Applicability Research on Flexitank Usage in ISO GP Containers

@tco * 2015

Contents

1. Background

In recent ten years, along with the rapid growth of flexitanks used in the global container transportation, more and more bulk liquids are transported by ISO GP containers which originally designed for general dry cargos. However, this so-called ‘new transport mode’ has frequently reported various accidents, which has aroused high attention and worry about the safety in this industry.

- **Accidents occurred: container sidewall bending & weld seam cracking**

1. Background

➢ **Accidents occurred:**

Flexitank leakage
Environmental pollution
Cargo losing

➢ **Questions:**

Whether this method of transportation is allowed or approved by relevant regulations/standards?

Is it safe?

To answer these questions, we should know the characteristics and transportation requirements of liquid cargo at first.

Contents

2.1 Characteristics of liquid cargo

a、Types of liquid cargoes

ordinary non-dangerous cargoes & dangerous cargoes

b、Mechanical property

Compared with ordinary dry cargo, flowable liquid cargo will effected by the following special properties:

- Sloshing effect: During transportation, the vehicle's acceleration and braking will cause the liquid flowing forth and back; when the vehicle turns in a curve, the liquid will surge to one side under the centrifugal force. Above dynamic movement of the center of gravity of the liquid results in huge impact on the container.
- Pressure transmission: The pressure on the container from the liquid may be transmitted in all directions. In contrast, the pressure of solid cargoes is generally in single direction, which is mainly exerted on the container floor and cargo securing system.

c、 Risk of leakage

Once the package or container was broken, liquid cargo leakage will occur, resulting in loss or spoilt product and environmental pollution.

Considering above b and c, for transporting the liquid cargoes, the containers should be specially designed and satisfy above mechanical properties. Meanwhile, the containers should have high tightness.

2.2 Transportation requirements on liquid cargo

- ISO 1496-3 Series 1 freight containers -- Specification and testing -- Part 3: Tank containers for liquids, gases and pressurized dry bulk

  Specifies the basic requirements on the tank containers for transporting ordinary liquids, gases and pressurized dry bulk cargos. For tank containers to transport dangerous cargoes (portable tank) may subject to additional international and national relevant conventions and regulations.

- International Convention for Safe Containers, 1972（CSC）
- UN Orange Book —Model Regulations
- International Maritime Dangerous Goods Code（IMDG）
- Regulation for rail International transportation of Dangerous goods (RID) and Agreement on Dangerous Goods by Road (ADR)
- ISO 3874 Series 1 freight containers -- Handling and securing
- Cargo securing manual(CS)
- National authority requirements on the dangerous goods transport, such as pressure vessel supervision in China

