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CONSIDERATIONS ON PRESENT SOLUTIONS FOR PASSIVE SAFETY SYSTEMS OF MOTOR VEHICLES

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ABSTRACT: Carmakers aim is to prevent, correct and protect any participant when an accident occurs. Because some accidents cannot be avoided, carmakers equips its vehicles with systems designed to protect all passengers, such as seatbelts, airbags, vehicle structure and the *Isofix* anchor point system.
The seatbelt remains the single-most effective item of safety equipment in any car. It is the most fundamental part of any restraint system and manufacturers are continuing to develop new and better seatbelt systems to provide ever greater protection. The first section of paper described the car's safety systems and the most important elements of the seatbelt and the importance of using it. In the second part of the paper were presented the materials used to manufacture the seat belt webbing, the advantages and disadvantages of these materials and their properties.

KEYWORDS: safety system, safety belt system, pretensioner, webbing

❖ GENERAL CONSIDERATIONS ON THE SOLUTION USED FOR MOTOR VEHICLE SAFETY SYSTEM

One of the most important features of a car is safety. In recent years, driving safety has taken a new dimension, with systems becoming more complex. The safety car's safety systems are divided into active and passive safety systems

Active safety includes everything that is there to avoid an accident: brakes, brake lights, headlights, ABS, ESP stability system, the monitoring system of wheels and tire pressure, anti-glare mirrors, height adjustable steering wheel, etc.

Passive safety includes constructive measures aimed at protecting vehicle occupants against injury or at least reduce the risk of injury: safety belts, airbags, impact absorption area, the guarding of the head, chest, etc.. Passive safety systems are all systems that react in situations with increased risk for the driver to help them overcome, this are shown in Figure 1 and Table 1.

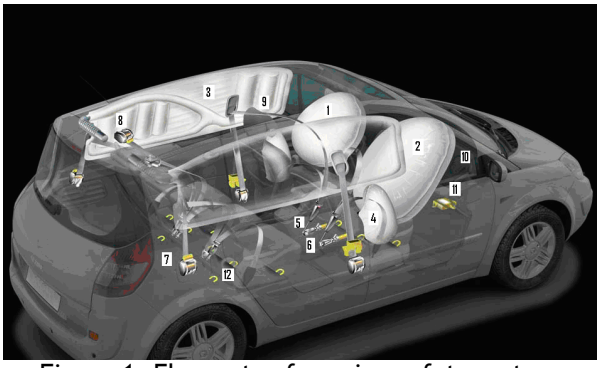


Figure 1. Elements of passive safety system

There is also a third category of security systems that post-accident, whose purpose is to avoid another bad incident, an accident occurred, which may take a lifetime survivors: for example, the fire, which can occur after an accident.

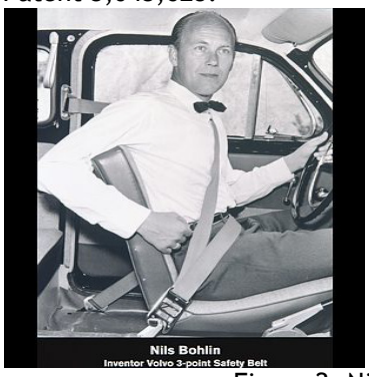
Table 1. Notation of passive safety system elements

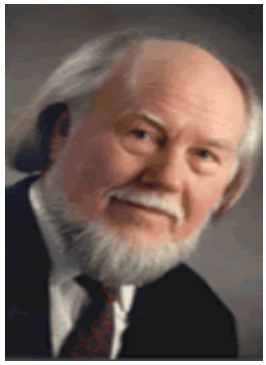
1. Front airbags for driver	7. Right-back pretensioner device
2. Airbag front passenger	8. Left-back pretensioner device
3. Side-curtain airbags for side windows (left and right)	9. Fixed headrests
4. Side airbag front (left and right)	10. Dashboard damped structure
5. Pretensioner device, driver	11. Calculator opening shock sensing airbag
6. Pretensioner device, passenger	12. Child seat fastening systems “Isofix”

Passive safety system comprises occupant restraint system crash (seat belts) and cushions (airbags) inflatable which increase surface contact and reduces shock. Body structure and bumpers must be designed and constructed that the central cell in which the vehicle occupants to remain intact, the impact energy being taken from the rest of the car, these factors are objective rules, such as STAS 6926 / 22-82, ISO 3208:1998, ISO 3560:1996, ISO 7862:1999, SRISO 3984:1996, ISO 3784:1996, ISO / TR 10982:1998.

