The measurement of contact surface of dunnage bag used for cargo securing in different gaps between cargo

Juraj Jagelčák, Ján Vrábel, Matej Pauliak[1]

[1]University of Žilina, Faculty of Operation and Economics of Transport and Communications, Department of Road and Urban Transport
jagelcak@fpedas.uniza.sk, vrabel@fpedas.uniza.sk

Abstract   This article provides comparison between the measured values of dunnage bag restraining forces and calculated values of restraining forces according to the draft version of Guidelines for Packing of Cargo Transport Units (CTU Code) for the dunnage bag of dimensions 60x120 cm and maximum filling pressure 0.2 bar.

Keywords   dunnage bags, CTU Code, contact surface, cargo securing

JEL   L91 - Transportation: General

1. Introduction

Accelerations during transport cause the movement of a cargo, especially sliding or tilting. When dunnage bags are used as cargo securing equipment they should be able to secure cargo against sliding and tilting for different accelerations occurred during transport. Dunnage bags are used to fill gaps between cargo units to avoid displacement of units during transport. Dunnage bags are an effective form of cargo protection against load displacement and subsequent damage. There are different kinds of dunnage bags on the market (material, size, strength, filling equipment etc.).

Dunnage bags are placed into the gaps among the cargo units. After that they are inflated and cargo is fixed. Following rules must be expected. The first thing is to choose the correct type of the dunnage bag (dimensions, strength or the blocking capacity). The next very important condition is that the dunnage bag should not be over the edge of the cargo (the size of dunnage bag should not be higher than the size of a contact surface of a cargo). Dunnage bags must not be in a direct contact with sharp edges which can damage the dunnage bag. Because of that, e.g. paperboard can be placed between the cargo and the dunnage bag.

Another very important condition is that they should not touch the floor and can't be placed between the last cargo section and container or trailer doors. It should also be determined whether the dunnage bag is suitable for the particular gap. Required size and strength of the dunnage bag is determined by the size and weight of the cargo, gap where the dunnage bag is placed and accelerations which can occur during transport. With respect to the strength of the dunnage bag the blocking capacity of the dunnage bag must be higher than the forces acting on the dunnage bag by secured cargo.

2. Forces acting on cargo during transport

For all kinds of transport maximum design values of inertia forces are settled for longitudinal, transverse and vertical axes. These values are also used in theoretical calculations of force acting on the dunnage bag during transport. The Association of American Railroads [6] distinguishes between dunnage bags for transverse securing of cargo and longitudinal securing of cargo. Dunnage bags used for cargo securing in longitudinal direction must be stronger than dunnage bags used for cargo securing in transverse direction.

Table 1.   Design acceleration coefficients for cargo securing

Transport	Forwards		Backwards		Sideways	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
Road	0.8	1	0.5	1	0.5/0.6	1/1
Rail	4/1	1/1	4/1	1/1	0.5/0.5	0.7/1
Sea A	0.3	0.5	0.3	0.5	0.5	1
Sea B	0.4	0.3	0.4	0.3	0.7	1
Sea C	0.4	0.2	0.4	0,2	0.8	1

Source: [2]

3. Theoretical calculations for determining the dunnage bag suitability

Firstly it is necessary to know if the dunnage bag can be used in the particular gap. Therefore, we need to determine the maximum gap for which a particular dunnage bag can be applied.
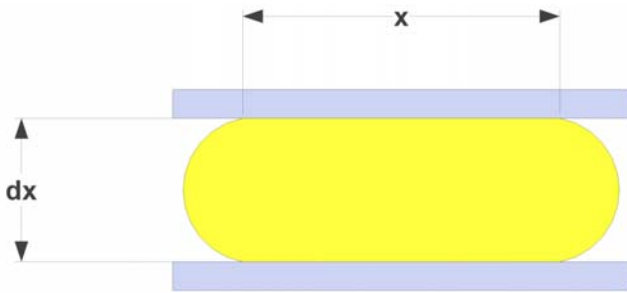

