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MINING MACHINES ELEMENTS PACKING AND SECURING ON PLATFORM CONTAINER

Summary. The scientific purpose of this paper was to analyse the problem related to intermodal transportation of mining components packed in containers or other cargo transport units coupled with the problem of its proper securing. In this article, the issue of exposing the load to the effects of inertia forces which might cause unintentional movement is presented. The methods of securing the heavy load in cargo transport units are reviewed in the context of cargo immobilisation possibilities while reducing the load sensitivity to mechanical forces. The research part of this article presents the methods of packing and securing an atypical load, which is a part of a mining machine weighing 18t. This paper presents the results of calculations of inertia forces acting on the transported cargo, packed on a container platform. Based on the results, the cross fixing method was selected to secure the cargo and further decisions were made on the type and quantity of conveyor lashings necessary for the safe and correct carriage of the atypical load.
Keywords: mining machines securing, lashing selection, platform container

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1. INTRODUCTION

Road transport vehicles are characterised by widespread availability, flexibility and speed. Due to the very large diversity of goods and means of transport used, the method of attachment must be adapted to the needs every time to maintain maximum safety for both the traffic load, vehicle and other road users. However, the results of vehicle inspections show that some of the loads carried are not properly secured on road vehicles. It is estimated that about 25% of accidents involving trucks result from improper cargo protection [2, 20].

The issue of freight transport security deserves special attention due to the huge, negative consequences that entail, for example, losing a heavy load during an emergency and uncontrolled situation. It is important to determine the impact of unsecured or incorrectly secured load packages in any transport unit on the effects in the form of collisions and accidents. More so, it is worth realising that responsibility for errors arising from unsecured loads, which, according to the European and global law, concerns all participants in the transport chain. Shippers, who usually pack goods for shipments are similarly responsible for the loads' safety in their supply chains [1, 2, 13, 19]. Human error [2-4, 6, 14, 21] and the problem of causality [7] in the analysis of accidents are widely investigated, providing enrichment of knowledge about methods, procedures and tools allowing incident and accident prevention or prediction [8].

The knowledge of cargo and packing dynamics has improved over the years [10]. Although there are many methods and tools supporting cargo security [5, 22], during road transportation, packed cargo is exposed to other independent random factors. One is the impact of inertia forces that can cause movement of packaged goods. The direction of these forces depends on changes in the speed vector of the vehicle, and in particular, in the direction of the vehicle during braking, towards the rear of the vehicle during the start-up, or facing transversely to the vehicle when the transport vehicle is travelling on a curvilinear arc. In each of the specified cases, the vector of inertia forces takes the direction of the acceleration vector and its value is proportional to the value of the vector resulting from the velocity. In addition, the load can be influenced by the forces resulting from the movement of the vehicle on the road with its significant inclination and uneven ground. However, there are some studies focused on non-lashing cargo securing methods [9, 11, 24].

Load sensitivities for mechanical effects can be reduced by appropriate immobilisation, that is, by employing suitable fastening elements. These fastening elements include fastening belts, chain hoists, rope hoists, locking elements, etc.

By selecting appropriate methods and tools for securing specific loads, it should be emphasised, that improper attachment of the load could result in a dangerous road situation; often resulting in loss of life or health of its participants.

Currently, legal acts are regulating the requirements for proper protection of loads during their transportation. Within the European Union, the legal issue of cargo carriage is regulated by EN-12195. In many countries, this standard has been obligatory for many years, but still not fully respected by the road hauliers community. However, it is known that the responsibility for properly securing the transported cargo lies directly on the carrier. Surprisingly, the fact remains that dangerous road events still occur, which can be traced to erroneously secured loads, the reason being lack of knowledge of the problem. These errors often arise at the loading stage and are often identified for non-typical loads. Load conditions are extremely important for assessing the carrier's reliability [12, 15, 23].

This article presents a practical example of correct safeguarding of an atypical, 18t load based on the calculated inertia forces acting on the transported cargo that is placed on the container platform. Securing the load was done with the cross fixing method.

2. NECESSITY OF CARGO IMMOBILISATION

Transportation of machines or other devices, which are usually oversized or extremely expensive, consists of complex actions involving the movement of cargo and handling operations (loading, unloading and reloading). Such transportation requires specialised knowledge and equipment and every part of the process should be carefully planned [15].

Fig. 1 presents the essential elements of significant transportation process planning. All elements indicated, affect the quality of the transported goods and the quality of transport service.

