KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Andrius Saulevičius

UPGRADE OF “VLD KAUNO CECHAS” TURNTABLE

Master’s Thesis

Supervisor:
doc. dr. R. Keršys

KAUNAS * 2015

KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

DEPARTMENT OF MANUFACTURING ENGINEERING

CONFIRM

Head of the Department

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INDUSTRIAL ENGINEERING AND MANAGEMENT (M5106L21)

Supervisor: doc. dr. R. Keršys ______________ (date, signature)

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DECLARATION OF ACADEMIC HONESTY

2015-05-25
KAUNAS

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Saulevičius, A. UPGRADE OF “VLD KAUNO CECHAS” TURNTABLE. Master of Production and Manufacturing Engineering final project / supervisor doc. dr. Robertas Keršys; Kaunas University of Technology, Faculty of Mechanical Engineering and Design, Department of Manufacturing Engineering.

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SUMMARY

The first part of this paper is dedicated to introduction of “VLD Kauno Cechas” activities. Here the problem of dual gauge muddle as well as the typical design solutions for turntable are examined. The main objectives of upgrade project are formed.

Later, the construction and working principles of railway turntable are examined in greater detail. In relation with company’s future vision the positive and negative factors of typical design approaches are investigated. The possibility of using special universal 1508 mm track gauge is introduced.

The final part is mainly design work. According to research data a CAD model is created. Turntables platform is checked and adapted to suit new track, assuring full functionality and safe operation of the turntable.

Keywords: railway, turntable, dual gauge, 1508 mm gauge

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SANTRAUKA

Pirmoji darbo dalis yra skirta bendrovės „VLD Kauno Cechas“ veiklos pristatymui. Čia taip pat aptariama dviejų standartų vėžių sudūrimo problema, pristatomos tipinės problemos sprendimo priemonės. Suformuluojami projekto uždaviniai.

Toliau, detaliau ištiriama grąžos rato konstrukcija ir veikimo principai. Atsižvelgiant į bendrovės ateities planus nagrinėjami tipinių grąžos rato schemų privalumai ir trūkumai. Pristatoma galimybė panaudoti bendrą specialią 1508mm pločio vėžę.

Paskutinė dalis skirta projektavimo darbams. Pagal tyrimų duomenis sukuriamas kompiuterinis grąžos rato platformos modelis. Platforma ištiriama ir pritaikoma naujai vėžei, atsižvelgiant į funkcionalumo ir saugumo reikalavimus.

Raktiniai žodžiai: geležinkelis, grąžos ratas, dviejų standartų vėžės, 1508 mm vėžė

KAUNO TECHNOLOGIJOS UNIVERSITETAS

MECHANIKOS INŽINERIJOS IR DIZAINO FAKULTETAS

Tvirtinu:

Gamybos inžinerijos katedros vedėjas

(parašas, data)

(vardas, pavardė)

MAGISTRANTŪROS STUDIJŲ BAIGIAMOJO DARBO UŽDUOTIS

Studijų programa PRAMONĖS INŽINERIJA IR VADYBA

Magistrantūros studijų, kurias baigus įgyjamas magistro kvalifikacinis laipsnis, baigiamasis darbas yra mokslinio tiriamojo ar taikomojo pobūdžio darbas (projektas), kuriam atlikti ir apginti skiriama 30 kreditų. Šiuo darbu studentas turi parodyti, kad yra pagilinęs ir papildęs pagrindinėse studijose įgytas žinias, yra įgijęs pakankamai gebėjimų formuluoti ir spręsti aktualią problemą, turėdamas ribotą ir (arba) prieštaringą informaciją, savarankiškai atlikti mokslinius ar taikomuosius tyrimus ir tinkamai interpretuoti duomenis. Baigiamuoju darbu bei jo gynimu studentas turi parodyti savo kūrybingumą, gebėjimą taikyti fundamentines mokslo žinias, socialinės bei komercinės aplinkos, teisės aktų ir finansinių galimybių išmanymą, informacijos šaltinių paieškos ir kvalifikuotos jų analizės įgūdžius, skaičiuojamųjų metodų ir specializuotos programinės įrangos bei bendrosios paskirties informacinių technologijų naudojimo įgūdžius, taisyklingos kalbos vartosenos įgūdžius, gebėjimą tinkamai formuluoti išvadas.

1. Darbo tema „VLD Kauno Cechas“ grąžos rato tobulinimas / Upgrade of “VLD Kauno Cechas” turntable;

Patvirtinta 20 15 m. gegužės mėn. 11 d. dekano įsakymu Nr. ST17-F-11-2 ;

2. Darbo tikslas pritaikyti bendrovės „VLD Kauno Cechas“ grąžos ratą Rusiško ir Europinio standarto vėžei;

3. Darbo struktūra galimų sprendimo būdų tyrimai, grąžos rato tobulinimo darbų projektavimas ;

4. Reikalavimai ir sąlygos projektuojant turi būti atsižvelgta ir į grąžos rato funkcionalumą ;

5. Darbo pateikimo terminas 2015 m. gegužės mėn. 25 d.

6. Ši užduotis yra neatskiriama baigiamojo darbo dalis

Išduota studentui: Andriui Saulevičiui ME M -3/9 gr.

Užduotį gavau

(studento vardas, pavardė) (parašas, data)

Vadovas

(pareigos, vardas, pavardė) (parašas, data)

INTRODUCTION

Since the early days of railways when British started to export their technology, 1435 mm track gauge was referred as *standard*. Many countries, mostly in Western Europe adopted this particular gauge, others mainly for political reasons adopted different gauges. In the XIXth century Lithuania was a part of Russian Empire, therefore wider 1524 mm gauge was used.

During vicissitudes of history, Lithuania has survived multiple changes in track gauge. For example in the interwar period a *standard* gauge was used. Unfortunately, after World War II, Lithuania fell into the hands of Soviet Union and *Russian* gauge was used ever since. In nowadays, seeking a better integration to European Union, Lithuania is participating in an international "Rail Baltica" project. The key change will be the *standard* gauge railway line, which will connect all Baltic States with the Western Europe.

This brings enormous changes not only for Kaunas railway station but to "Vilniaus Lokomotyvų Depo Kauno Cechas" ("VLD Kauno Cechas" in short) company as well. Just to be able of servicing locomotives of both gauges, some fundamental changes in the depot's infrastructure have to be made. Part of it is the XIXth century turntable.

Turntable is a device used to turn around or direct locomotives to the stalls of the roundhouse. Since company is planning to convert two stalls to suit 1435 mm gauge it is necessary to upgrade the turntable to fit both 1520 mm and 1435 mm gauges. This inevitability forms the base for this final project.

The main goal of the project – upgrade of the turntable to suit both 1520 mm and 1435 mm gauges.

Regarding to this the following **tasks** are formed:

1. To examine existing multi-gauge turntable designs;
2. To apply or design track over turntables platform to suit both standard (1435mm) and wider (1520 mm) gauges;
3. To examine and modify, if necessary, turntable's platform to support new tracks;
4. To ensure simple and safe operation of the upgraded device.

1. PROBLEM (OBJECT) ANALYSIS

1.1. Object

1.1.1. “VLD Kauno Cechas”

In 1851 Russian tsarist government agreed on construction of railway line Saint Petersburg–Warsaw (it was conceived to build 1250 km of railways). Construction works in Lithuanian territory of section Daugavpils-Vilnius-Grodno with a branch Lentvaris-Kaunas-Kybartai (Virbalis) of this line were started in 1859 [1]. The earliest opening for the public transport was in section Kaunas-Kybartai (Virbalis) on April 11th, 1861, - this date is officially marked as the beginning of railways history in Lithuania [12].