Figure 1. Contact distance x of dunnage bag in gap dx

Source: Authors

Maximum gap in which the dunnage bag can be placed depends on chosen ratio between the contact transverse distance x and breadth of dunnage bag b in non-inflated state as follows:

$$d_x = 2 \cdot b \cdot \frac{1 - \frac{x}{b}}{\pi}$$

Following figure shows different maximum gap d_x for different ratios x/b and different breadth of dunnage bags.
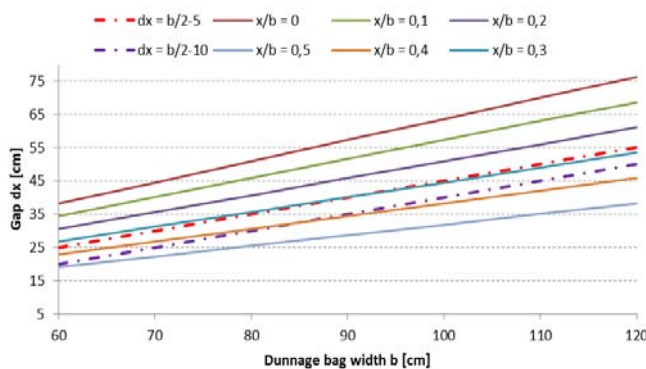

Figure 2. Maximum gap distance dx of dunnage bags of different breadths

Source: Authors

When the calculation of maximum gap for dunnage bag is $d_x = b/2-5$ [cm], it gives the results close to $x/b = 0.3$, so about 30 % of breadth of dunnage bag is in contact with a cargo. When the calculation of maximum gap for dunnage bag is $d_x = b/2-10$ [cm], it gives the results close to $x/b = 0.4$, so about 40 % of breadth of dunnage bag is in contact with a cargo.

The force which the dunnage bag is able to secure depends on the contact area of the dunnage bag which the cargo is resting against and the maximum allowable pressure in the dunnage bag. The blocking capacity of the dunnage bag is calculated according to the CTU Code [1] as follows:

$$F_{DB} = A \cdot 1000 \cdot g \cdot P_b \cdot SF \ [daN]$$

F_{DB} – force that the dunnage bag is able to secure without exceeding the maximum allowable pressure [daN]

A – contact area between the dunnage bag and the cargo [m²],

P_b – bursting pressure of the dunnage bag [bar],

SF – safety factor
0.75 for single use dunnage bags,
0.5 for reusable dunnage bags.

For the calculation of the maximum permissible force it is necessary to know contact surface A, which is expressed according to the CTU Code [1] as follows:

$$A = \left(b - \pi \cdot \frac{d}{2}\right) \cdot \left(h - \pi \cdot \frac{d}{2}\right)$$

b – width of the dunnage bag [m],

h – height of the dunnage bag [m],

A – contact area between the dunnage bag and the cargo [m2]
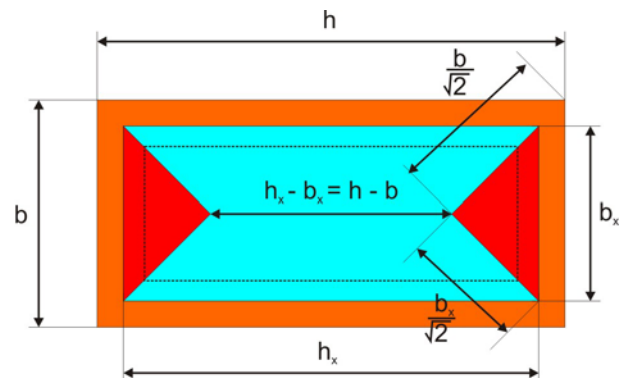
d_x – gap between packages [m],

π – 3.14159

Figure 3. Contact surface of dunnage bag in gap dx calculated according to the CTU Code