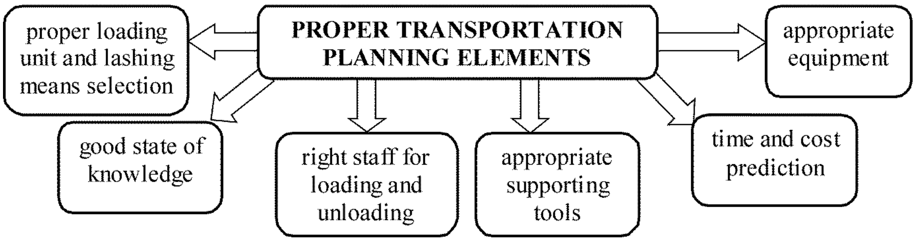


Fig. 1. The basic elements of proper and safe transportation planning

When planning both recurring and single shipments, a proper loading unit must be selected and adapted to the type of load and the mode of transport. The appropriate choice of means of transport (loading unit) for the shipment is influenced by several factors, such as mode of transport, type of package, delivery time, density and quantity of the product, requirements for previous loads, additional equipment, load and securing type or vulnerability to the external transport conditions. Some of them refer to the conditions of transporting goods, and others to the packages or transport units used or even to the requirements for equipment and supplies [16].

Requirements for equipment, supplies, and loading/unloading technique should be confirmed with the carrier to maximise optimisation [12]. This information will help the carrier easily organise the transportation of specific goods. For some products, the package or transport unit used must be specially designed to maintain safety in the transport process. Ensuring safe transport depends on many factors, including the correct selection of packaging or transport unit and fixing means [17]. The decision, however, depends on the forces acting on the load.

2.1. Proper load securing

Securing of loads during transport is reduced to balance the inertial forces acting on the load when the vehicle is moving during acceleration, braking, cornering or overtaking manoeuvres, etc. The frictional forces that occur between the surface of the cargo floor of the vehicle and the lower surface of the load are often insufficient to ensure that the load does not move. Vertical movements of the load during driving due to bumps and vibrations reduce the frictional force resulting from contact. For fixing packages or loads on vehicles, elastic belts, ropes or chains, equipped with mechanical tensioning devices (latches, clamps, stabilisers tensioners) are used. The carrier responsible for securing the cargo before transport selects the appropriate number of fixing lashings by him or herself, considering the mass of the transported load and its external dimensions, which affects the choice of type and strength parameters of the fastening elements as the basis of the decision. These principles refer to different types of cargoes, except liquid cargoes and gas. The most common cargoes, their stowage and calculation are container cargoes, reefer cargoes, bulk cargoes including grain and grain products, heavy lift cargoes, timber cargoes, steel cargoes and ro-ro cargoes [18].

The appropriate computational analysis is required to determine the forces transmitted by the load securing elements. This analysis must consider the following three basic situations that are usually encountered during road transport:

- braking of the vehicle while driving straight ahead,
- braking on the curve of the road when the load on the vehicle is inertia, both in the driving direction and in the lateral direction outside the arc,
- intensive braking of the vehicle when driving straight ahead on uneven surfaces,
- vibration of the vehicle causing reduction of the load pressing the load to the floor of the cargo hold, thus reducing the friction between the cargo and the cargo area.

These problems refer not only to the cargo packed inside transport units but also to the transport units themselves (egg containers) that have to be properly secured [19].

2.2. Forces acting on packed cargo in transport

The maximum acceleration acting on the load while driving is determined by the acceleration product *g* and the acceleration factor *C* as defined in the standards [3, 19]. Acceleration factors are regulated by European standards and the IMO, and differences in values are detailed in Table 1. In addition to the guidelines contained in the IMO, the United Nations Economic Commission for Europe recommends using the EN 12195-1 standard in which it has drawn up the European Commission guidelines on cargo security, and the differences between those provisions are shown in Fig. 2. Many experts from the European Commission and scientists worked to elaborate parameters acceptable to obtain the European standard [1, 3, 19].

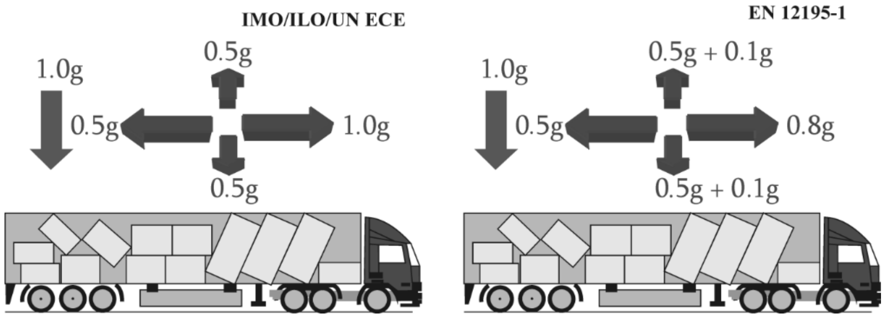


Fig. 2. Accelerations acting on the transported cargo in road transport according to standards

The German standard, VDI2700, explains the basic forces acting on the cargo, its proper location and the practical way of installing the fastening devices. Standard VDI2701 refers to load fixing devices, and the VDI2702 standard describes the method of calculating the forces required to correctly load the most common loads with no complicated shapes. Compared to the EN 12195-1:2010 standard, VDI is more complex with typical examples and drawings showing how a particular type of transported cargo should be properly secured, for example, metal circles, large panes of glass, steel pipes, etc.

