KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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IMPROVEMENT OF MINI DUMPER

Final project Master degree

Supervisor
Assoc. Doc dr. Inga Skiedraitė

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KAUNO TECHNOLOGIJOS UNIVERSITETAS
MECHANIKOS INŽINERIJOS IR DIZAINO FAKULTETAS

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1. Darbo tema: “Mažos talpos savivarčio tobulinimas”; “Improvement of Mini Dumper” (angl.)

Patvirtinta 20 ___ m. _____ mėn. ___ d. dekano įsakymu Nr. _____

2. Darbo tikslas: Patobulinti mažos talpos savivartį, tobulinant mažos talpos savivaržio rėmo konstrukciją, rėmo ir cilindro sujungimo elemneto konstrukciją, parenkat medžiagas.

3. Darbo struktūra: Apžvelgti puspriekabes, apžvialgti tobulinamą savivartį, patobulinti rėmo konstrukciją, atliekant skaičiavimus, parinkti medžiagas, patubulinti cilindro ir rėmo fiksavimo mazgą, pagrįsti rezultatus grafiškai, pateikti išvadas.

4. Reikalavimai ir sąlygos: Atlikti mažos talpos savivarčio rėmo konstrukcijos tobulinimą, siekiant sumažinti gamybinius kaštus, laikantis saugumo reikalavimais. Patobulintas savivarčio rėmas turi atlaikyti 10 t. svorį.

5. Darbo pateikimo terminas 20__m. _____ mėn. _____ d.

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Išduota studentui Dariui Lukoševičiui

Užduotį gava Darius Lukoševičius _____
(studento vardas, pavardė) (parašas, data)
Vadovas Doc. dr. Inga Skiedraitė _____
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KAUNAS UNIVERSITY OF TECHNOLOGY

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Industrial Engineering and Management 621H77003

(Title and code of study programme)

"Improvement of Mini Dumper"

DECLARATION OF ACADEMIC HONESTY

___ _____ 20__

Kaunas

I confirm that a final project by me, **Darius Lukoševičius**, on the subject "Improvement of Mini Dumper" is written completely by myself; all provided data and research results are correct and obtained honestly. None of the parts of this thesis have been plagiarized from any printed or Internet sources, all direct and indirect quotations from other resources are indicated in literature references. No monetary amounts not provided for by law have been paid to anyone for this thesis.

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Lukoševičius, D. Improvement of Mini Dumper: Industrial Engineering and management master degree final project / supervisor Assoc. Doc. dr. Inga Skiedraitė; Kaunas University of Technology, Faculty of Mechanical Engineering and Design, Department of Production Engineering.

Kaunas, 2015. 48 p.

SUMMARY

At the beginning there is made an overview of different types of semi-trailers and deep analyze of the chosen semi-trailer. There is made the research what kind of problems are the most common in the semi-trailer construction. After defending all problems they were analyzed and there were suggested possible improvements and made changes in order to ameliorate semi-trailer. There was designed mechanical and kinematic model of semi-trailer. The model was drawn based on real dimensions and other parameters.

Strength and safety factor were calculated based on software. With reference to the obtained results there were chosen the most suitable solutions of the problems. The calculations and results are showed in the figures and explained in the figures. Conclusions are made at the end.

Lukoševičius, D. Mažos talpos savivarčio tobulinimas: Gamybos inžinerijos magistro baigiamasis darbas / mokslinis vadovas Doc. dr. Inga Skiedraitė; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas, Gamybos inžinerijos katedra.

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SANTRAUKA

Pradžioje trumpai apžvelgiama savivarčių tipai, toliau yra nagrinėjamas pasirinktas savivartis, analizuojamos iškilusios savivarčio konstrukcijos problemos Išanalizavus problemas pateikiami galimi sprendimo būdai. Mažos talpos savivarčio tyrimui buvo sukurtas mechaninis ir kinematinis mažojo savivarčio modelis. Modelis sukurtas remiantis realiais savivarčio matmenimis ir papildomais parametrais. Naudojant programinę įrangą, atlikti konstrukcijos stipruminiai skaičiavimai, nustatyti atsargos koeficientai. Pagal gautus rezultatus parinkti tinkamiausi kostrukcijos sprendimo būdai. Skaičiavimai ir gauti rezultatai pateikiami grafiškai. Darbo pabaigoje pateiktos išvados.

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INTRODUCTION

Different types of machinery started to be used long time ago. In these days it is impossible to imagine that any work in constructions, agriculture can be done without various types of cranes, trucks or semi-trailers.

Today's industry has covered the entire area and became a laddering business direction. Time is one of the most important factories which can affect all indicators of the company. Working in a fast and efficient way can increase productivity and incomes of a big company or a small business. This is especially relevant for the agricultural business, where everything should be just in time. All processes in agricultural work require a lot of efficiency because there are produced perishable goods.

There are various types of agricultural machinery. All of them are important in a certain way and are needful in the different processes. It is almost impossible to distinguish which of them is useful more and which one is not so. It is clear that semi-trailer is really important price of equipment which can be used for majority of tasks which are related to transportation.

Nowadays metals are is expensive, so in order to save metals and money it is necessary to make accurate estimates before starting the production of the semi-trailers. Accurate calculations can lower the prime cost and also to decrease the waste of metals to the minimum level. Despite the fact that for a company it is very important to have everything done at lowest costs, the trailer has to be designed and manufactured qualitatively. So it is important to find a balance between price and quality.

In this research project it was chosen to improve the semi-trailer - mini dumper and to concentrate on the analysis of the frame. It is obvious that frame is one of the most important parts of the mini dumper because on this element depends how many kilograms trailer will be able to transport and for how long it can be used.

The aim: The aim of the thesis – to analyses all possible improvements of mini dumper trailer. To compere all possible improvements among themselves in order to choose the most convenient.

Tasks:

- To analyze which material can be chosen for the Mini Dumper
- To make improvement by analyzing strength analyzes of semi-trailer – "Mini Dumper" frame
- To make the research of possible improvements

1. REVIEW OF SEMI-TRAILER

1.1 Trailer classification

A trailer is generally vehicle without engine and towed by a powered vehicle. It is usually used for the transport of goods and materials. Sometimes recreational vehicles and travel trailers where people can camp or stay have been referred to as trailers. Enclosed toy trailers and motorcycle trailers can be towed by commonly accessible pickup truck or van, which generally require no special permit beyond a regular driver's license. There are some specialized trailers which are accessible to small automobiles: bicycle trailers are smaller, they, as rare some ordinary trailers, held by a dawbar and driving on a single set of axles. Other type of semi-trailers, such as agricultural trailers, universal trailers and traveling trailers or come in single and multiple axle varieties, to allow for varying sizes of two vehicles [1].

In Fig. 2.1 is shown trailer classification scheme which classifies trailers by weight per axle. “O“ class is dedicated for not agricultural trailers and “Ra“ is dedicated for agricultural trailers.

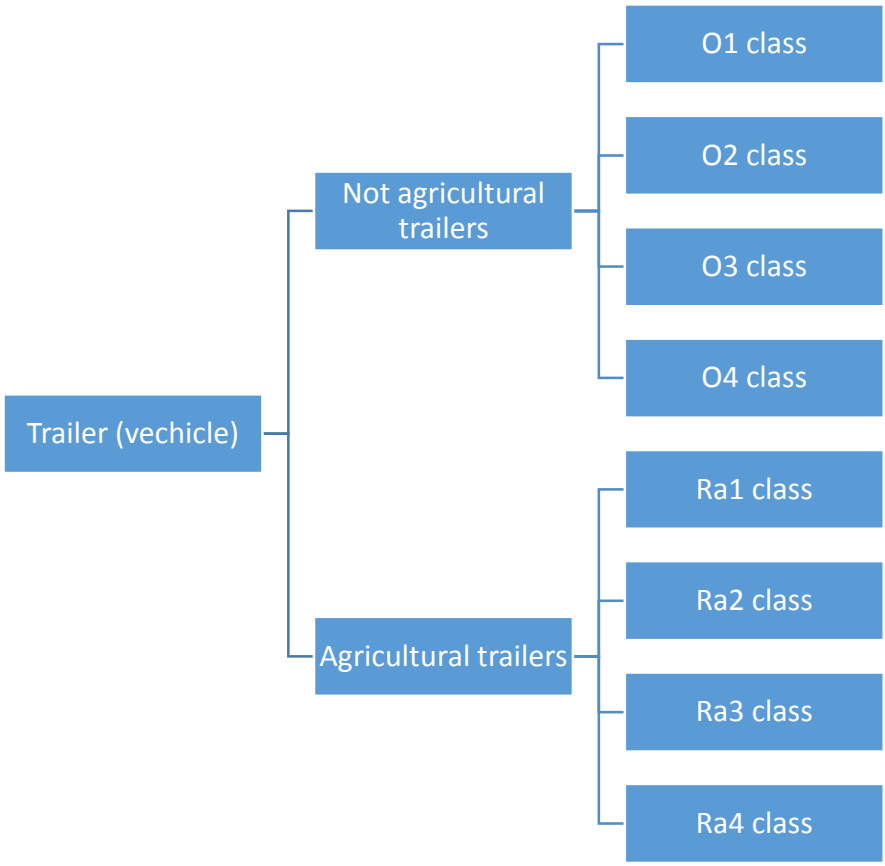

Fig. 1.1 Trailer classification scheme by weight per axle

1.2 Not agricultural trailers

In earlier days, many of these vehicles were towed trailers. While practically any powered vehicle having an appropriate hitch can be used to pull trailers for personal or small business use, some trailers are one of the part of large trucks called semi-trailer trucks [2].

O1 class

O1 class vehicles – this class consist mostly of small cars trailers. These are trailers with a maximum mass around 0.75 tones. The trailer can be enclosed with shelving units or specific mechanism installed, as well as installed as a flat-bed open-air trailer. Popular are utility trailers which are meant to haul some sort of equipment, or for professional or recreational use. Trailers are very suitable for short moves, especially for home affairs or reconstruction projects. These small trailers are very useful because they can be towed with any type of car. It is one of the biggest advantages of them. Landscaping and other related projects are easy to accomplish with the additional load capacity of 0,75. It is important to mention that most trailers do not have braking system. Trailers past a certain weight and length, however, must have a braking system to work in coordination with the towing vehicle. Some trailers are enclosed to protect the items being hauled from theft, weather, and debris. Example of O1 class semi-trailer showed in Appendix 1 [2-4].

O2 class

O2 class vehicles are trailers with a maximum mass exceeding 0.75 tone but not exceeding 3.5 tons. Trailers are popular amongst construction companies, builders, local authorities, landscapers, and hire companies the important point why these trailers are popular because workers can rely on the durability and strength of trailer. Trailer range includes tipper trailers, plant trailers, flatbed trailers, tilted trailers and General duty trailers, which can all endure the rigors of heavy use. Example of O2 class semi-trailer showed in Appendix 2 [2,3].