❖ SAFETY BELT SYSTEM

The man who brought the seatbelt in car was Swedish engineer Nils Bohlin. He invented the 3 points of support to Volvo, which starting in 1959, each vehicle equipped with new inventions under U.S. Patent 3,043,625.





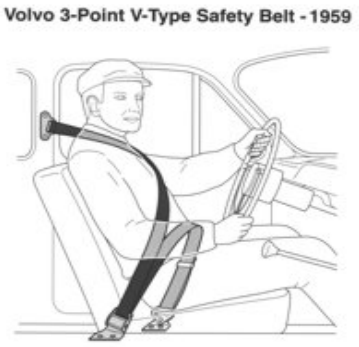


Figure 2. Nils Bohlin – Inventor Volvo 3-point Safety Belt

Bohlin's invention application for registration was filed with the German Patent Office in 1958, and belt geometry invented by Swedish engineer is a V upside down, placed obliquely.

Safety belt is so effective that he retained the features and purpose of 1949, when Volvo introduced the first car equipped with such, until today. Even if, over the years, modifications and improvements have been made seatbelt, its purpose has remained the same: a fabric belt, polypropylene, resistant to huge forces, designed to keep the body attached to the chair, in case of an accident. Seat belts were the first attempt by carmakers to address what auto researchers in the 1960's called the "second collision" that occurs during crashes. First collision is when the car hitting something - other car, a tree, a road sign. The second collision involves riders in the car hitting parts of the car's interior. Simply, a car's occupants are traveling at the same speed as the car when it hits an obstacle, and the harsh reality is that absent some form of restraint, occupants will crash into the dashboard, steering wheel, seatbacks, window pillars etc., at that same speed. According to NHTSA, three-point belts are very effective in reducing the chance of death or serious injury from a second collision. Government officials estimate the belts reduce fatalities by 45 percent and serious injury by 50 percent.

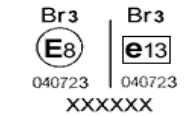
According to consecrate already in the literature, failure to use safety belts in the back seat is, in case of accident, unimaginable effects: every year between 8 and 15 people who travel on the front seats are injured, killed by people traveling in the back seat and not wearing seatbelt. The impact force is equal with 30 times your body weight.

It is important to note that all models equipped with modern airbag if the seat belt is not connected, it does not work airbag. And the reason is obvious: the human body to impact, with no belt holder, will throw to the bag, but its power can easily break column. Many such fatalities happen, especially in cars whose drivers have taken care to escape the noise signal of belt mounted, putting it behind the seat in normal position. There have been cases of fatalities caused by the airbag, not necessarily an accident.

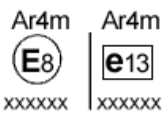
A belt should be clearly marked to indicate that it is authorized by recognized international standards for example – "E" (*Economic Commission for Europe*), or "BSI" (*British Standards Institute*). Components seatbelt requirements of Directive 77/541/EEC, and then amended by Directive 2005/40/EC and ECE Regulation 16.04.

Seatbelt webbing it was made of nylon strap. Swedish carmaker *Volvo* introduced in 1959, for the first time in 3-point car belt, patented a year earlier. This was also the same size, 2 inch, and built everything from nylon.

In 1962 *Saab* introduced the 2-point belt, and in 1968 one in three points. In 1965, U.S. automobile manufacturers began installing on all machines the 2-point safety belts. From January 1968 the *U.S. National Highway Traffic Safety Administration* has made the mandatory 2-point and the 1974 *NHTSA* allowed in only those three points.



E –ECE approval
e – EEC approval



A = 3 or 4 point mounting Lap and Diagonal Belt
B = 2 point mounting Lap Belt
r= Safety belt with retractor
3 = Automatic locking retractor
4 = Emergency locking retractor
m = Multiple sensitivity

Figure 3. Notations for European Standard

Seat Belts are tested and approved to European and National Standards as and when required. Seat Belts and Harnesses generally comply with one or more of the following: ECE R16 and EEC 77/541,

FIA 8854/98, FIA 8853/98, SAE J386 & SAE J2292, ISO6683. Identification of the relevant standard is carried on the product. Products are also marked as required to identify the manufacturer, product, types etc.