Together with the first railway line many engineering structures were built as well. The largest of these was: Kaunas and Paneriai railway tunnels (built in the autumn of 1861), bridges over Neris, Vilnelė, Merkys, and Nemunas river in Kaunas. In this line the first train stations (21 station) in Lithuania were built [1]. One of the largest, first class Kaunas railway station was opened on February 21th, 1862.

Fig. 1.1. Kaunas depot 1935-1940 [18]

From the very beginning, near the Kaunas passenger train station, auxiliary service buildings were built as well. That is: various warehouses, water tanks, workshops, locomotive depot, etc. One of the most important buildings of Kaunas depot – roundhouse with the locomotive turntable. Kaunas depot had two locomotive turntables (see Fig. 1.1.), however area had been devastated during years of World War II, and second turntable did not survive [12].

Fig. 1.2. Kaunas depot turntable, modern day view

Since the last remaining locomotive turntable (see Fig. 1.2.) in "VLD Kauno Cechas", as well as some other service buildings, can be traced back to the XIXth century it is now protected by the state as an immovable cultural property object.

Today "VLD Kauno Cechas" plays a vital role in Lithuanian railway network. The main tasks of the depot are: [11]

1. To organize and carry out transportation of both freights and passengers, to perform maintenance and permanent repair operations of both rolling stock and sea containers;
2. To ensure good technical condition of both rolling stock and engineering equipment, belonging to the depot; to assure quality of maintenance and permanent repair operations of both rolling stock and sea container's;

3. To ensure safe: train traffic, freight and passenger transportation, shunting operations; to assure: follow of traffic schedules, work discipline, work safety and healthcare, electrical and fire safety, civil and environmental protection;
4. To prepare and implement technical-technological projects, increasing both durability and dependability of rolling stock, engineering equipment, and technological equipment;
5. Rationally use property designated by “Lithuanian Railways”.

Depot, individually, performs the following functions: [11]

1. Provides quality and operative transportation services;
2. Takes care of work, household, and leisure conditions, provided in the collective agreement, assurance and quality;
3. Ensures compliance with metrology norms;
4. Advertises “Lithuanian Railways” services, ensures their quality;
5. Assures depot compliance with worker’s healthcare and safety, fire safety, environmental and other regulatory requirements.

However, the most important function of “VLD Kauno Cechas” remains the service and maintenance of locomotives: [11]

- M-62 V120;
- M-62 K;
- TEM TMH;
- TEM-2A;
- TEM-2;
- TGK-2.

“VLD Kauno Cechas” is capable of performing all maintenance (TP-3), and permanent repair (ER-1) operations. Maintenance (TP-3) operation include all maintenance (TP-2) jobs and some additional checks requiring some special workshop equipment.

Usually during (TP-2) locksmith brigade perform noise and visual checks for different assembly’s work; excessive bearing noises; leaks; fuel, oil, and air pressures. Electric checks for measuring devices; voltage regulators; switches; relays; automatic signalling devices; emergency stop, and radio devices; fuses; alternators. These checks are performed while diesel engine is idling. [11]

When diesel engine is stopped, further inspection are continued. Locomotive is checked for lose assemblies; defective mechanisms, driving belts, fan impellers. Visual inspection is performed on wheel-sets, coupling devices, brake system, suspension. Level of operating fluids are checked, all necessary joints greased; breather tank is drained.

During (TP-3) main diesel engine assemblies (cylinders, pistons, crank shaft bearings, rockers and lifters, turbo-compressor, blower, nozzles) are checked. All filters are cleaned or changed. Main alternator and auxiliary electrical machinery condition is checked. Chassis, automatic brake system, speedometer, vigilance control devices are checked with special care this time. [11]

Again, permanent repair (ER-1) include all maintenance (TP-3) jobs, and some additional operations. Those include planned removal and servicing of certain assemblies. Quality of repairs is checked in special test stands. [11]

All these operations are performed in "VLD Kauno Cechas" roundhouse. So you can imagine how important turntable is for assuring workshop's functionality.

1.1.2. Dual Gauge Muddle

Supported by European Commission transport infrastructure policy (also known as *TEN-T*) member states of European Union will be eventually joined into a powerful trans-European network. Part of that policy is "Rail Baltica" project.

"Rail Baltica" is a strategic long-term railway project which aims at developing high-quality passenger communication and freight transportation among the Baltic States, Poland and other EU countries. The modernized railway lines will enable effective land communication among the Baltic and Northern Europe countries (especially Finland), and in the long-term with Central Asia. Improved communication by railway will have environmental advantages, reduce traffic jams in European road network, enhance access to Baltic States and stimulate faster regional development in the relevant countries.

The long-term objective of the international project "Rail Baltica" is comprehensive implementation of the principles related to combination, interrelation, reliability, safety, security of different modes of transport, provide favourable conditions for using the most environmentally-friendly modes of transport. It shall be noted that "Rail Baltica" project is not only the creation of railway infrastructure, but also of logistics chain which will form the flows of freight and passengers [8].

“Rail Baltica” line will connect Warsaw, Kaunas, Riga, Tallinn, and also Helsinki by a railway ferry. The key change to the existing infrastructure is European standard (1435 mm) railway line. It is a fundamental change for the Kaunas station, because all approaching tracks as well as turntable itself and a roundhouse are dedicated for wider (1520 mm) Russian standard gauge. In order to provide services for standard gauge locomotives the upgrade of “VLD Kauno Cechas” infrastructure is required.

The trouble that “VLD Kauno Cechas” is facing – the upgrade of depot roundhouse together with its turntable is not included to the “Rail Baltica” project. That means that responsibility of upgrading these engineering structures lies on “VLD Kauno Cechas” management.

The upgrade of Kaunas depot turntable plays a vital role in this project, especially for Kaunas region, because, it becomes a true bottleneck, where two standards of gauges (1435 mm and 1520 mm) really collide. Normally (see Fig. 1.3.) such dual gauge line would share the same railway bed, but would use a completely separate set of tracks. For this, though, we are limited in width of the turntable platform, therefore both gauges should fit inside wider 1520 mm gauge, for which the turntable was originally designed.

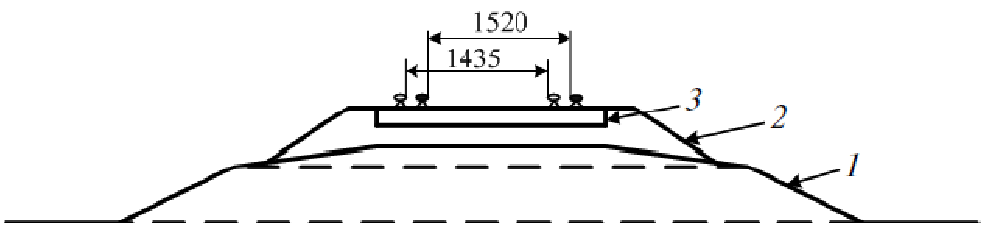
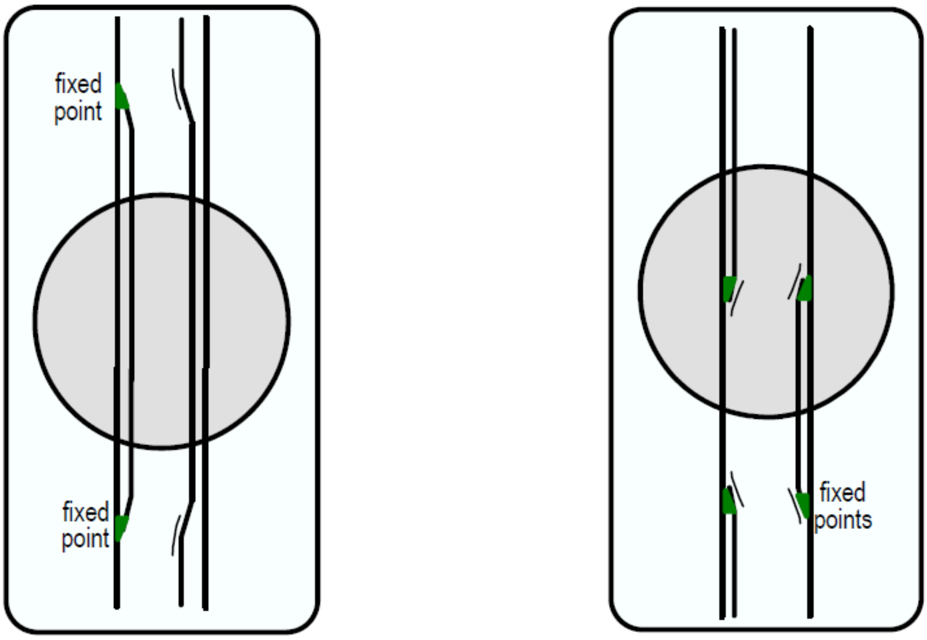


Fig. 1.3. Dual gauge railway line 1435 mm / 1520 mm [17]
1 – Railway bed; 2 – Ballast; 3 – Railway sleeper.