Road Transport Inspection and similar institutions checks are very accurate at the security control of cargo, which greatly contributes to the improvement of safety in international transport since the vehicle with improperly secured load is stopped in the parking lot and cannot set out on a further route until it is rectified. This is related to vehicle downtime and the need to supply the driver with appropriate fastening means.

Tab. 1

Normalised values of the acceleration factor C depending on the direction of inertia of the moving vehicle

Direction of inertia force	Acceleration factor value *C*	
	IMO	EN 12195-1
In the direction of the longitudinal movement, at the moment of braking	C=1.0	C=0.8
In the direction of the opposite longitudinal movement at the moment of starting	C=0.5	C=0.5 (+0.1)
In the transverse direction when driving on the arc of the road		
Vertical direction when driving on uneven roads	C=1.0	C=1.0

3. CONTAINER PACKING AND SECURING OF MINING CONVEYOR – A CASE STUDY

3.1. Load characteristics

The case study in view is based on an order received by a multimodal transport operator from a global mining machinery and equipment manufacturer specialising in underground mining, open-pit mining, and bulk cargo transport and handling. The subject of the order was the transport from Poland to Jakarta Port in Indonesia of five coal conveyors to carry coal in the open-pit mines. The whole project was divided into four stages, including multimodal transport. The transported machines were divided into 122 separate load units due to their size. Transport took place on standard semi-trailers: tarpaulin of dimensions: width: 2.48 m, height: 2.70 m, length of 13.6 m and container and cargo units 40 feet plate-type Flat Rack Containers or multi-purpose containers.

The untypical load analysed in detail in this article is the opencast mine belt conveyor system of which loading by a reach stacker is shown in Fig. 3. The mass of the load is mL=18 000 kg, width d=3.2 m, height h=3.0 m and length l=9.5 m.

3.2. Selection of cargo securing method

When attaching an atypical load to an open container platform, it is important to consider inertia forces acting on the cargo during its transportation. The theoretically transported cargo can be immobilised by belt anchorage or appropriate cargo blocking. The load should be secured by the carrier with elastic fastening elements using the strap cross fixing method shown in Fig. 4. The surface of the loading platform is made of painted steel sheet on which wooden supports are laid. Basing on the friction coefficient table, the coefficient of friction $\mu=0.20$ was calculated for further estimations. Each of the fastening elements was stressed by a perforce of $F_w=1000$ N.

Fig. 3. Belt conveyor drive system for open-pit mine loading process

Fig. 4. Fastening of cargo on a 40 ft Flat Track container

Atypical load should be secured with ten lashing elements in the form of straps (1, 1’, 2, 2’, 3, 3’, 4, 4’, 5, 5’) according to the scheme in Fig. 5.

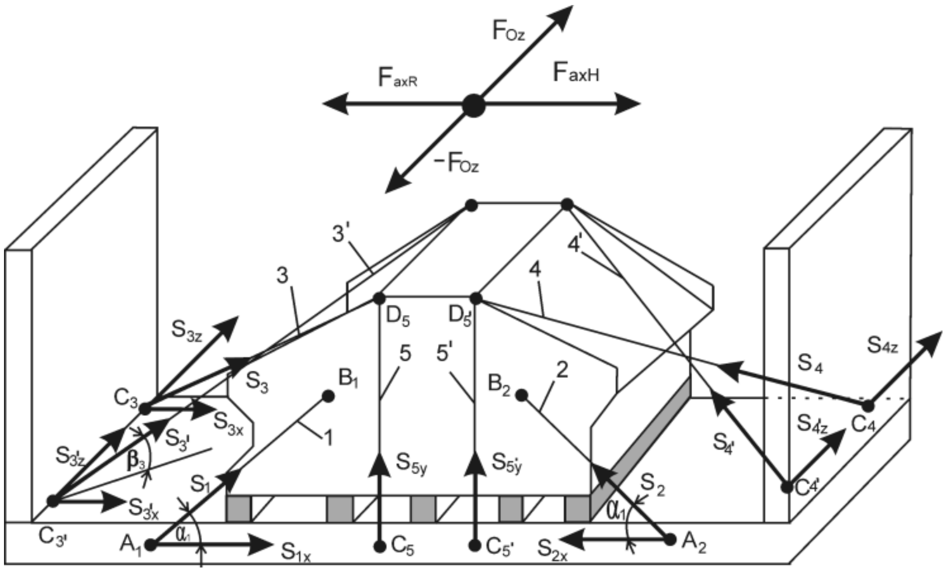


Fig. 5. Scheme of belt conveyor system securing method on a container platform

For further analysis, the following indications were determined according to Fig. 5:

- S_1, $S_{1'}$, S_2, $S_{2'}$, S_3, $S_{3'}$, S_4, $S_{4'}$ – tensile forces in fixed lashings no. 1,1',2,2',3,3',4,4';
- S_{1x}, $S_{1x'}$, S_{2x}, $S_{2x'}$, S_{3x}, $S_{3x'}$, S_{4x}, $S_{4x'}$ – force components of S_1, $S_{1'}$, S_2, $S_{2'}$, S_3, $S_{3'}$, S_4, $S_{4'}$, acting respectively in the directions of the axis O_x;
- S_{3z}, $S_{3z'}$, S_{4z}, $S_{4z'}$ – force components of S_3, $S_{3'}$, S_4, $S_{4'}$ acting respectively in the directions of the axis O_z;
- S_{1y}, $S_{1y'}$, S_{2y}, $S_{2y'}$ – force components of S_1, $S_{1'}$, S_2, $S_{2'}$, acting respectively in the directions of the axis O_y;
- α_1, α_2 – angles between the lashings S_1, $S_{1'}$, S_2, $S_{2'}$ and the plane of a container platform;
- β_{3x}, $\beta_{3'x}$, β_{4x}, $\beta_{4'x}$,– angles between the axis O_x and the lashings projection on the platform plane;
- β_{3z}, $\beta_{3'z}$, β_{4z}, $\beta_{4'z}$ – angles between the axis O_z and the lashings projection on the platform plane.

3.3. Forces acting on the transported cargo

In the longitudinal direction, the F_{ax} inertia force acts on the load that occurs during the braking F_{axH} and the acceleration F_{axR} of the vehicle. While driving along the curvilinear path, centrifugal force F_{oz} is created, because the uneven surface of the road is a source of inertial force F_{by} acting vertically. The values of the forces of inertia are calculated as the product of the acceleration of gravity C and derived from the load being transported Q_L according to the formula:

$$F_{bxyz} = C_{xyz} \cdot Q_L \tag{1}$$

The values of C_{xyz} acceleration factors are normalised for the different directions of inertial forces and the values were shown in Table 1 according to the European standard.

3.4. Calculation and selection of lashings for conveyor attachment on a container platform

The cargo on the container platform of the vehicle should be protected against slipping while driving, to ensure the safety of the driver, the traffic and to secure the load from possible damage. Different methods of fixing cargo on means of transport are used in transport. The basic ones are: blocking, anchoring using lashing, increasing the value of friction force of the load on the floor of the body by the belt lashing method. In practice, combinations of these methods are usually used. The purpose of this combination is to improve the efficiency of the loaded cargo.
For the mounting of the conveyor belt drive system, the cross anchoring method with belt lashing was used. The cross anchoring method allows attaching a heavyweight load using only four lashings that secure the load from moving in both the transverse and the longitudinal directions. However, a necessary condition for using this kind of protection is that the load has special handles to fix the lashings used.

The selection of cross anchoring lashing is to determine the minimum value of the LC lashing capacity for each of the lashes located at the front (LP_p) and the back (LC_t) of the container platform. To determine the lashing capacity, it is necessary to analyse the inertia forces of the transported load at the time of the most unfavourable conditions (like roadblock overcoming) occurring in road transport. During breaking, the inertia force F_{axh}, is determined by the following relation (2) (Fig. 6) and is calculated as follows:

$$F_{axh} = m_L \cdot a_x = 141\ 264\ \text{N} \tag{2}$$

where: a_x - accelerated deceleration at braking, m_L - load mass.

Therefore, while braking the F_{axh} inertia force acts on the load with 141 264 N.