Standards Bodies are: *ECE - Economic Commission for Europe, EEC - European Economic Community, ISO - International Organization for Standardization, FMVSS - Federal Motor Vehicle Safety Standard, SAE International - The Engineering Society for Advancing mobility Land, Sea, Air & Space*. The European Standards notation shown in Figure 3 and the number after 'E' and 'e' denotes country where approved: (i.e. France - 2, Italy - 3 & Luxembourg - 13). The first series of numbers denotes approval number. The bottom series of numbers denotes serial number.

❖ SUBSYSTEMS AND COMPONENTS

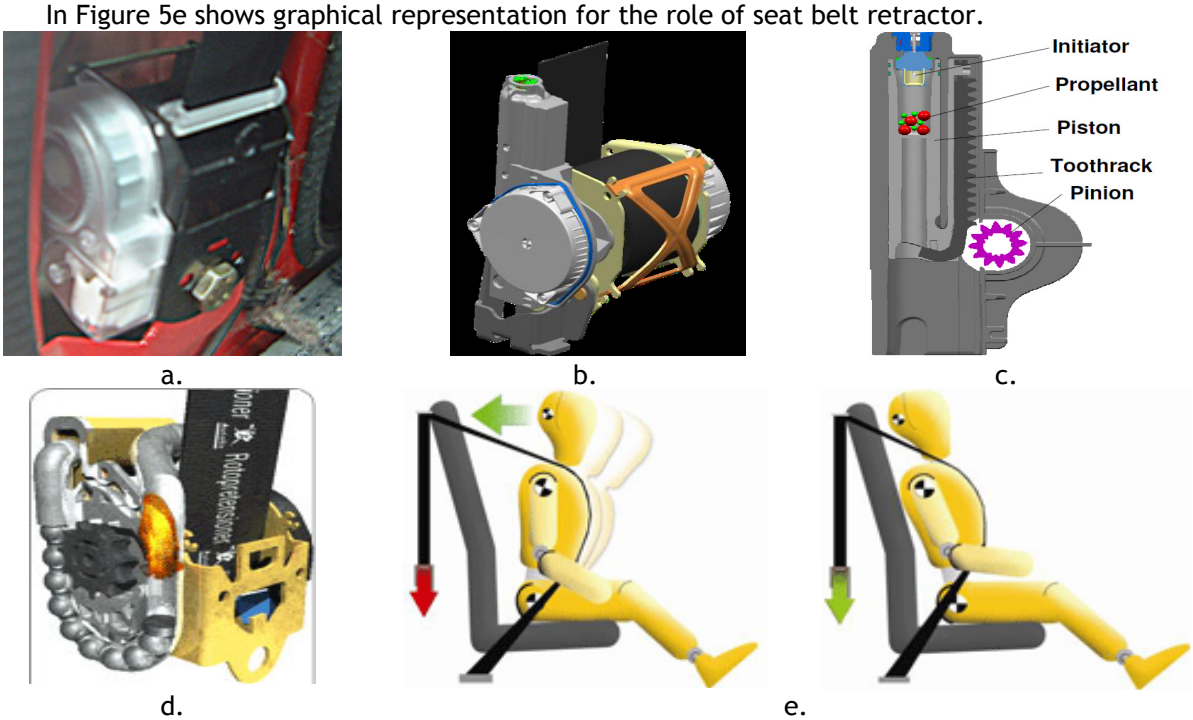
The components of a safety belt system are shown in Figure 4. Webbing is a flexible component of the seatbelt system designed to maintain the body and transmit the requests to the anchor elements. The webbing is made of thousands of woven polyester yarns, generally black. Made to a high specification and designed to elongate by 10% to 15% in an accident to absorb energy. Other colors in the standard range: Red, Blue, Grey and Beige. Webbing is generally about 50mm wide, wider webbing (i.e. 75mm) is used on some "special" applications and Race/Rally Harnesses.

Figure 4. Seatbelt components

A properly used seat belt fits snugly over the pelvis and across the chest. In a crash, the seat belt retractor locks and the webbing prevents the occupant from moving into contact with hard portions of the vehicle's interior, thus reducing the potential for injury. Seatbelt pretensioners are routinely operated pyrotechnic devices that are designed to eliminate the space between the belt and the occupant's body. Depending on where they are mounted in relation to seat belt pretensioners different types of devices can be grouped into the following categories:

- ***Pretensioners with belt retractor mechanism*** of the front seats are usually mounted on the inner side of the upright pole as can be seen in Figure 5a and Figure 5b.