Typical approach to dual gauge turntable design is to use one of the most commonly used layout schemes (see Fig. 1.4.).



Symmetrical Asymmetrical

Fig. 1.4. Typical multi gauge turntable layout schemes [14]

Symmetrical multi-gauge use both rails for each gauge laid on a common centre-line. This is an unusual configuration for the rest of the rail yard and conversions of the track arrangement are required on each approach to the turntable. [14] Symmetrical design is the best solution from the balancing point of view. In such case locomotive's track gauge would not have any side effects on turntables structure. The whole system would remain balanced longitudinally as well as transversely.

An asymmetrical design uses a common rail table track with a transition in the centre. Transitions required on the approaches depend on the dominant yard configuration and whether the turntable is accessed from one or both ends of a given turntable rotational position. [14] The transition of the common rail in the middle of turntable helps to minimize the unwanted effects on the construction, especially on pivot point. Unfortunately, not always it is possible to use such layout because of geometry of both gauges, turntable overall dimensions etc.

In case of two gauges being very close in their dimensions, like in our case (difference between standard and wider gauges is only 85 mm) rises the need of special rail profile (see Fig. 1.5.). This profile features two heads and common foot.

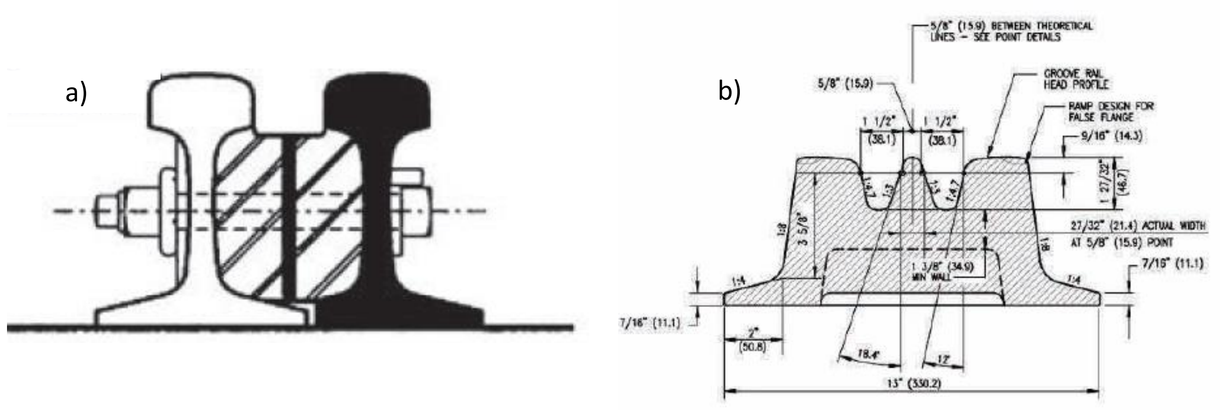


Fig. 1.5. Examples of special rail profiles [7]

Depending on available resources special profile might be manufactured using commonly available railway track elements like ***a)*** in Fig. 1.5. or entirely from scratch, similar to railway switch monoblock frog cutaway profile ***b)***. It is probably, cheaper to manufacture something from readily available railway elements, but it takes a lot of time and requires a very committed labour force.

Even now we can state that otherwise simple exercise of relaying railway tracks, because of geometrical parameters of both gauges as well as original turntable design, will grow into a major project requiring some careful analysis and perhaps unconventional engineering solutions in order to successfully adapt hundred and fifty year old turntable to serve 1435 mm gauge rolling-stocks that eventually will reach Kaunas due to "Rail Baltica" project.

1.2. Requirements and Objectives of the Project

From the very beginning of this project a few requirements were set clear:

- Rail head height;
- Visual appearance;
- Safety.

First of all, rail head height on top of turntable platform must remain the same. And the reason for that is the necessity to adjust height of the every single approaching line to the turntable. That would, inevitably, result in major ground works, affecting all major activities of the company. To prevent this from happening, it is agreed that rail head height must remain the same.

Another requirement is related to the origins of Kaunas turntable. Since it was originally built in the XIXth century, it is now protected by the state as immovable cultural property. That means, that we are very limited to what we can do, in terms of structural changes and general appearance. However, considering many upgrades performed on the turntable during its long history, and the fact that it is vitally important for organization activities, it is agreed that at least general appearance should remain as original as possible. Upper deck was changed, anyway, (there are many welded joints, modern fasteners etc.) so planned upgrade should not harm the historical value of the device.

And finally there is safety. No matter how we are planning to upgrade this device, we just need to make sure that all changes are adequate and capable to withstand locomotive's weight, there is no possible way for locomotive to derail while rolling on the turntable, etc.

Keeping in mind all requirements and the main task the following objectives for the upgrade project are formed:

1. To design track over turntables platform to suit both standard (1435mm) and wider (1520 mm) gauges;
2. To modify turntable's platform to support newly designed track;
3. To ensure safe operation of the upgraded device;
4. To ensure full functionality of the upgraded turntable;
5. To protect the heritage of the original turntable.

2. RESEARCH PART

2.1. Working Principles

As mentioned before "VLD Kauno Cechas" turntable dates back to the XIXth century. Therefore, it is constructed using technologies that were available during that time. Probably the biggest difference from modern construction techniques is the type of joints used to assemble it. The main girders are riveted from steel plates, sheets, and standard profiles, using large (approx. 20 mm in diameter) rivets (see Fig. 2.1.). Two main girders are joined together with both transverse and diagonal braces.

Fig. 2.1. Turntable construction elements

Turntable is a rotating girder platform which rotates full 360 degrees around a pivot bearing. The weight of the locomotive is concentrated on a centre-bearing pivot mechanism, with the girder span acting as cantilever. The pivot bearing also allows the span to tilt so that each end, by two supporting wheels, may bear upon the circular rail in the floor of a 23-meter-diameter concrete pit (see Fig. 2.2.). Ideally turntable should be balanced not only longitudinally but transversely as well, to avoid any excessive stress to the pivot bearing or supporting wheels.

For locomotive to be able to ride over the turntable platform standard *P50* rails are laid on top of the girders. Weirdly, rail tie plates, which provide a decent place for a rail to sit on and, more importantly, stable fixing point, are welded directly to the girder top span. On other examples from the same period, rails are usually laid on railway sleepers. Further, rails are fixed using standard railway industry fasteners (see Fig. 2.3.).

