ACCELERATION TEST MACHINE

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Abstract: Road transport of cargo is increasing year by year. The European action program on transport safety aims at an increased safety level. One important aspect of transport safety is load securing: in normal road conditions - including sudden change of lanes and emergency braking - the cargo should not move on the vehicle. In this text a very simple and efficient method for load securing is described. The method is based on the idea of "rigid load units". Also a test machine to certify and optimize the rigidity of a load unit is described.

Keywords: road transport, cargo safety, acceleration test.

1 Cargo Securing Methods

The idea behind cargo securing is that the cargo should not slide, tilt, wander nor deform on the truck. Sliding and tilting can easily be understood. Inertia forces that can cause sliding or tilting are known very well: 0,8g in the forward direction, 0,5g in the sideward and backward directions. Wandering is a phenomenon related to vibration of the vehicle. At inspection it is found that the cargo or part of the cargo has moved several cm or even more in a random direction. Also deformation of the load is unacceptable. Deforming load units can cause unacceptable inertia forces and can endanger the stability of the vehicle, e.g. a heavy piece of metal sliding sideward in a rigid crate, can cause a truck to turn over.

Cargo securing can be done based on 3 different principles, as outlined below.

1.1 Top Over Lashing – Friction Lashing

Friction between the loading platform of the vehicle and the bottom surface of the cargo should prevent sliding. Friction is increased by top over lashing: some lashings over the load pull down the load and increase friction between the load platform and the cargo. At the same time, friction between several layers of the load is increased, thus preventing sliding between layers. Top over lashings at the same time prevent tilting and wandering.

Top over lashing is very well known by almost all truck drivers. On the other hand, it has three major disadvantages:

1. In most cases the number of top over lashings is very high. On average for a full truck of 25 tons up to 80 top over lashings are necessary (depending on the type of lashings used, depending on the materials and the position of lashing points). Fixing and removing the necessary lashings can take up to 2 hours, causing an unacceptable workload for the driver and an unacceptable cost for the transport company.
2. The top over lashings have to be tensioned, in most cases up to a tension force of 200 to 500daN depending on the design of the tensioning device. A tensioned lashing can damage the cargo unless some corner protection is used. This will increase cost, weight and material usage.
3. Very often the tension in a top over lashing decreases during transport due to vibrations and/or small movements of the cargo. In that case, load securing is inadequate.

1.2 Direct Lashing

Load securing devices such as lashings, steel wire ropes or chains are fixed between the load and lashing points on the vehicle superstructure. For un-deformable loads such as heavy construction machinery, … four different tensioning devices are used to compensate for the inertia forces. For palletized goods, one lashing device for each direction is used: e.g. to compensate for the forces during braking, a lashing is put horizontally in front of the load and tensioned backwards at each side of the load. Typically the actual tension force in the tensioning device during transport is not important. The tension will increase if the load tends to move. This means that in most cases, the load will not be damaged by the tensioning device and that no repetitive tensioning during transport is necessary. For palletized goods direct lashing can be an economical solution if the load units do not tend to tilt nor deform.

1.3 Blocking

The load is blocked against a certified part of the vehicle or another part of the load. In this case a so called XL-coded vehicle is very interesting: the European standard EN12642:2006, code XL, guarantees that the walls of a vehicle superstructure will resist the forces from the load if this load is “un-deformable” and put against the wall without a gap. The walls of an XL coded vehicle type are tested statically or dynamically. The front wall resists a distributed load of 50% of the loading capacity of the vehicle, sidewalls resist 40% and the back wall resists 30% of the loading capacity. Such rigid walls and the friction between load platform and load compensate for the inertia forces. Gaps and deformation of load units are unacceptable since these can cause impact forces that are much higher than the inertia forces. Only a small gap of some cm between the pallets and the walls is generally accepted: 2 pallets of 120cm or 3 pallets of 80cm can be put between two sidewalls of a standard XL coded vehicle without further load securing. In many cases the loaded products are somehow smaller than the pallet. Such a gap between the products on neighbouring pallets is no problem if the load units are really rigid.

Blocking is the most efficient load securing method for palletized products. The load securing efficiency does not depend on the efforts of the driver. If the products are fixed rigidly on the pallet and the XL coded vehicle is loaded without gaps between pallets and vehicle walls, no additional load securing action is required. A new XL coded vehicle should not be more expensive than another vehicle. No time is lost for load securing. The main uncertainty is the rigidity of the load units.