Source: Authors

# 4. Measurement and evaluation of measured values

Testing gap is settled at the beginning of each measurement. Testing construction used to test the dunnage bag is in Fig. 4. The upper plate is connected with four threaded bars connected with four load cells at the bottom.
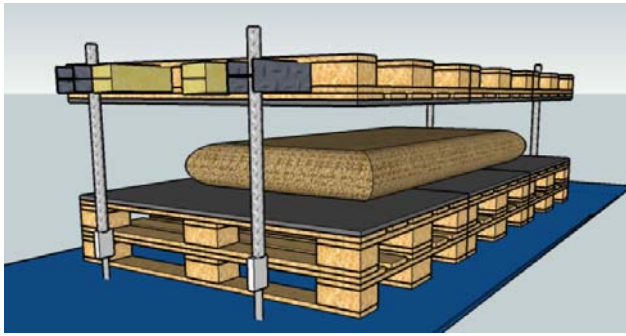
Figure 4. Testing stand used to test dunnage bag 60x120 cm in gap d_x of 10 cm, 15 cm, 20 cm and 25 cm (d_{max} = 25 cm)
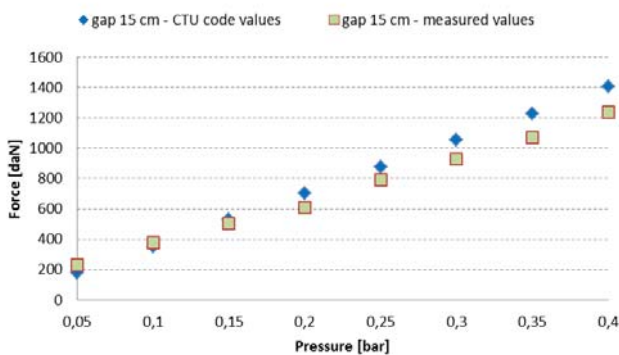
Source: Authors

The biggest difference between the measured value of force and the calculated value of force by the CTU Code in a gap of 10 cm was at a pressure of 0.4 bar (9.53 %). The smallest difference occurred at a pressure of 0.3 bar (2.2 %).
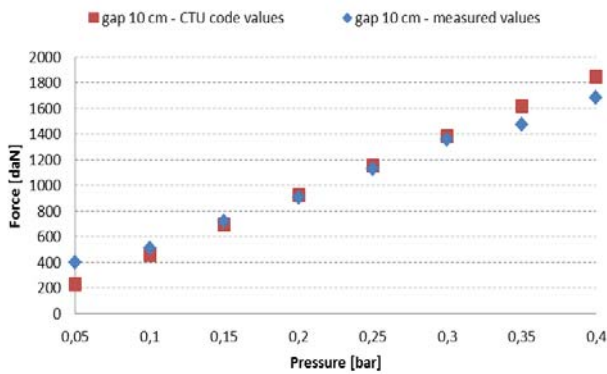
Figure 5. Test results for dunnage bag 60x120 cm in gap dx of 10 cm
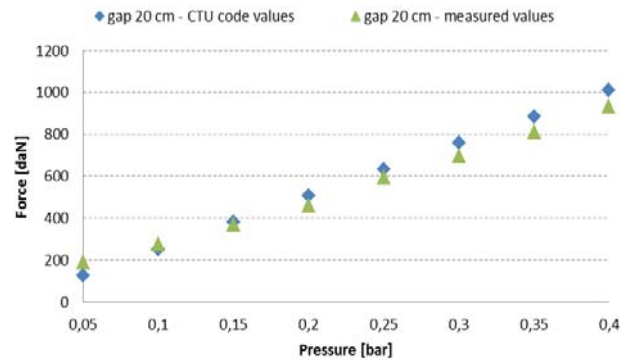
Source: Authors

At the gap of 15 cm the smallest difference was at filling pressure of 0.15 bar (5.0 %) and the largest difference was observed at a pressure of 0.2 bar (15.4 %). The curve of the measured values and the curve of the calculated values according to the CTU Code cross between 0.1 and 0.15 bar.

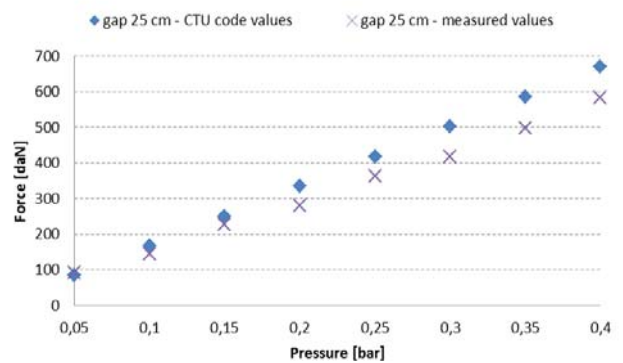**Figure 6.** Test results for dunnage bag 60x120 cm in gap dx of 15 cm

Source: Authors

At the gap of 20 cm the smallest difference was at filling pressure of 0.15 bar (2.38 %) and the largest difference of securing forces at pressure of 0.2 bar (9.61 %).

Figure 7. Test results for dunnage bag 60x120 cm in gap dx of 20 cm

Source: Authors

Comparison of forces in a gap of 25 cm gives the smallest difference at pressure of 0.15 bar (10.59 %) and the biggest difference at pressure of 0.3 bar (20.4 %).