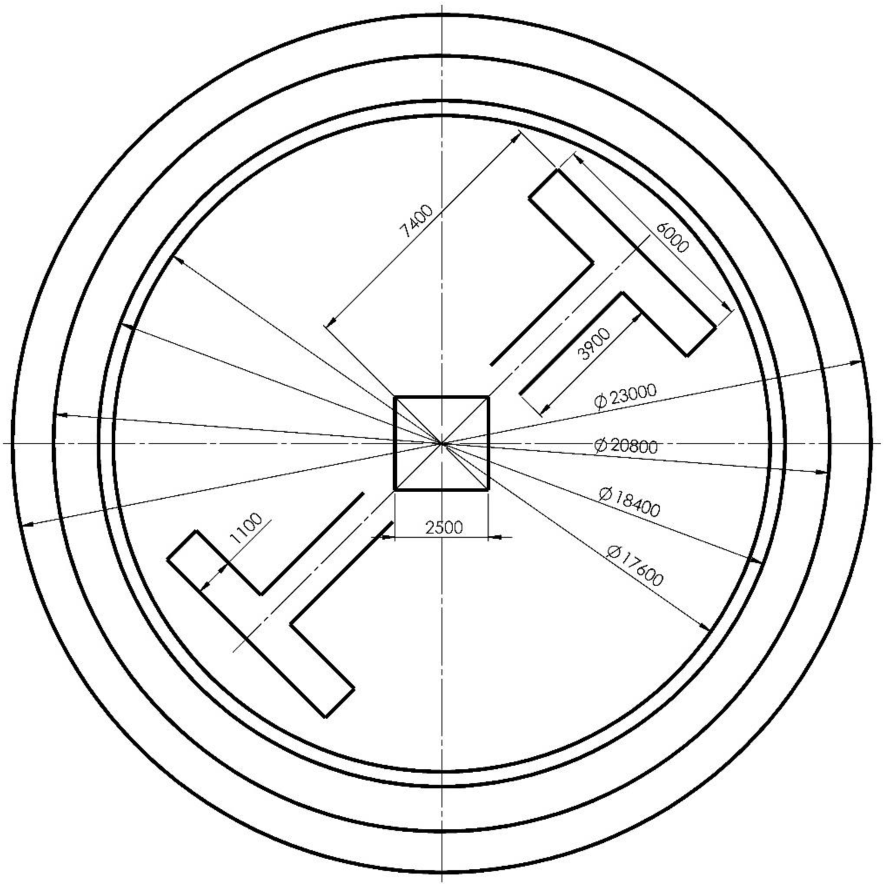


Fig. 2.2. Turntable pit dimensions

Fig. 2.3. Rail fasteners

Each rail is fixed in 30 points, approx. 800 mm apart. At each end there is one additional fixing point between the last two points for extra support. The ends of rail experience the biggest dynamic loads while locomotive is rolling on and off the table.

During its long service time "VLD Kauno Cechas" turntable was repeatedly modernized. As far as we know it was a bit shorter in the past. The major upgrade was carried out in 2009, when a modern microprocessor control system was installed along with hydraulic locks to stabilize turntable while locomotive is rolling on or off the table. Now it is very functional and easy to operate, one person is required to operate it from the control panel.

2.2. Future Vision

As already mentioned, the plan is to upgrade turntable in such a way, that it would be capable of accepting locomotives of both narrower (1435 mm) and wider (1520 mm) gauge track. For that station yard infrastructure will be changed. "VLD Kauno Cechas" representatives have mentioned that, for the simplicity, there will be two new narrow gauge tracks approaching turntable from the area marked red in the Fig. 2.4., rather than the whole yard reorganized to fit both gauge standards.

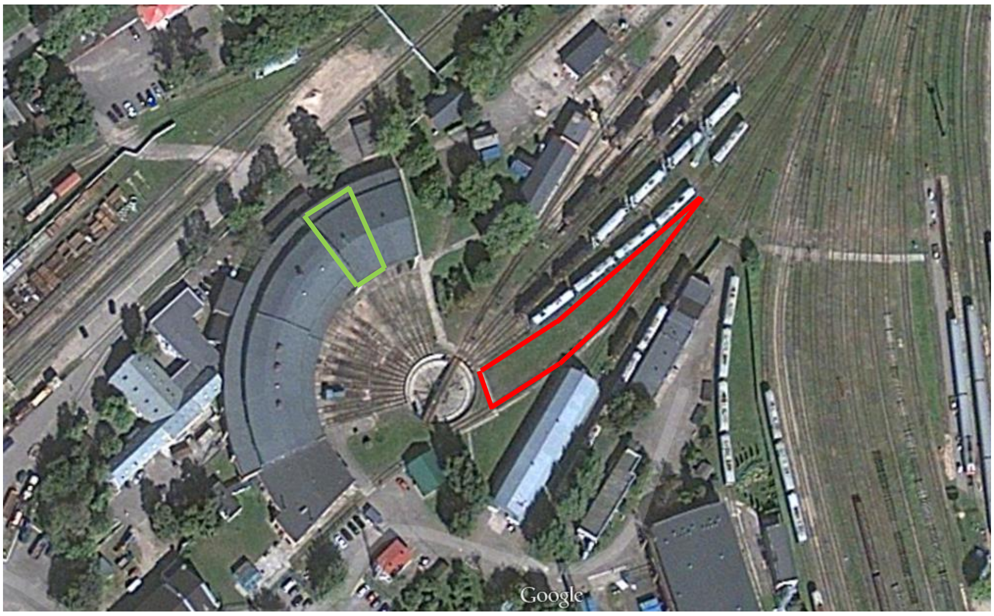


Fig. 2.4. Location of new standard gauge tracks and stalls

Similarly only two stalls (marked green in the Fig. 2.4.) in the roundhouse will be transformed to European standard gauge. That should fully cover capacity requirements for the depot workshop.

2.3. Upgrade solutions

2.3.1. Symmetrical Layout

Normally this is the best solution from turntable balancing point of view, because both gauges (wider and standard gauge) would be laid using common centre line, which crosses the turntable's pivot point. As mentioned earlier, this is vitally important in order to reduce overload on both pivot bearing and supporting wheels.

Symmetrical layout is also preferred because of its simpler fulfilment. If dimensions of both gauges allow, usually they are laid by using separate tie plates. That self-support inevitably greatly reduces design time of the project. There is less or even no special components, which reduces or eliminates all together the component manufacturing time.

In addition to, symmetrical layout scheme, symmetrical multi-gauge turntable layout eliminates all contemplations about turntable's functionality. For example, after turntable's modifications, all existing wider gauge infrastructure, including turntable locks, would remain untouched. Therefore symmetrical layout scheme looks so tempting.

Unfortunately, standard (1435 mm) and wider Russian standard (1520 mm) gauges are too close to each other for symmetrical multi-gauge turntable layout scheme succeed in our upgrade project (see Fig. 2.5.).

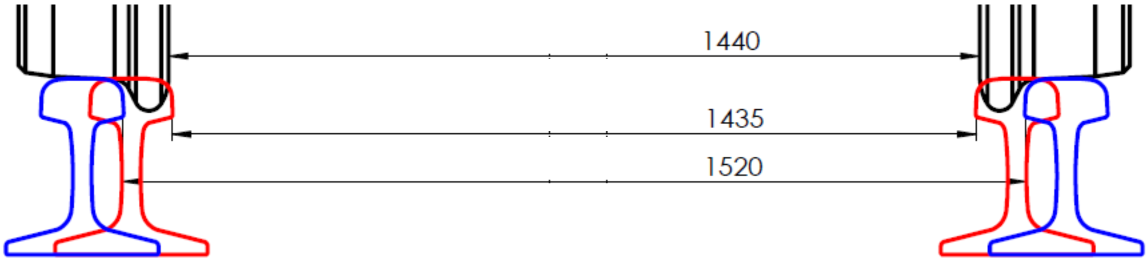


Fig. 2.5. Symmetrical layout, wider gauge wheel-set, *P50* profile rails

As you can see from the picture flange of standard wider gauge wheel-set would interfere with 1435 mm gauge rail head (marked red in the picture). That eliminates even a slight chance of designing special profile rail which would serve both gauges. Therefore, symmetrical turntable layout scheme cannot be used for upgrading "VLD Kaunao Cechas" turntable.