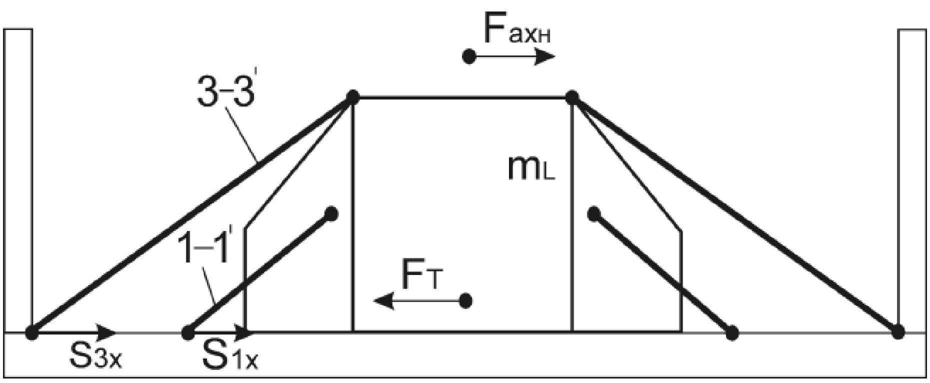


Fig. 6. Diagram showing forces reaction at the moment of braking

At the moment of braking, the load is secured with 1, 1', and 3, 3’ lashings. In addition to F_{axH} inertial force also opposes the F_T frictional force between the surface of the platform container and the wooden sleepers under load. The friction force F_T (3) is directed opposite to the force causing the load shifting according to the relation (Fig. 7).

$$F_T = \mu \cdot N \tag{3}$$

For wooden beams and metal substrates, the coefficient of friction is in the range μ=0.2-0.5. The most unfavourable value was considered, that is, μ=0.2. In the case of cargo resting horizontally on the platform, the load force N and the gravity of the load G are equal (N=G). Apart from these forces, in this case, the load was additionally compressed by the 5 and 5' belt tension. Then on the force of pressure N, in addition to the gravity G, there is also the pressing force P_n, derived from the tension of the belts 5 and 5'. Thus, the load pressure on the substrate, including the fixing straps, is:

$$N = G \cdot P_n \tag{4}$$

where: P_n - additional force pressing the load to the cargo platform of the container.

Belt tensioners increase the clamping force by an additional value of Pn = 5000 N (standard tension force S_{TF}). After substituting the appropriate size and calculating the frictional force, F_T has the following value:

$$F_T = \mu \cdot N = \mu \cdot (G \cdot P_n) = \mu \cdot (m_L \cdot g) \ \cdot P_n = 36\,316 \text{ N} \tag{5}$$

The frictional force, after considering the forces from the load and the pressing straps, is F_T=36 316 N. At the moment of braking, after taking into account the force of friction of the load and the pressing of the belts, the final inertial force F_{axH} is applied to the transported load with the following values according to the following relation:

$$F_{axH} = F_{axh} - F_T = 104\,948 \text{ N} \tag{6}$$

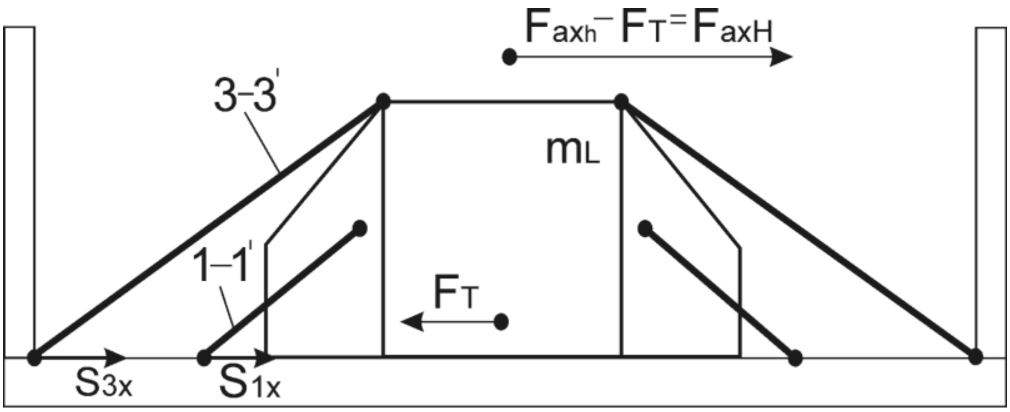


Fig. 7. Scheme of inertia force at the moment of braking

The resulting value (6) is inertial force F_{axH} that acts directly on the load at the time of braking and to which should be secured with lashing equipment no. 3, 3' and 1, 1'. After determining the magnitude of the inertia force acting on the load at the moment of deceleration, the centrifugal force F_{oz} acting on the load at the moment of travel on the curve is determined according to the relation (Fig. 8):

$$F_{oz} = \frac{m_L \cdot v^2}{R} \tag{7}$$

where: m_L - load mass, v - speed of the vehicle with the load, R - radius of the road arc.

