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Automated load securing system for cargo vans

Automatisiertes Ladungssicherungssystem für Kleintransporter

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The use of lashing means, for example load securing straps or nets, is often time-consuming, especially for courier, express and parcel-services (CEP) using a lot stops. The following article describes the development of an automated load securing system with a three-dimensional-preformed net. Mainly two components interact in this system. On the one hand, an anti-skid system is integrated, which uses the advantages of a low-friction surface for loading and the anti-slip properties of an adhesive coating for the transport. On the other hand, a flexibly adaptive net consisting of high-performance synthetic fibers and integrated shorteners lash different sized transport units. Especially, the automatic lashing should increase the acceptance of the drivers for the new load securing system.

[Keywords: automated, load securing, cargo van, load securing net, load securing straps, anti-skid mat]

Besonders für Kurier-Express-Paket-Dienste (KEP) mit vielen Haltepunkten sind verfügbare Mittel zur Ladungssicherung, wie z.B. Sicherungsnetze oder Sicherheitsgurte viel zu zeitaufwendig in der Anwendung. Im vorliegenden Artikel wird die Entwicklung eines automatisierten Ladungssicherungssystems mit dreidimensionalem-vorgeformten Sicherungsnetz vorgestellt. Für die Ladungssicherung wirken zwei Kernkomponenten zusammen. Zum einen ist ein Antirutschsystem integriert, welches die Vorteile einer reibarmen Oberfläche zum Beladen und die rutschhemmende Wirkung eines haftenden Belags beim Transport ausnutzt. Zum anderen werden unterschiedlich große Transporteinheiten durch ein sich flexibel anpassendes Netz überspannt, welches aus hochfestem Material, mit integrierten Netzverkürzern besteht. Die automatische Bedienbarkeit soll vor allem bei den Fahrern die Akzeptanz für das Ladungssicherungssystem erhöhen.

[Schlüsselwörter: automatisiert, Ladungssicherung, Kleintransporter, Ladungssicherungsnetze, Spanngurte, Antirutschmatte]

1 INTRODUCTION

The load securing for vehicles is required by law. According to the German Road Traffic Act (StVO) the driver and the loader are responsible for load securing [StV01, StV02], and the vehicle owner is obligated to provide lashing means for them [StV03].

Appropriate securing equipment, prescribed clamping forces and their calculations are published in applicable standards [VDI01, DIN01, DIN02]. In contrast to trucks, the cargo vans have more stops and their volume is not constant. The lashing means often have to be adjusted to the actually load situation by the driver. This also means a non-negligible time exposure. The VDI 2700 also shows examples of cargo nets [VDI02]. However, the application of the presented solutions is very inconvenient for the drivers.

At present, the goods are piled up to the partition and side walls. Having stacked them up to the roof of the cargo van, the goods are positively inserted in driving direction. At several stoppages and the unloading of goods, load securing is necessary. A backward prescribed load securing does not exist. In the worst case, packages without load securing could become dangerous projectiles. Otherwise, the good's change of position could affect the driving behaviour negatively. This represents a high safety risk for the driver and other traffic participants.

Cargo vans have a payload of about one ton which is very low in contrast to trucks. Although there is a legal obligation, load securing is insufficiently implemented in cargo vans. Obviously, due to lower payload, a declining awareness for the risk of accidents contributed to this misconduct.

Having recognized the lack of assurance, some enterprises offered different securing systems with webbing nets already. However, these still have deficits in their application. The driver has to put hooks into lashing lugs or

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locking bars into lashing rails, which is perceived as a nuisance. On the other side, there are no controls of the cargo securing. This encourages driver's oppositional attitudes during the launch of new securing systems. For these reasons, the new load securing system must meet the following requirements: A fast and easy use, a high reliability and the compliance with safety standards. For the development regional companies and research organisations out of the logistic-sector, conveying engineering and textile industry have joined together.