O3 class

O3 class vehicles are trailers with a maximum mass exceeding 3.5 tones but not exceeding 7.5 tones. This type trailers are without a front axle. Normally this kind of trailers are equipped with landing gear (legs which can be lowered) for the reason to support it when it is uncoupled.

In road haulage, trailers predominate over full-trailers because of their flexibility. If a power unit fails, another tractor can replace it without disturbing the cargo. A rigid truck and full trailer are articulated inside the cargo area length, so a semi-trailer can have a longer continuous cargo area. Because of this a semi-trailer can haul longer objects (logs, pipe, beams, and railway track). Example of O3 class semi-trailer showed in Appendix 3 [2-4].

O4 class

O4 class vehicles are trailers with a maximum mass exceeding 7.5 tunes. With a unique and highly flexible platform, these trailers are modular and easily customizable allowing for quick configuration of the optimal combination for each load's specifications. There are some significant advantages compared to conventional multi-wheel, heavy haul trailers in modularity, increased stability as well as self-load and unload capabilities. The trailers are assembled by putting together sections of axle lines and spacer decks to make various lengths – from 6 axle lines to more than 14 axle lines long. In addition, axle lines can be connected side-by-side to build trailers that are 1.5 to 2 times wider than a standard trailer width.

The large platform design of hydraulic platform trailers makes them perfect for transporting oversized and overweight weight loads across long distances. Example of O4 class semi-trailer showed in Appendix 4 [2-4].

1.3 Agricultural trailers

Such trailers are designed and built to operate in the most demanding of agricultural environments. The trailer is used for transporting goods and materials from one place to the other. An agricultural trailer is a vehicle that does not have its own power that is drawn or towed and used exclusively: for the carriage of bulk fruit bins and constructed, as an agricultural implement, for transporting the comb of a grain header, as a bulk bin used exclusively for holding grain and constructed for that purpose.

Ra1 class

Ra1 class vehicles are trailers axle load up to 1,5 tunes. The smallest model of trailer, which is perfectly sized for use in the leisure industry, in gardens or on small holdings. However it is still built to high, exacting standards to guarantee durability and functionality.

The drop side design provides excellent versatility, allowing the trailer to be used as a flat-bed or a proper trailer. The trailer also has the option of mesh sides, which further improves its versatility and makes it a perfect product for the leisure industry.

These class trailers mostly is built from 2 – 3 mm steel, which is the perfect blend between strength and manageability; these sides still can be easily removable. The hinge points for the sides are also reinforced to prevent cracking or twisting under heavy loads. For the improvement of rigidity the trailer also has a fixed headboard, reducing flexing during loading and transport. Example of Ra1 class semi-trailer showed in Appendix 5 [2-4].

Ra2 class

Ra2 class vehicles are trailers axle load up to 1,5 -3,5 tones. The drop side design provides high level versatility, which allows the trailer to be used as a flat-bed or a proper trailer. These trailers mostly have the option of mesh, grain or silage sides making it an even more versatile part of kit and maximizing the trailers functionality.

These class trailers mostly are built from 3 – 4 mm floor and 2 - 3mm sides, still allowing them to be easily removed if requires. To improve rigidity the trailer also has a fixed headboard, which reduces flexing during loading and transport. In addition to these design features the trailers body is tapered allowing loads to be safely discharged without the risk of them sticking in the trailer. Example of Ra2 class semi-trailer showed in Appendix 6 [2-4].

Ra3 class

Ra3 class vehicles are trailers axle load up to 3,5 - 21 tones. These type trailer is an extremely popular trailer among the farming areas with narrow roads and lanes. The large cubic capacity of the trailer means it has enough space to carry a significant load, but remains small enough to easily maneuver. Trailer also has the advantage of tandem axles, which gives for the customers the option to spec either rockers or springs as a no cost option. The body is constructed from 3 – 5 mm. sides and a 4 – 5 mm. flat floor, complete with a significant number of spacers and bearers to guarantee durability and strength. The strength of the trailer is further enhanced by heavy-duty channels forming a square chassis that extends the length of the trailer and also reduces flexing when loading the trailer. The flat floor also prevents premature rusting of the trailer, since there are no joints for water to sit in. In addition to this the main part of the trailer is tapered as standard to allow loads to be safely discharged without the risk of them sticking in the trailer. Example of Ra3 class semi-trailer showed in Appendix 7 [2-4].

Ra4 class

Ra4 class vehicles are trailers axle load exceeds 21 tones. The semi-trailer box is made with 4mm sides and a 5mm flat floor. These types of semi-trailers have a large number of supports and bearers to warranty durability and strength. The flat floor also prevents premature rusting of the trailer, since there are no joints for water to sit in. This semi-trailer box is tapered as standard to allow loads to be safely discharged without the risk of them sticking in the trailer. Trailer also has the advantage of pair rams, which are able to remove the problem of corrosion and improve reliability of the trailer. These types of trailers have the good blend of strength and flex. Example of Ra4 class semi-trailer showed in Appendix 8 [2-4].

2. THE OVERVIEW OF THE SEMI TRAILER – “MINI DUMPER”

Nowadays mechanical engineering cannot be imagined without computer design systems. CAD helps to accelerate the development of components and simulation, assembly, to create drawings. Also it is possible to see how the device is designed and how looks in three dimensions, which makes much easier work for engineers. For Mini-dumper system design will be used computerized design software “SolidWorks 2013”. This program allows to create 3D models. Also with this program possible creation of drawings and documentation processing. The main requirements for semi-trailer design:

- to select technology-driven blanks and materials;
- to ensure safety at work;
- to seek comfort, aesthetics, ergonomics;
- the construction product, which is easy operation and maintenance;
- to evaluate deformations,
- try to design technological details of structural shapes;
- to ensure the structural composition of workability;
- try to use the same standard components and parts.

Structural solutions have a significant impact on production costs, duration and quality. Constructor task - to choose those solutions to the required quality product can be produced at the lowest cost and in the shortest time. It should follow the rule and simplicity. The simpler the design, the more economical it [5-7].

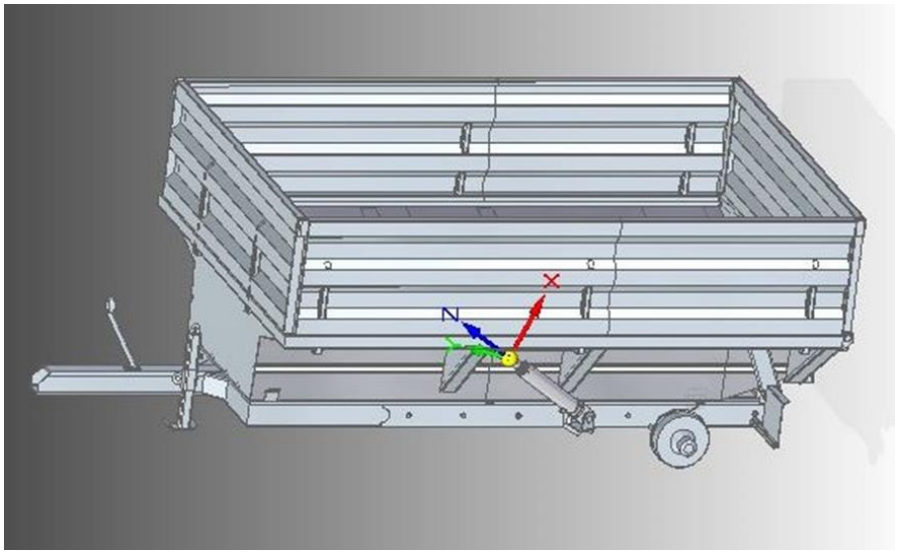

Fig. 2.1 Example of Semi-trailer model in SolidWorks environment

2.1 Semi-trailer – Mini Dumper

The Mini Dumper (Fig. 2.2) is an extremely versatile and robust trailer, capable of handling the toughest jobs around. It's large carrying capacity makes it an ideal trailer for a variety of jobs, whether it is simple farm maintenance tasks or heavy use on a construction site.

Some Mini Dumper has a 4 mm Raex floor and sides, which provide an extremely robust body that can cope with carrying rocks and other heavy loads that could potential damage a lighter trailer. The body of the trailer also has a generous number of bearers and spacers that further enhances the strength of the body. The trailer comes with a tapered rear-end as standard, providing the dual benefits of easy loading and rapid discharging of a load.

The chassis on this model uses tried and tested design perfected over 15 years of trailer manufacturing, providing excellent strength and stability. The trailer also has a high tipping angle of 50 degrees guaranteeing loads are safely and efficiently discharged. On top of this all dumpers are fitted with lights and hydraulic brakes as standard ensuring that they meet all health and safety regulations. Trailers are finished with 120 microns of paint, applied with an electrostatic system to ensure complete coverage. The top coat is a hard wearing two pack acrylic high gloss paint. [8]

Fig. 2.2 Mini Dumper trailer

2.2 Classification of advantages and disadvantages

In more detail analyze it is necessary to talk about different advantages and disadvantages of this trailer. In this part of work will be analyzed advantages of working with this trailer and existing problems. There will be, also, suggested changes and solutions for the problems.

Before talking about benefits and drawbacks it is necessary to analyze the concrete model. In Table 2.1 it is shown all the most important parameters.

Table 2.1 Mini Dumper specification

Model	**ST-1**
Length (mm)	4720
Width (mm)	2340
Height (mm)	1750
Height without side borders (mm)	1010
Wheels	520
Weight (kg)	580
Load (kg)	4000
Angle of dumping (°)	55

According to this parameters it will be analyzed advantages and disadvantages of the trailer.

The advantage of semi-trailers over other trailers types is their universality. Due to the different types backdoors and extra expansion that are accessible, the trailers uses are boundless it can be used for different transportation works, such as: including soil, manure, dung, corn, etc. Semi-trailers are useful for farmers as well as different companies for loading work in landscaping, forestry, harvesting, etc. The advantages of Mini Dumper Trailer's:

• strong box;

• durable bottom frame;

• dependable dumping system;

• bogie axle with springs that relieve heavy loads and hydraulic drawbar suspension for larger models;

• hydraulic or air brake system, according to the customer optional.