2.3.2. Asymmetrical Layout

Continuing our research in typical multi-gauge turntable layout schemes we have an asymmetrical design. Now, it is sort of a compromise, especially for cases, like ours, when there is not enough space between two gauges for symmetrical layout scheme to work properly. The main principle behind the asymmetrical scheme is the use of common rail in one side of the turntable (see Fig. 2.6.).

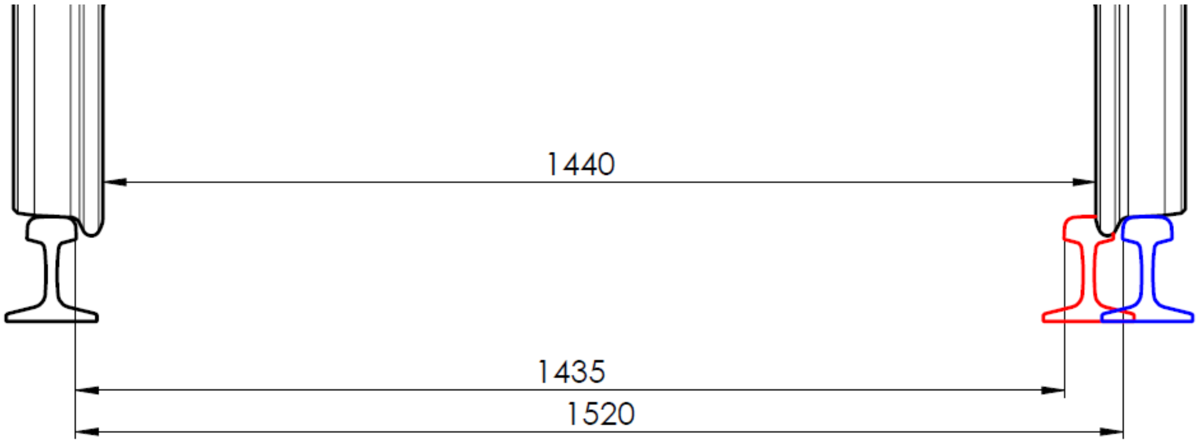


Fig. 2.6. Asymmetrical layout, wider gauge wheel-set

This time it is still close, but now flange of wider gauge wheel-set at least clears rail web of standard gauge rail (again marked red in the picture). That means, that now rail head could be modified and a special rail profile could be created. That could work, because standard rail profile is designed symmetrical and after one side of the profile is worn-out rail could be turned around. That effectively doubles the rail's operational time.

For our purposes we can sacrifice almost half of standard rail head (see Fig. 2.7) which gives us just enough clearance for wider gauge wheel-set.

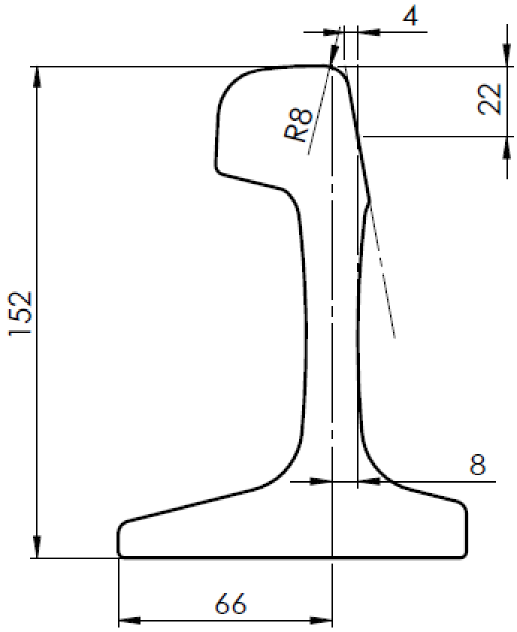


Fig. 2.7. Special profile rail for asymmetrical layout

In order to minimize contact stresses to the special rail's head it was optimized by altering radius *R8* and offset of the cutting line *4*. Results of optimization exercise you can see below in Table 2.1.

Table 2.1.

Special Profile Rail Head Optimization

***Offset*, mm**	3	4	5	3	4	5	3	4	5
***Radius*, mm**	8	8	8	10	10	10	12	12	12
***Max. Stress*, MPa**	**424**	**384**	**430**	**444**	**411**	**479**	**491**	**546**	**629**

As you can probably see, second combination: offset 4 mm and radius 8 mm, results in the lowest stresses in contact with rolling stock wheel. It is a great result especially as you compare it with identical simulation performed for standard *P50* rail profile (see Fig. 2.8.). For all this vertical load of 110,25 Newton metres was used, which is the half of maximum axial load allowed in Lithuania.

In accordance with new rail head shape, special dual-head rail profile could be created. That, as you already know, might be something manufactured using commonly available railway track elements or new solid profile, designed entirely from scratch. In such a small country like Lithuania it is easier and presumably cheaper to modify standard railway elements. Especially if resources and expertise required are taken into account.

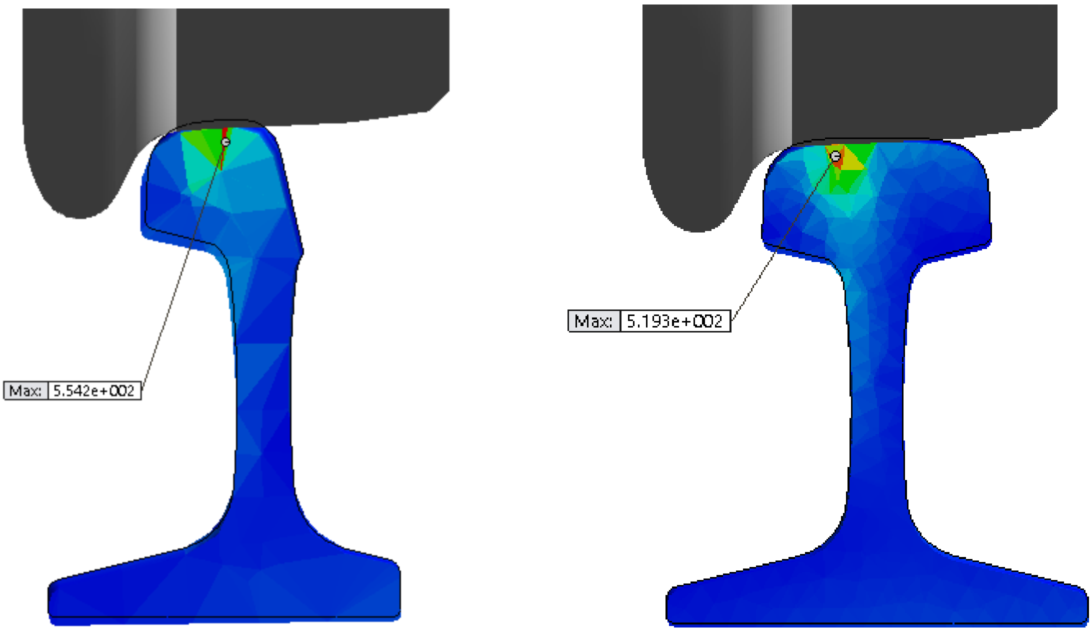


Fig. 2.8. Rail profile stress comparison

Another important consideration is the mounting of this rail. There is no possible way to fix two halves separately, because simply there would not be enough space for the tool to clear the head of the outer rail. Another way is to mount special rail as a single unit. For that special rail needs to be manufactured as an assembly.

Typical for our case, special measures must be undertaken again. Losing a half of rail head for an inner part of a special profile rail (previously marked red in Fig. 2.6.) we are losing one tapper surface, usually, very conveniently, used for joining two rails with braces. That, unfortunately, forces us to use the web of rails for bracing. That leads into all kinds of problems. Rail web surface finish is not as precise as that taper part or it. Also, it is not a flat surface, it has few radiuses. That significantly aggravates both manufacturing and fitting of special braces designed for special profile rail assembly.