2 TARGETS

The development of an automatic operable cargo load securing system, in general cargo vans was the main target. Reliability and timesaving should meet a high approval of CEP-Drivers. In the future, whole car pools could be equipped with the new system. Therefore, a high level of reliability has to be reached in the prototype state. In addition, the new system may minimally impair the loading capacity. The base of the prototype is the cargo hold of a Mercedes-Benz Sprinter. In particular, a high rate of availability of the system, easy operation and a short clamping time will provide a high acceptance among drivers. To sum up, the major objectives were as following:

- damage-free transport of packages (cardboard boxes, wooden boxes, load carriers, etc.),
- cargo height between 0.2 and 1.6 meters,
- high reliability,
- minimal impairment of loading capacity,
- automatic lashing,
- clamping time < 30 seconds,
- high efficiency,
- high usability.

3 METHOD

The first product and patent research gave an overview of the current market of load securing systems. Those were analysed, and the advantages and disadvantages were explicated to formulate restrictions. The collection of relevant standards and guidelines was equally important, especially for cargo vans. On this base, the targets and tasks were defined and the context was determined by the partners. In close cooperation, they made first concept sketches. Amongst others, different positions for mechanical drives were discussed and were evaluated using selected criteria. For instance, the required space, the installation effort and the recoverable clamping force belong to these criteria. Based on the preferred position of drives, the sketches were adapted and evaluated for a second time. 3D CAD models were generated out of the sketches. They were used for a better imagination and demonstration of functions. The preferred solution was implemented into a true-to-scale reproduction of the cargo hold from a Mercedes-Benz Sprinter. This testing station consists of a welding steel box section frame. All lashing lugs can be used like in an original vehicle. In addition, it is upgradable with different measuring devices.

Individual operations and functional principles of the system were tested in laboratory trials. The adjusting of mechanical units took place in the testing station. After the system reached a high reliability, it was ready for field trials. The installation of the load securing system in a real cargo van was successfully implemented, especially with Car-Managements knowledge of vehicle bodies.

4 STRUCTURE AND FUNCTION

In a defined loading area the load securing system prevents sliding and removing of goods. The cargo net (1) encloses the goods positive and non-positive-locked. Two lashing drives (2) tense loading straps (figure 1). The straps (5) were guided through clamping eyelets on the long side of the cargo net. The straps pull the net from the roof up to the bottom and lash the goods. The strap's ends are mounted at the lashing lug in the partition and at the winch cylinder. Deflection rollers (6) on the floor improve the force transmission. The loading area starts fifteen centimeter behind the partition and has a width of 1.1 m and a length of 3.45 m. Packages can be stacked until a height of 1.6 m. Therefore, the possible load-capacity amounts 6 m^3. The lashing drives are located between the back door and the back wheel housing. Heart of the lashing drives are two 600 W 12 V/DC motors which reach a lashing force between 700 and 900 N. The motors stop if a default electrical current is reached. The clamping takes 13 seconds.

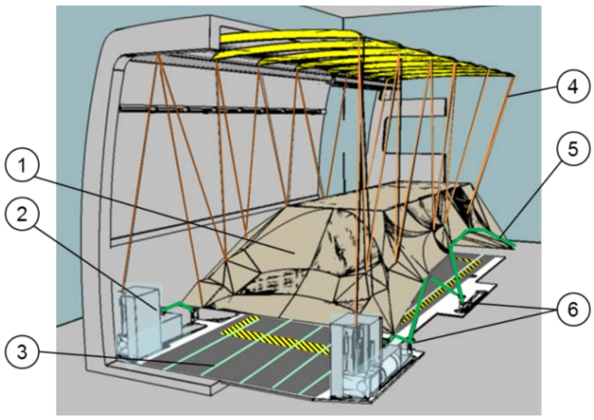

Figure 1: Automatic load securing system in lashed position

Haulback lines (4) return the cargo net below the ceiling in less than 25 seconds in order to unload. The haulback lines are threaded through snatch blocks located at the roof bows and in the net. The tensioning stops if a default value is reached, too.

The second interacting component is a new developed anti-skid system on the floor (3). It consists of sliding rails positioned between non-slip strips. When the driver loads the goods on the floor, he can use the sliding properties to shunt them.