All these items could be classified in the groups of advantages, which are presented in Figure 2.3

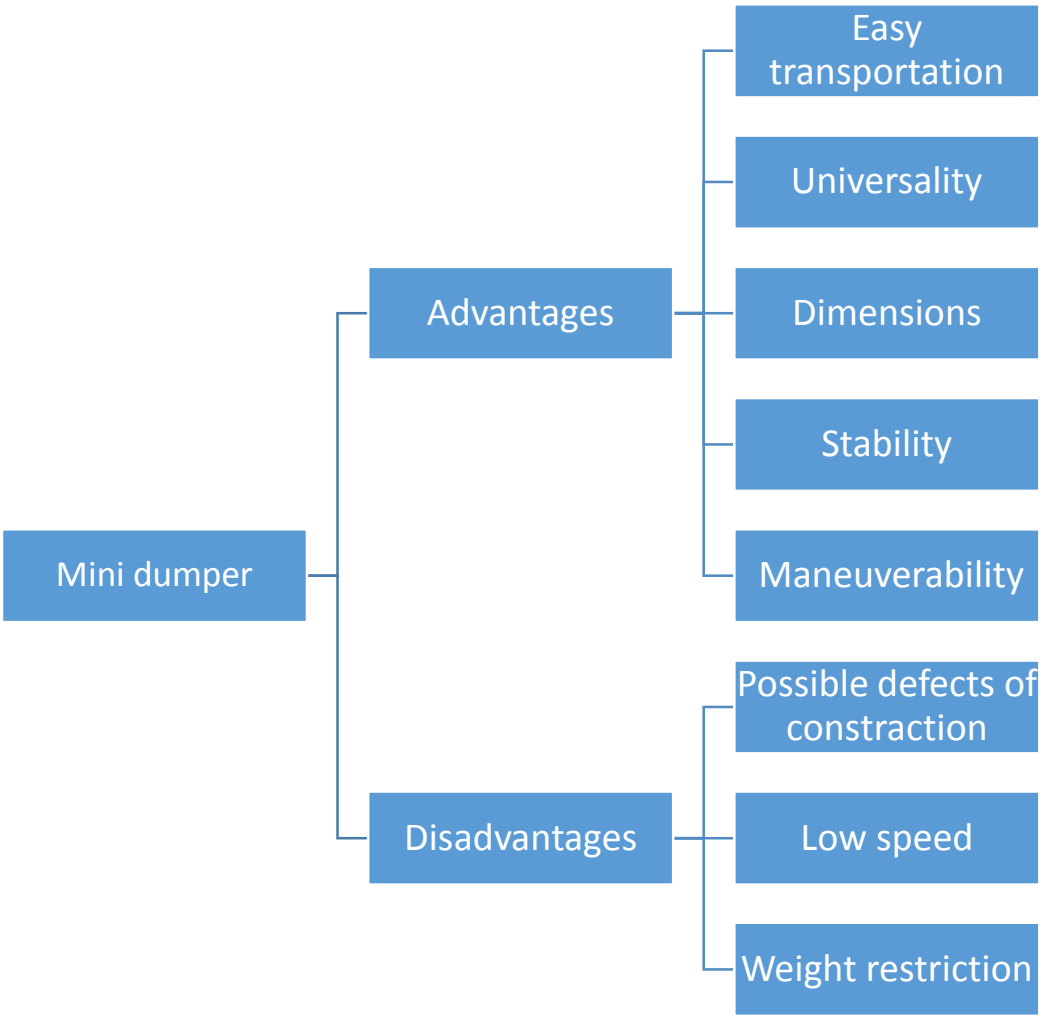

Fig. 2.3 Mini Dumper advantages and disadvantages

In the next chapter will be analyzed possibilities to transport trailer to the final destination. There will be presented usual way how it is done. There will be, also, explained the universality of mini dumper trailer and some requirements for dimensions which can effect stability and the rest of mentioned criteria.

2.2.1. Analyze of "Mini Dumper" advantages

Mini dumper have a lot of advantages and disadvantages. In this chapter will be analyzed main advantages of Mini Dumper.

Easy transportation. Mini Dumper trailer is easily assembling and dismantling. It means that it could be transported without any difficulties to different places, even different countries. Usually it is transported by tracks with tilt trailer. The standard with of tilt trailer is from 2,42 till 2,47 meters and the with of the mini dumper trailer is 2,34 meters, the length of standard till trailer is from 13,2

till 13,37 meters and the length of mini dumper trailer is 4,72 meters. The height of till trailer is 2,49 meters and the height of mini dumper trailer is 0,74 meters and the height of sides (which could be removed) is 0,81 meters. this height is without wheels (0,52 meters.) because usually, during the transportation, they are removed and lived inside of the trailer. Consequently it means that with one till trailer it is possible to transport two mini dumper trailers [2,3].

Universality. Mini dumper trailer can be used for different kind of agricultural works. It can be used for different transportation works, such as those involving soil, manure, gravel, grain, etc. Dump trailers are perfect for farmers as well as companies for loading work in landscaping, forestry, harvesting, etc. But usually it is used in order to drive away stones from fields. The reason for this is mentioned before. Mini dumper trailers have strong boxes, which can withstand heavy weight, there are used stronger metals which have a longer work live and are not depreciated as fast as the others [3].

Dimensions. Mini Dumper trailer is a not high - without sides is 0,74 meters, so it makes easier for people who is working with this trailer to put everything inside. But even more important is to talk about dimensions. The height of the trailer, with tires inflated at the recommended pressure, when measured from the level supporting surface to the top of the platform (see C in Fig. 2.4) shall be 1.5 m. The height of the trailer, with tires inflated at the recommended pressure, when measured from the level supporting surface to the top of the sideboard (see D Fig. 2.4) shall be 2.2 m. The overall width of the trailer (see A in Fig. 2.4) measured between the extreme points shall not exceed 2.5 m. 7.3 The overall length of the platform (see B in Fig. 2.4) shall not exceed 5 m for trailers up to 4 tones capacity. In this case the dumper trailer meets the all necessary requirements [4].

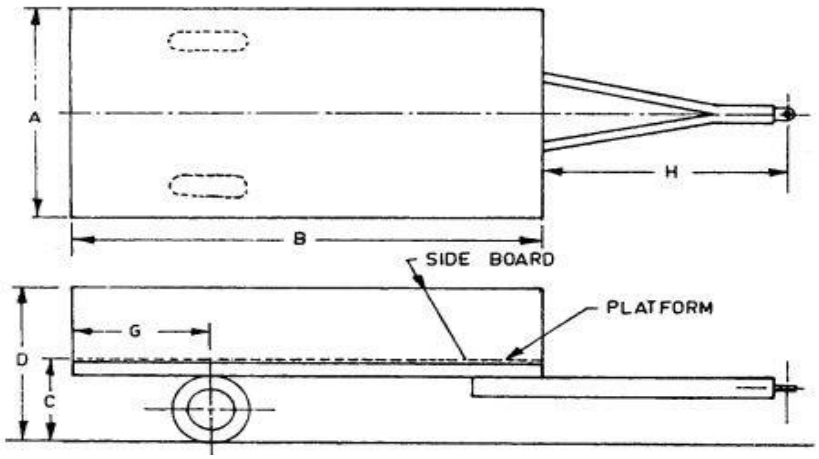

Fig. 2.4 Semi – trailer drawing [4]

Stability. Stability is one of the key elements which have to be analyzed talking about trailers. There some factors which can influence the degree of stability. In case of semi-trailer, the load transfer from the trailer to the tow eye of the trailer shall not be more than 20 percent of the trailer capacity.

Assuming that the trailer is loaded uniformly to the entire length of platform and the center of gravity lies in the lateral vertical plane at half the length of platform from rear edge, the value of G can be derived from the following formula:

$$G = \frac{\frac{WB}{2} - R(H + B)}{(W - R)}$$

Where:

W = gross load;

R = load transfer, percent.

On the basis of 20 percent load transfer from the trailer to the tow eye, the above formula can be written as follows:

$$G = \frac{3B-2H}{8}$$

Mini dump trailer feature side-mounted double-acting cylinders to provide superior stability and to provide the industry's shortest dump cycle time. This type trailers are designed to load pavers without sacrificing weight distribution and also this trailers are design places more payload at the front. Consequently when dumper trailer is raised up the weight is gradually moving down and it helps to keep the balance [10].

Maneuverability. Maneuverability - the short wheelbase of a standard dump truck makes it more maneuverable than tractor dump trailer combinations. The shorter dump box allows for maneuverability in tight quarters and stability when raised for dumping. Buyers should ensure that the small trailer can support the weight of the items they plan to haul while still maintaining maximum maneuverability. With this size of the trailer it is quite easy to maneuver in the woods, fields and on the road. It is, also, much easier going in reverse if necessary.

2.2.2 Analyze of “Mini Dumper” disadvantages

Possible frame deformation

Sometimes because of the big load the frame of a trailer can deform. Lifting cylinders are built in the sides of the trailer so consequently it is clear that this part of the trailer and frame gets a peak load.

Possible solutions: To protect the frame of the deformation usually it is strengthened with additional mounting plate. This is shown in the Figure 4. There is another way to solve the problem by changing the tubes. There could be changed pipes which can withstand bigger load.

Possible pin and cylinder node deformation

Another problem which could happen in the production is related to the pin of the cylinder, this part is shown in the Figure 2.5 - detail No 3. As it can be seen in the figure the pin (no. 3) touches the cylinder (no. 1) for this reason it cannot move. On one hand, cylinder can settle down because of the big load but one other hand this is the defect of the production. Sometimes this problem can be caused by the traders because the detail No. 1 - cylinder is bought in Italy and the part No. 2 the pin is weld in Lithuania. So consequences from this process could be different parameters each time. Even if the difference is just a few millimeter it can affect the work of cylinders. The example showed in Figure 2.5 happened after big load when cylinder was raised up but could not went down.

Fig. 2.5 Cylinder and support node

Possible solution: One of the possible solutions how to avoid errors related with this particular component of the “Mini Dumper“ is to draw the drawing with all necessary strict dimensions for this product and send to responsible company. Because as it was mentioned before the companies which produce this detail in Lithuania without this drawing could be made different parameters each time.

Possible defects of material

As it was mentioned before, usually mini dumper trailer is used for stones. To make it clearer it would be reasonable to mention that in order to sow the seeds and to grow the yield at the beginning it is necessary to take out the rocks of the fields. To complete this process it is used dumper trailer. It is logically that after some time, thrown stones can cause damages. Different kind of damages can decrease its useful life and increase depreciation.

Depreciation can depend of the used metal. In Table 2.1 it is shown some the most important parameters of some most used metals.

Table 2.1 Parameters of metals [13]

Properties	Construct steel metal S235	Construct steel metal S355	Raex 500
Thickness (mm)	5	5	4
Tensile strength (MPa)	360 - 510	470 – 630	1600
Minimum yeald strenght (MPa)	235	355	1250
Price (Eur/kg)	0.75	0.81	1.39
C (%)	0.22	0.23	0.3
Mn (%)	1.6	1.6	1.7
P (%)	0.05	0.05	0.025
S (%)	0.05	0.05	0.015
Si (%)	0.05	0.05	0.80
Cr (%)	0.3	0.3	1.5
Ni (%)	0.3	0.5	1,0

Possible solutions: If for a box of the trailer is used construct steel metal S235, the box can depreciate faster because this metal is not very resistible. If in the production there is used construction steel metal S355, the resistance is bigger but the best quality can be reached by using RAEX 500. The parameters of this metal are shown in a Table 2.1.

In the Table 2.1 can be seen that usually RAEX metal is used thicker than the rest, the reason for this is that RAEX is hardly banded, to comer it to construct steel S235 and S355.

RAEX is one of the hardest cold-formed steel tube. It is almost three times harder as construct steel S355. Its martensitic, homogenous microstructure throughout the tube wall guarantees a long lifetime in abrasive materials pumping applications for loading equipment into dump trailers due to the higher weight concentrations between cross-members. In the Figure 2.6 can be seen the difference among useful lives of the metals.