Now, when it comes to mounting the special profile rail, modified tie plates are needed. Naturally, anything available on the market would be too narrow. Typically tie plates are then mounted on railway sleepers (see Fig. 2.9.), which is the simplest and, therefore, the most commonly used way.

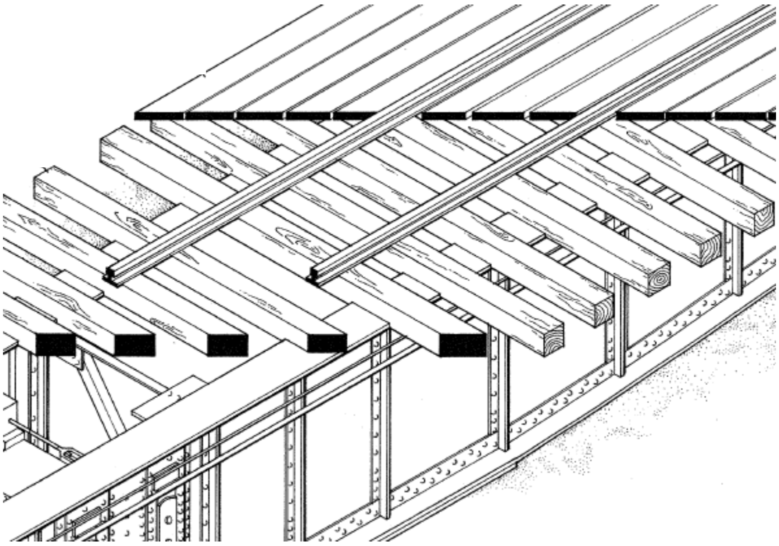


Fig. 2.9. Use of timber railway sleepers [9]

But we are restricted in rail head height above the main girders of turntable platform. Currently it is about 192 mm. That leaves a 40 mm gap between rail foot and top of the girder. Put that into perspective, height of the standard timber railway sleeper is 180 mm. So that is not an option.

In current situation, distance between centres of the girders meets the distance of wider gauge track. Inevitably, some sort of beams must be used to support special profile rail, which otherwise would not have any support between the main girders.

Another important consideration is the upgraded turntable's functionality. As it was mentioned in the first chapter, to an asymmetrical turntable layout scheme to work properly, it is essential to design the transition of the common rail in the middle of the turntable platform. Because of the close proximities we have in our case, we simply cannot use this option for this upgrade project.

Problem is, that standard gauge locomotive turned around on the turntable, would not be able to drive of it. That is because special profile rail would not line up with approaching track. Fortunately, even for this solution was found. Special layout of approaching tracks as well as roundhouse stalls would still allow to turn locomotive around (see Fig. 2.10.).

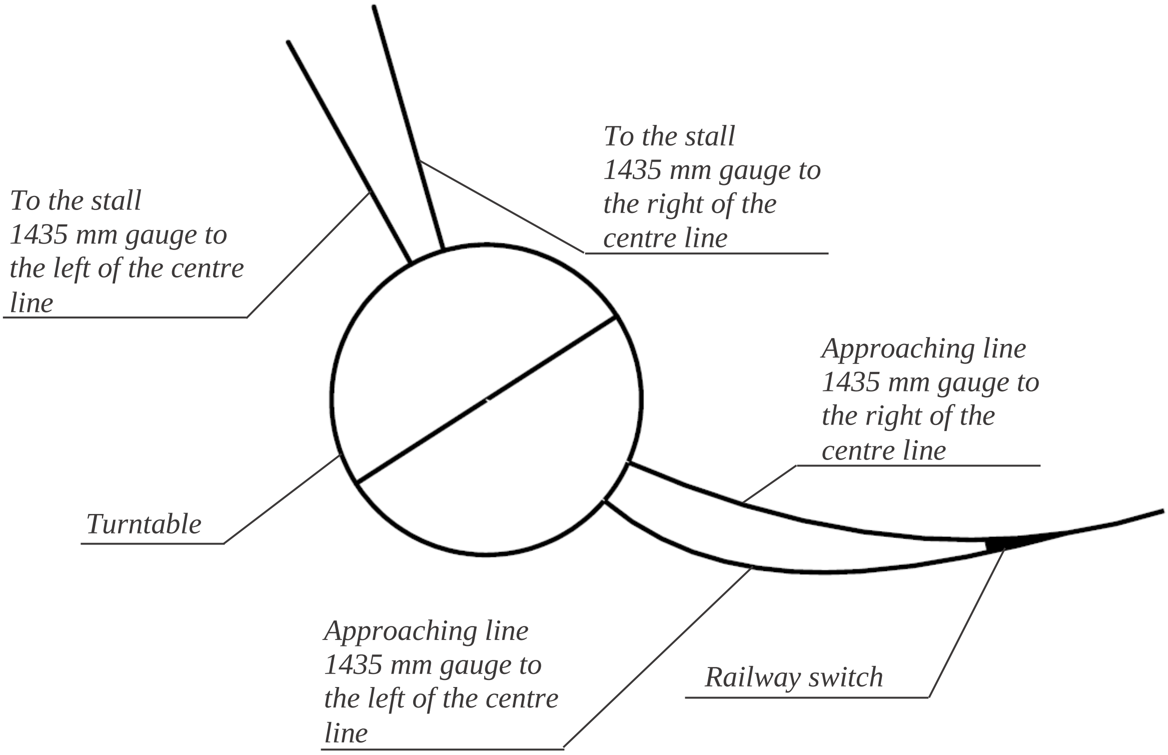


Fig. 2.10. Special profile rail for asymmetrical layout

By having one approaching line and stall to the left of the turntable's centre line and one of each on the opposite side it is still possible to turn locomotive around or to drive it in whichever end is preferred. However, drawback of such scheme is that turntable is fully functional as long as all approaching roads are empty.

Just as an asymmetrical layout scheme starts to form a basis upon which all further design of upgrade project could be developed, let's look at the drawbacks of such scheme. All things considered, asymmetrical turntable layout scheme is a sort of a compromise. It is never a primary option, because, supposably, designers often forced to use it.

One of the main shortcomings of asymmetrical turntable layout is, rather predictably, is the centre of gravity transfer. We know, that the maximum axial load is 220,6 kN (22,5 t) and average locomotive has a six axles. Then a torque transferred to a central bearing by 1435 mm gauge locomotive is 56,3 kNm.

Other concern is safety. From this perspective, asymmetrical layout is not ideal, because of the lateral movement of the wheel-set on the rails, it is possible for wider gauge locomotive to hit the inner part of the special profile rail while rolling on a turntable platform. To prevent this the ends of special could be chamfered, but that would compromise an already tight working surface of the special rail for standard gauge locomotive.

In the end though, if there would not be any alternative approach, accept typical turntable layout schemes, an asymmetrical layout, despite its cons, would be the way to go. Fortunately, the alternative solution was found in the completely different area of railway infrastructure.

2.3.3. Universal Gauge Layout

The gauge in question is used in border stations for bogie exchange operations, where break of gauges occur. 1508 mm gauge (see Fig. 2.11.) is used for border stations where standard and wider (1520 mm) gauges meet.