Cellular rubber tapes are located below the sliding rails. This material shows an individual time-dependent compression set quality. If the goods are stacked the packages at the bottom, it will increase the contact area with the non-slip surface as a result of lowering of the sliding rails.

5 COMPONENTS

5.1 LOAD SECURING NET

The Load securing net, which is the main component of the securing system, was developed by the Saxon Textile Research Institute according to different load characteristics. For the net structure, which is formed as knotless net by the use of the warp knitting technology, high performance fibers have mainly been used. Through upgrading of an RL-warp knitting machine of the type RS8 EL6M from E18 to E6 and the modification up to six stitch-forming guide bars to use a three thread system, a functional model could be made with a working width of 50 inches. Different net structures from square, rhombic to hexagonal were studied and selected for the application based on their best physical characteristics.

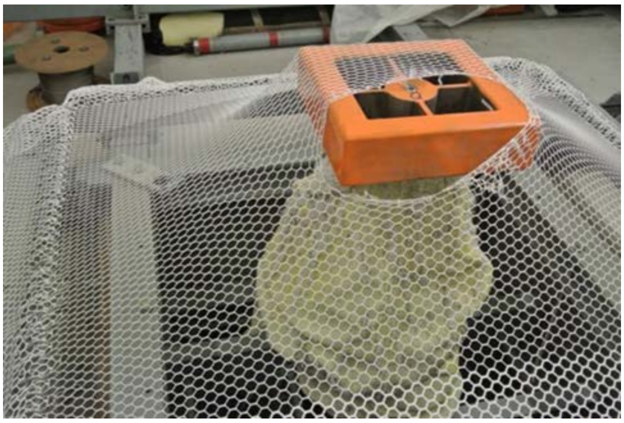

Figure 2: Determination of the main breaking force [STFI e.V.]

The tests of the net were performed not only based on the net mesh test (ISO 1806 and EN 1263-1) but also on the hole net on an special test bed and test method developed is the STFI [STF01]. In accordance with DIN EN ISO/IEC 17025:2005-08 in this test process, the load is initiated by a cuboid reference body (figure 2). The individual possibilities for clamping the net enable a comparison between idealized and application-oriented testing. Thus, the fracture behavior of the net was adapted to a small number of mounting points in the transporter by using a rectangular reverence body (50 x 50 cm).

The result is a preformed net with highest-possible utilization of the substances, which has specially reinforced meshes in the border areas for the application of force from the mounting points to the load securing net. The net meshes in the center, where the net is to enclose the packets are single mesh legs whereas they are double in the border areas (figure 3).

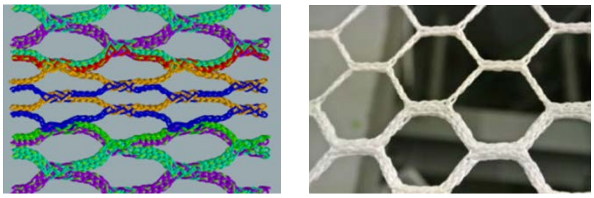

Figure 3: Computer-aided mesh construction (l.), Passage single/double net mesh legs (r.)[STFI e.V.]

A pattern repeat from an average of 50 mm has been found as advantageous with respect to the application of force and the drape behavior of the load securing net to the load. The breaking load of the net is dependent upon the clamping of the net in the test bed and is at about 24 kN by the use of a cuboidal test body (50 x 50 cm). The breaking load of each double net mesh in the edge region is about 2.58 kN and for a single net mesh at 1.47 kN.

5.2 LOADING STRAPS

The specially developed loading straps from F.J.RAMMER GmbH are inflexible narrow fabric constructions. This construction is made of a mixture of polyester and a high performance filament yarn. The handling and reliability of the winding and unwinding operations have been tested directly in the test stand. In accordance to the standard for determining tensile properties, a minimum breaking strength of 22.6 kN at 9% elongation at break was achieved by a 32 mm wide and 1.35 mm thick weave [DIN03]. The average force at 7% elongation was 12.4 kN.