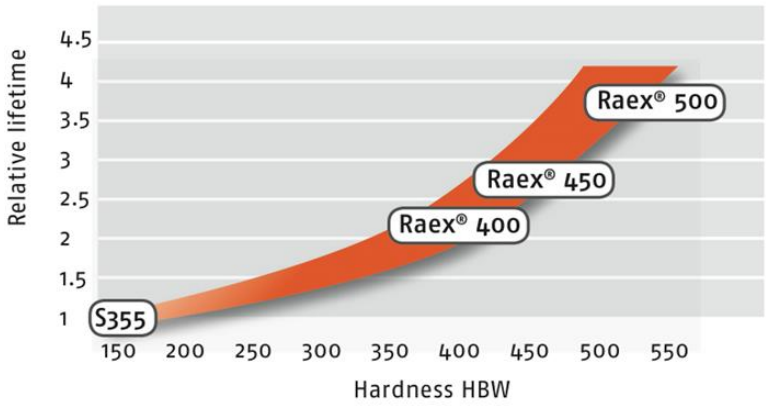

Fig. 2.6 Metals properties [13]

From the Table 2.1 it is clear the metal RAEX 500 can maintain much bigger load and can stay more durable. So consequently it is clear that to use RAEX would be much better, but there is a big difference between prices so usually producers prefer to use cheaper metal. Best solution for this Mini Dumper box is to choose steel S355.

Weight restriction

Another fact which could be taken as a disadvantage is weight restriction. Every this kind of machinery has a weight restriction but on another hand it is difficult to measure that weight during the work process. In case of overweight there could be caused some problems with cylinder. To big load can misbalance cylinder and a box of the trailer could not be raised. In another case if the box of the trailer was raised with bigger load but cylinder was to weak it could fall down with all the cargo. In this case damages could be really big if the load was to heavy and the box fall down with high force, than it could brake not even the frame but the box can crack to, if the metal was not strong enough. Another risk caused by overweight could be related with tires. If the load is to big and tractor with trailer is moving to fast tires may crack. The tiers may not withstand the weight and explode.

Possible solution: Consumers always have to follow restrictions of the Mini Dumper all otherwise the repairs could cost a lot of money and time.

Low speed

Low speed is another disadvantage which is maintained by agriculture workers. The trailer which is discussed in this paper is not fitted with an air braking system, ABS and a load sensing valve.

Possible solutions: This equipment is necessary for those trailer which may be drove with the higher speed. But in the case of mini dumper trailer it does not have a reason and necessity to have this equipment because of the high price. Mini dumper trailer is created for another market for cottagers.

3. RESEARCH AND IMPROVEMENT OF SEMI-TRAILER

3.1 Research and improvement of semi-trailer frame construction

Some of the most important goals of the machine industry are: to maximize the production of the semi-trailer and to facilitate overall weight while maintaining the strength of established norms. Accordingly, this work follows the same design principles to minimize its costs. The main objective of the research improvement – to improve the semi-trailer frame structures in order to minimize the overall weight of the structure to keep the boundary conditions. In this way we reduce the production costs and the costs involved. Improvement research of the semi-trailer frame was done using computer-aided design system SolidWorks, the model is showed in the Fig. 3.1. Studies were selected according to the value of its accountability structure and the stresses.

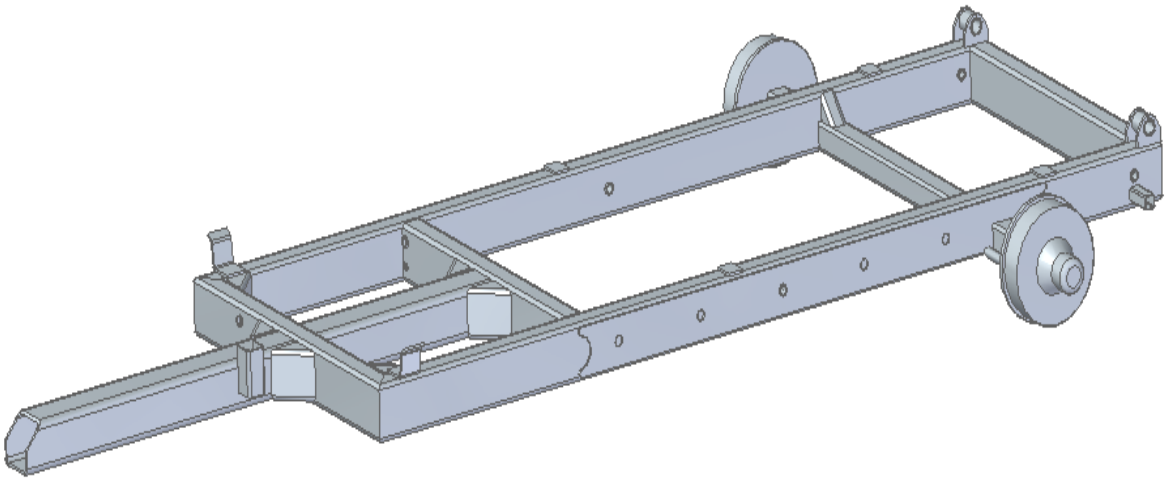

Fig. 3.1 Model of semi-trailer frame

Research of the improvement involves a number of characteristics, which asked boundary conditions, such as: the maximum stress concentration zone and the frame target minimum weight. For this purpose, we perform the analysis of the strength of the frame, from which we determine stress concentration distribution of the frame, the maximum displacement values and the minimum safety factor.

In order to restore real frame using conditions, the frame structure strength analysis assesses static loads. There will be analyzed two types of possible solutions. Metal seat frame material used - steel S235. The frame welds are not include in research.

3.1.1 Research of semi-trailer construction problem

Static load calculation.

To analyze the statics we present a typical case of loading and unloading of a semi-trailer. It is assumed that the semi-trailer is being levelled by the hydraulic system to the level of the loading box. Force distribution on semi-trailer while loading is shown in Fig. 3.2.

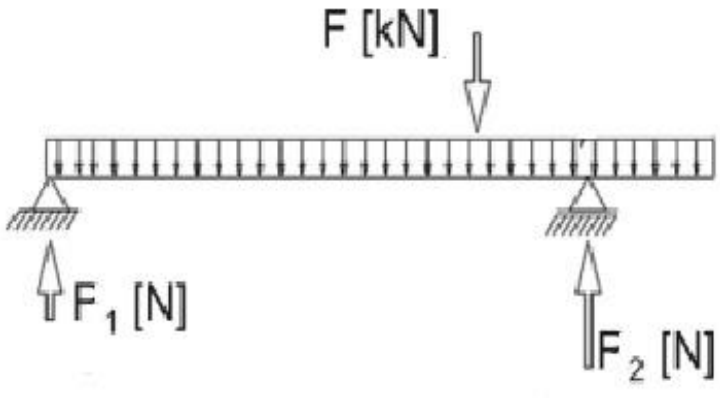

Fig. 3.2 Force distribution on semi-trailer

The frame structure acting static load generated from the impact of several forces. The inner forces are generated:

- Tipper box weight (weight 1000 kg);
- Maximum semi-trailer load weight (weight 4,000 kg.);

An overall assessment of all the tipper frame weights and summing up that frame weight is 5000 kg. Tipper frame weight load:

$$F = mg = 5000 \bullet 9.8 = 49 \text{ kN} \quad (1)$$

F here - the force resulting from the box weight and the maximum possible load weight, N; m - frame weight, kg; g - free fall acceleration, m/s^2.

Frame strength analysis.

Frame strength analysis is carried out computer design system SolidWorks 2013 Simulation environment. Frame material is steel S235. The support area on which the frame structure is fixed on the front of the frame and at the frame wheels area (Fig. 3.3). The research evaluated the structure dead load, indicating the free fall acceleration - 9,81 m / s^2 (red arrow)

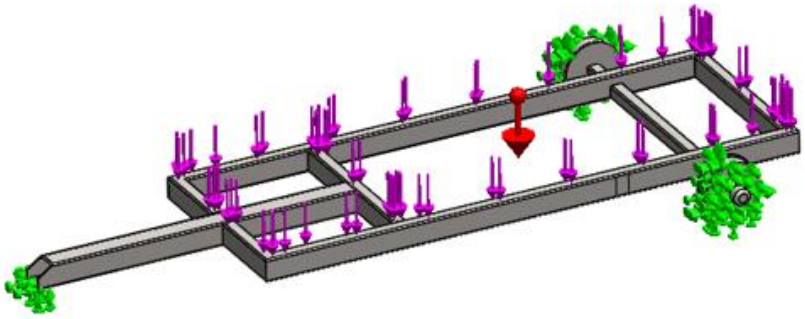

Fig. 3.3 Semi-trailer with forces

The second step calculations are made, reviewed the results obtained. Von Mises stress concentration distribution (Fig. 3.4). After the calculation of the frame when the box is not raised, we see that the stress concentration at the front of the frame does not exceed the limits of material strength S235. Tensile strength of 248,168 MPa.

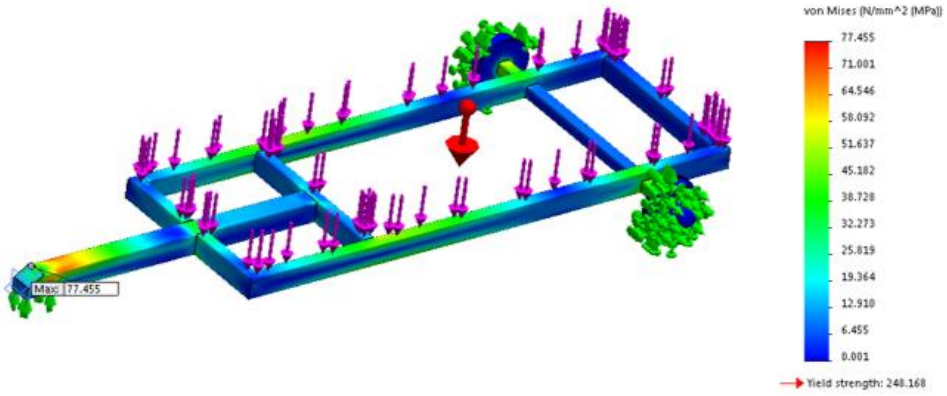

Fig. 3.4 Von Mises stress distribution of concentration fields

The factor of safety is 3,20.

$$n_y = \frac{\partial_{adm}}{\partial_y} = \frac{248{,}168}{77{,}455} = 3{,}20 \qquad (14)$$

n_y - Semi trailer factor of safety, N; ∂_{adm} - material tensile strength, MPa; ∂_y - free maximum stress, MPa.

It should be taken to the consideration that after the load of semi-trailer there could be some displacement of construction, especially this happens after the maximum restricted weight loading. The effect of this displacement is shown in the Fig. 3.5 The maximum displacement of the frame is near 3,5 mm. Usually it happens after the maximum aloud weight loading.