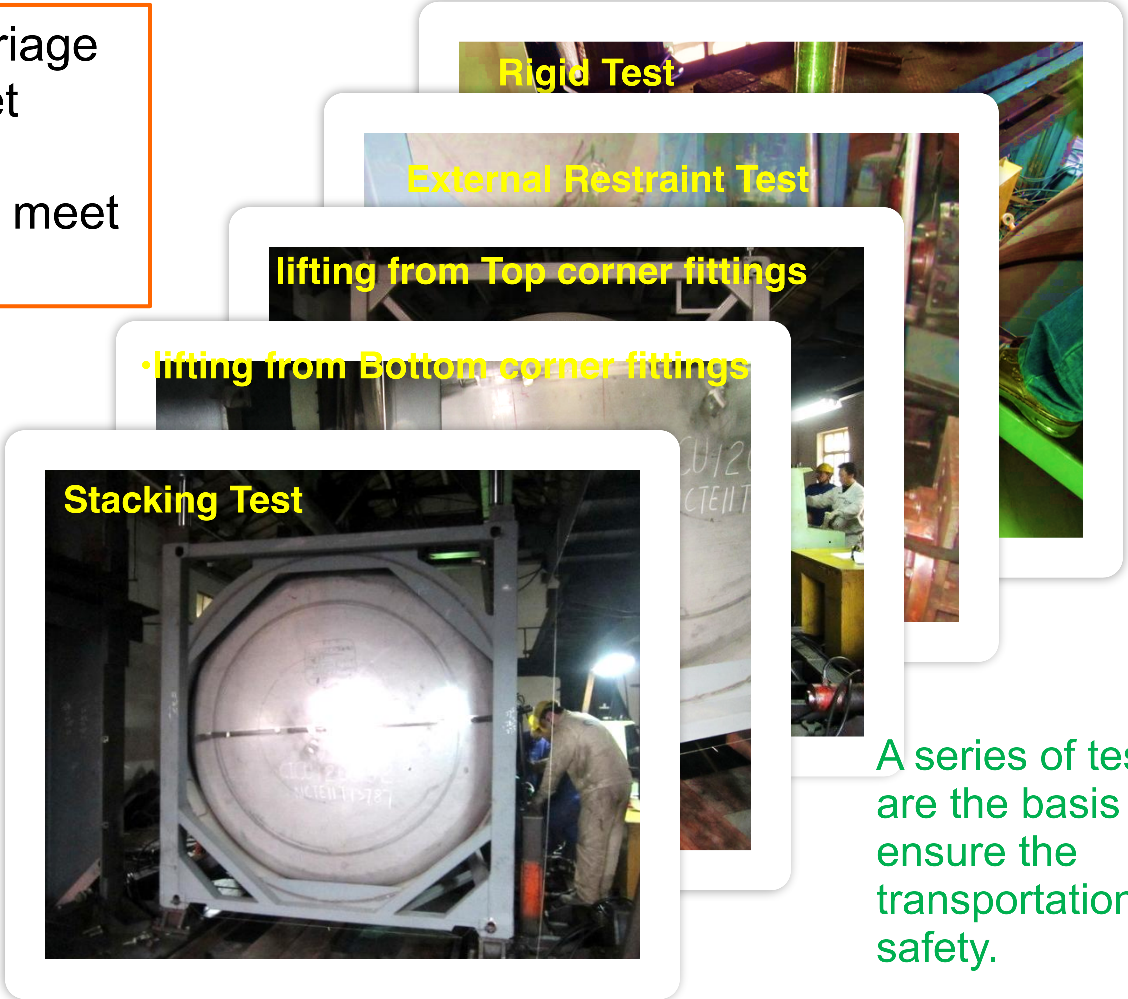
2. Liquid Cargo Characteristics and Transportation Requirements

2.2 Transportation requirements on liquid cargo

- ✓ The containers for the carriage of liquid cargo should meet ISO1496-3.
- ✓ ISO GP containers should meet ISO1496-1.

A. The same test items of above two standards:

- Stacking Test
- Lifting from Bottom corner fittings
- Lifting from Top corner fittings
- External Restraint Test
- Rigid Test

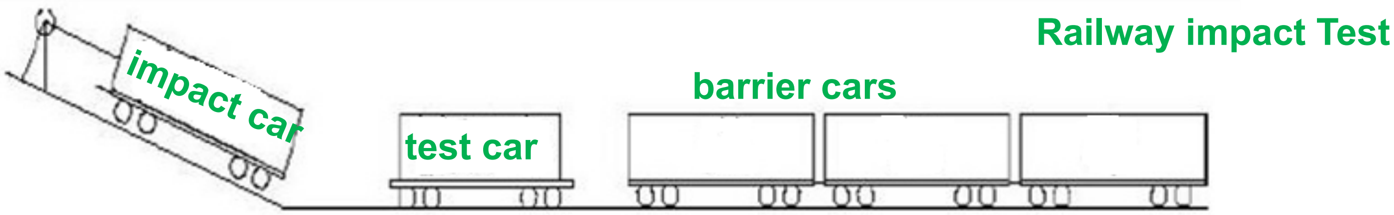


A series of tests are the basis to ensure the transportation safety.

2.2 Transportation requirements on liquid cargo

B. Tests only in ISO1496-3 standard

- Impact test (replaces the “Internal Longitudinal restraint Test" according to Amd.1, 2006)
- Internal transverse restraint test of R / 5min
- Load transfer area test of 2R / 5min
- 300kg walkway strength test (if fitted)
- 200kg ladder strength test (if fitted)
- 30min Hydraulic pressure test
- Leak test after the piping installation
- Thermal performance test for the cryogenic tank