In Figure 5e shows graphical representation for the role of seat belt retractor.



a. b. c.

d. e.

Figure 5. Retractor pretensioner

Depending on operating mode, pyrotechnic belt retractor can be triggered with mechanical or electrical, but the latter showing a lower safety in operation as a mechanical impact, although minor, may induce the arrival of the trigger pyrotechnics.

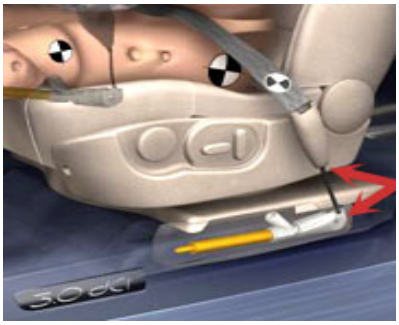
Safety belt retractor is designed to bring the occupant's body in a safe position to bodily integrity, because during a collision under the action of inertia forces, it tends to continue moving the vehicle in motion printed, also known as Roll-up device, Retracting, Inertia Reel, Automatic Reel and Automatic Seat Belt. Designed to stow webbing not in use and lock in a predetermined situation.

The safety belt must support the case for passengers in an accident, which is necessary to set tight. This requirement is not observed in all cases due to the clothes of passengers and automatic system running too loose: this effect is called the belt loosening. Device safety belt pretensioners with pyrotechnic trigger tension offset by weakening its belt in an impact.

- ***Pretensioners attached to the safety belt restraint system***

Tensioning devices are currently set in the area at the bottom of the front seats, inward, as can be observed in Figure 6a and Figure 6b before and after activating the device. Horizontal cylinder contains a piston, which is powered by a gas generating pyrotechnic charge, shown in Figure 7. In turn, the piston cable leads attached belt buckle (Figure 8) that with draws strong strap belt tensioning.

Pyrotechnic pretensioner systems are controlled by the crash sensors responsible for deploying the vehicle's air bags. When activated the pretensioner pulls down on the seat belt buckle or rewinds the belt's retractor spool in order to eliminate any slack in the system. Most pretensioners use a small pyrotechnic charge to help quickly remove slack, if present, from the seatbelt system and restrain the occupant earlier in the event. Pretensioners can be integrated into the buckle or retractor and take up seatbelt slack using the retractor mechanism or by pulling the seatbelt buckle downwards toward the vehicle floor.



a.

Before activation – free seat belt

b.

The piston is driven along the tube from left to right. The compression in the lap belt stalk after activation.

Figure 6. Pretensioner devices attached to the safety belt restraint system

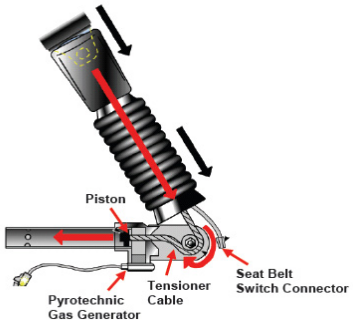


Figure 7. Pretensioner - compression in the lap belt

Figure 8. Seat belt buckle

Once the pretensioner has fired, additional occupant safety system components such as TRW's seat belt retractors and airbag system will work together to help further manage the energy of the occupant. Pyrotechnic pretensioners, like airbags, need to be replaced once they have been activated.

Device safety belt pretensioners are triggered by a gas generator control system through the airbag. Limit the trigger device for seat belt pretensioners is lower than the front airbag, which means that in some cases, it will act in a serious accident which is not sufficient to trigger the airbag loader. Considering that the body belt is closer to passengers, they perceive faster deceleration of the vehicle and the body burden is distributed more evenly throughout the capture process, which reduces the risk of injury.

Pretensioner can be:

- **"System with double pretensioners and seat belt passed limiting the effort"**, Figure 6a, which aims to suppress the space between the strap and body belt and allows the occupant to get the maximum deflection due to vehicle depreciation during shock.