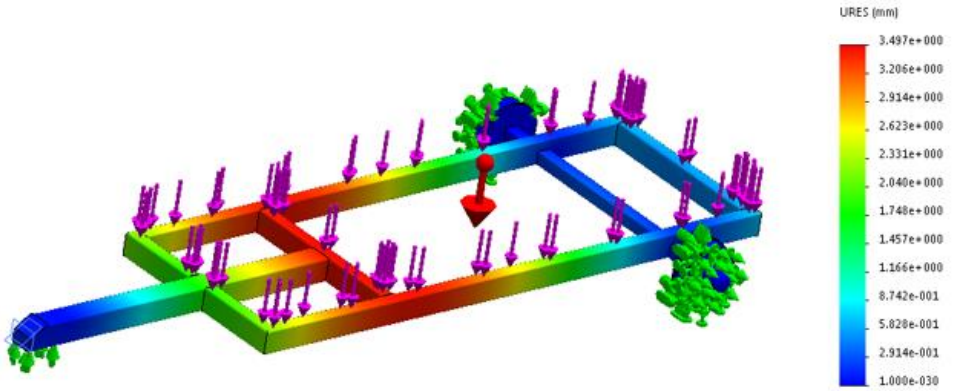

Fig. 3.5 Displacement of construction

When the box of semi-trailer is raised, it has the full force of those places where the cylinders are fixed to the frame. As a result, there are increases of the concentration of stress at these locations. As can be seen from Fig. 3.6 material strength is the strength which is close to range. Based on this results it is possible to calculate the factor of safety. For this calculation is used a formula.

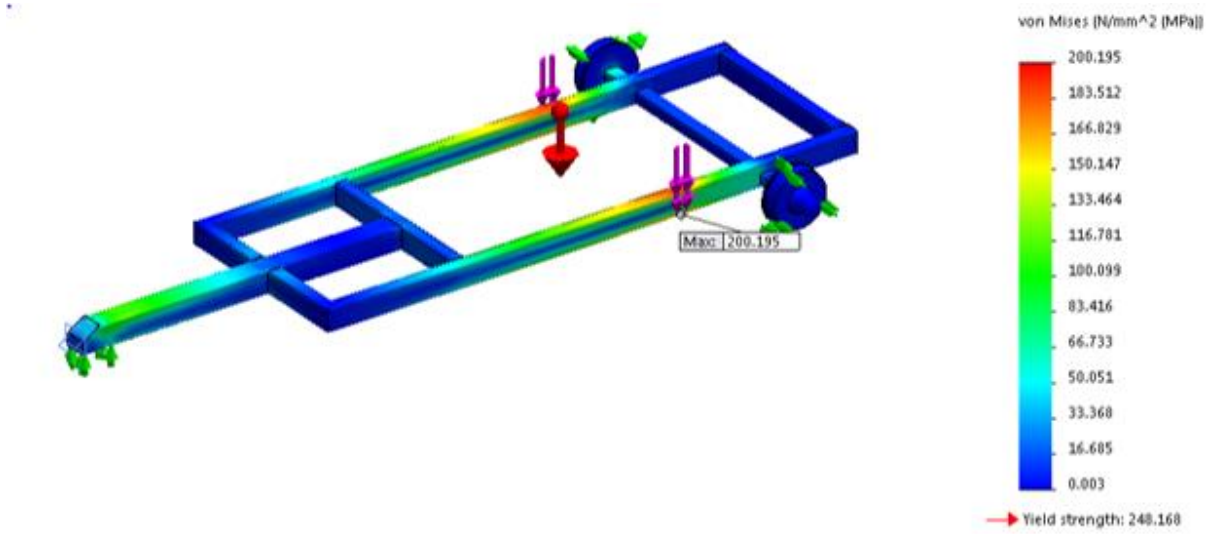

Fig. 3.6 Von Mises stress distribution of concentration fields when box is loading

The factor of safety is 1,24.

$$n_y = \frac{248{,}168}{200{,}195} = 1{,}24$$

n_y - Semi trailer safety factor.

Moreover, the deflection obtained is much higher when the box is raised. Fig. 3.7 This happens because of the force which is concentrated in small area. This accident highly effects the construction

of frame. After the loaded box raised the displacement increased more than twice. To compare the two load boxes when one of them is raised and another is not the displacement raises from almost 3.5 till 9.24 mm.

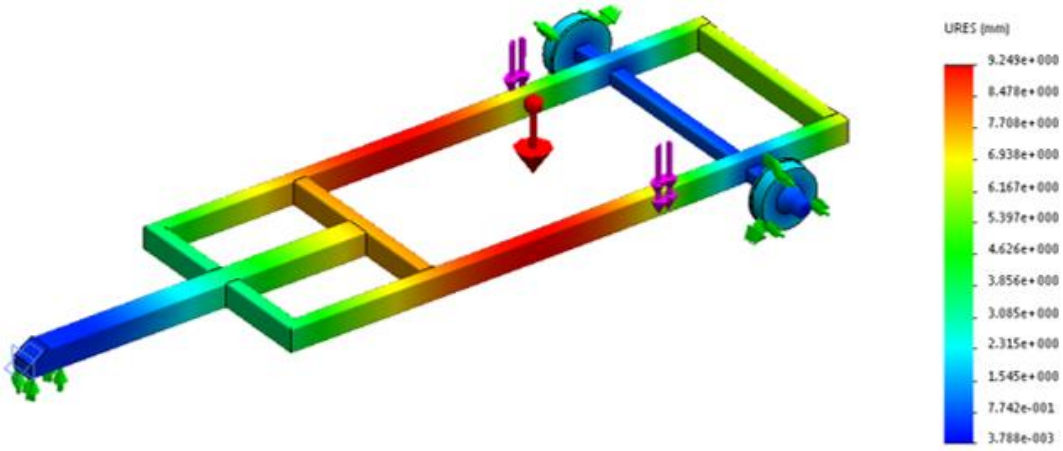

Fig. 3.7 Displacement of construction when box is loading

3.1.2 Research of possible frame's improvement I

After the analyzes of raised problems it is necessary to take some important decisions to solve those problems. As it was mentioned before, because of the big load the frame of a trailer can deform. The first possible solution is to select suitable reinforcements. This significant change can have this consequences: maximum stress reduced by almost two times. There are made some calculations which shows safety factor after semi-trailer frame possible improvement. To compare to the previous one (1,24), a new one shows that the situation with semi-trailer frame improved.

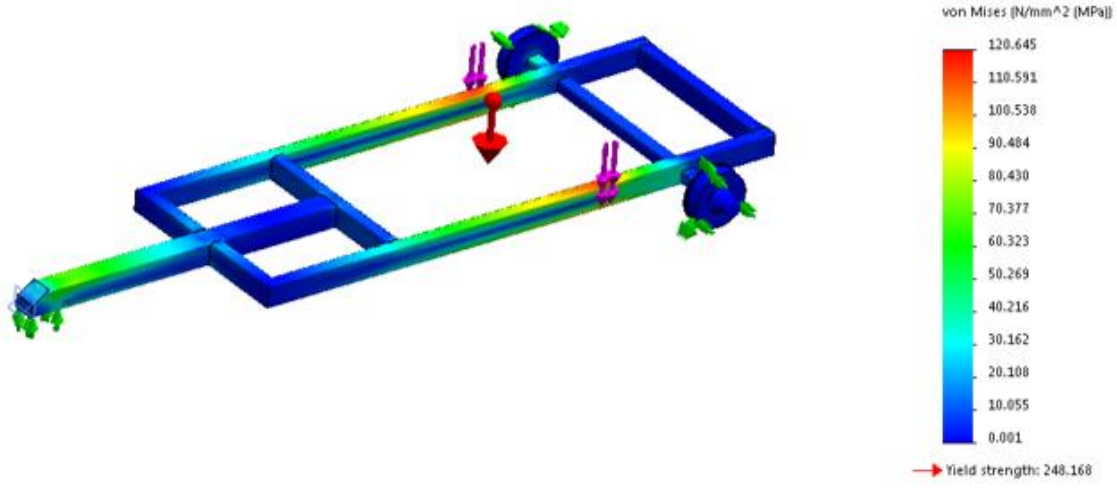

Fig. 3.8 Von Mises stress distribution with reinforcement

The factor of safety is 2,06.

$$n_y = \frac{248{,}168}{120{,}645} = 2{,}06$$

n_y - Semi trailer safety factor.

After the made changes there still exist frame construction displacement. It is worth to mention that after made improvement the indicator of displacement decreased almost two times. This shows the positive effect which appears after the made improvement.

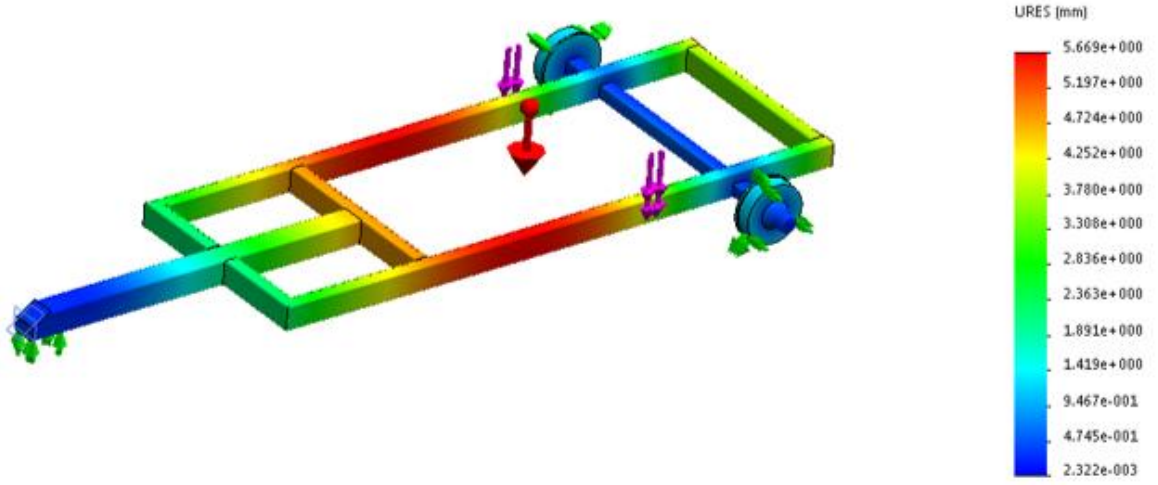

Fig. 3.9 Displacement of construction with reinforcement

Price calculation of the made improvement

In order to assess all possible criteria and make a decision which improvement is better, it is necessary to calculate all costs. There will be needed these parts:

Tubes. S235 160x80x6 cost 15,65eur/m

For frame model it is used 6,7m tube.

$Cost_1 = 15{,}65 \bullet 6{,}7 = 110{,}95$ eur.

For reinforcement it is used: 8 mm steel plate. The price of it is 543eur/tone, for two reinforcements it used 0,018 tone.

$Cost_2 = 543 \bullet 0{,}018 = 9{,}73$ eur.

In order to reinforce frame, it is necessary to fix steel plate to frame. It can be done by drilling holes in order to weld the steel plate to the frame enhanced. Approximate cost of drilling one hole is 0,5 eur.