2 Test Methods for Load Unit Rigidity

A load unit on a pallet that is blocked, has to resist inertia forces of 0,5g or 0,8g depending on the direction. The rigidity depends on several parameters such as the product type (e.g. fertilizer grains, liquid washing powder, concrete tiles, …), the primary packaging (paper or PE bags, glass or PE or PET bottles, carton boxes, …), the secondary packaging (tray, American box, shrink film, …) , the stacking pattern (interlocked, …), the transport packaging (wrapped foil, stretch head, tie sheets, corner protection, straps, …). It is not possible to predict rigidity at a glance. Therefore a test method has been developed.

2.1 Inclination Test

In the transport community, an inclination test is well known. According to Newton’s law an inclination of 26,7° is supposed to be equivalent to an acceleration of 0,5g. As Newton’s law is not valid for deformable goods, this test is not valid to test the rigidity of palletized goods. Even for many un-deformable goods this test is not applicable, e.g. a concrete prefab wall of 10cm thickness and 2m height will tilt if inclined under 26,7°.

2.2 Vibration Test, Impact Test

In the packaging community these two types of tests are very well known. Vibration tests are being used to simulate transport conditions in laboratory circumstances. The deformation of the load unit strongly depends on the frequency of the vibration. Standardized frequency spectra or measured frequency spectra can be used. In most cases a vibration test will predict problems related to primary and secondary packaging during road transport, but it does not lead to an unambiguous conclusion on transport packaging efficiency.

To test the transport packaging an impact test is very well known. The load unit hits a wall with a certain velocity. During such an impact, the deceleration forces can rise up to 3 or 15g depending on the damping material that is being used. However the duration of these forces is very short: 10 up to 80 ms. The effect of an external force on a deformable product is a deformation vague going through the product. The effect of the external force will depend on the duration of that force. During road transport, the inertia forces can occur for seconds. Therefore in most cases an impact test does not predict the effect of real inertia forces in a truck.

2.3 Real Truck Test

Of course a real truck test is a relevant test to certify the rigidity of a load unit. In practice a certification test on a vehicle is very expensive and difficult to do. The load unit is put on the loading platform of a vehicle and sliding is prevented, e.g. by putting a high friction material in between the platform and the load unit. The vehicle is equipped with some measuring system in order to measure accelerations in forward and sideward directions. A series of movements are performed with increasing inertia forces. The load unit is inspected permanently during this test.

2.4 Laboratory Acceleration Test

An acceleration test that can be performed in laboratory circumstances appeared to be necessary. Therefore an acceleration test machine has been developed (Fig. 1). A table is put on sliding bearing and can move along a horizontal trail. A very high torque servo motor has been developed to move this table. The acceleration of the table is controlled based on a feedback loop in which the actual position of the table is measured permanently. The acceleration of the table can be chosen between 1 and 10m/s². A load unit is put on the table and is subjected to the chosen acceleration in the same way as in a vehicle. The deformation of the load unit during the acceleration can be monitored by means of a high speed video. The permanent deformation of the load unit after the test can be measured in detail after the test.

Figure 1: The acceleration test machine after an acceleration test, with a failed load unit.

Up to 1200 tests with different load units have been done until now. The influence of several parameters of the test, has been examined.

2.4.1 Acceleration or Deceleration.

The acceleration test machine can be used in two possible ways: the load unit can be accelerated slowly (eg.0,2g) up to a certain speed and decelerated with an accurately controlled deceleration (eg.0,5g). Alternatively the load unit can be accelerated in a controlled way (e.g. 0,5g) in order to check the rigidity and decelerated slowly (e.g. at 0,2g). The results of both alternative tests should be the same for an un-deformable load unit.

A real load unit of palletized goods is somehow deformable and the results of both types of tests are in most cases not identical: an acceleration will deform the products in the backward direction. During braking the deformed products are forced to move back in the forward direction starting from a deformed shape. In the second type of test, the slow acceleration does not cause any deformation. The deformation during braking starts from un-deformed products. Therefore the acceleration - deceleration sequence is the most demanding and is chosen as the basis for a test standard.

2.4.2 Duration of the Acceleration.

The elastic and permanent deformation of a load unit depends on the duration of the acceleration. Several experiments have been done with four types of load units: palletized bricks, palletized bags with PE granulate, palletized laminate planks, palletized carton boxes. About 10 identically packed pallets of each type have been accelerated for different durations. Increased duration of the acceleration results in increased deformation up to a certain acceleration duration. For palletized bricks a duration longer than 0,12s does not result in more deformation. For palletized bags with PE granulate, an acceleration over 0,25s does not result in more deformation. Therefore an acceleration duration of 0,275s is put forward as a basis for a test standard.

