Spring 61

SEATBELTS

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THE VALUE OF THE AUTOMOBILE SAFETY BELT,

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The main purpose of the safety belt is to reduce the risk of serious injury in accidents or near-accidents. To serve this purpose, the belt should prevent ejection from the car and offer a better way of reducing the speed of the occupant than does the interior of the car. But we cannot expect that a device, simple enough to be used in everyday traffic, should be able to do so in any type of car accident. Therefore some limitations must be accepted. Now the most dangerous accidents are those involving head-on collision and the most dangerous injuries are those sustained by the head and thorax.

The greatest reduction in the risk of serious injury would be obtained if the belt were to function along these two lines and in accidents where the passenger compartment was mainly left intact.

It has been shown that there is a different risk of injury for different seats in the car much higher in the front seats and highest in the front passenger seat. Why is it so?

One explanation is that, in practically all head-on collisions, the front seat is torn loose and slides forwards increasing the weight to be stopped and decreasing the space for the front seat occupants. At the same time, the space for the back seat passengers increases as the frontal limitation moves forwards when they reach it, adding their weight to it.

For the driver, the situation is not the same as for the front seat passenger. He has a better chance to be prepared in case of emergency with his feet resting on the pedals and his arms on the steering wheel. In this situation his muscle power will be practically no help, but a considerable part of his body weight will be decelerated with the car.

We must bear in mind these different situations affecting each occupant. As it is generally accepted that each safety belt is intended for one person only, the belt should in principle not be expected to take extra weight from seats, baggage or back seat passengers. Therefore it should be capable of taking the full weight of the occupant which is not decelerated with the car itself. It has seemed reasonable to the authorities in Sweden to calculate with a maximum of 60 kg for an adult, since his feet are supposed to rest on the floor.

Deceleration should take place in a frontal direction where enough space is available. The sideways-directed forces are, in the majority of accidents including those of overturning, so slight that they are no real problem with a properly designed safety belt.

The degree of deceleration varies considerably in different types of accidents and of course with the impact speed. It is often said that hitting a wall would give the highest deceleration, but there are still worse examples to be found. At the moderate speed of, say, 40 km/h it is often very dangerous to hit a lamp-post or a tree with the centre of the front, where practically nothing is in front of the engine to take the load, resulting in a very abrupt stop. When two cars of the same weight, travelling at the same speed, hit each other symmetrically, it would theoretically be the same as if one of them hit a wall at the same speed. But if one of them is heavier or has a higher speed, the other one will not only be stopped but will be pushed backwards. In other words, the latter's speed will be reduced not only to zero but to a negative level. What we call impact speed is therefore the difference between original speed at the moment of contact and the speed after impact, being negative if the car moves backwards and positive if it moves forwards. It is very seldom zero after impact.

Since the deceleration of the car varies within wide limits, for what value of the peak deceleration should the belt be designed? That is no doubt a complicated question, and even the formulation of the question is somewhat inadequate. Deceleration is not the only quantity that determines the degree of damage to the human body. Impact speed itself is also an important quantity. It is evident that, under the conditions prevailing in car accidents, some parts of the human body are somewhat insensitive to deceleration, but very sensitive to impact speed, that is the degree of damage of these parts is the same whether the belts are stretched two or three dm or not at all. Among such parts of the human body are probably certain internal organs. Other parts of the body, especially certain skeletal parts are, in car accidents, sensitive to the deceleration itself and there are for instance evidences of severe localised injuries to the bone structure near the site of the belt if the belt has been too stiff. Other evidence is sometimes found in cases where people have fallen from high altitudes, such as eight or ten metres, on to hard ground and survived with only a few fractures. In these cases, deceleration has been extremely high but impact speed has been sufficiently low. From this we may conclude that it is desirable to stretch the belt as much as possible in order to avoid certain types of injury. An upper limit is given by the construction of the car, as the belt cannot reduce the risk of serious injury if the passenger compartment is not left mainly intact during the accident.

It is quite obvious that a high peak deceleration can be reduced by a proper stretching of the belt, but then the time that the force acts upon the occupant will be longer. But it is not only force, time and speed that have influence on the tolerance. The direction of the force is also important. The tolerance against deceleration in the long axis of the body is much lower than against deceleration in the upright seated position.

Our requirements for a good safety belt should thus be:

1. It should be designed for one person only.

   All extra weight from seats, baggage or back seat passengers should if possible be prevented from acting on the belts.

2. It should ensure that at least the vital parts of the body are held together within the car during deceleration.

3. It should maintain the occupant in an upright

seated position during deceleration.

The tolerance is best in that position, and the vital parts of the body are as far away as possible from dangerous fitments.

