INNOVATIONS AND SAFETY ISSUES IN CONTAINER HANDLING

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Abstract

Early versions of standardized containers were used in Europe before World War II. Construction of these containers had a steel frame with wooden walls, floor, roof and doors. Current containers meet strict requirements set by the International Convention for Safe Containers (CSC). Today the owners know where their container is located through Internet of things technology. [1] Their container passes from the dispatch point [2] up to the destination point with no touch to its contents. Application of container cranes, spreaders, frames, centralizers ensure a full safety for goods, equipment and even working personnel.

Keywords: container, spreader, frame, centralizer, crane

1 Introduction

The standardized shipping container designed and built for intermodal freight transport can be used across different modes of transport [3] from ship to rail to truck without unloading and reloading their cargo. [4] containers. Intermodal containers exist in many types and a number of standardized sizes, but ninety percent of the global container fleet are so called general purpose containers, durable closed steel boxes mostly of either twenty or forty foot (6 or 12m) standard length. The common heights are 8 feet 6 inches (2.6 m) and 9 feet 6 inches (2.9 m) – the latter are known as High Cube or Hi-Cube containers. These containers are a means to bundle cargo and goods [5] into larger, unitized loads, that can be easily handled, moved, and stacked, and that will pack tightly in a ship or yard. Intermodal containers share a number of key construction features to withstand the stresses of intermodal shipping, to facilitate their handling and to allow stacking, as well as being identifiable through their individual, unique ISO 6346 reporting mark. The paper gives an overview of the latest equipment allowing a remote container management (RCM) technology, that improves cargo security and safety, ensures regulatory compliance, gains full container supply chain visibility, reduces container fleet operating costs, automates port and container terminal processes and many more.

Fig. 1 *Container transportation on a train*

2 Conventional rules and calculation methods

The technical requirements placed on containers are enshrined in the standards and the International Convention for Safe Containers or “CSC”. These days, higher permissible loading capabilities are practically the rule. The Convention incorporates a series of design requirements. (e.g., very precise dimensions at each corner of the container so that equipment that lifts and moves containers can always find the holes in each corner casting), minimum functionality and weather tightness plus various measurements of capacity, weight and resistance to the amazing forces that containers receive while underway at sea on ships or on land with trains and trucks.

Modern commercial vehicles are equipped with more powerful brakes and steering assistance systems. This means that higher acceleration forces may be expected. The roads themselves are better and engines are more powerful, and these factors result in higher speeds. Loading technology has been mechanized and thoroughly rationalized, which does not necessarily improve the conditions for securing units of cargo. This is compounded by time pressure and a lack of staff, with the result that both expenditure on and the quality of cargo securing measures could be under threat. On the other hand, better securing equipment is available, and the availability of calculation software boosts the attractiveness of more complex calculation models for planning and checking securing strategies.
All these aspects need to be taken into account. Ultimately, it is important that any simplified rules and approaches to calculation are only published in conjunction with the underlying philosophy and stating the way in which they were derived, so that nobody runs the risk of taking the simplifications as true reflections of reality and exploiting them in the name of the laws of physics. [6]

2.1 Full braking

Full braking is the greatest load to which a forward securing arrangement is exposed. Recent developments in the field of truck tires, coupled with modern brake systems and asphalt roads, permit braking deceleration values that are perfectly capable of approaching 0,8g[1]. Other factors, such as the distribution of axle weights, also play a role in this context.

The connection between the loading area of a truck or semitrailer and the tyre footprints is not rigid but resilient, which means that the inertial force of the cargo does not follow directly from the braking deceleration, but instead initially brings about a forward tilting of the loading area. This “pitching angle” is not a steady state throughout full braking, but has pitching oscillations superimposed on it. The amplitude of the pitching oscillations is very highly dependent on buildup time, i.e. the time taken for the braking force to increase to its full value.

During full braking, the following forces act forwards on the cargo in the coordinate system of the loading area (parallel to the loading area):

- Inertial force component from the braking maneuver,
- Downhill force (weight component) arising from the geodetic inclination of the loading area (pitching angle and gradient of road),
- Inertial force arising from tangential acceleration from superimposed pitching oscillation.

The normal force acting from the cargo on the loading area is generally reduced by two causes, namely, as a result of the inclination of the loading area, by the

- Upwardly directed vertical component of the inertial force,
- Reduced normal component of the weight-force.