Belt pre-tension takes place in two stages: first, pre-tension is manifested in the diagonal strap and is accompanied by limitation of effort, thereby protecting the chest cavity and the clavicle occupant; this process is launched under a force of at least 400 daN. Then, in operation a second system that works similar, but the waist belt strap, whose end is equipped with a stress generally set at a value of 600 daN is fixed on the coupling of the belt to sedan model (the fastening system of seat coupé).

- **„The device with safety belt pretensioners repetitive"** contained in the pre-collision equipment that have appeared on the market with PRE-SAFE system from *Mercedes Classe S* (e.g. one called ACR for Active Control Retractor, manufactured by the company Automotive, 2002, electronically controlled and powered by a DC motor) is detected when the serious risk of collision, the system automatically pretensioned safety belts, equipment allowing repetitive restriction strap belt tensioning device which acted fireworks can not provide.

Evolution of the seat belt effort depending on the time of impact, for seatbelt with or without pretensioners system, can be seen in the graph in Figure 9.

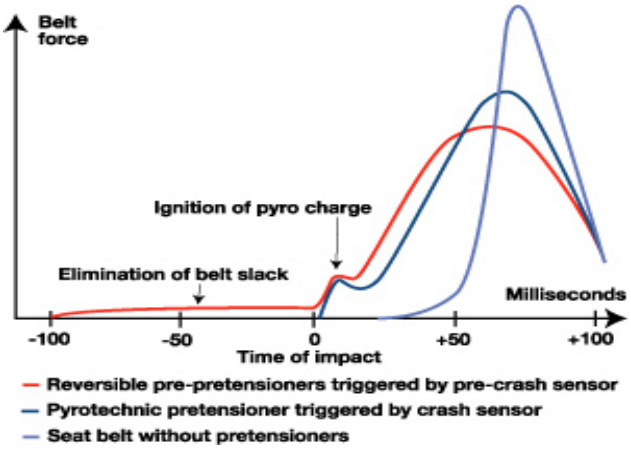


Figure 9. Evolution of the seat belt effort depending on the time of impact

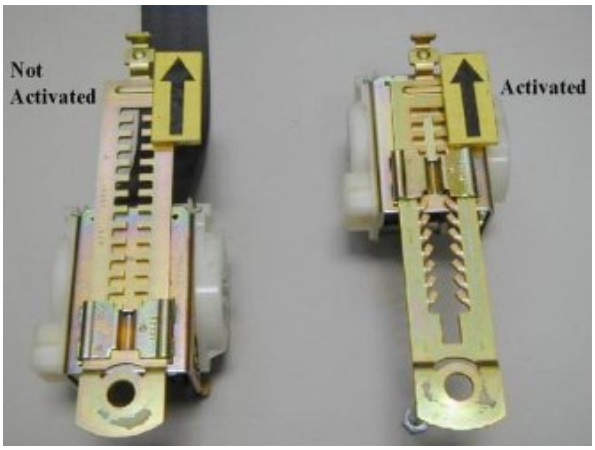


Figure 10. Mechanical load limiting device

Load limiters absorb the load in a crash in a very efficient way by keeping the belt force at a controlled and pre-defined level; this is shown in Figure 10. This is accomplished by a mechanism in the retractor that allows webbing to be pulled out slightly – and in a controlled way – if the load on an occupant's body becomes too high in a violent crash. The system is typically used in combination with an airbag which then absorbs the excessive energy. This is especially important for elderly, since studies have shown that a 60 year old person can only take half as much load on his rib cage as a twenty year old person. A load limiter is designed to allow the seat belt force applied the chest to rise only to a point where serious injury is unlikely. This is especially important for the elderly who have less tolerance to high collision forces.

A seatbelt buckle must be able to withstand extremely high loads during a crash. At the same time, it must be easy to open even when heavily loaded (if, for instance, a person is left hanging upside down in the belt).

A number of manufacturing companies (for example, *Autoliv*) have developed a unique system patented by the buckle is designed to withstand high accelerations in all directions, without opening. The solution is considered critical when the seat belt system includes a device with pretensioner, because it quickly pulls the buckle to the floor.

In general, most current safety belts are equipped with coupling devices of the kind shown in Figure 8.

❖ MATERIALS USED FOR MAKING SEAT BELT WEBBING

After 1970, automobile manufactures have begun replacing the nylon fabric used as seat belt webbing with other materials such as polyester, polypropylene and cotton, or combinations of these.