$Cost_3 = 8 \bullet 0{,}5 = 4$ eur.

And one of the most important tasks is to cut out the steel plate of the right proportions of the big steel plate. The process of one meter costs 1.5 eur.

$Cost_4 = 1.5 \bullet 8{,}2 = 12{,}3$ eur (1)

All cost:

$Cost_{all} = 110{,}95+9{,}73+4+12{,}3 = 136{,}98$ eur.

3.1.3 Research of possible frame's improvement II

Another solution which could be made is a replacement of a tube which can withstand the highest load. Taking to the consideration that this replacement or enhance can be made during the design of the model. In the model the frame can be enhanced by changing the thickness of the same profile. After the replacement of the frame's tubes in those areas where cylinders are fixed, so mentioned areas get similar stresses as frame with reinforcements. The result can be seen in the picture Fig. 4.10 and proof for that is new factor which is calculated in the formula. A new factor 2,02 shows safety improvements of frame construction.

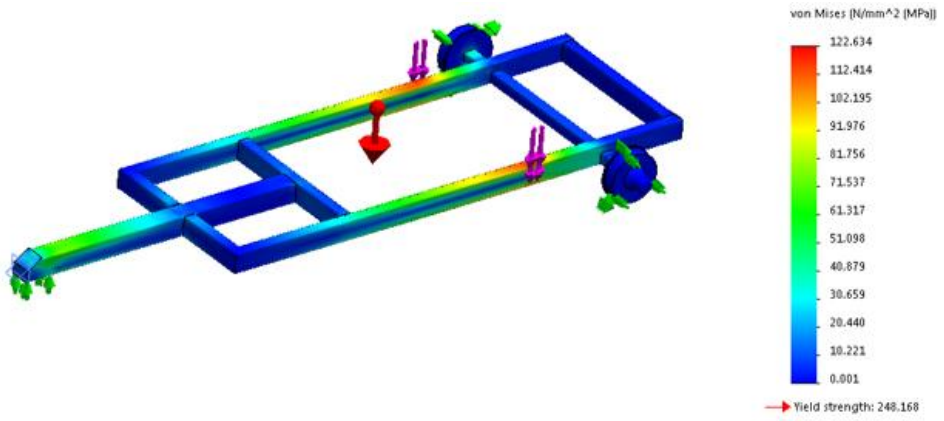

Fig. 3.10 Von Mises stress distribution with bigger tube

The factor of safety is 2,02.

$$n_y = \frac{248{,}168}{122{,}634} = 2{,}02 \quad (3)$$

n_y - Semi trailer factor of safety, N; ∂_{adm} - material tensile strength, MPa; ∂_y - free maximum stress, MPa.

After the placement of the new tubes which were designed in the model there still exist frame construction displacement. This shows the positive effect which appears after the made improvement. The lower construction displacement shows that after the placement of new tubes the result is even better.

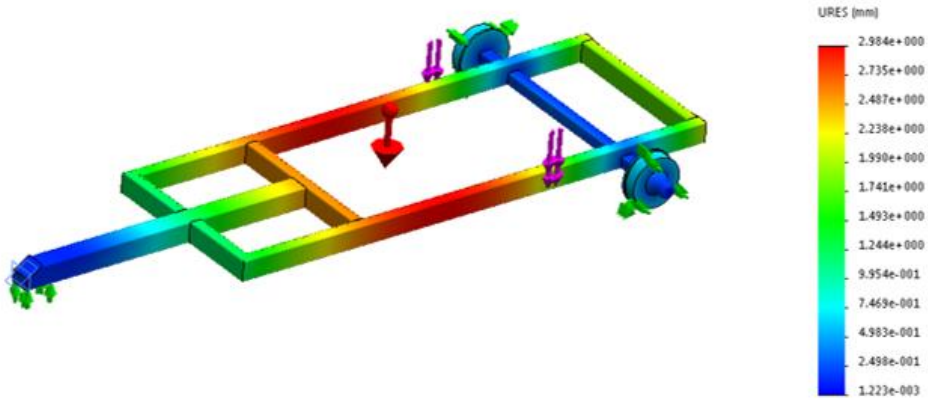

Fig. 3.11 Displacement of construction with bigger tubes

Improvement price calculation

Another calculation is made in a similar way the only one difference is other type of tube. For this improvement it is necessary to calculate tube S235 160x80x8 price. This tube's price is 24,34eur/tone. For semi-trailer construction is used 6,7 m. tube.

Cost =24,34 • 6,7 = 163,01 eur

3.1.4 The analyzes of possible improvement of the frame

After the analyzes of two different options how it would be possible to solve the problem of frame construction it would be useful to compere those two options in order to choose the best way of improvements. There will be compered 4 issues: stress distributions on the frame, displacement of construction, factor of safety of contruction and price.

Von mises stress distribution on the frame is higher with the bigger tubes, but it does not give a lot of advantages in comparison to the simple tube with reinforcement. The results of the comparison it is possible to see Figure 3.12

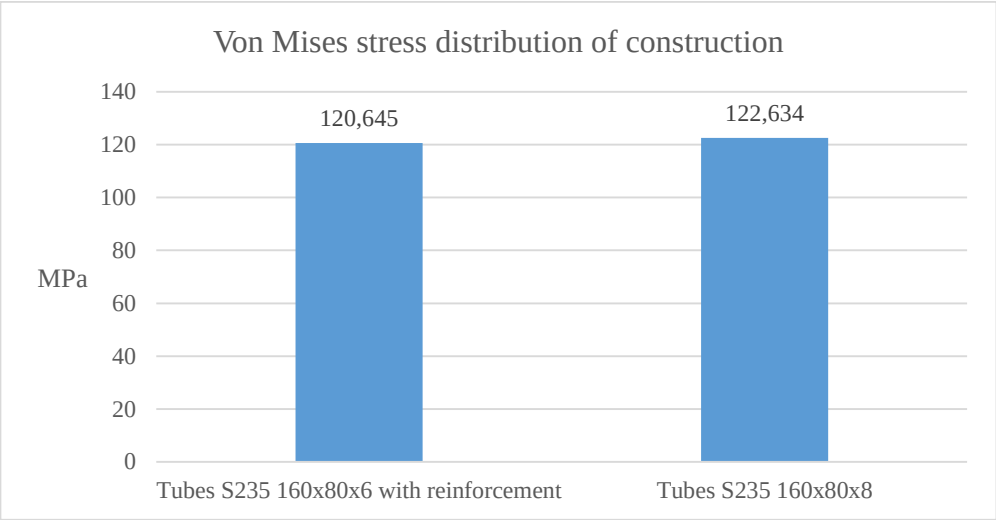

Fig. 3.12 Von Mises stress distribution

Other criterion which was analyzed is displacement of construction. After the made comparison it is clear that bigger tubes displacement of construction is almost twice smaller. Therefore, simple tubes with reinforcement also satisfies the requirements of the construction, It means that it is allowed to use both constructions. Two different displacement of construction are visualized in Figure 3.13

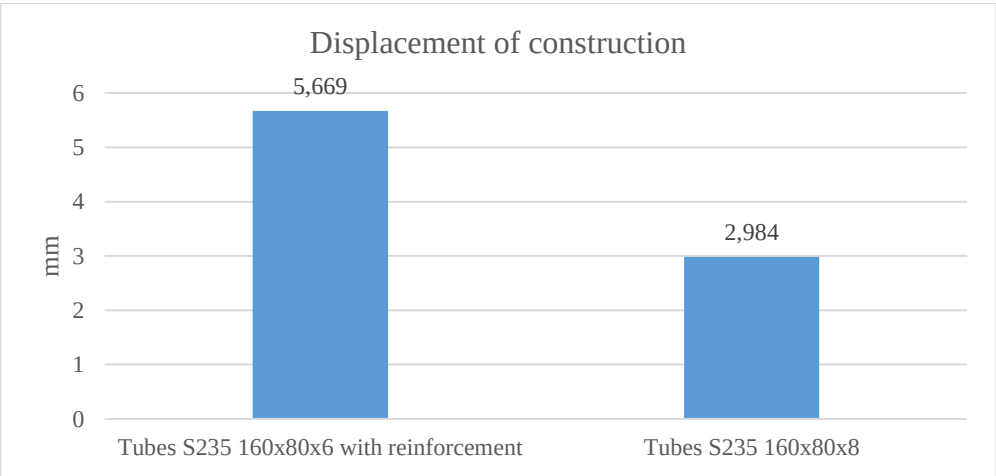

Fig. 3.13 Displacement of construction distribution

During the research it was analyzed two types of Mini Dumper frame constructions. For the finale choice of construction it was used factor of safety, which shows, which one construction is

stronger and which one will hold the aloud stress. There is recommended that the factor of safety factor should be around 2. If this requirement is fulfilled, it means that existed maximum stress is not exceeding aloud material's tensile strength of construction. It means that construction will keep the aloud stress. To see the different which one option would be more durable there is made a comparison.

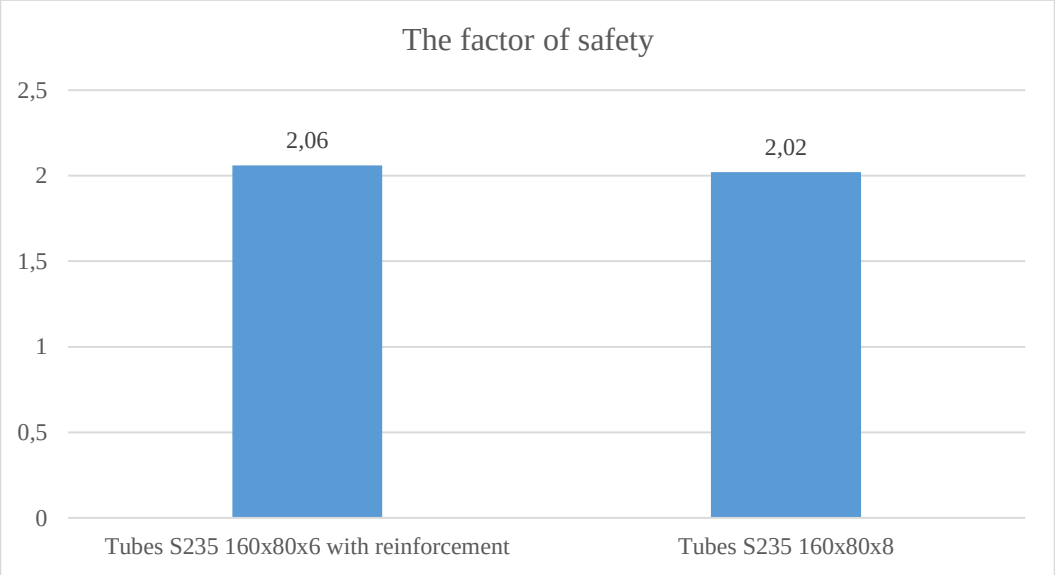

Fig. 3.14 The factor of safety distribution

From the chart it is possible to see that first option - simple tubes with reinforcement is higher by 3 points. It is not a significant change but preferable.