2. Liquid Cargo Characteristics and Transportation Requirements

2.3 Special structural designs on liquid tank containers

	Features	Structural Design
1)	Good pressure bearing performance	Pressure vessels (Using cylindrical tanks)
2)	Overall impact protection	Cylindrical tank within a rectangular outer frame (i.e. having integrated crash protection), insulation, bottom outlet valve protection zones
3)	Leakage prevention	Bottom outlet valve design includes an internal valve, ensuring that when in the worse scenario should the valve be submitted to a direct impact that there is still guaranteed sealing to prevent leakage
4)		Tanks built using high quality stainless steel, with high strength, good ductility, resilient to most impacts, reducing resultant damage & ensuring no product leakage
5)	Thermal protection	Insulation of tanks can reduce the heat loss during transport, and also protect the tank when it is involved in a fire, when the insulation can prevent a rapid temperature rise of the goods, and to win the time for firefighters to dispose the accident.
6)	Improved security, preventing incorrect operation	Pressure/vacuum safety valves, baffle plates, control of the product volume, no fork lift pockets
7)	Withstanding four direction's acceleration	Conforms to the relevant static & dynamic testing requirements i.e. ISO1496-3

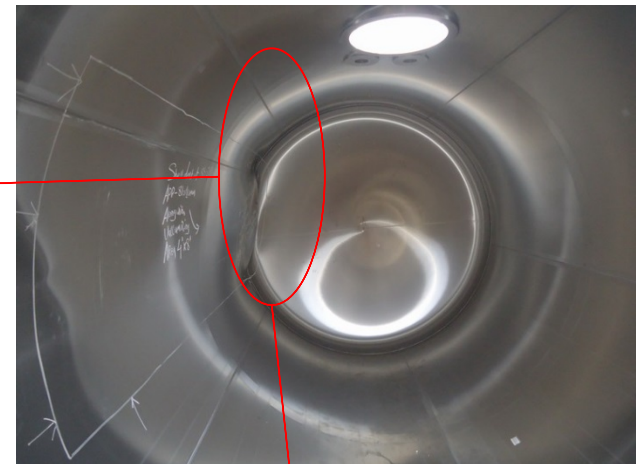
2. Liquid Cargo Characteristics and Transportation Requirements

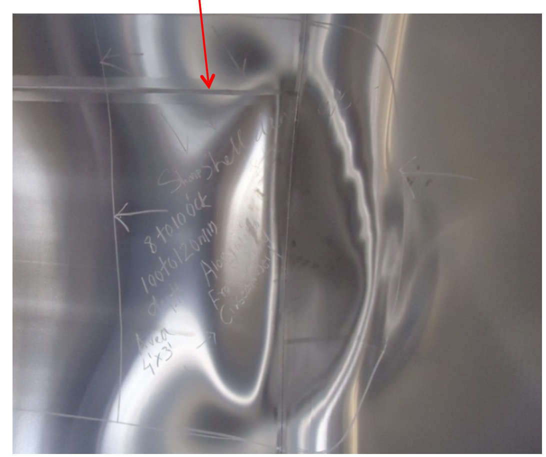
2.3 Special structural designs on liquid tank containers (Example)

When suffered impact or even the vehicle turned over, the tank was still basically intact due to the protection of the frame.

2. Liquid Cargo Characteristics and Transportation Requirements

2.3 Special structural designs on liquid tank containers (Example)





Although the tank was impacted greatly, no broken and leakage occurred, because of the good ductility of tank material.

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3. Application Analysis on Flexitank Used in ISO GP Containers

3.1 Finite Element Stress Analysis

The mainly phenomena in the accidents during flexitank transportation are the deformation and leakage. In order to investigate the reasons and to understand the status of stress exerted on the dry container during flexitank transportation, a FEA analysis has done as following.

➢ **Model and Material Properties**

A. ISO 20'GP container:

Gross mass 30,480Kg, without additional strengthening structure.

B. Flexitank: two kinds of flexitanks commonly used are selected, and assume they comply with PAS 1008.

【Note: above flexitanks don’t meet the requirements on the package for dangerous goods, see clause 6.1 in IMDG Code】

① 16KL，the height of liquid in contact with the side wall is 1100 mm

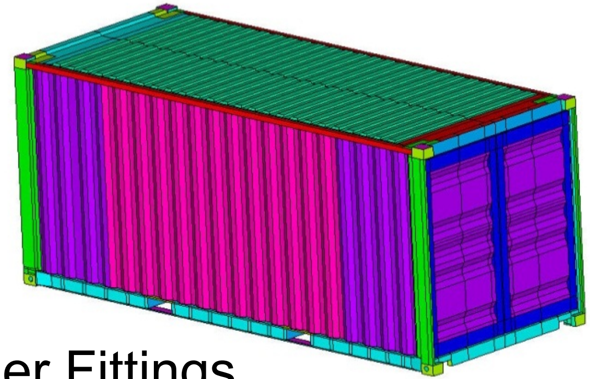
② 24KL， the height of liquid in contact with the side wall is 1300 mm