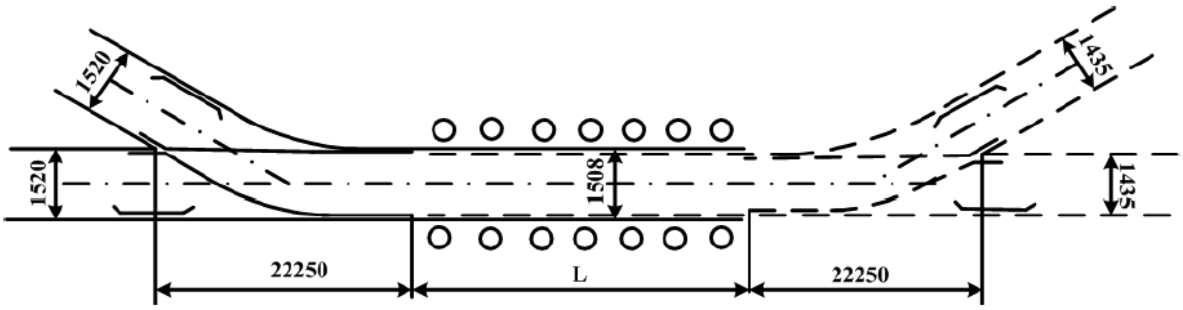


Fig. 2.11. Track arrangement for bogie exchange operation [18]

Bogie exchange for different width of gauges is performed by changing carriage's bogies to other pre-prepared bogies. Exchange is carried out on special exchange track, equipped with check rails, where the width of gauge is 1508 mm. Boogie exchange track widens from one side, switches to 1520 mm gauge, and narrows from the other – to 1435 mm gauge. Both 1435 mm gauge and 1520 mm gauge carriages can ride on the part of the track where width is 1508 mm. [17]

The crucial part of 1508 mm gauge is the check rails (see Fig. 2.12.). While wider gauge wheel-set fits a little bit tighter on this track, in comparison with its nominal 1520 mm gauge track, the standard gauge wheel-set could easily derail.

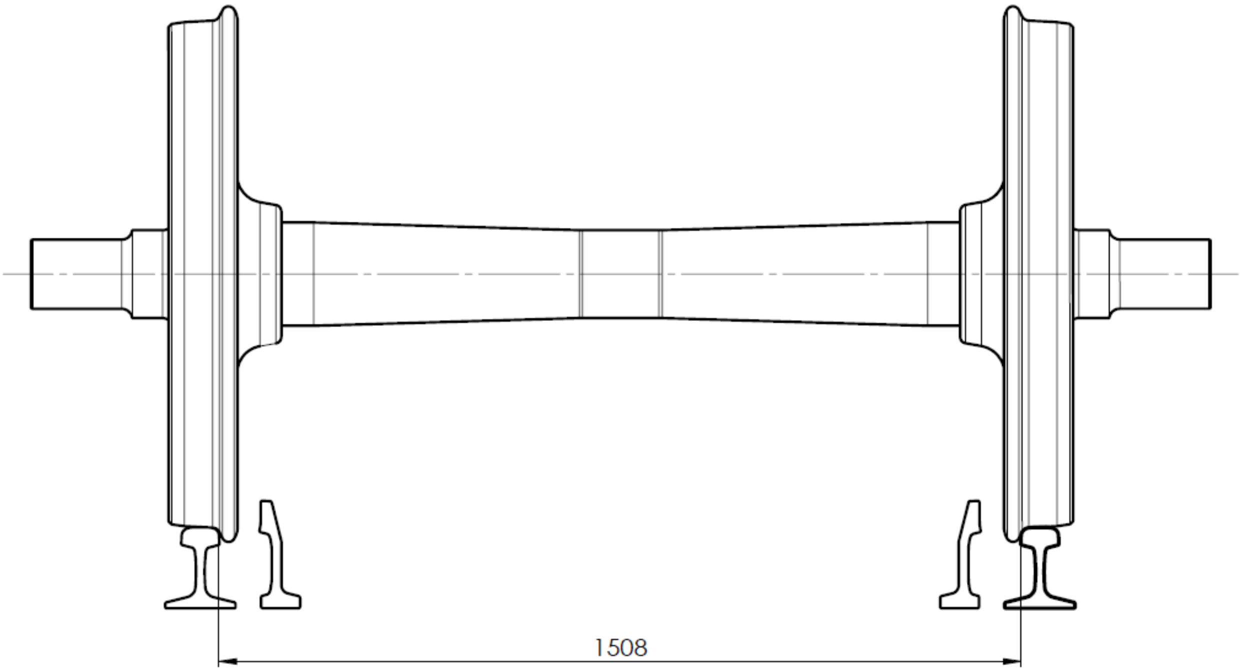


Fig. 2.12. Wider gauge wheel-set on 1508 mm gauge track

Effectively, check rails on 1508 mm gauge track replaces the function of standard gauge wheel-set flanges. That is, limits the wheel-set's transversal movement and prevents it from derailing.

The best part of introducing this layout scheme to our project is that it provides advantages of symmetrical layout scheme. The centre line of both gauges would be perfectly centred to the turntable, therefore it would remain transversely balanced as it was originally designed. Moreover, from functionality point of view, turntable would remain symmetrical from both sides, which, again, eliminates all the trouble, that asymmetrical layout scheme would cause.

Another advantage over traditional turntable layout schemes is that, at least in our case, it does not require so much specially fabricated components. Both rails and check rails are standard profiles, so it is only a matter of cutting it to length. Majority of fasteners, again, could be standard elements. That reduces not only the costs of the upgrade project, but implementation time as well. As we know, the substitutability is the key factor of any engineering project.

Only the mounting of check rails would require more attention, because, as we spoke earlier, between two girders of the turntable's platform there is nothing to support the direct load of the locomotive. That, as in asymmetrical layout case, could be additional beams, on top of which the check rails could be mounted. Check rails themselves could be mounted as simply as in (Fig. 2.13)

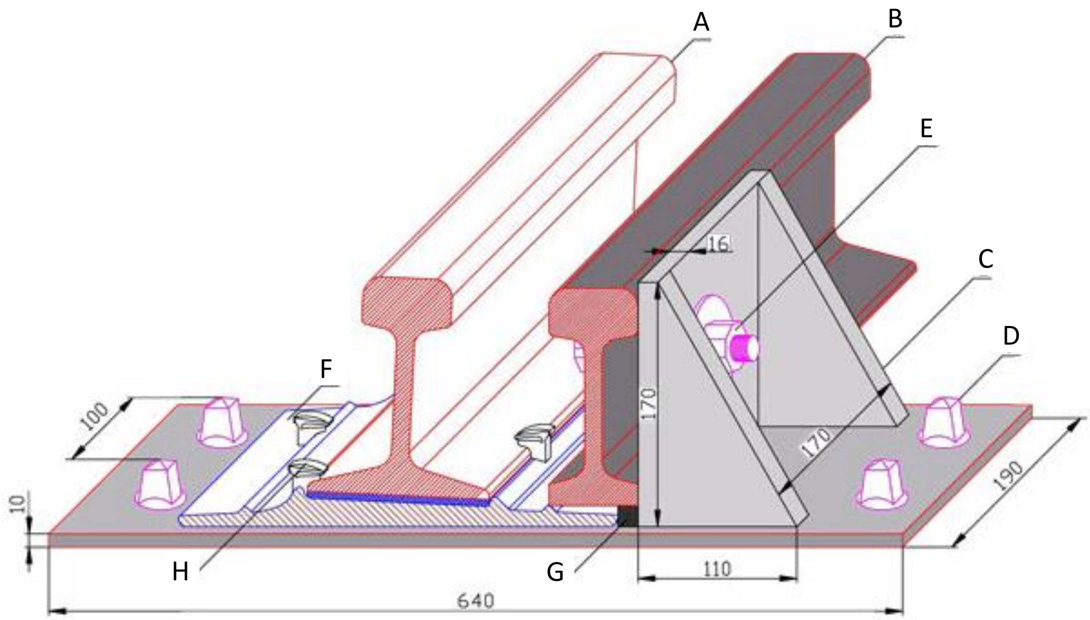


Fig. 2.13. Mounting of the check rail [20]

A – Main rail; B – Check rail; C – Check rail support; D – Track screw M24x170; E – Bolt M22x115; F – Standard tie plate; G – Plate; H – Track nail 16x16x230.