5.3 HAULBACK LINE

The haulback lines return the cargo net below the cargo roof. The tested lines are differently twisted and braided. The hollow weaves and the core-sheath ropes amount a diameter between 3 and 4 mm. Elastic ropes are also used. During the project, the mesh size of the cargo net reduced and more blocks were mounted. Due to the growing weight of the net, the load of the lines increased, and also the alternating bending gets higher by using about 13 blocks per line for the return process. What is more, not only alternating bending leads to wear, but also

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high tension forces between the layers of lines in the lashing system.

Core-sheath robes failed significantly earlier than hollow weaves. A reduced diameter of the core and friction between core and sheath are the reason for this. Especially, tension forces above 0.20 kN effected a jamming of the last winding between the last layers. This leads to loops which reverse the direction of rotation. In this case, the process has to be disturbed, or breaking points would fail. Elastic ropes were overloaded and lost their flexibility. In the field trial, the haulback line is a hollow weave with 12 wires and a 4 mm diameter. The line reached a 12.2 kN breaking load at an elongation of 5.59% tested in accordance with DIN ISO 2301.

5.4 ANTI-SKIT SYSTEM

The concept based on a weight-dependent function. As is well known, there are a high number of different-sized transport units. The dimensioning used a smaller selection which contained packages from shoeboxes up to bigger-sized removal boxes. In this way, typical weight-dependent properties could be calculated. For the first trials, materials out of synthetic or natural rubber were used. The load-deformation behavior could be recorded according to DIN ISO 7743 [DIN05]. The test specimen (diameter d = 29 mm, height h = 8 to 30 mm) were compressed 3 times by 35%. Afterwards, the compression modulus at 10%, 20% and 30% elongation was calculated. The generated measurement data using this standard allows no conclusion to the material's time-dependent compression set quality. Also, the geometric dimensions of the tested specimen differ from realistic dimensions. New tests were created due to those reasons considering the time-dependent deformation. In this test, the testing stamp rested for 30 seconds before recording compression modulus at 25%, 40% and 65% in the measure cycle. In addition, the compound out of sliding rails and cellular rubber material were proved. Under the maximum area load level, the deformation of the required material should be between 40% and 60%. A middle area load should deform the material by 20% to 40%. In the material selection measurement, curves were evaluated and compared with each other.

A compound out of PE-UHMW sliding rails and a synthetic EPDM rubber were chosen for the first prototype. The non-slip strips are composed of Regupol® 7210 LS. This material has the highest friction of rest and highest sliding friction value against cardboard (μ_{rest} = 1.14; μ_{slide} = 0.92) out of all proved materials. This shows the first single tests. The sliding rail is composed of Murtfeldt's Original Material "S" green®. It has a low sliding friction and a low friction of rest against cardboard (μ_{rest} = 0.30; μ_{slide} = 0.21). The friction values were proved with the following measurement assembly. In this single test, a specimen A is pulled over specimen B (length l > 0.4 m) with a constant velocity (velocity v = 15.2 mm/s) by a spindle motor. Different non-slip materials and sliding materials belong to the specimens A. Specimen B is a dry dust-free cardboard of a removal box. The 40x40 mm specimens are fixed in a holding device, and they are weighted down with 513 g. The friction values are average values of five measuring distances.

In composition of the anti-skit system the sliding rails have a slight elevated position about 2 mm. In this way, low weight packages can easily be moved over the floor. On the other side, heavy weight or stacked goods lower the sliding rails. The higher contact area between packages and the non-slip material stabilised the goods during the journey. Figure 4 shows the schematic construction. One of the results of friction tests is illustrated by the following figure 5.