Figure 8. Test results for dunnage bag 60x120 cm in gap dx of 25 cm

Source: Authors

Table 2. Difference between measured and calculated force according CTU Code for measured gaps and selected pressures

Gap Pressure	10 cm	15 cm	20 cm	25 cm
0.15 bar	-4.16%	5.00%	2.38%	10.59%
0.20 bar	2.31%	15.40%	9.61%	19.54%
0.30 bar	2.20%	13.84%	8.99%	20.40%
0.40 bar	9.53%	13.63%	8.44%	15.02%

Source: Authors

Following figure shows exact securing force difference between the measured and calculated force for different gaps and filling pressures.
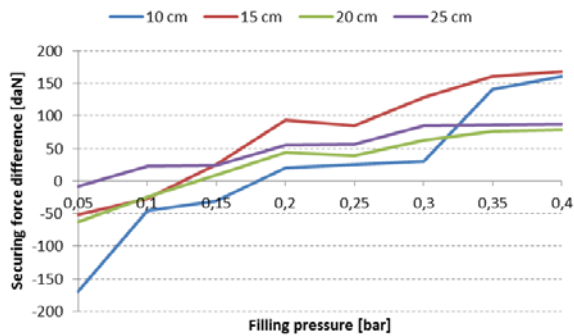
Figure 9. Force difference between measured values and calculated values for dunnage bag 60x120 cm in different gaps and filling pressures

Source: Authors

5. Conclusions

When we compare the values of measured forces and forces which are calculated according to the CTU Code we find out that the calculation of contact surface according to the CTU Code overestimates the contact surface and, therefore, also overestimates the securing force of the dunnage bag. The contact surface according to the CTU Code is a rectangle but in reality it is a different shape. To describe the exact surface of a dunnage bag, more measurements with different sizes of bags, gaps and pressures must be performed.

It is also important to note that this paper provides the results only for the small dunnage bag with dimensions of 60 x 120 cm in gaps to 25 cm and filling pressure up to 0.4 bar. We expect even bigger differences when bigger dunnage bags are used in bigger gaps at higher pressures.
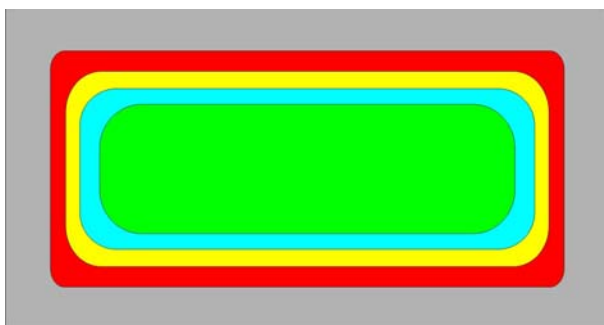

Figure 10. Approximate contact surface of dunnage bag 60 x 120 cm (grey) in a gap of 10 cm (red), 15 cm (yellow), 20 cm (blue) and 25 cm (green) marked by a marker pen during tests

Source: Authors

REFERENCES

[1] Code of Practice for Packing of Cargo Transport Units (CTU Code). IMO/ILO/UNECE. Draft version April 2013

[2] STN EN 12 195-1:2011 Upevňovanie nákladu na cestných vozidlách Bezpečnosť časť 1: Výpočet upevňovacích síl. 2011

[3] JAGELČÁK J.: Nakladanie a upevňovanie nákladu v cestnej doprave. Žilinská univerzita v Žiline, 2008. ISBN 978-80-8070-858-0

[4] JAGELČÁK, J. – DÁVID, A.-ROŽEK, P.: Námorné kontajnery - 1. vyd. - Žilina: Žilinská univerzita, 2010. - 262 s., AH 20,74, VH 21,14 - ISBN 978-80-554-0207-9

[5] JAGELČÁK, J.: Nakladanie a upevňovanie kusových zásielok nebezpečných vecí v námorných kontajneroch - 1. vyd. – Žilina EDIS – Vydavateľstvo ŽU, 2013 - 81 s., AH 7,04, VH 7,41. - ISBN 978-80-554-0623-7

[6] General Information Bulletin No. 9. Product performance Profile for Pneumatic Dunnage. Association of American Railroads 2012