C. Assuming the liquid medium is water.

Material	Elasticity Modulus E(MPa)	Yield Strength (MPa)	Tensile Strength (MPa)	Poisson Ratio
Corten-A	2.06e5	350	490	0.3
Wood Floor	Ex=10000,Ey=3500, Ez=3500	--	--	Vxy=Vyz=Vxz=0.4

3. Application Analysis on Flexitank Used in ISO GP Containers

3.1 Finite Element Stress Analysis



- **Four conditions simulated**

I. ISO1496-3, 6.3, Lifting from Four Top Corner Fittings

II. ISO1496-3, 6.4, Lifting from Four Bottom Corner Fittings

III. ISO1496-3, 5.1.5, Transportation Condition 1, Transverse Inertia Force 1Rg, gravity 1 g

IV. ISO1496-3, 5.1.5, Transportation Condition 2, Vertical Inertia Force 2Rg, gravity 1 g

Note 1: According to ISO1496-3, 5.1.5, the design requirement for the longitudinal force is 2Rg. Whereas PAS 1008 also requests that the GP container having flexitank inside must pass the impact test of 2g. So this condition is not calculated here.

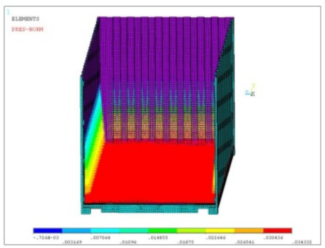
Note 2: The above requirement of 2g impact test in PAS 1008 is different from the 4g impact test requested in ISO1496-3 Amd.1:2006.

3. Application Analysis on Flexitank Used in ISO GP Containers

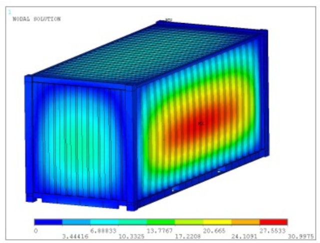
3.1 Finite Element Stress Analysis

I. Lifting from four top corner fittings

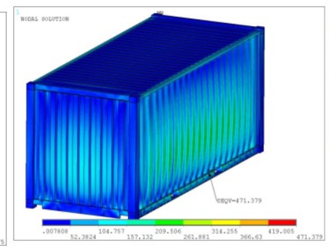
The Case of 24KL Flexitank



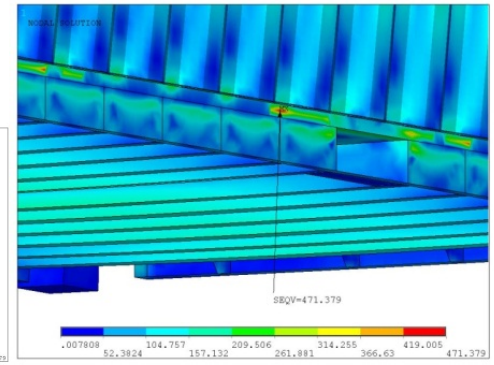
Liquid Pressure Distribution



Sidewall Deformation

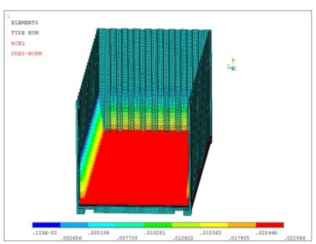


Equivalent Mises Stress

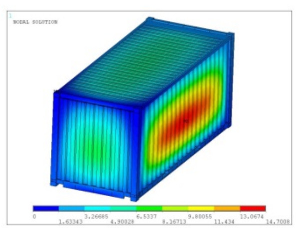


Maximum Stress Position (view from outside the box)