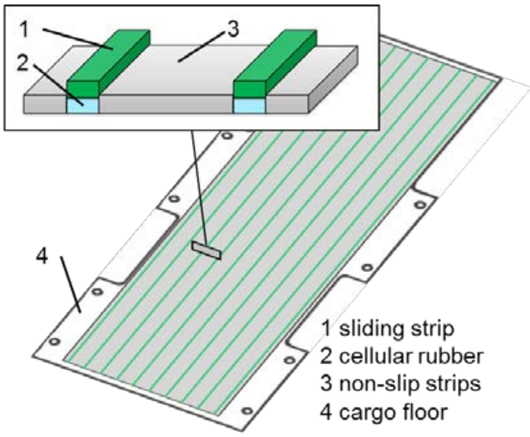

Figure 4: Structural composition of anti-skit system

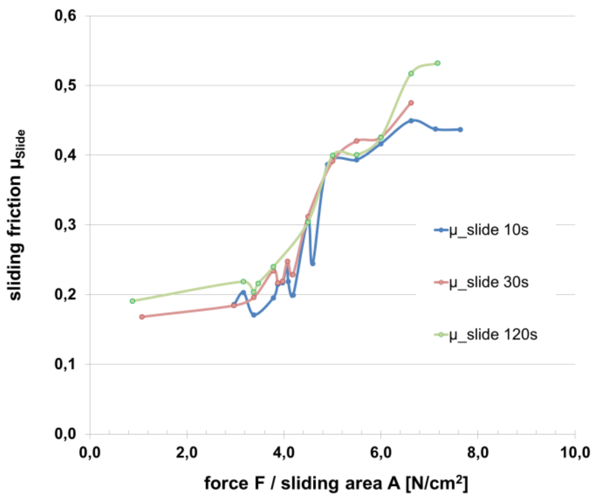

Figure 5: Sliding behavior of anti-skit system after different resting times

For this test, a cardboard box (size: 24 cm x 31 cm) was pulled over the anti-skit system. It is weighted down with 14 to 40 kg on the sliding area on the surface of the rails. A winch pulled the test box over a distance of 1.2 m

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divided into 3 to 5 single measure distances. After a resting time of 10, 30 and 120 seconds, the test box was accelerated for 2 seconds at the single measure distance. The winch accelerates it until it reaches the even velocity of 1.45 m/min for further 8 to 10 seconds. The results show a great increase of the friction coefficients between 0.37 and 0.50 kg/cm^2. This corresponds to a weight range from 18 to 24 kg. Due to a longer resting time from 10 to 120 seconds, the values of friction are partly 20% higher.

5.5 Shortener

Shorteners are used to reduce the net width quick and easily. For example, there is a wider cargo net needed for the maximum as for the minimum cargo volume. With the help of shorteners a re-hanging of clamping eyelets is not necessary anymore.

In this research project, different ways of tying were tested. The tying techniques are used to reduce the width by abridging the distance between two rows of clamping eyelets at the net's long side as traction mechanism ropes and belts were used. One of the ropes was the modified Isilink® developed by Manfred Huck GmbH & Co. KG and STFI e.V. (figure 6).

Figure 6: Shortener – advancement of Isilink® with high-strength filaments for 3d transmission of force (l.), clamping lock straps (r.)

Both traction mechanisms are able to reduce the width of the net by abridging the distance of a pair of clamping eyelets. The Isilink® is a high-strength rope with eyelets. With a spring hook, the length of the Isilink® rope can be adjusted, but the traction forces are withstood by the high-strength filaments. The using of the climbing lock straps is very simple. 14 of them are fixed in the cargo net. Due to these straps, the net-width can be reduced about 1.5 m.

For time saving reasons, tying techniques were tested. Beside pure cross- and parallel tying techniques, other modified techniques were applied. On the one side, a fast shortening is possible, but on the other side, the re-opening is too inconvenient. The disadvantages are a length shortening of the net, the inconvenient opening and high time costs. For safety and time saving reasons, clamping lock straps are used for further tests.

5.6 Controlling

A very simple usability was required from the load securing system. Therefore, the driver can use two primary pads located at the side and back door to control the lashing drives. They have three buttons to pull the net up or down, or to fix it in its position.

For the testing of drives and gearshifts, an extensive program is needed. In these cases, the master pad is used. It has several functions, and it is programmed on a SPS-logic module "Siemens LOGO! 6ED1052".