One of the most important things which can be compered and can strongly influence the decision is price. After the made comparison of the prices of two methods it appears that to produce a tube with reinforcement is cheaper around 17% than the production off bigger tubes.

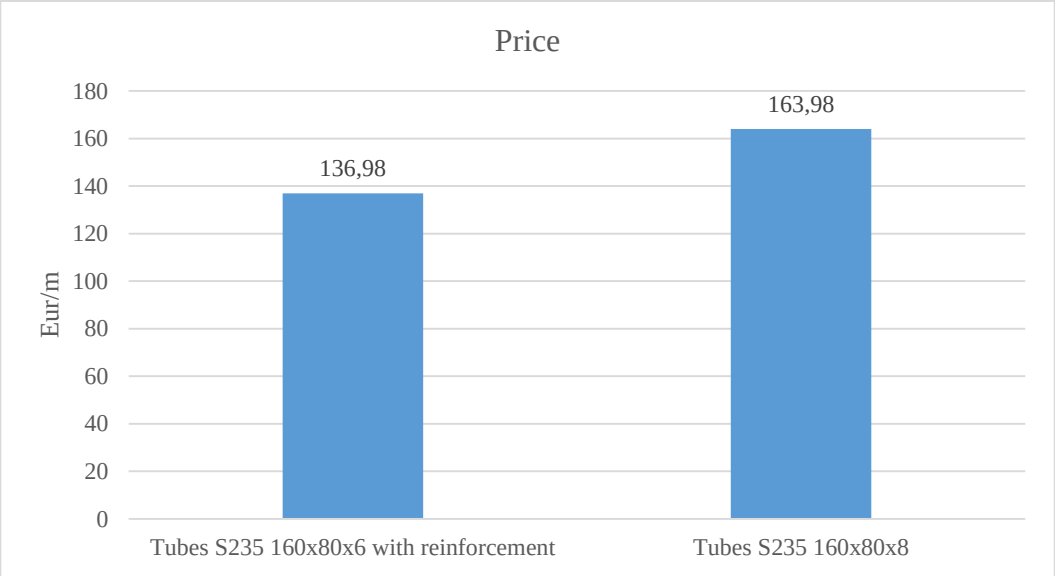

Fig. 3.15 Price distribution

3.1.5 Analyzes of mini dumper frame construction before and after improvement

After all researches and made analyzis it is made a decision that more technological and cost effective solutions is to choose tha construction of a frame with the smaller tube and to strengthen the side panels of the places which receive the maximum load. To see the differences before optimistaion and after optimisation it were made sone comperisons. In the charts below are compered parametars before improvement and after the improvement with the choosen method.

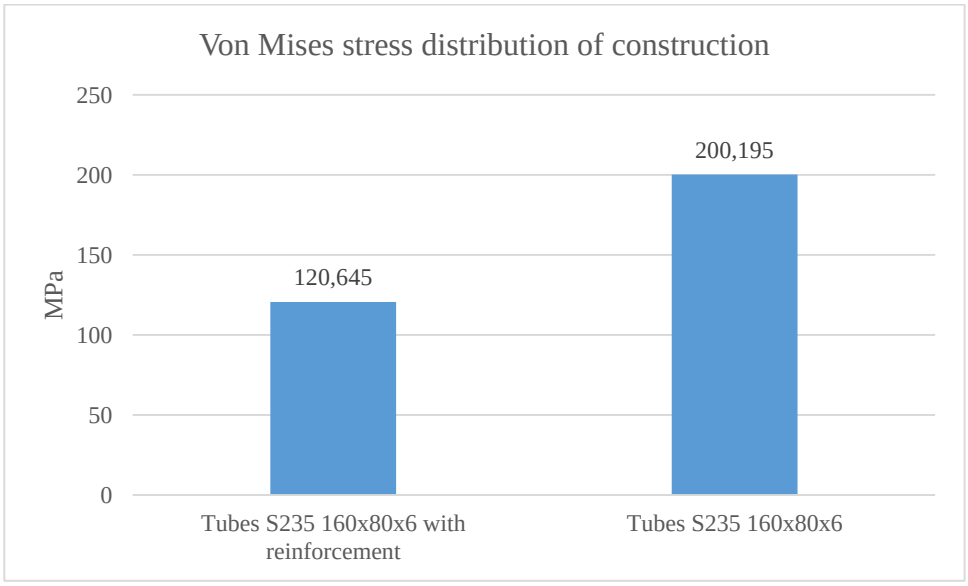

Fig. 3.16 Von Mises stress distribution before and after improvement

After the reinforcement of the frame with the side panels the maximum stresses are much lower. Consequently it means that the designed construction became more durable. It proves that made decisions were positive and improved the frame of semi-trailer.

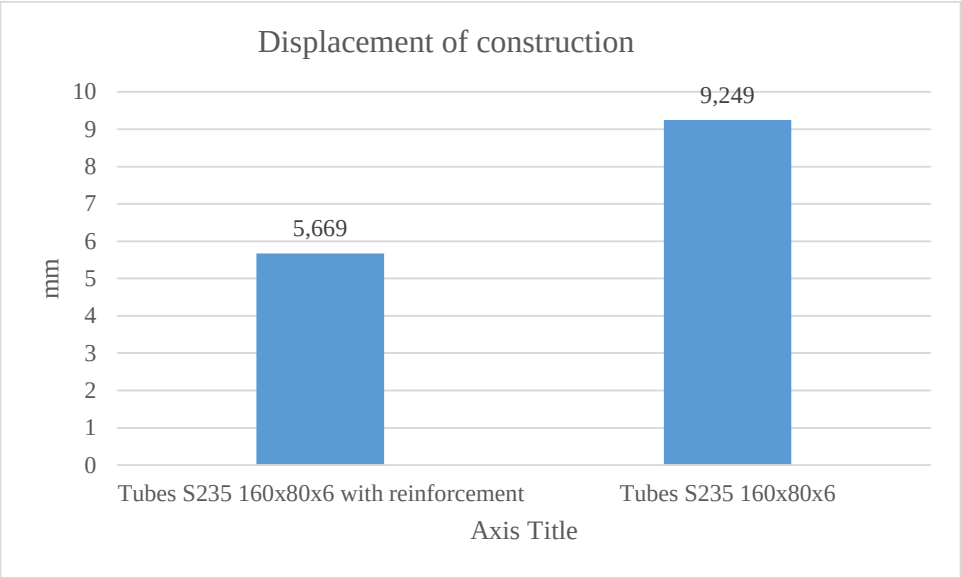

Fig. 3.17 Displacement of construction before and after improvement

Other made improvement is referred to the displacement of construction. After the reinforcement simple tubes with the side panels, the displacement of construction decreased almost twice. It could show that the frame can be used for a longer period of time without any deterioration

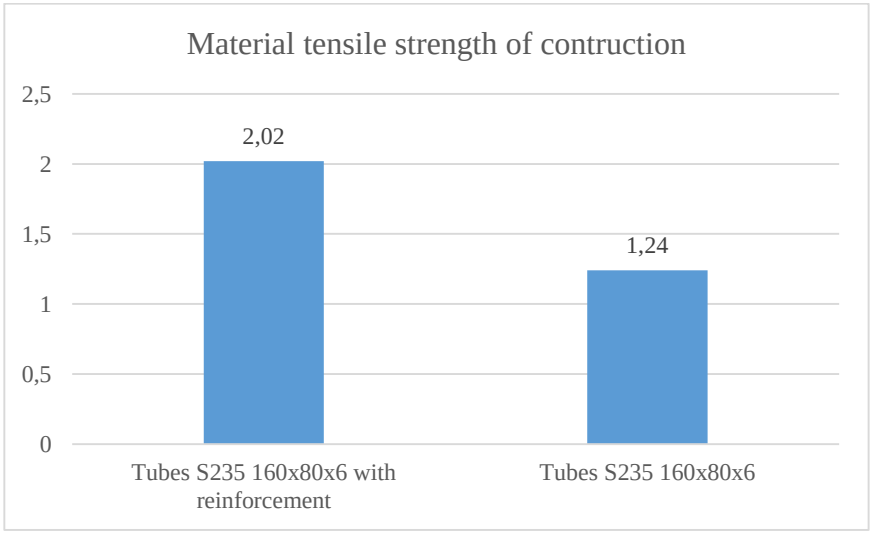

Fig. 3.18 Material strength of construction before and after improvement

Really important factor for the agricultural equipment is the factor of safety of construction. It is important because in the agricultural work it is difficult to measure the load and usually the semi-trailer is exploit even more than 100 %, it means that the load can be bigger than it is alowed and if the factor is low the frame cannot weather a bigger load. It is recommended that this factor should be close to the number 2. If it is bigger it is even better but at the same time it is more expensive. In this case the factor is very good, it is bigger but not too expensive which means that the frame will be lasting and the production will not be too expensive.

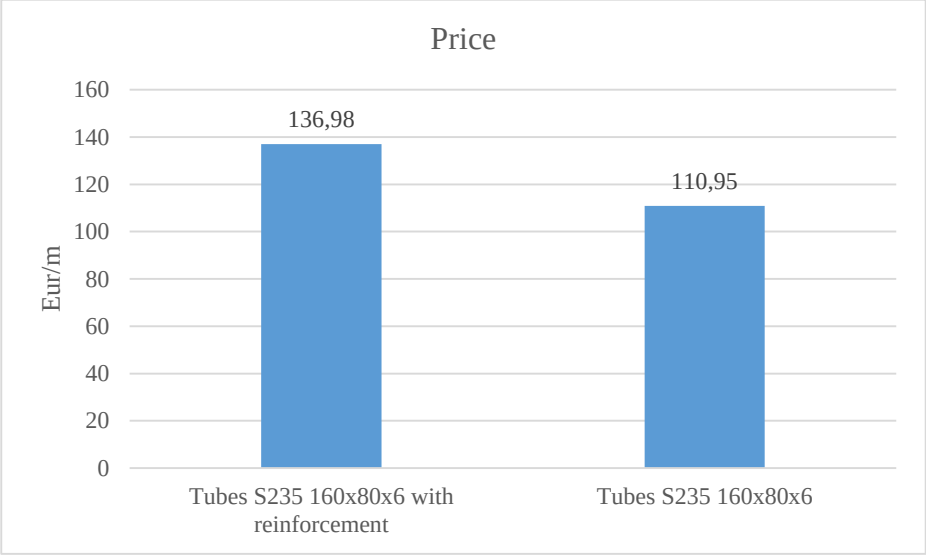

Fig. 3.19 Price of construction before and after improvement

As it was mentions before price is one of the most important feature for the productions. To compere the price of the frame with simple tubes and the frame with the reinforced tubed there is seen that the last one is a bit more expensive. It should be taken to consideration that the increase in the price is because of the increase in a quality. It can ve stated that made improvements were useful and and not too expensive.

All analyzed improvements were done and it can be seen in Figure 3.20 As it can be seen in the right picture the steel plate was fixed to frame of semi-trailer. In this way the frame's construction was improved and the result of analyze shows that frame can withstand maximal stress with certain reserve.

