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EQUATION OF THE STANDARD EN 12195-1 STIPULATES UNREASONABLE DEMANDS FOR CARGO SECURING

Cargo securing is a factor influencing safety and quality of transport considerably. In this paper the problem of calculation of over top lashing to prevent tipping is mentioned. "European standard EN 12195-1 Load Restraint Assemblies. Safety. Part 1: Calculation of lashing forces" stipulates unreasonable demand for number of over top lashings to prevent tipping of load. The calculation of number of lashings gives infinite results for certain lashing angles. The reason can be found in equation (8) of the standard.

1. Introduction

How many lashing do we need, is often a big issue when it comes to cargo securing. There are various demands for cargo securing in European countries. The demand for the number of lashings is really confusing for international road haulers. The lorry driver travelling through different countries of Europe is often afraid of how many lashing straps or other equipment the controlling authorities and consignors at loading sites will want to see and if the straps are proper to use and fulfil the demands of standards or guidelines. Over top lashing, as the most frequent lashing method, is used everywhere when it comes to cargo securing by lashing. But what the effectiveness of over top lashing is each driver must take into consideration. The driver knows what the friction and acceleration are and he also knows that the force on the opposite side without a tensioner is lower when compared to the tensioner side. These points are the main points influencing over top lashing and these points create controversy between the EN 12195-1 standard for calculation of lashing forces and IMO/ILO/UN ECE Guidelines for packing cargo transport units (CTU's). The discussion was opened during the work on *European Best practice guidelines on cargo securing for road transport* of the European commission, and led after some years to the revision of European standard EN 12195-1 which is in a revision process now. The standard is, as national standards, implemented in the EU but not obligatory in all the member states. In several states the standard is only on a voluntary base. The discussions of experts showed that the standard stipulates very high and costly demand on cargo securing when it comes to over top lashing. Therefore it has been called for the revision.

The main points of discussions were about friction, acceleration sideways and k-factor. K-factor was always the biggest problem during the discussions. The standard defines it as the "*coefficient which allows for the loss of tension force due to friction between lashing and load*".

Because of the friction on the corners the force on the opposite side is usually lower than the force on the tensioner side. This is presented in the calculation by k-factor with value 1.5 for over top lashing with a tensioner on one side of the lashing only. The value 1.5 means that on the side without a tensioner there is only half of the force of the tensioner side. Of course, this value is very conservative and measurements [9], [10] showed that also the values more than 2 are possible to measure. The value of k-factor mainly depends on the corner friction. The issue is clear. The use of k-factor lower than 2 influences the number of lashings and which is important to highlight is that no hauler wants to increase the number of lashings because it costs money.

2. Over top lashing securing load against tipping

The results of equation (8) of standard EN 12195-1 for over top lashing to prevent tipping are shown below. The illustration from the standard is given in the following figure. By solving practical examples it was found out that equation (8) of the standard, as defined, creates unreasonable results which are practically unusable.

According to equation (8) holds:

$$F_{x,y} \cdot \frac{h}{2} + n \cdot F_T \cdot h \cdot \cos\alpha = F_z \cdot \frac{w}{2} + n(k-1) \cdot$$

$$\cdot F_T \cdot w \cdot \sin\alpha + n(k-1) \cdot F_T \cdot h \cdot \cos\alpha \qquad (1)$$

Modification of equation (8) gives the following equations for a number of lashings:

- for load with the centre of gravity (CoG) in the geometrical centre:

$$n \geq \frac{1}{2} \cdot \frac{m \cdot g \cdot (c_{x,y} \cdot h - c_z \cdot w)}{F_T \cdot [(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha]}$$

$\Rightarrow$ equation (11) of the standard (2)

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- for load with CoG off the geometrical centre:

$$n \geq \frac{m \cdot g \cdot (c_{x,y} \cdot d - c_z \cdot b)}{F_T \cdot [(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha]} \tag{3}$$