4. It should reduce the peak deceleration to values within the tolerance of the skeletal system by a proper stretching of the webbing.

The stretching should be limited to prevent the occupant from hitting dangerous fitments and to be well within the tolerance of internal organs. The energy stored in the webbing during stretching should not be released to cause a serious rebound effect.

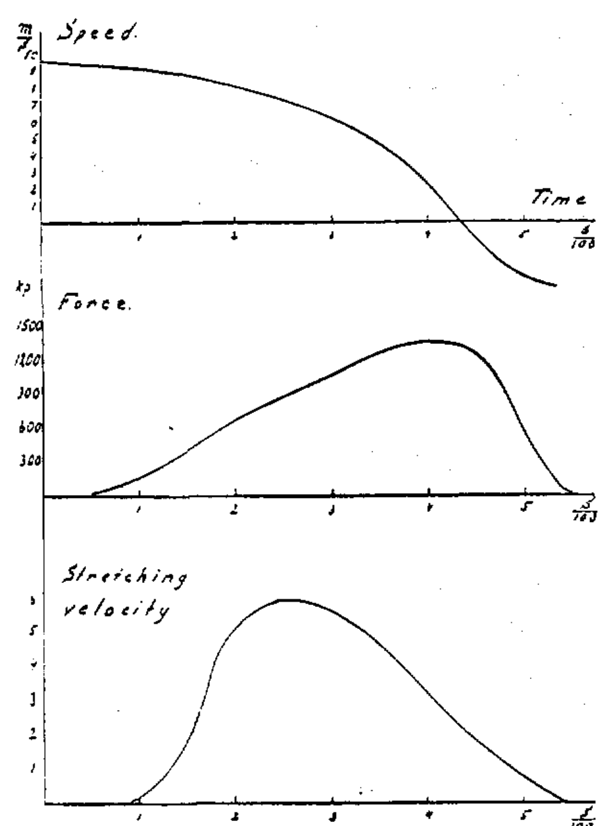
5. It should be designed in such a way that the forces acting on the occupant during deceleration are tolerable.

There should be no risk of the belt forming a loop around the occupant's neck or the soft parts of his abdomen, nor should it compress the back of the occupant during deceleration.

Within the above-stated limitation—decelerative forces during automobile accidents where the passenger compartment is left mainly intact—we shall of course use the belt up to the possible limit of deceleration, otherwise we have not reduced the risk of serious injury to the utmost. Is it possible to make such a safety belt? To answer that question, we have to study the problem dynamically and I would like to stress the point that it is not possible to draw sufficient conclusions from a static test only.

Is there enough time for the stretching to take place before the force reaches its top value? The answer is yes. As you can see from the curves in fig. 1 the top value of the force is reached at about the time the speed of the weight loading the strap is about zero. Increasing the weight will not change the shape of the curve. So the differing weight of the adult occupant will not cause much trouble. But what happens if we increase the impact speed?

Fig. 1.



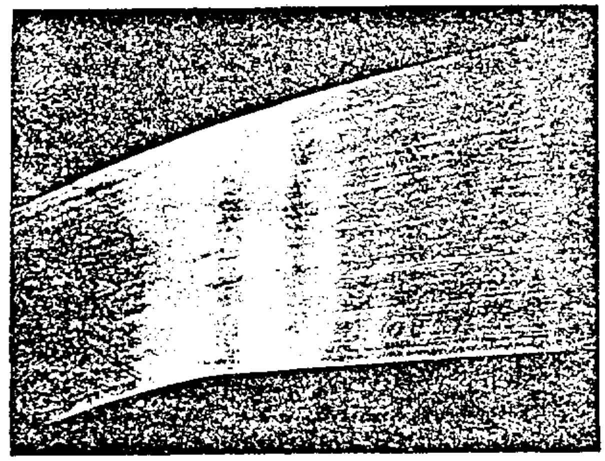


Fig. 2.

That raises a very interesting problem because increasing speed will increase the load much more than increasing weight. To answer the question we will have to study the stretching velocity in the strap. In these curves the stretching velocity is plotted on the vertical axis, the horizontal axis representing time. We can see here that the stretching velocity is not at its highest when the force is at its highest. That means that overloading the strap by increasing weight will cause breakage when the stretching velocity is decreasing or when the speed of the loading weight has been considerably reduced. That is even if the belt is overloaded by weight to cause breakage, it takes a considerable amount of energy before breakage and the force acting on the occupant is determined by the tensile strength of the strap.