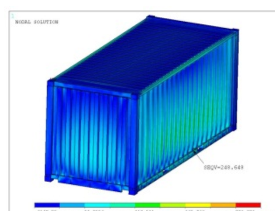
The Case of 16KL Flexitank



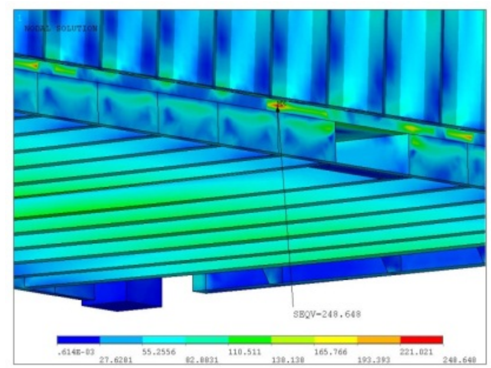
Liquid Pressure Distribution



Sidewall Deformation



Equivalent Mises Stress

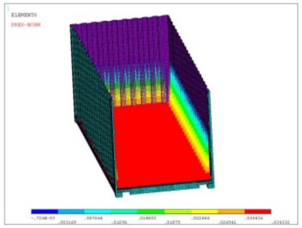


Maximum Stress Position (view from outside the box)

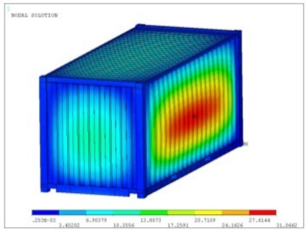
3. Application Analysis on Flexitank Used in ISO GP Containers

3.1 Finite Element Stress Analysis

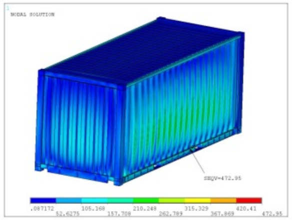
II. Lifting from four bottom corner fittings



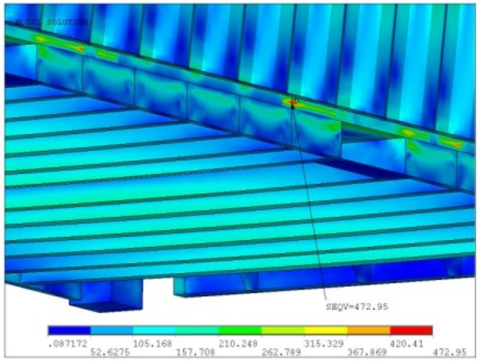
Liquid Pressure Distribution



Sidewall Deformation

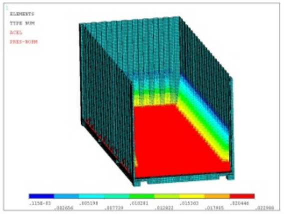


Equivalent Mises Stress

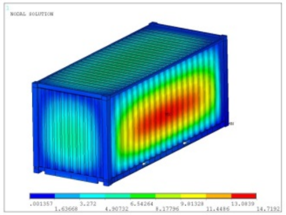


Maximum Stress Position (view from outside the box)

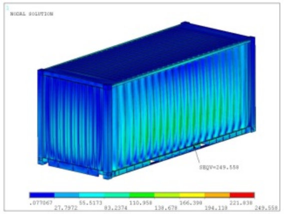
The Case of 24KL Flexitank



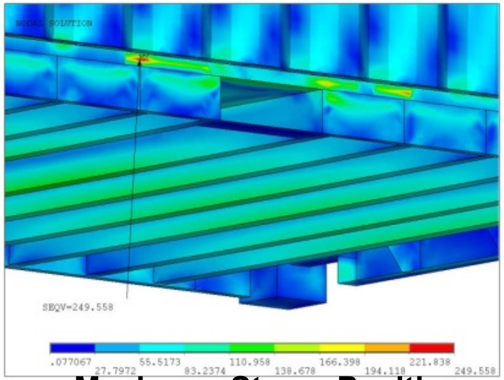
Liquid Pressure Distribution



Sidewall Deformation



Equivalent Mises Stress



Maximum Stress Position (view from outside the box)

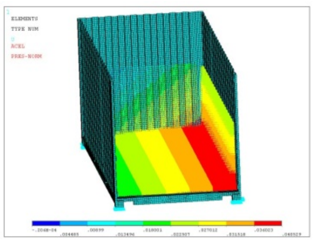
The Case of 16KL Flexitank

3. Application Analysis on Flexitank Used in ISO GP Containers

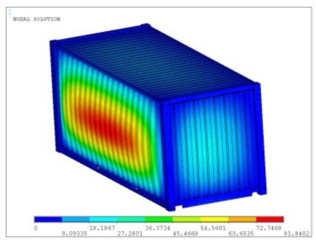
3.1 Finite Element Stress Analysis

III. Transportation condition 1 (transverse inertia force 1Rg)

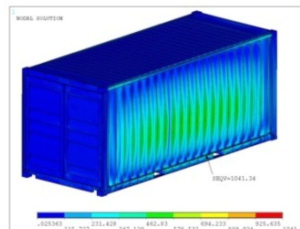
The Case of 24KL Flexitank:



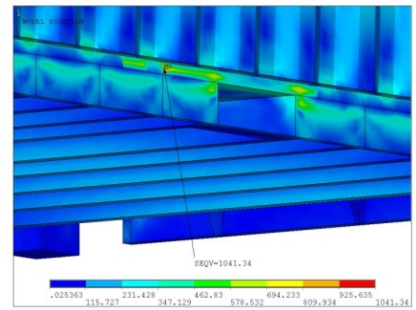
Liquid Pressure Distribution
(sidewall pressure> 30t)



Sidewall Deformation

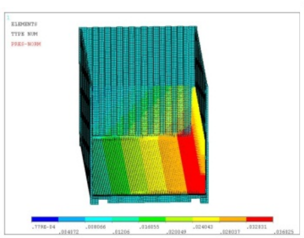


Equivalent Mises Stress

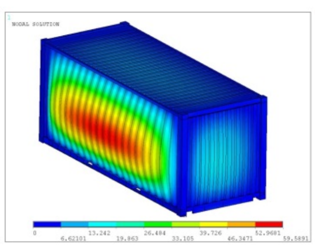


Maximum Stress Position (view from outside the box)

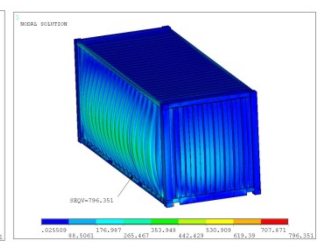
The Case of 16KL Flexitank:



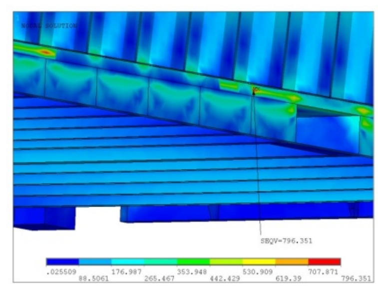
Liquid Pressure Distribution
(sidewall pressure> 20t)



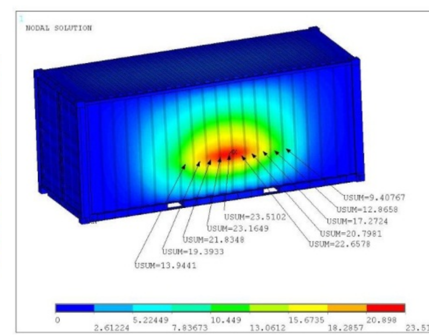
Sidewall Deformation



Equivalent Mises Stress



Maximum Stress Position (view from outside the box)



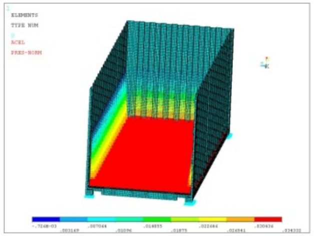
Residual deformation of the sidewall
(maximum>20mm)

3. Application Analysis on Flexitank Used in ISO GP Containers

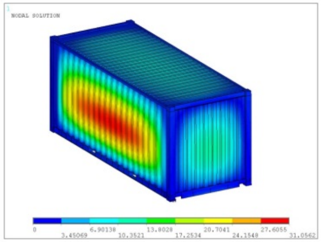
3.1 Finite Element Stress Analysis

IV. Transportation condition 2 (vertical inertia force 2Rg)

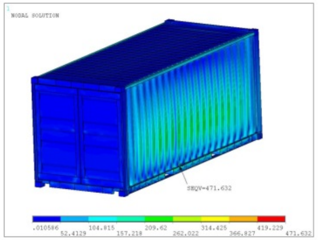
The Case of 24KL Flexitank:



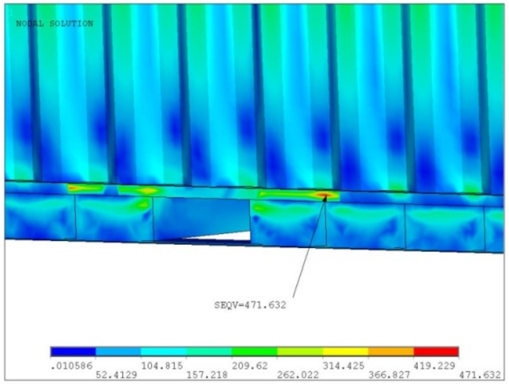
Liquid Pressure Distribution



Sidewall Deformation

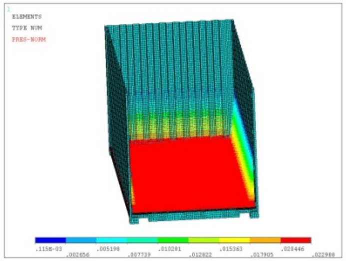


Equivalent Mises Stress

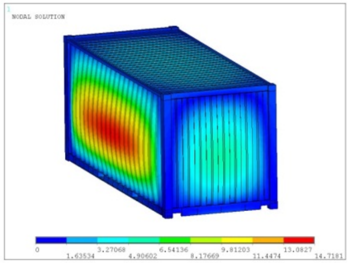


Maximum Stress Position (view from outside the box)

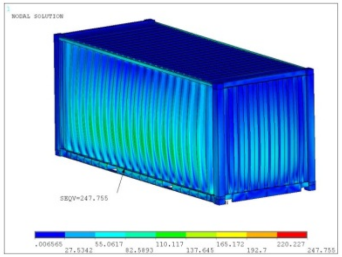
The Case of 16KL Flexitank:



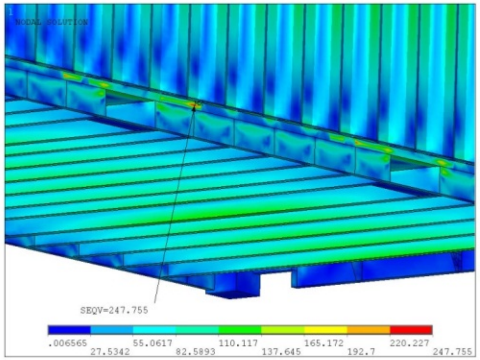
Liquid Pressure Distribution



Sidewall Deformation



Equivalent Mises Stress



Maximum Stress Position (view from outside the box)

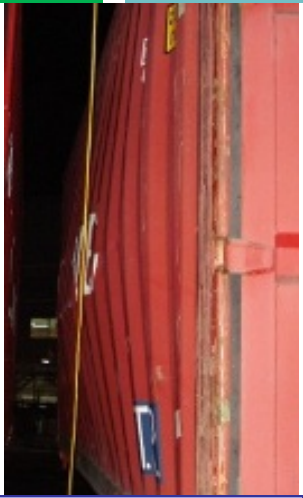
3. Application Analysis on Flexitank Used in ISO GP Container

3.1 Finite Element Stress Analysis - Summary

Flexitank	Conditions		Max. Stress (MPa)	Material Tensile Strength	Max. Elastic Deformation (mm)	Max. Residual Deformation (mm)
24KL	1	top lifting	471	490MPa	31	
	2	bottom lifting	473		31	
	3	transverse inertia force 1Rg	1041		82	
	4	vertical inertia force 2Rg	472		31	
16KL	1	top lifting	249		15	
	2	bottom lifting	250		15	
	3	transverse inertia force 1Rg	796		60	20
	4	vertical inertia force 2Rg	248		15	

3. Application Analysis on Flexitank Used in ISO GP Containers

3.1 Finite Element Stress Analysis - Conclusions



- **In four conditions, the maximum deformation occurred in the middle of the side wall.**

The maximum elastic deformation is occurred in the transportation condition 1 (transverse wave), which was up to 60mm for 16KL flexitank, and 82mm for 24KL flexitank. After unloading, the permanent deformation was up to 20mm (16KL). It has severely exceeded the outline of the container, and influence the normal operation of the container, which doesn't meet the requirements of ISO1496 series standards.

- **In four conditions, the maximum stress was always occurred in the vicinity of the forklift pocket, where cracking of the welding seam often occurred**

The highest stress is occurred in the transportation condition 1 (transverse wave), which reached 796MPa on 16KL flexitank, and 1041MPa on 24KL flexitank. These stress are far greater than the material tensile strength of 490MPa. The container will be damaged as a result.