The control cabin receives its electricity directly from the primary battery. The lashing drives are supplied by a second battery positioned in the motor compartment. The charging line is connected to both batteries via a cut-off relay and the car's alternator. A running engine starting ignition can be warranted.

6 Experiments

6.1 Cargo net test

According to the VDI 2700, the payload has to be secured with 80% of its weight in driving direction, 60% of it in cross direction and 50% backwards [VDI03]. This specification is valid for vehicles with a laden weight between 2.0 and 3.5 t. The German BG Transport and Traffic published a test specification for a cargo net test, called GS-V-31 [GSV01]. In this test, the shift of lashed goods is measured. After that, the measured data is compared to the maximum allowed shift. The force on the test carriage is generated by a lifting cylinder. The carriage embodied the goods, and it consists of welded steel angles. Based on this specification, two measurements were realized.

Instead of the specification, an inclined plane was used for generating the force in the first measurement. The test carriage (length x width x height 1.2 x 0.8 x 0.8) was mounted on feed-rollers. Its weight is 413 kg. Along a 16.7 degrees inclination, a generated force of 1161 N is reachable. The carriage is mounted on feed-rollers to reduce the friction influence to a minimum. In the premier test of the first measurement, the averaged net-width is 2.6 m. The cargo net covered the carriage completely, and the loading straps ran parallel to the floor. In the second test, the width was shortened up to 1.8 m. In this case, the counterforce of the cargo net could be raise about 57% while the allowed shifting is reached. The mesh size of the first measurement was $l_m = 210$ mm.

Figure 7 illustrates that great shifts were observed after the carriage passed a mesh. In the second test, a calculation shows that 326 kg load-weight could be saved using an anti-skit mat ($\mu_{slide} = 0.6$). The forces transmitted through the net into the goods are able to damage them.

Table 1 shows the modification of the parameters in both measurements. Figure 7 records the forces in relation to the shift. It allows conclusion to the maximum reachable, securable load-weight of the system.

Table 1: Parameter modification

	Measurement 1		Measurement 2				
Parameter	T1	T2	T1	T2	T3	T4	T5
net-widht [m]	2.6	1.8	2.2	2.2	2.2	2.0	1.8
no. of deflection rollers	2	3	2	3	3	3	2
carriage position	l.	l.	l.	l.	t.	t.	t.

l…longitudinal, t…transversal

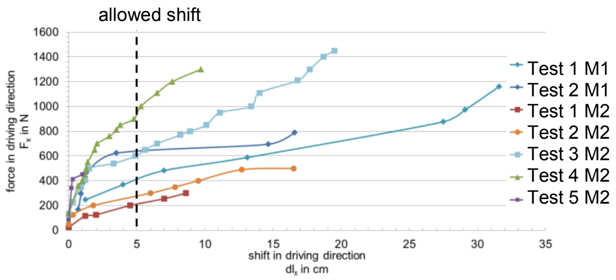

Figure 7: Force-shift-graph

The maximum securable load-weight m [kg] is calculated by using the value of the force F_x [N] at the point of allowed shift dl_x and the value for the sliding friction μ_{slide} of the contact pair.

$$m = \frac{F_x(\mathrm{dl}_x = 50\,mm)}{g \cdot (c_x - \mu_{slide})} \qquad (1)$$

The secure coefficient c deduces from inertial forces (driving direction c = 0.8, cross direction c = 0.6, backwards c = 0.5) [VDI03]. The gravitational acceleration is $g = 9.81\ m/s^2$.

In the second measurement, a lifting cylinder generated the force instead of an inclined plane. The net-meshes were smaller (l_m = 50 mm) and the carriage position were modified. Due to smaller meshes, the shifting would be reduced. Both measurements positioned the carriage in the middle between partition and lashing drives. As a part of the development process, the drives also had been changed. For the second measurement, drive's power was reduced from 1.1 kW to 0.6 kW, and with a lower gear ratio, the return time and lashing time also could be reduced.

6.2 Endurance Test

In the endurance tests, all integrated test could be examined together for the first time. The load securing system was tested on its reliability and on control technique as well as mechanical weaknesses. In this way, it was submitted to 500 load cycles in four different loading conditions. Two load conditions are illustrated by figure 8 to 10.

