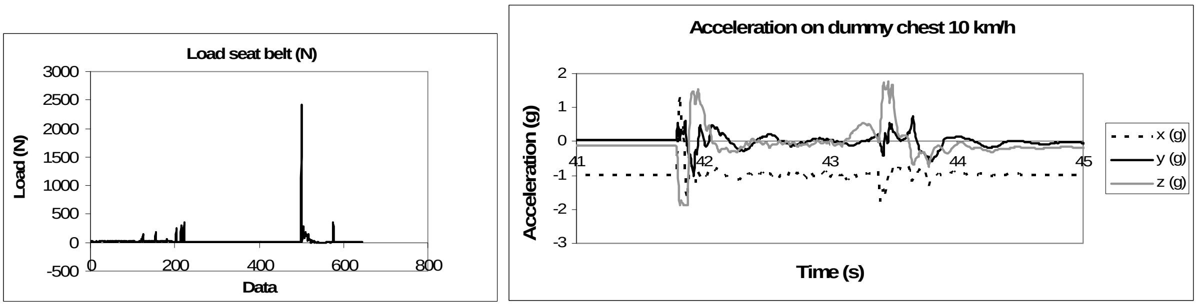

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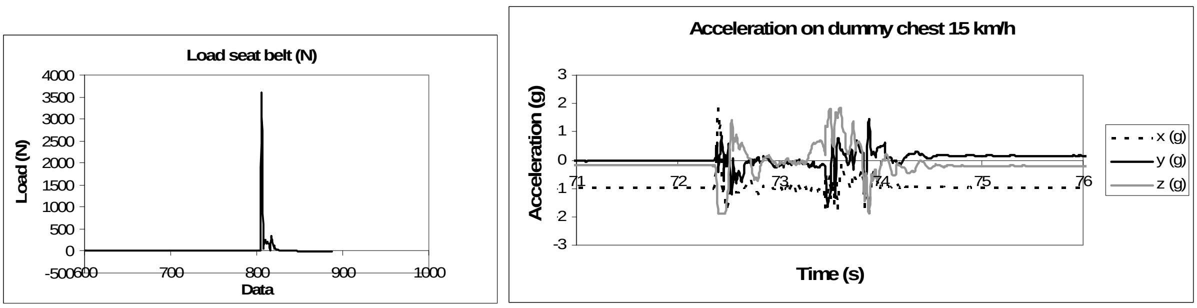

(c)

Figure 8. Undamaged sled test results a) Strength of seat belt and acceleration of dummy chest at 5 km/h; b) Strength of seat belt and acceleration of dummy chest at 10 km/h; c) Strength of seat belt and acceleration of dummy chest at 15 km/h

CONCLUSIONS

The SOSBET system is still in prototype stage; other tests are planned and modifications on releasing mechanism and spring will follow. Impact tests were performed by two different methods. In the first method, sled was hit to the reinforced wall with hard foam and loads and accelerations were measured. According to test procedure written in the code, tests for anchorages are only applied statically for simulating an overturning accident. This test does not cover collisions such as going off road, hitting to pedestrian, on highway collisions etc.

Therefore this test should be considered again. An extra test can be applied without any angle or at angle of 10-15^o to the horizontal for checking the slide of seat and frontal accident. Moreover, tractors have been identified as moving 40 km/h (25 mph) or less but some new tractors may now travel up to 72 km/h (45 mph). Therefore seat belt test loads should be considered respect to probable tractor speeds.

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