2.4.3 Acceptable Deformation.

Almost all palletized load units will deform under inertia forces, most often with some permanent deformation. No scientific basis was found to establish criteria for an acceptable permanent deformation. Therefore several tests have been done with different types of products on different pallet types. Most industrially palletized products are somehow understacked, meaning that the product on the pallet is smaller than the pallet. Around the pallet some cm of the pallet is not used. On the other hand, some products are overstacked, meaning that the product is larger than the pallet.

Most often understacking is preferred since it protects the products during manipulation. Understacking and overstacking are very unfavourable for the rigidity of a load unit, e.g. an understacked load unit that is wrapped with foil will tend to slide on the pallet if the acceleration force is higher than the friction between products and pallet. The wrapped foil will not prevent or reduce sliding until the border of the product is aligned with the border of the pallet. On the other hand, sliding of the product on the pallet is not harmful as long as the product does not continue to slide over the border of the pallet. Therefore, a criterion for an acceptable deformation must distinguish between sliding on the pallet and deformation of the palletized products. Several tested products have been categorized by 20 transport or packaging experts in acceptable and unacceptable permanent deformation. Unacceptable deformation can be described as: displacement before and after the test measured in any horizontal plane is smaller than 6cm and smaller than 4% of the height of the pallet.

3 Additional Advantages of Load Unit Rigidity

The initial purpose of an acceleration test is the verification of the rigidity of a load unit for reasons of load securing. A rigid load unit in an XL certified vehicle does not require further lashing if gaps can be avoided. Some multinational companies systematically implemented this strategy for load securing. Unexpectedly this led to two additional advantages.

3.1 High Speed Camera Recording

When doing an acceleration test with a conventionally packed load unit, the deformation is filmed with a high speed camera. In most cases the deformation is unacceptable and in some cases the load unit collapses. The deformed or collapsed load units are very well known from pictures of palletized goods arriving at their destination. However, these pictures do not give a lead for improvement of the packaging. This problem is overcome by the videos. The cause of the failure can be found, e.g. the damage starts with inclination of the boxes on the second layer, followed by tearing up the foil at the foot of the pallet. The cause of the damage is not a lack of rigidity of the foil at the foot of the pallet, but an un-sufficient stiffness of the foil at the level of the second layer. The transport packaging can be improved systematically by correcting the primary failure modes, in the above example by increasing the pre-stretch of the wrapped foil at the level of the second layer. At the same time packaging material that does not contribute to the rigidity can be removed. In many cases wrapped foil in the upper half of a pallet can be decreased, the number of tie sheets can be decreased, …

The videos can provide information related to the stacking pattern also. In most cases some mixture of stacking strategy turns out to be most efficient. Columnar stacking (one box on top of the other with the same orientation) can be preferable for the lower layers since this type of stacking can carry higher loads. The stability of the load unit can be increased by interlocked stacking (other position or other orientation of the boxes in different layers) in the top layers. The use of interlayer sheets (paper, corrugated board, high friction paper, …) strongly influences the optimal stacking pattern. In case of a secondary packing including corrugated board (trays, boxes, display boxes, …), a global optimization of secondary packaging, interlayer sheets, stacking pattern and wrapped foil can give rise to considerable savings, e.g. up to €20 per pallet.

3.2 Cost Reduction

Two independent large scale studies in Europe conclude that approximately 4% of products are damaged upon arrival at their destination. Probably this percentage is even higher since most (small) companies do not keep records of this type of losses and they do not like to publish this kind of figures. Insurance companies pretend that in some industry sectors the percentage is about 6%. The additional costs for the shipping company are even more considerable (disturbed customer relation, emergency delivery, claims, processing of damaged products, …) The real cause of the damage is in most cases not known: damage related to manipulation, to forces occurring during transport, to environmental conditions, …. In the past months the transport packaging of several load units has been optimized and a rigidity up to 0,5g has been certified. In at least 5 different cases the figures of damaged products before and after the optimization are available. On average for the 5 different cases, the percentage of damaged products has decreased by 50%. Two types of products are delivered as full truck loads directly to the customer. At loading time in the production plant they are most likely not damaged. They are transported by road and inspected upon arrival. Damaged products are in many cases not unloaded. Damage is thus most likely related to forces occurring during road transport. In both cases the damage percentage was reduced by 80%.

4 Conclusion

Load unit rigidity is very important for efficient load securing of goods during road transport. This rigidity cannot be quantified with conventional standard tests available in the packaging sector. Therefore an acceleration test machine has been developed and a new test standard is proposed.

The load unit is accelerated for at least 0,275s and no significant permanent deformation is allowed. This acceleration test does not only allow for certification of load unit rigidity, it also allows to optimize transport packaging in a systematic way. In almost all cases this leads to a reduction in packaging material and a reduction in damaged products upon arrival. In many cases this even leads to a reduction of the total packaging cost.

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