Fig. 3.20 Part of trailer frame‘s construction

3.2 Research and Improvement of semi-trailer cylinder retainer node

In some cases, conventional trailers are equipped with a single hydraulic cylinder in which the unloading is done automatically without the use of manual labor. However, mostly the conventional design cannot be easily equipped with the hydraulic mechanisms, as its cylinder’s stroke length is larger due to which it is very costly and bulky in appearance. To overcome the problems of a trailer equipped with single cylinder, a mechanism with two hydraulic cylinders is used in the proposed design (instead of a single bulky cylinder); which not only increases the efficiency of working but also maintains the cost within the limit. In addition, if one cylinder fails while working there is another cylinder, which will sustain the load and prevents the sudden fall of a bucket. The arrangement is working on hydraulic pressure which is controlled by the driver. The bucket is lifted up to a certain angle depending upon the stroke of the cylinders used in the hydraulic mechanism. In proposed design.

Fig. 3.21 Location of cylinder

In proposed design, the cylinders are located at the bottom side of the trailer (Fig. 3.21). These two cylinders are located in such a manner that the bucket will lift up easily and very less effort is required to lift up the box. The cylinders are hinged up with the pins, one pin is welded at the frame and the other is bolted with the box. The lifting height of the trolley is based on the stroke of cylinders.

3.2.1 Research of cylinder pin problem

As it was mentioned before problem which could happen in the production is related to the pin of the cylinder, this part is shown in the Figure 3.22 - detail No. 3. As it can be seen in the figure the pin (no. 3) touches the cylinder (no 1) for this reason it cannot move. On one hand, cylinder can settle down because of the big load but one other hand this is the defect of the production. The example showed in Figure 3.22 happened after big load when cylinder was raised up but could not went down.

Fig. 3.22 Cylinder retainer node 1. Support, 2. Cylinder pin 3. Cylinder

3.2.2 Simulation of semi-trailer pin

For the present study a solid modeling design software (SolidWorks 2013) was implemented. Such software, generally referred as 3D CAD, allows design, visualization and modeling of three-dimensional digital prototypes, simulating different operating conditions in terms of loads and relative movements. Implementation of simulation software in general brings clear advantages in design and testing of new vehicles, cylinders node: reduces time and costs for development of new products, allows mechanical verification of different design variations both for single elements and for whole

structures and eventually allows dynamic, static simulation to foresee vehicle maneuverability. For the specific study, 3D design software was implemented in order to recognize vehicle critical parts and verify their mechanical behavior when undergoing high solicitations. Additionally CAD simulations allowed foreseeing trailer dynamics, to better understand it showed in Figure 3.23.

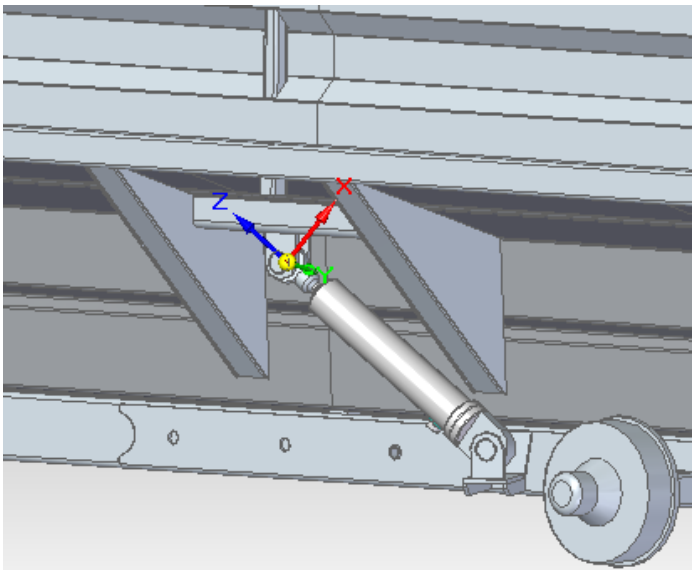

Fig. 3.23 Cylinder retainer node simulation

3.2.3 Research of possible solution for fastening unit

First of all, it is necessary to mention that cylinders which are used in the semi-trailer are made in Italy and Lithuanian companies import them. The cylinders in Italy are made in the standard way, it means that they are not very suitable for this particular model of semi-trailer. In Lithuania those cylinders are being improved, to the cylinders there are fixed the holders which are used to fix the cylinder to the frame.

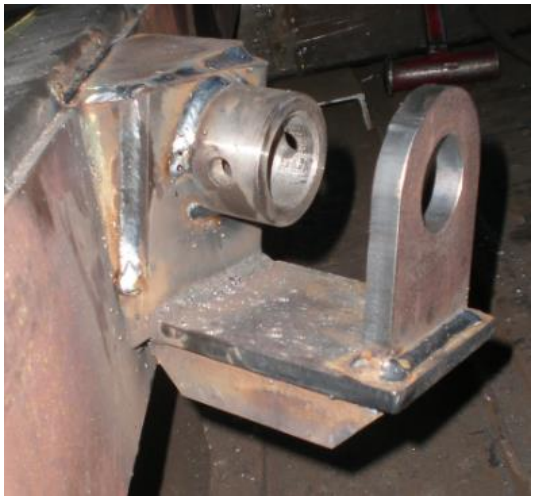

Fig. 3.24 Cylinder fastening unit

In the Figure 3.25 it is seen the fastening unit to which one the cylinder is attached. This part is significant because it is necessary to choose the right distance and angle between the cylinder and the fastening unit. Without the right proportions the cylinder will not be able to function well. Those significant changes were not done before the improvement, because of this reason semi-trailer could not function as intended.

In the Figure 3.25 is shown the dimensions which were used in the design of the model. It has been assessed that during the lifting process the cylinder may turn so taking in to the consideration that it will need to have the space, it was chosen to make the distances of showed size Fig. 3.25. These changes improved all process because before the cylinder was blocked during the process of lifting so it was difficult to use semi-trailer as intended.

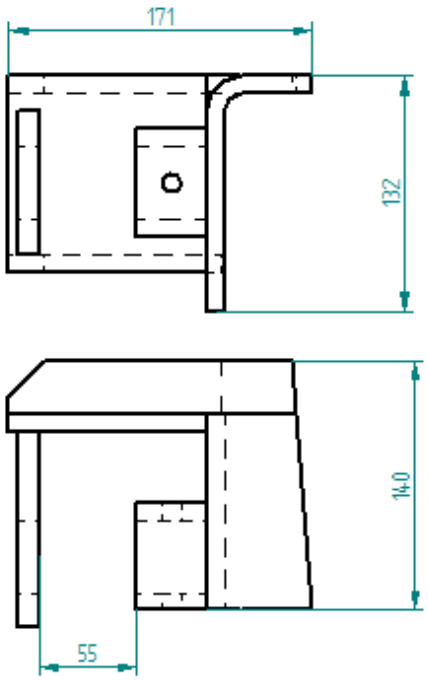

Fig. 3.25 Drawing of cylinder fastening unit

The most important thing which was done in this improvement it was right choice of the bigger distance between the cylinder and the fastening unit. It helped for the right function of the cylinder when the load is being raised and after, when the box is being taken down.

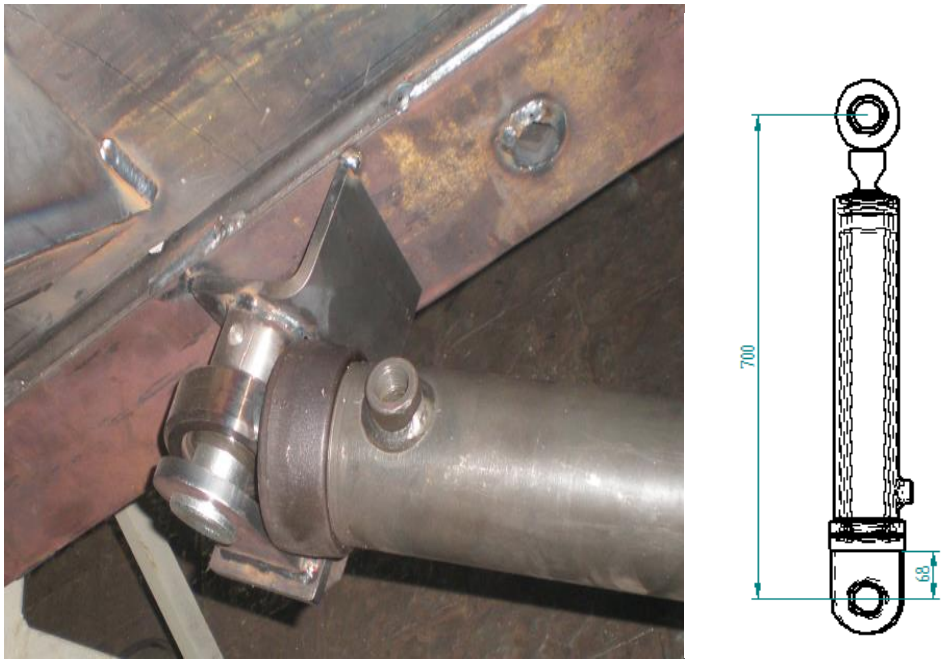

Fig. 3.26 Cylinder fastening unit construction and drawing of cylinder

In the Figure 3.26 can be seen the design of the fastening unit. The most important part is in the bottom and is measured 68 mm. Exactly this part is the significant one because it helps to avoid friction and blocking effect.

4. CONCLUSION

- After the analysis of the semi-trailer literature it was observed that different types of machinery are used in the agricultural work and “Mini Dumper” is part of the equipment which is used on daily basis. It is commonly used for the transport of goods and materials. The aim was to improve material, it is done by analyzed three types of different metals. For the Mini Dumper it was chosen steel metal S355. This metal was chosen because it is quite easy to blend and also this steel have a good strength parameters.
- There were analyzed two main options how to reinforce and improve frame construction: to change the thickness of the tube or to fix the steel plate to the area where the biggest stress is concentrated. After the analysis of the mentioned improvement's options, there was made the reasonable decision that fixing the steel plate to the area where the biggest stress is concentrated is more cost effective. The decision for the improvement was made according to the analysis of these parameters: stress distribution of construction – 120,645 MPa, displacement of construction 5,669 mm, factor of safety 2,06 and price – 136,98 eur.
- Other analyzed problem is related to the cylinder. The problem was solved by choosing the right distance and angle between the cylinder and the fastening unit. It add some additional space so in this way it was avoided friction and blocking effect. All these changes improved the way the cylinder can be used.

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APPENDIX

1 APENDIX

Example of O1 class semi-trailer

2 APENDIX

Example of O2 class semi-trailer

3 APENDIX

Example of O3 class semi-trailer

4 APENDIX

Example of O4 class semi-trailer

5 APENDIX

Example of Ra1 class semi-trailer

6 APENDIX

Example of Ra2 class semi-trailer

7 APENDIX

Example of Ra3 class semi-trailer8 APENDIX

8 APENDIX

Example of Ra4 class semi-trailer