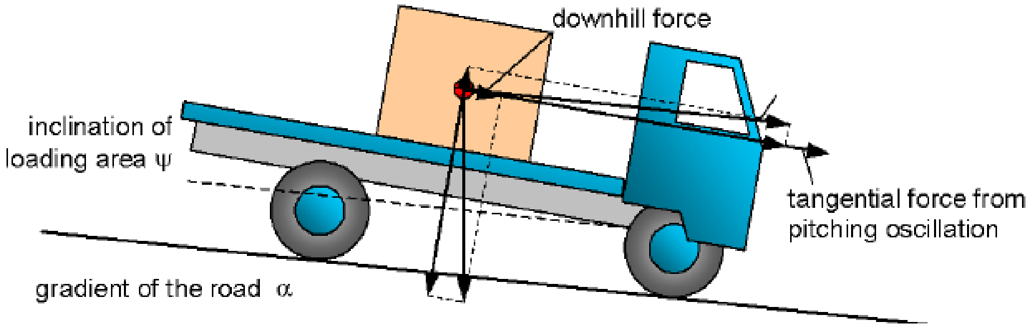

Fig. 2 *Full braking on a downward sloping road*

Figure 3 shows a chart of a full braking on a level road from 90 km/h with 0,8 g braking deceleration and 0,3 s buildup time with a stopping distance of 42,9 m.

It shows the numerical solution of the equations of motion over a period of 6 seconds. The forces acting on the cargo have been converted into units of g. The vehicle is stationary after approx. 3.3 seconds. The truck is loaded in such a way that, at 0.8 g deceleration, a steady-state pitching angle of 4° is obtained. The maximum pitching angle after 0.9 seconds amounts to 5.5° as a result of the superimposed pitching oscillation. This oscillation is strongly damped and largely subsides by the time the vehicle is at a standstill, but is re-excited by the familiar jerk at the end of the braking maneuver. The maximum longitudinal load on the cargo at 0.9 seconds amounts to 0.98 g, at which point the normal force has simultaneously declined to 0.92 g. [7] Numerous further simulated full braking maneuvers at other speeds, uphill and downhill road gradients and other vehicle types (e.g. semi trailer with a smaller pitching angle) reveal similar profiles. The following general conclusions may be drawn:

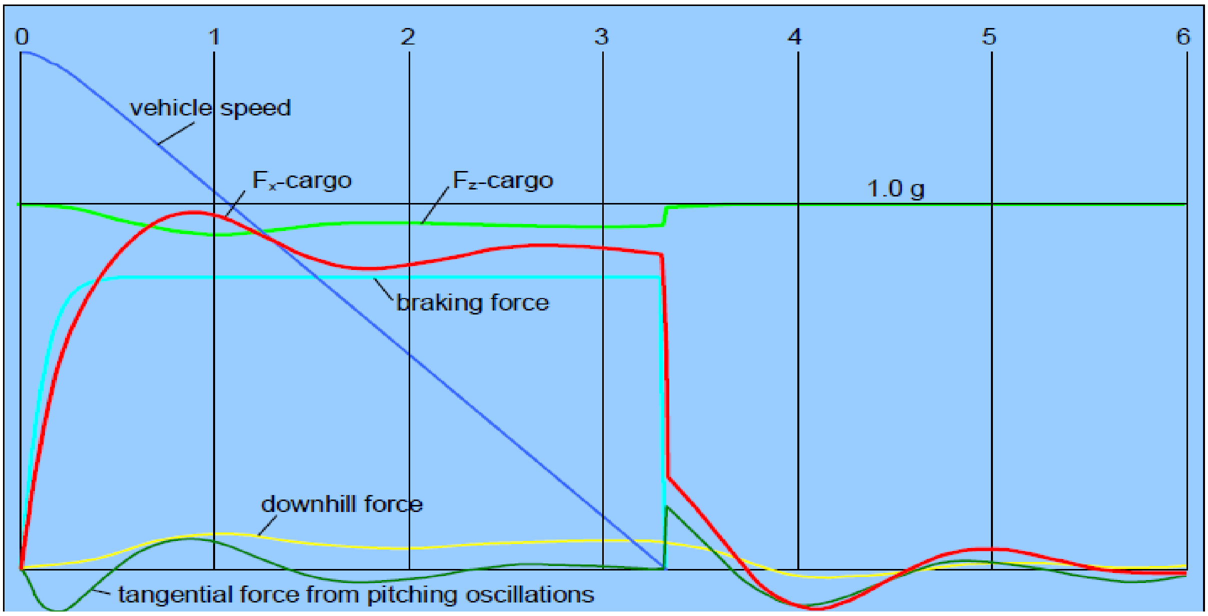

Fig. 3 *Chart of a full braking*

- Calculating on the basis of braking force transfer corresponding to 0.8 g, cargo securing must be designed for just about 1.0 g, because the downhill force from the pitching angle plus the tangential force from the superimposed pitching oscillation add about 0.2 g.
- Full braking from lower initial speeds results in only insignificantly more favorable results. Only at speeds of below 15 km/h may it happen that the vehicle is already stationary before the maximum longitudinal force has been reached.
- Semi trailers, which are assumed to have half the pitching angle, experience approx. 3% lower longitudinal forces and a 4% lower reduction in normal force. The outcome is no more favorable than this because the pitching oscillation period simultaneously becomes shorter and the amplitudes of the pitching oscillations are only insignificantly smaller than in a vehicle with a 4° steady-state pitching angle.
- - The more rigidly is a loading area mounted, i.e. the less it responds to deceleration with a pitching angle and with pitching oscillations, the closer the longitudinal force acting on the cargo approximates to the pure inertial force from the braking deceleration.
- Gentler braking maneuvers with buildup times of longer than 2 seconds result in virtually no superimposed pitching oscillations. Calculating on the basis of 0.8 g maximum braking deceleration, the only further allowance which need be made is for the parallel component of the force of gravity from a steady-state pitching angle. The allowance is obtained from the sine of this angle.
- On full braking uphill from a speed of 50 km/h, the braking force is increased by the backward downhill force and, as a result, the braking distance is distinctly shorter than on a level road. The effective pitching angle is, however, reduced by the rearwardly directed inclination of the road, such that the difference in longitudinal force on the cargo is almost equalized compared to the situation on a level road. Under the selected conditions according to Figure 2, the cargo should be secured against acceleration of 0.99 g.

- On full braking downhill from a speed of 50 km/h, the longitudinal force on the cargo is somewhat smaller than in the event of full braking on a level street. The effective braking force is smaller and the braking distance greater. The downhill force is, however, increased by the inclination of the road. Under the selected conditions, the cargo should be secured against acceleration of 0.96 g.
- Calculation methods for dimensioning longitudinal cargo securing should take suitable account of the decrease in normal force (weight).

$$\mathrm{J}_{\mathrm{homogeneous}} \approx \mathrm{m}_1 \left(\frac{\mathrm{b}^2+\mathrm{h}^2}{12}\right) [\mathrm{kg.\,m}^2] \tag{1}$$

$$J_{hollow} \approx m \cdot \left(\frac{(b+h)^2}{12}\right) [\mathrm{kg.m}^2] \tag{2}$$

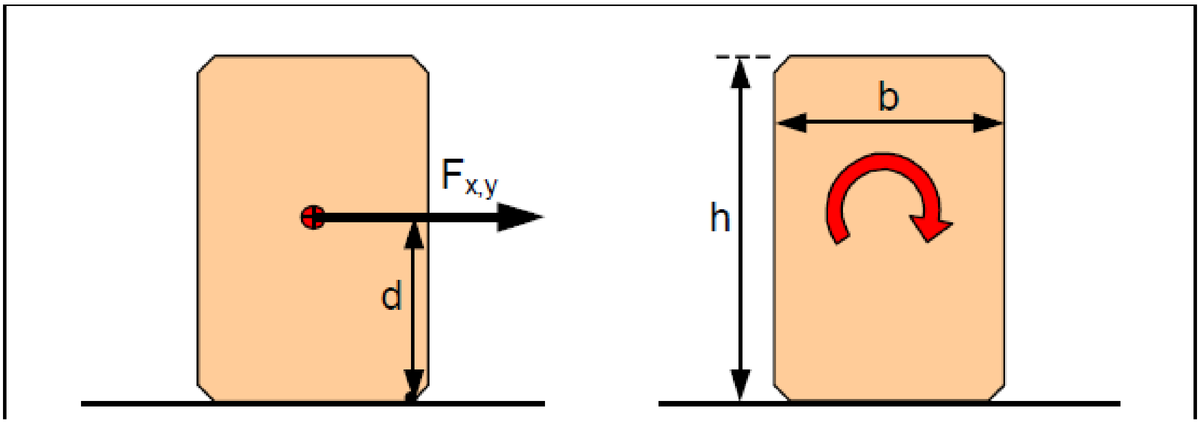

Fig. 4 Static and dynamic tipping moment

3 Stackers

If you deal with shipping container engineers, builders, designers or startups, inevitably you will hear the conversations start to involve a wide range of acronyms including ISO, IMO, BIC and CSC abbreviations (International Convention for Safe Containers). [8] The aim of the Convention is to achieve the highest possible level of safety of human life in the handling, stacking and transporting of containers. The Convention applies to all containers used for international transport, except containers developed especially for air travel. Convention incorporates a series of design requirements (e.g., very precise dimensions at each corner of the container so that equipment that lifts and moves containers can always find the holes in each corner casting), minimum functionality and weather tightness plus various measurements of capacity, weight and resistance to the amazing forces that containers receive while underway at sea on ships or on land with trains and trucks.