- The pressure from flexitank to the sidewall of dry container exceeds its design load 0.6P.

In transportation case 1 (transverse wave), the pressure is greater than 20t (for 16KL) and 30t (for 24KL). Whereas the design load of the dry container sidewall is 0.6P = 17t. In case of that, the sidewall will be severely deformed .

3. Application Analysis on Flexitank Used in ISO GP Containers

3.2 Structural problems

a) According to ISO1496-3, 5.1.9, liquid cargo containers should not be fitted with the forklift pocket.

Forklift transport of tank containers is considered dangerous because of stability problems with loaded or partly-loaded tanks and the danger of impact damage from the forks of forklift trucks.

Whereas a 20‘GP container is provided with forklift pockets. In following cases, workers may make mistakes of using forklift during container operation, and result in the liquid sloshing, container unstable, and even fall or tip over.

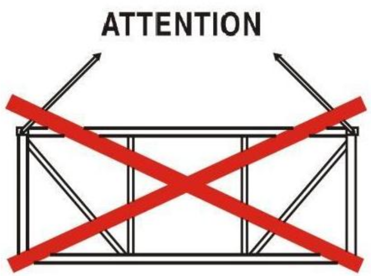
- Identification of the container containing liquid is not clearly indicated;
- Lack of knowledge that forklift pocked is banned for liquid containers;
- Taking a risk just for the sake of convenience;
- Lack of supervision by relevant departments.

b) According to IMDG 4.2.1.9.6, liquid loading space should be separated by baffle plate or corrugated plate, and baffled compartment capacity is not to be more than 7500L for liquids having a viscosity less than 2,680mm^2/s at 20°C and with a filling more than 20% but less than 80%.

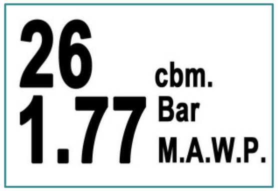
Whereas there are no this kind of structures on flexitank structure.

3. Application Analysis on Flexitank Used in ISO GP Containers

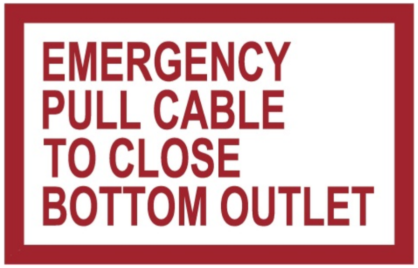
3.3 Marking/signage problems



Markings on the containers should applied according to the relevant provisions of ISO 6346, IMDG, UIC, TIR, CSC and other standards and conventions.



Useless. The forklift pocked must be blocked.



3. Application Analysis on Flexitank Used in ISO GP Containers

3.4 Problems during Loading and Unloading Operation

	Problems	Reasons	Requirements
1）	Packaging, securing, loading and unloading don't meet the requirements	No supervision	Liquid cargo packaging, securing and unloading, etc. should comply with ISO 3874, UN Orange Book and Classification Securing Manual, etc. For example, according to the regulation of IMDG 4.2.1.9.6, when loading liquid goods, the goods volume should be less than 20% of the total volume, or greater than 80%.
2）	Easily lead to overloading of vehicles and containers	No supervision	Should not be overloaded
3）	Tilting during lifting operation	The change of gravity center	Should guarantee the operation safety
4）	Overturning when turning corners	The change of gravity center	Should guarantee the operation safety
5）	Dangerous driving	No supervision	The driver should be qualified for driving dangerous goods

Contents

4. Conclusions

1

The use of ISO GP containers for liquid cargo does not meet the requirements of relevant **standards and regulations**.

2

The current **structure and strength** of ISO GP containers without any additional reinforcement don't meet the special requirements on transporting flowable liquid cargos.

3

Reluctant using of ISO dry containers for liquid cargo transportation might bring various **risks**, such as cargo leakage, box damage, vehicle overturning, traffic congestion, casualties, environmental pollution, etc.

4. Conclusions

4

For the liquid cargo transportation, tank containers which comply with relevant standards and conventions should be applied. Any **substitution containers**, no matter what shape and structure, should meet the design requirements of ISO1496-3, and pass the relevant tests accordingly, and other conventions and regulations .

5

Liquid cargo packaging, securing, handling and transportation should be effectively **supervised and controlled** by relevant authorized organization.

Safety, Economy, Environment friendly


Thanks for your listening!
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