POLYAMIDE 6.6 or, as is known in popular terms, nylon has exceptional torque characteristics, moisture, water absorption is very weak, has high resistance to chemical and biological agents, is non-crease, retain high heat, can be smooth, matt , semi or gloss with exceptional traction and abrasion resistance, gives smoothness and elasticity and has good insulating properties.

The disadvantages of nylon are: sensitivity to light, electrostatic charges has great tendency to pilling-site training, and the molten droplets during combustion is dangerous drops penetrate into the skin which causes severe burns.

It is used in blends with cotton, which leads to increased resistance to wear and stretching, weight decreases and knit fabric. It is used in technical products such as ropes, nets, straps and pneumatic belts.

Nylon-6.6 (PA66) is semi crystalline polyamide commonly used in fiber applications such as carpeting, clothing, and tire. It is also used as an engineering material in bearings and gears due its good abrasion resistance and self-lubricating properties. Nylon is strong and elastic, it is easy to launder and dries quickly, it retains its shape, and it is resilient and responsive to heat setting.

POLYPROPYLENE is very easy - the PP is easy and only one with a density less than 1, products obtained are non-crease, has very high resistance to chemical and mechanical resistance is not attacked by insects and mildew and is a very good insulator heat.

The disadvantages are that they are hard to remove greasy stains, has a very weak absorption of perspiration and low resistance to the action of UV and weathering

Pure polypropylene is used for carpets, filters, sports and stringed mixed with wool is used to achieve tracksuits, sweaters, and cotton blend as underwear.

It is used for making high strength geo-textiles because it is not moldy and rot in the field of transport is used for truck tarpaulins belts due to abrasion resistance and low weight at the seams due to industrial and high resistance.

COTTON FIBERS are resistant to breakage have good hygroscopicity which makes it hygienic, pleasant to wear, resistant to solvents and weak acids, and giving flexibility, strength and elasticity. Disadvantages of cotton fibers are flammable, decompose at about 160° C and are sensitive to sulfuric acid. They are used in clothing, lingerie, industrial and technical fabrics.

Cotton it is soft and comfortable, it wrinkles easily and absorbs perspiration quickly, it has good color retention and is good to print on, and is also strong and durable; it is easy to care for, easy to wash.

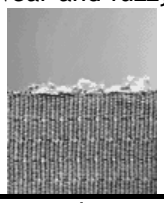
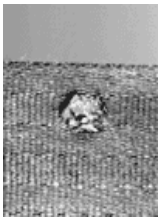
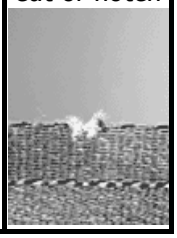
Properties of cotton fibers are presented in Table 2 and properties of nylon and polypropylene in Table 4.

Various signs of wear or degradation of the safety belt strap, which lowers the resistance in case of an accident, are shown in Table 3, and examples of weakened webbing supported and ultimate strength is shown in Figure 11.

Table 2. Cotton properties

Property	Fiber cotton
Shape	Fairly uniform in width, 12-20 micrometers; length varies from 1 cm to 6 cm (½ to 2½ inches); typical length is 2.2 cm to 3.3 cm (⅞ to 1¼ inches).
Tenacity (strength)	
Dry	3.0-5.0 g/d
Wet	3.3-6.0 g/d
Density	1.54-1.56 g/cm^3
Moisture absorption	
raw: conditioned	8.5%
saturation	15-25%
mercerized: conditioned	8.5-10.3%
saturation	15-27%+
Resistance to :	
acids	damage, weaken fibers
alkali	resistant; no harmful effects
organic solvents	high resistance to most
sunlight	prolonged exposure weakens fibers.
microorganisms	mildew and rot-producing bacteria damage fibers.
insects	silverfish damage fibers.
Thermal reactions :	
to heat	decomposes after prolonged exposure to temperatures of 150°C or over.
to flame	Burns readily.
Filament tex (tex)	0.24
Peak extension (%)	5.4
Peak strength (mN/tex)	152.2
Favorable travel temperature range:	below 25°C (77°F)
Optimum travel temperature	21°C (70°F)
Glow temperature	205°C (401°F)
Fire point	210°C (410°F)
Autoignition temperature	407°C (765°F)
Coefficient of friction	0.25 (for raw dry cotton, otherwise strongly changes for treated and/or wet fiber)