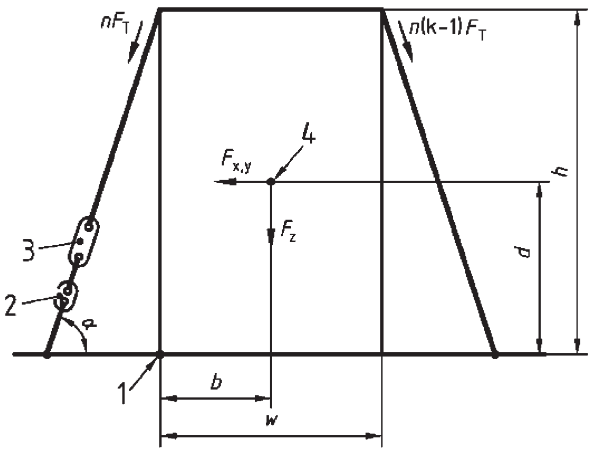

Fig.1 Fig. 4 from EN 12195-1

When unstable loads are to be secured against tipping the situation is quite different. The EN 12195-1 standard calculates this equation by using the tensioners on one side only. The equation (8) should hold for load secured by one over top lashing only. For load where more lashings are necessary the results of equations are wrong.

The following example explains the situation. The load with weight $m = 2000$ kg, height $h = 2$ m and width $w = 0.9$ m are to be secured sideways by over top lashing** with the lashing angle of 66° and friction factor 0.3. The load is unstable sideways. For this load we need, according to the formulas in the standard, 3 lashings to prevent sliding but 300 lashings to prevent tipping.

The number of lashings to prevent sliding: according to equation 5 of the standard:

$$n \geq \frac{m \cdot g \cdot (c_{x,y} - \mu_D \cdot c_z)}{k \cdot F_T \cdot \sin\alpha \cdot \mu_D} =$$

$$= \frac{2000 \cdot 9.81 \cdot (0.5 - 1 \cdot 0.3)}{1.5 \cdot 3750 \cdot \sin 66° \cdot 33} = 2.55 \Rightarrow 3 \mathit{lashings} \tag{4}$$

The number of lashings to prevent tipping according to equation 11 of the standard:

$$n \geq \frac{1}{2} \cdot \frac{m \cdot g \cdot (c_{x,y} \cdot h - c_z \cdot w)}{F_T \cdot [(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha]} = \frac{1}{2} \cdot$$

$$\cdot \frac{2000 \cdot 9.81 \cdot (0.7 \cdot 2 - 1 \cdot 0.9)}{3750 \cdot [(1.5-1) \cdot 0.9 \cdot \sin 66° - (2-1.5) \cdot 2 \cdot \cos 66°]} =$$

$$= 300.08 \Rightarrow 300 \mathit{lashings} \tag{5}$$

This happens because the calculation supposes the tensioners on one side only.

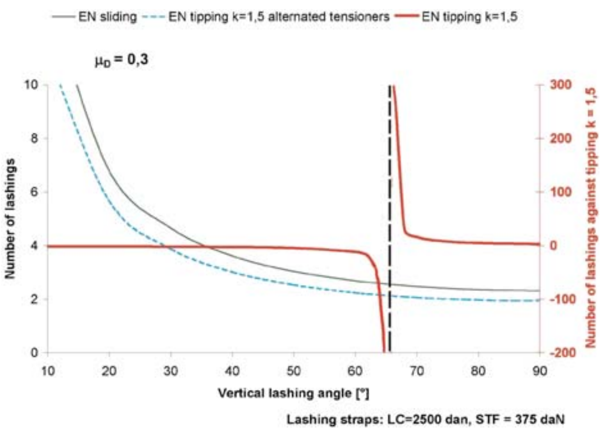

Fig. 2 Influence of transmission factor "k" for number of lashings to prevent tipping by using over top lashing according to EN 12195-1

The comparison of different calculation methods is shown in the figure above. The worst situation is for tipping with k factors different from 2. For certain lashing angle the value is infinity and for lower angles the values are negative. That means, from practical point of view, that infinite number of lashings can't be used. As it can be seen from the figure above this doesn't correspond to the expected hyperbolical trend. What is the cause? The cause is *k* factor, strictly speaking, the difference between forces on the tensioner side and opposite side. If we lash the load according to the method in Fig. 1 then, from theoretical point of view, the lashing itself creates instability of the load and can cause tipping of the load with a sufficient number of lashings. This means, from practical point of view, the tensioners can't be placed on one side of the load only but must be placed alternately. This is also the general demand for securing of load.