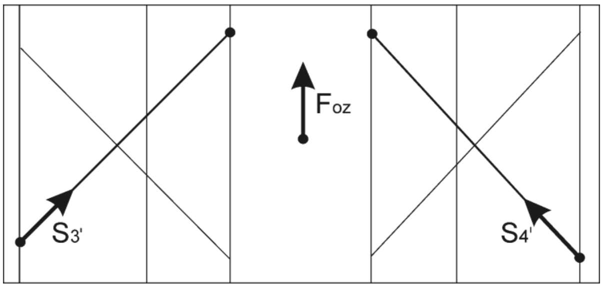


Fig. 8. Scheme of the lashings reaction system exhausts to
the centrifugal force on the curve of the road

Fig. 8 shows that at the time of driving on a curve road, centrifugal force F_{oz} influences the 3' and 4' lashing rods. To determine the centrifugal force, the most disadvantageous road conditions are assumed. The calculation assumes that the load can travel at maximum speed v=80 km/h=22.2 m/s. This speed applies to motorways, expressways and 2-lane roads outside the built-up areas of Poland. For roads having the minimum speed curve radiuses are R=250 m. By substituting these values for the dependence (7), the centrifugal force at the level F_{oz}=35 520 N is obtained. On the other hand, considering the European standard and other adverse road conditions related to sudden lane change such as avoiding an obstacle, the centrifugal force is:

$$\mathrm{F_{ot}} = \mathrm{m_L} \cdot \mathrm{a_z} = 90\ 000\ \mathrm{N} \tag{8}$$

Taking into account the frictional force of F_T, the final centrifugal force F_{oz} acting on the considered load is:

$$F_{oz} = F_{ot} - F_T = 53\ 684\ N \tag{9}$$

The determined values of forces acting on the conveyor drive system on a container platform are presented in Table 2.

Tab. 2

Values of forces acting on a conveyor drive system packed on a container platform

Direction of force	Force value
In the direction of the longitudinal movement, at the moment of braking	$\mathrm{F_{axh}} = 141\ 264$ N
In the direction of the opposite longitudinal movement at the moment of starting	
In the transverse direction when driving on the arc of the road	$\mathrm{F_{oz}} = 53\ 684$ N
Vertical direction when driving on uneven roads	$\mathrm{F_{by}} = 90\ 000$ N

Sensors of vectors of the reaction forces in lashings no. 1, 1', 2, 2', 3, 3', 4 and 4' are opposed to the return forces during transport loads on the platform of the container. The inertia force F_{oz} is directed forward and its effect is transferred to the cross-lashings no. 4, 4' and longitudinal lashings no. 2, 2'. F_{oz} centrifugal force acts transversely to the direction of travel, and its operation is transferred to the cross lashings no. 3 and 4. When F_{oz} centrifugal force changes, the reactions will occur in 3’ and 4’ lashings. Tilt angles of lashings are required to determine the reaction forces. Fig. 9 shows the angles β_1, β_2, describing the arrangement of cargo lashing in the O_{xz} plane at reaction point C.

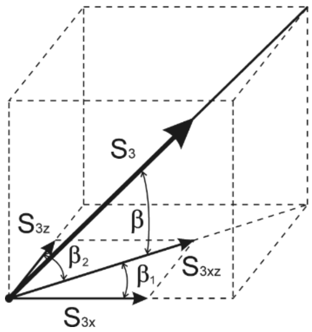


Fig. 9. Angles of lashing no. 3 alignment at the C_3’ attachment point

Reactions considered at points C and C’ are the condition of the load when the transported load on the container platform is affected by the forward inertia force F_{axH} as a result of the vehicle braking. The reactions at points C and C’ have the same values ($S_{3x}=S_{3'x}$) since the fixing lashing are arranged symmetrically. Strength S_3 was decomposed into components acting in directions O_x, O_z.

$$S_{3x} = S_{3C} \cdot cos\, \beta_{3x} = S_3 \cdot cos\beta_3 \cdot cos\beta_{3x} \tag{10}$$

$$S_{3z} = S_{3C} \cdot cos\, \beta_{3x} = S_3 \cdot cos\beta_3 \cdot cos\beta_{3z} \tag{11}$$

Similarly, the S_1 force in the direction of O_x and Oz was decomposed into the force of the reaction of lashings 1 and 2 at points C_1 and C_2.

$$\mathrm{S_{1x} = S_1 \cdot cos\alpha_1} \tag{12}$$

$$\mathrm{S_{1y} = S_1 \cdot sin\alpha_1} \tag{13}$$

The S_{3x}, $S_{3x'}$ and S_{1x}, $S_{1x'}$ reaction forces maintain the charge in equilibrium when the inertial force at the moment of braking F_{axH} is acting in the longitudinal direction. The load remains in balance if:

$$\mathrm{S_{3x} + S_{3x\prime} + S_{1x} + S_{1x\prime} \geq F_{axH}} \tag{14}$$

When $S_1=S_{1'}$, $S_3=S_{3'}$, then the equation takes the following form:

$$\mathrm{2S_{3x} + 2S_{1x} \geq F_{axH}} \tag{15}$$

After substituting the relations defined in equation (10) and (12) into equation (15), we obtain:

$$\mathrm{2(S_3 \cdot cos\beta_3 \cdot cos\beta_{3x}) + 2(S_1 \cdot cos\alpha_1) \geq F_{axH}} \tag{16}$$

Equation (16) presents the state of equilibrium at the moment the vehicle brakes. To determine the forces in the S_3 and S_1 lashings, tensile forces in lashings 3 and 4 arising from the centrifugal force at the moment of the arc or other lane change manoeuvre must be determined.