If, on the other hand, the impact speed is increased, the stretching velocity will increase, the breakage point moving forwards in the curve and at a certain speed the strap will break before it has been able to take up much energy. It has therefore been of interest to study the nature of the stretching process in textile straps.

Theoretically the stretching of the strap would not be an even movement but a strain-wave would pass along the strap at high speed causing an uneven movement in the strap. But would it be possible to register such a wave in the strap? It has been possible and in fig. 2 it has been photographed passing along the strap several times during the few hundredths of a second that the stretching takes place. The speed of the strain-wave is in this case about 250 m/s. It is evident that if one end of the strap is given that velocity the strap will immediately break, independently of the loading weight. In fact this will occur even for lower velocities. The lower limit of these velocities is called the critical velocity and may perhaps be about 50-100 m/s for materials of this kind. That limit is probably high enough to give a fair margin in automobile accidents.

The stretching of the belt is a combination of an elastic and a plastic deformation and it is important that the plastic deformation remains the dominating part under any conditions or the occupant will be snapped back by the belt after impact and thus will increase his impact speed. But if the plastic deformation is the dominating one, we must remember that the occupant will probably leave the belt in the foremost position and then the movements of his body will not necessarily be under the control of the belt. It is important to remember this in judging the effect of the belt.

We have now seen that it is possible to reduce the peak deceleration and thereby the peak force on the occupant by a proper stretching of the belt. From experience gained in Sweden we know that reducing the stretching too much will increase the risk of damage to the skeletal system. The same result will ensue if the belt is not properly adjusted so that the occupant is thrown against the belt upon impact. But how will the stretching interefere with the tolerance of internal organs? That highly complicated question is subject to a very careful investigation but has not been definitely answered yet. From the experience gained in hundreds of accidents where belts complying with Swedish standards have been used, it seems that the risk of injury to internal organs is very low. But of course the question of whether the belts could be improved still remains. I should like, therefore, to give some information about the dynamic action of some types of belts.

The single lap strap does not comply with the above mentioned requirements: it does not maintain the occupant in an upright position, it does not protect the head and thorax and it does not hold the vital parts of the body together within the car during an accident, so it has not been considered as a safety belt in Sweden.

The shoulder harness was one of the first types to be used in Sweden and it was thought to give very good protection. As you can see from fig. 3 it has certain disadvantages. It consists of one lap strap anchored at one point just behind the seat and attached to it in front two shoulder straps, anchored at another point at least 35 cm behind the first. If the occupant is wearing thick clothes it is practically impossible to place the lap strap low enough with only one anchoring point and

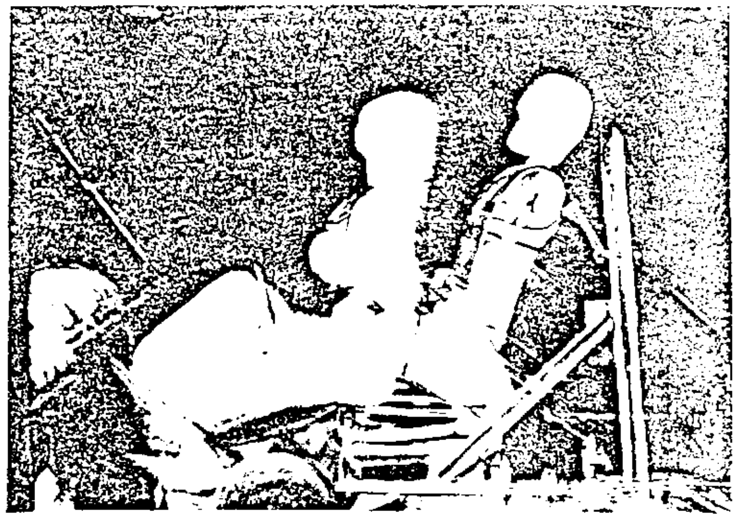


Fig. 3.

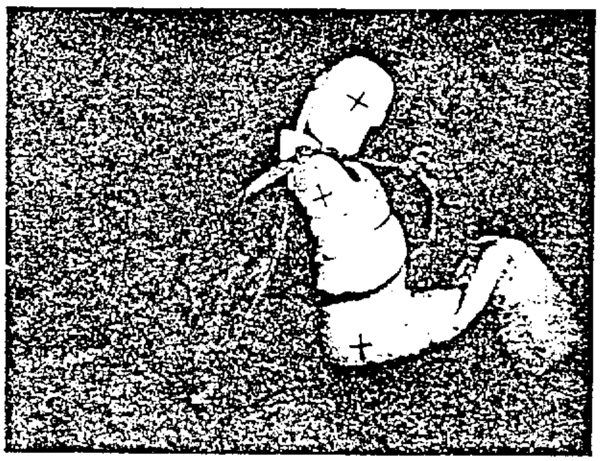


Fig. 4.

during deceleration the shoulder strap will tend to move the lap strap upwards, sometimes as high as the edge of the lower ribs. Now the anchorage of the shoulder straps to the floor will result in them being placed at a very unsatisfactory angle, so that the upper part of the dummy is pushed forwards and downwards during deceleration. If therefore the belt is overloaded and the lap strap is broken the belt will form a loop around the occupant's neck (fig. 4).