The lashing angle for infinite number of lashing can be found out from a denominator of eq. (11) of the standard:

$$(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha = 0 \tag{6}$$

$$\alpha = \mathrm{arctg}\left(\frac{2-k}{k-1} \cdot \frac{h}{w}\right) \tag{7}$$

And for our example a is as follows:

$$\alpha = \mathrm{arctg}\left(\frac{2-k}{k-1} \cdot \frac{h}{w}\right) = \mathrm{arctg}\left(\frac{2-1.5}{1.5-1} \cdot \frac{2}{0.9}\right) =$$

$$= 65.77225468... \tag{8}$$

So we get real lashing angles for infinite number of lashings. Of course, this lashing angle is not possible to use but the angles around this value still stipulate very high and also negative results.

** lashing straps $LC = 2500$ daN, $STF = 375$ daN

In case of alternating tensioners the situation is as follows:

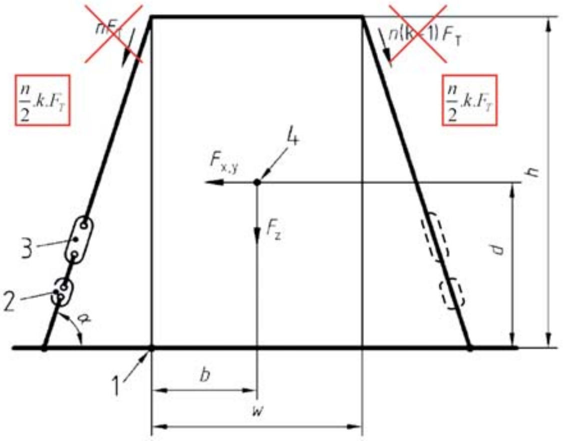

Fig. 3 Modified Fig. 4 of the standard EN 12195-1 for tensioners placed alternately

Modified eq. (8) of the standard is as follows:

$$F_{x,y} = \frac{h}{2} - F_z \cdot \frac{w}{2} - \frac{n}{2} \cdot k \cdot F_T \cdot sin\alpha \cdot w = 0, \qquad (9)$$

- for the load with CoG of the geometrical centre (GC):

$$F_{x,y} \cdot d - F_z \cdot b - \frac{n}{2} \cdot k \cdot F_T \cdot \sin\alpha \cdot w = 0 \qquad (10)$$

Then equations for the number of lashings should be as follows:

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{k \cdot F_T \cdot \sin\alpha}, \text{ CoG in GC} \qquad (11)$$

$$n \geq \frac{2 \cdot m \cdot g \cdot (c_{x,y} \cdot d - c_z \cdot b)}{k \cdot F_T \cdot w \cdot \sin\alpha}, \text{ CoG off the GC} \qquad (12)$$

where, for our example, holds:

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{k \cdot F_T \cdot \sin\alpha} =$$

$$= \frac{2000 \cdot 9.81\left(0.7 \cdot \frac{2}{0.9} - 1\right)}{1.5 \cdot 3750 \cdot \sin 66°} = 2.121 \Rightarrow 3 \mathit{lashings} \qquad (13)$$

if $k = 2$ and $c_y = 0.5$ which present the requirements given in IMO the result is as follows

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{k \cdot F_T \cdot \sin\alpha} =$$

$$= \frac{2000 \cdot 9.81\left(0.5 \cdot \frac{2}{0.9} - 1\right)}{2 \cdot 3750 \cdot \sin 66°} = 0.318 \Rightarrow 1 \mathit{lashing}. \qquad (14)$$

According to the latest agreement from revision works the experts decided to delete k factor in all equations of the standard to avoid confusion in the future. As the calculations in the standard are based on theoretical principles, operational factors (when applying top-over lashing) can positively or negatively impact the required number of lashings, e.g.

- retention not feasible,
- self-tensioning effect,
- influence of the corner frictions.

To compensate these uncertainties the safety factor of 1.1 is to be included. The *k* factor shall be deleted in all the equations [11]. According to the other agreement unstable goods in combination with over top lashing shall be calculated as follows

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{F_T \cdot \sin\alpha} \cdot 1.1 \qquad (15)$$

which, for our example, gives

$$n \geq \frac{2000 \cdot 9.81\left(0.5 \cdot \frac{2}{0.9} - 1\right)}{7500 \cdot \sin 66°} \cdot 1.1 = 0.350 \Rightarrow 1 \mathit{lashing}.$$

3. Conclusion

This paper presents that the calculation of over top lashing to prevent tipping according to standard EN 12195-1 is practically unacceptable. For certain lashing angles an unreasonable number of over top lashings is calculated. Therefore, the work of experts, participating on revision works to achieve reasonable level of cargo securing in road transport and to obtain the European standard practically applicable all over the Europe, is very important.

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