When driving on the arc of the road, lashings 3 and 4 are tensed under the influence of the centrifugal force F_{oz}, based on the dependence:

$$F_{oz} = S_{3z} + S_{4z} \tag{17}$$

After substituting dependence (11) and assuming that S_{3z}=S_{4z} due to the symmetry of the attached load, the equation (17) takes the following form:

$$F_{oz} = 2S_3 \cdot \cos\beta_3 \cdot \cos\beta_{3z} \tag{18}$$

After transforming the equation (18) to S_3, we obtain the equation of the force in fixing lashing 3 and simultaneously in lashing 4.

$$S_3 = \frac{F_{oz}}{2 \cdot \cos\beta_3 \cdot \cos\beta_{3z}} = 52\ 083.3\ \text{N} \tag{19}$$

It is clear from the calculation that the fixing lashings 3 and 4 have a tensile strength of 52,083.3 N. It follows that the forces acting on the lashings of cross attachment $S_{3,3'}$=52 083.3 N. If the load acting on the 3 and 4 lashings is known, the force that tenses the 1 and 1' lashings can be determined. Due to the symmetry, only S1 may be calculated. After substituting the force S3 for the equation and the corresponding transformation, we obtain the force $S_{1,1'}$=20 290.85 N.

The analysis shows that for the conveyor drive system transported on the container in the individual attachment lashings force values appear as presented in Table 3.

Following the analysis, associated with the forces, selection of appropriate fixing equipment should be done according to lashing capacity (LC).

Tab. 3

Size of forces calculated on individual lashings securing conveyor drive system

No. of fixing lashing	Determination of tensile force of fixing cable	Value of maximum forces in tension [N]
1	S_1	20 291
1'	S_1'	
2	S_2	
2'	S_2'	
3	S_3	52 083
3'	S_3'	
4	S_4	
4'	S_4'	
5	S_5	22 500
5'	S_5'	

3.5. Selection of lashings securing transported cargo

To secure the conveyor on a container, according to the guidelines contained in the standard, the following fixing lashings should be applied: S_1, S_1' and S_2, S_2', lashings should have a tensile strength of $S_{1,2}$ =20 291 N, lashings S_3, S_3' and S_4, S_4' should have a tensile strength of $S_{3,4}$=52 083 N and lashing S_5=22 500 N.

Lashing straps recommended by the carrier was selected for conveyor attachment. Lashing straps usually consist of artificial fibres (usually polyester according to EN 12195-2). Each tape harness is labelled with the appropriate information, shown in Fig. 10, which is lashing capacity (LC) in decaNewtons (daN- official force unit corresponding to 1 kg), standard tension force (STF) which is obtained when the manual force is applied to the tensioner (SHF) [3, 19].

Breaking force 4000 kg
LC 1600 daN
SHF 50 daN / STF 400 daN
100% POLYESTER
LGL 10 m
! NOT FOR LIFTING !
IRU CIT
VAT No. XXXYYY-YYYY
2017
EN 12195-2

Fig. 10. Cargo lashing belt label according to the EN 12195-2 standard

Fixing equipment in the form of fastening belts should be made following the EN 12195-2 standard. Companies that manufacture these types of fastening belts have the straps in their assortments in the following ranges:

- lashing strap width from 25 to 75 mm,
- lashing strap maximum load from 250 to 10 000 daN,
- safety factor of the securing straps is 2.

When attaching an 18t load on conveyor drive system, the following fastening belts should be used [12]:

a. for lashings: S_1, S_1' and S_2, S_2' one-piece belt with manual tensioner was used (Fig. 11)

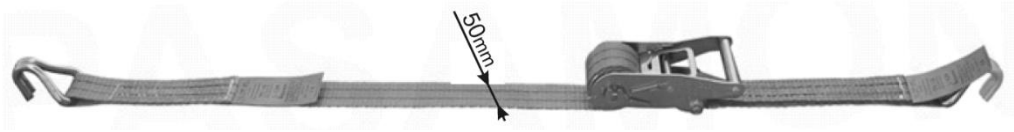


Fig. 11. Fastening strap used for lashings S_1, S_1' and S_2, S_2'

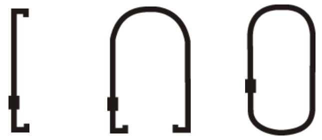
This type of lashing strap has the following parameters and implementations used (Table 4):

- strap width 50 mm,
- lashing capacity LC=2 000 daN.