Figure 8: Left side, open net, cargo height 1.0 m

Figure 9: Left side, lashed net, cargo height 1.0 m

The cycle duration was 1.5 minutes. The cargo net stayed for 30 seconds in lashed position before it was pulled back to the roof. Already during the attempts, system changes were carried out to reduce the failure rate. Any unplanned interruptions and their causes were recorded. Numerous changes during the endurance test were able to reduce the number of incomplete cycles of 50% to 11%. Amongst others, a prematurely switching off drives in the return process and unsymmetrical lashings are incomplete cycles. Another incomplete cycle was caused by loading straps jammed in the winch cylinders of the lashing drives. The test program did not have to be interrupted immediately after these mentioned errors. Only an increased occurrence of an error, like the jamming straps, led to interruptions and improvement of the system. The number of interruptions could be reduced from 26% to 4% clearly. Various types of causes could be identified. The unsymmetrical lashing was due to different drive speeds although two identical drives were used. The speed

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difference amounts about 10%. The asymmetry could be compensated by a time-delayed start of the drives. Different power consumption was already a first indication for the different behaviour.

Figure 10: Backside, open net, cargo height 0.8 m (transversal test carriage in front)

Especial the haulback lines and the mini blocks were affected by wear. Hence, robes with a bigger diameter are chosen for the field test. Using collision protecting devices the load of the mini blocks to be reduced.

6.3 FIELD TRIAL

Finally, the company ECL euro.COURIER Logistics GmbH carried out a 3-week field trial. During the trial, about ten stops per shift were completed in the vicinity of 50 km. Accompanying camera admissions in the cargo hold and in the cabin documented the load securing system during the trail. The system could be used from a cargo height of 0.6 m, which corresponds to a minimum cargo volume of 1.2 m^3. The figure 11 shows the lashing of 4 m^3 cargo volume (cargo height: 1.2 m).

Figure 11: Cargo hold with load securing system

The evaluation showed that in 75% of the trips, in which lashing tools have been used, the new developed system lashed the load exclusively. In contrast, the loading straps were used only in 19% of the cases. In 6% of cases, the new load securing system as well as conventional lashing means was used in combination.

The average maximum cargo volume amounted to 2.9 m^3. Furthermore, the maximum cargo volume of 6 m^3 could be tested. The load considered out of plastic load carriers (60 x 30 x 40 cm).

7 CONCLUSION

The field trial shows a flexible usability of the new load securing system with regard of differently sized cargo. It was tried to cover a large margin of cargo volume. The developed system fulfils this demand nearly completely. Cargo between 1.2 to 6.0 m^3 could be covered. Doubts that the system would limit the cargo hold too strong could be disproved during the field trials. Just in 1% of cases, the maximum cargo volume of the load securing system has been exceeded.

With regard to the lashing time of 13 seconds and a return time less than 25 seconds the expectations of the project partners are fulfilled. Also, the clearance of 1.7 m for loading processes is absolutely defensible (figure 10). Figure 8 indicates the freely accessible side doors. The expectation of securing a payload of about one tone could not be fulfilled in the face of a required damage-free transport. The results of the cargo net test showed that the securing of a payload about a half tone is quite possible. The system is currently adjusted to the allowed load of cardboard boxes.

The test specification [GSV01] of the BG Transport and Traffic excluded that there will be different cargo sizes and do not consider its different constitution. The good's ability to withstand the required clamping forces is also not regarded.

The tests and shared experiences as well as the interviews with the driver intimate that a further development is quite necessary to be ready for series production. Therefore, the limited cargo hold has to be extended to lower volume less than 1.2 m^3. Changing the number of reflecting rollers could raise the quality of force transmission. A new gear draft has already been developed for such future constructive changes. In view of an increasing number of courier, express and parcel-services, there will be more controls in the field of delivery-services by police in future times. In this case, the using of automatic lashing systems is inevitable.

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8 CREDITS

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