Fig. 5 *Container reach stacker and stacker*

The purpose of the Convention is to insure that containers are safe and consistently built. The taxonomy for the standards that are the basis for CSC testing is complicated and involves the United Nations, the International Maritime Organization, the International Standards Organization, various national standards organizations and a structured set of committees and working groups that focus on specific design or use issues. [9]

4 Spreaders

Spreader is a rigid rectangular framed container spreading device for handling ISO certified containers. The spreader has been designed to cope in extremely tough conditions.

Huge range of container spreaders suit a variety of application.

- Fully Automatic Spreaders
- Semi Automatic Spreaders
- Special Model Spreaders
- Easy Spreaders
- Spreaders for indoor use

C-lift, a semi-automatic fixed frame container spreader is assigned to handle ISO certified containers. It can be operated by most types of hook operated cranes, such as quay crane, mobile crane, overhead cranes and ship mounted cranes. C-Lift has semi-automatic operation, however the spreader can also be operated manually using the pre-installed handles. [10] Operation of the spreader is based on the 'gravity and lift' principle, locking and unlocking of the twist locks is made by the lowering and lifting of the spreader by the crane operator. The spreader is available to suit 20ft, 30ft & 40ft ISO containers. C-lift spreaders are available from 32t up to 40t lifting capacities.

Fig. 6 *C-lift*

Fig. 7 *Frame of a container spreader*

The spreader offers unique advantages for the operator, such as:

- Safety interlocking system
- Safety Torque Limitation (STB-system)
- Corner guide arm system for safe and fast approach to the container
- Extremely low tare weight (e.g. 1200 kg for a 20ft incl. wire sling)
- Visual indicator for twist lock position
- Attachments for over height handling of open container and flat racks
- Flexible construction for uneven conditions

Highly visible panels are an option – these help to inform the crane driver of the position of the cones.

The four twist locks work in conjunction with the safety interlocking system. If one or more of the twist locks are blocked, caused by a pressure put on the twist locks from beneath (for example the spreader twist locks are resting on the container roof), then the twist locks are prevented from locking (STB-system). In this instance the twist locks will remain in the opened position and the visual indicator will highlight the spreader unlock condition to the crane operator. The main slings consist of 2 x 2 part wire rope slings for attaching to the crane hook. 2 x forklift pockets are mounted to the top of the spreader to assist with transportation and stacking of the spreaders.

The mechanical locking system provides simple yet failsafe operation, leading to very low downtime for maintenance and servicing. [11] All spreaders are CE marked and supplied with certificates of load testing. All spreaders are fully inspected in line with quality control requirements prior to delivery.

5 Centralizers

Stevedoring companies and ship-owners are today focusing on methods to provide safer and more rapid handling of cargo. The gravity centraliser offers a unique method to safely control the handling of cargo that have a centre of gravity offset from the centre of the load due to either incorrectly stowed cargo or through an asymmetric design. [12]

With the gravity centraliser the crane operator is able to adjust and set a correct lifting point to ensure the cargo is handled in a safe and correct way. [13] This means a reduced risk of jammed containers in cell guides and collisions due to side way movements from uneven loads. The centraliser can operate with any brand of fixed frame 20ft or 40ft container spreaders. The centraliser has an extremely low tare weight of only 425 kg.

The Centraliser is equipped with 2 x master links 400x200x50 50T and 2 x shackles KL-8 M42 40T for attaching to the crane twin-hook.

The attachment to the fixed frame spreader is via a 32mm chain, grade 8, The chain is 2976 mm long (the chain is used to provide load centralising) and is supplied with anchor shackle KL-8 M42 40T to each end, connected to 2 x 2-part wire slings to the spreader.

Fig. 8 *Centralizer*

6 Conclusion

Transportation of goods is a final step of a distribution process, when a danger of damage and loss of goods is very high. The innovations in loading and discharge equipment include several types of container stackers avoiding non-controlled movements of the container and resulting forces, as well as upgraded versions of a semi-automatic container spreaders and centralizers. The innovation has led to increased production and safety in container port operations.

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