Fig. 5 shows a diagonal sash or a two point belt anchored to the doorpost and to the floor. Here you can see that the dummy is bending somewhat over the belt as it is decelerated a little below the point of gravity. If the belt is placed a little higher on the body the lower part of it will tend to move forwards. Therefore it is important to place the anchoring points properly and to adjust the belt correctly to the occupant.

Fig. 6 shows the combined diagonal sash and lap strap or the three-point belt anchored to the doorpost and at two different points to the floor. Here the diagonal and the lap strap are two parts of the same strap which allows a certain degree of self-adjustment, making it rather comfortable to use—the dummy is moving practically parallel with itself. The proper placing of the anchoring points is of course important even here.

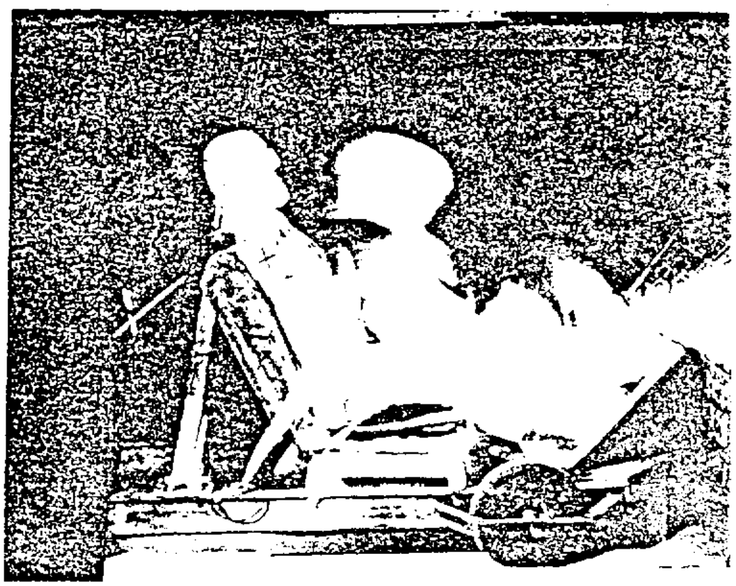


Fig. 5

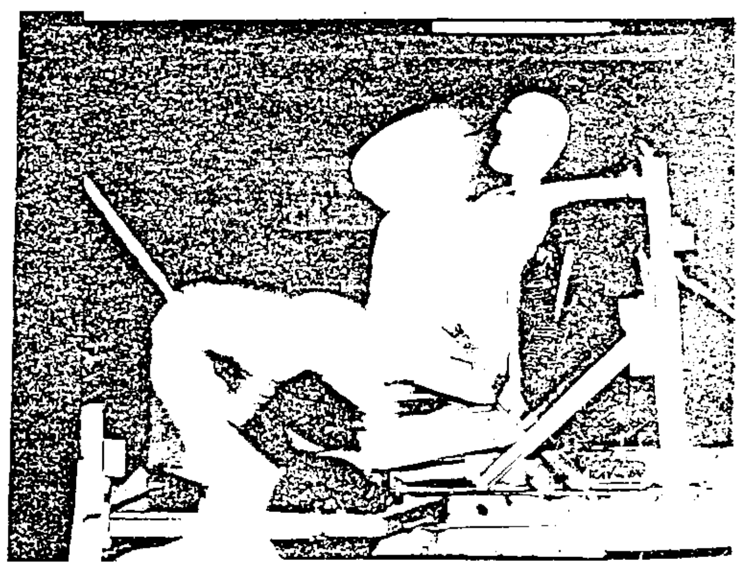


Fig. 6

The good safety belt should also have a quick-release buckle to give the occupant a chance to leave the car if it should catch fire or fall into water after the accident, for even if that happens very seldom the use of a safety belt is the best way to remain conscious after such an accident and thereby having a chance to get out of the car.

Even if we are far from knowing how the ideal safety belt should be designed, because our knowledge is very scanty, we must admit that a good safety belt can save many lives and much suffering if it is used in automobiles during an accident—and since we never know when an accident will happen, the belt should be used on every car trip, even at low speed.

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