Tab. 4

Fastening strap types used for lashings S_1, S_1' and S_2, S_2' of conveyor securing

LC - lashing capacity			Implementation possibilities
2000 [daN]	4000 [daN]	4000 [daN]	



Two-piece with profile hooks
Two-piece with U-type hooks
Two-piece with carabiners hooks
One-piece with a closed circuit

b. for lashings: S_3, S_3' and S_4, S_4', the following fastening straps were used (Fig. 12):

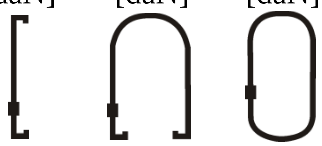
Fig. 12. Fastening strap used for lashings *S_3, S_3'* and *S_4, S_4'*

This type of lashing strap has the following parameters and implementations used (Table 5):
− strap width 75 mm,
− lashing capacity LC=5 000 daN.

Tab. 5

Fastening strap types used for lashings S_3, S_3' and S_4, S_4' of conveyor securing

LC - lashing capacity			Implementation possibilities
5000 [daN]	10000 [daN]	10000 [daN]	



Two-piece with forged security hooks
Two-piece with profile hooks
One-piece with a closed circuit

c. for lashings: S_5 and S_5' fastening straps of the following parameters should be used (Fig. 13): strap width - 50 mm, lashing capacity LC=2 500 daN with different types shown in Table 6.

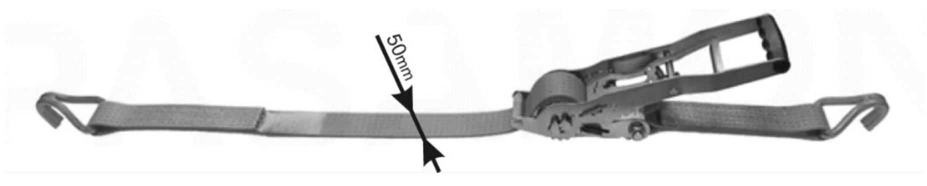
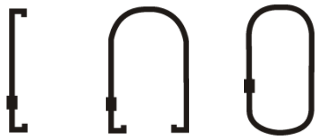


Fig. 13. Fastening strap used for lashings S_5 and S_5'

Tab. 6

Fastening strap types used for lashings S_5 and S_5' of conveyor securing

LC - lashing capacity			Implementation possibilities
2500 [daN]	5000 [daN]	5000 [daN]	



Two-piece with profile hooks
Two-piece with U-type hooks
Two-piece with carabiners hooks
One-piece with a closed circuit

For load safety, the use of a similar procedure for choosing the form of security and fixing means selection is recommended, analysing each case separately at the planning stage of the transport process according to standardisation [1, 3, 19].

4. CONCLUSIONS

This article is focused on intermodal transportation of mining components packed in containers or other cargo transport units together with the problem of its proper securing. Using appropriate equipment, method of cargo securing and correct transport unit are very important elements among the six key factors mentioned as most important of proper and safe transportation planning. The decision of packaging and fixing means selection, however, depends on the forces acting on the load. EN 12195-1 standard is usually used for calculation of securing forces which contains the European Commission guidelines on cargo security. However, many carriers use the VDI2700 German standard where the basic forces acting on the cargo, practical way of proper location and installing the fastening devices are explained. Furthermore, this article presents a case study of container packing and securing of a mining conveyor, which was sent from Poland to Indonesia. First, the strap cross fixing method was determined with five lashings. Thereafter, considering the friction forces of the load and the lashing pressing forces, final inertial force (F_{axH}=104 948 N) while vehicle braking was calculated. It should be secured with lashing equipment no. 3, 3' and 1, 1'. While driving on a curve road, centrifugal force (F_{oz}=53 684 N) influences the 3' and 4' lashing rods. Then, forces acting on the lashings of cross attachment $S_{3,3'}$=52 083.3 N were determined and are the same for lashings 4 and 4'. Basing on this knowledge, lashing strap of 75 mm width and lashing capacity LC=5 000 daN was selected for cargo securing. Similarly, forces acting on lashings 1, 1' and 2, 2' were determined ($S_{1,1'}$=20 291 N) and appropriate strap of 50 mm width and 2 000 daN lashing capacity was proposed. For lashings 5 and 5' ($S_{5,5'}$=22 500 N), strap with 50 mm width and LC=2 500 daN lashing capacity is proposed. Finally, various types of usable selected belts with different hook variants were presented.

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