Table 3. Typical signs of wear and degradation

Typical signs of wear, holes and degradation:		
wear and fuzzy 	broken buckle 	weak bonds 
retractor damaged or broken 	holes 	cut or notch 

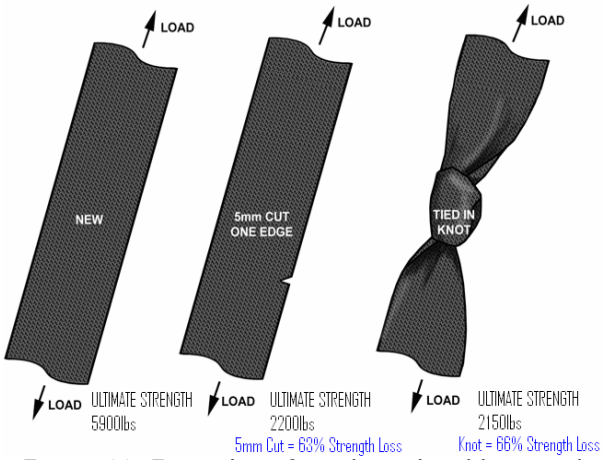


Figure 11. Examples of weakened webbing and ultimate strength supported

Table 4. Polyamide 6.6 and polypropylene properties

Physical Properties	Nylon 6.6 – Polyamide 6.6.	Polypropylene
Density	1.02 - 1.49 g/cc	0.886 - 1.70 g/cc
Water Absorption	0.420 - 9.00 %	0.000 - 1.00 %
Moisture Absorption at Equilibrium	0.170 - 8.00 %	0.100 %
Water Absorption at Saturation	7.00 - 9.00 %	0.0100 %
Viscosity Measurement	36.0 - 260	80.0 - 500000
Melt Flow	13.0 - 148 g/10 min	0.200 - 2000 g/10 min
Mechanical Properties		
Hardness, Rockwell M	55.0 - 90.0	20.0 - 117
Hardness, Shore D	55.0 - 84.0	47.0 - 83.0
Ball Indentation Hardness	85.0 - 170 MPa	62.0 - 106 MPa
Tensile Strength, Ultimate	20.7 - 170 MPa	9.00 - 80.0 MPa
Tenacity		0.203 - 0.441 N/tex
Tensile Strength, Yield	13.5 - 110 MPa	12.0 - 369 MPa
Elongation at Break	3.50 - 1500 %	3.00 - 900 %
Elongation at Yield	3.40 - 65.0 %	3.50 - 35.0 %
Modulus of Elasticity	0.240 - 5.50 GPa	0.00800 - 8.25 GPa
Flexural Modulus	0.290 - 8.30 GPa	0.0260 - 6.89 GPa
Flexural Yield Strength	11.0 - 135 MPa	20.0 - 180 MPa
Compressive Yield Strength	7.00 - 90.0 MPa	34.5 - 55.2 MPa
Coefficient of Friction	0.260 - 0.420	0.250
Thermal Properties		
Melting Point	197 - 265 °C	61.0 - 180 °C
Deflection Temperature at 0.46 MPa (66 psi)	60.0 - 246 °C	13.0 - 238 °C
Deflection Temperature at 1.8 MPa (264 psi)	37.8 - 250 °C	37.0 - 149 °C

❖ CONCLUSIONS

This paper refers to general considerations on the solutions used for passive and active safety systems in motor vehicles, represented by constructive measures aimed to avoid accidents and protect vehicle occupants against injury. The paper also refers to the seat belt system, which is its constituent parts, and materials used to make belts and situations of poor quality or damage that may occur over time and lead to an inefficient use of safety belts.

Over the years technology has evolved so that vehicle manufacturers, but not only them, put great emphasis on occupant safety, devoting a whole concept *SQCD (Safety - Quality – Cost – Delivery)*. Thus the choice of product safety comes first, from the smallest element that goes into safety systems and to the choice of purchasing a new or used car.

Even small improvements in the safety system can have an amazing effect on the final customer – the owner / driver of the vehicle. An increasing number of new functionalities that enhance safety and driving performance or increase the level of comfort are included in modern cars, while first passive safety systems like airbags were integrated, later systems, that directly affect the driving process, like active cruise control were added. Additionally more and more complex information systems, for example: navigation systems, restaurants guides or telephone systems have become in recent years of general interest and driving safety has taken a new dimension.

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