As you can see, not only special profile check rail could be used. In this example, standard rail is modified so that it could be used and be mounted as the proper check rail. Again, as we talked earlier, that might not be the best solution, because to prepare 23 metre long check rail not only takes time but requires a special equipment as well.

Another side of this layout scheme is that all approaching tracks no matter if it is 1435 mm gauge or 1520 mm gauge must be modified in order to ensure the safe transition to the 1508 mm gauge. For 1520 mm gauge it might be as simple as narrowing width of the track at the ends of approaching track. In this way, narrowing track would direct 1520 mm wheel-sets to the turntable eliminating the possibility to hit end of the rail of narrower width track.

Contrarily, 1435 mm gauge track cannot simply widen before the turntable. Due to the geometry of both standard gauge wheel-set and 1508 mm track, wheel-set could not only hit the ends of the check rails, but it can actually derail and fall between the two rails. Therefore, change of the width of the approaching standard tracks must be enhanced by the check rail. That is because, as we mentioned earlier, the function of wheel-set's flanges, on 1508 mm track is taken over by the check rails.

Although, universal gauge turntable layout scheme brings some challenges, we just cannot ignore the advantages it provides over the asymmetrical layout scheme.

2.4. Selection of the turntable layout scheme

All things considered, the universal gauge turntable upgrade layout scheme is chosen. The main argument in favour of this scheme is balance of the turntable. Reality is, that it is the only way, in our case, to keep turntable transversely balanced. That will prevent unnecessary strain to the centre-bearing pivot mechanism and, in the long run, will save all important maintenance costs.

That aside, we still need to examine how narrower 1508 mm gauge track will affect the main girders and if necessary to design additional supports. In either way, supports will be also needed for the check rail mounting. Afterwards, there should be no trouble to find the way of laying new track on top of the turntable's platform.

The last part of the turntable's development will actually focus on the approaching roads and the tracks leading to roundhouse stalls. In order to ensure full functionality and moreover safe operation of upgraded turntable we need to look into transitions from wider gauge track to 1508 mm as well as from standard gauge to 1508 mm.

Only when we will find solutions for all these problems we will be able to state that adaptation of the "VLD Kauno Cechas" turntable to a standard gauge track is successful.

3. DESIGN PART

3.1. Development of the Model

3.1.1. CAD Model

First of all a detailed analysis on turntable's platform have been carried out and as a result of that a relatively accurate CAD model was created (See Fig. 3.1.). For simplicity, it was treated as a solid body rather than an assembly, therefore you would not be able to see any rivets on the model. Since we are only interested on stresses of platform construction all additional gear (that is: control post, all the running gear, pivot bearing mechanism, support wheels) were excluded from this model as well.

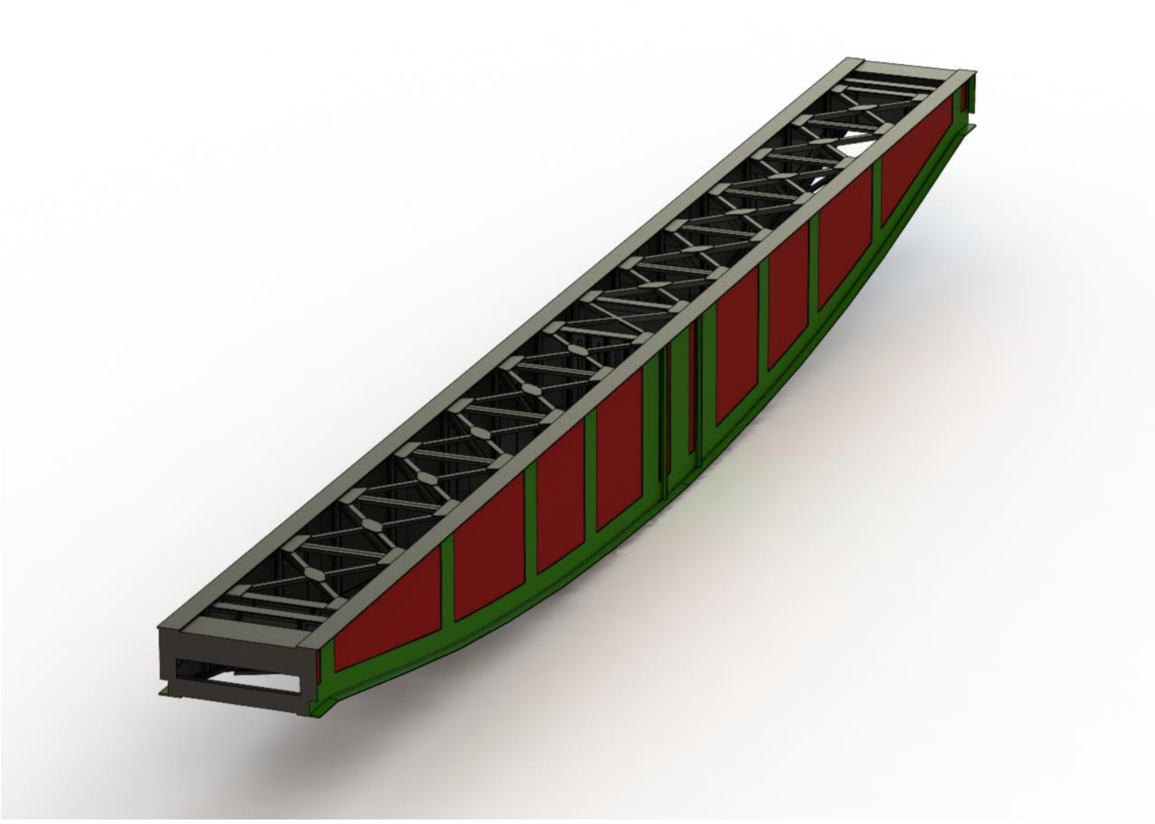


Fig. 3.1. Turntable platform CAD model

Now, from experience, we can state, that this model would serve for design and layout purposes of the new components, but for stress analysis it is far too complicated. There are many fine elements, relatively thin wall features in comparison with the overall size of the model. Therefore, it is more preferable to test the effects of narrower gauge track to the turntable on the segment of the main girder rather on the whole model.

3.1.2. Operating Loads

As we have already mentioned the maximum axial load allowed on Lithuanian and in fact European railways is:

- $P_0 = 220{,}6\ \mathrm{kN}\ (22{,}5\ \mathrm{t})$

Lateral load on rails caused by cone-shaped surface of the wheel-set could be found as a resultant force from geometry of the wheel to rail contact point (see Fig. 3.2.).

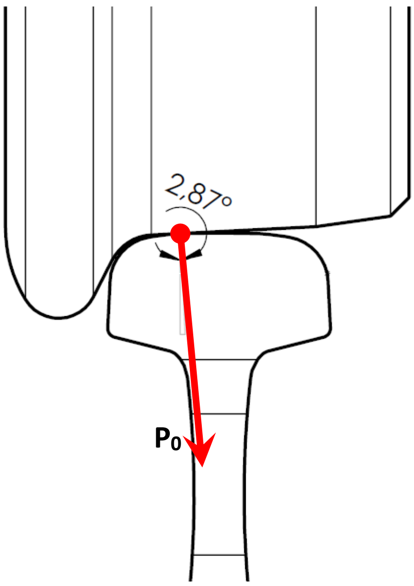


Fig. 3.2. Force on the rail head in the contact point

Then the lateral component of a wheel load:

- $Y = P \tan 2{,}87° = 110{,}3 \cdot \tan 2{,}87° = 5{,}5\ \mathrm{kN}$

Furthermore, we need to determine load on the check rail. For most of the time, a railway wheel-set will steer itself along the track without either flange touching the rails. The purpose of the flange is to prevent the wheel from falling off the rail surface when buffeted by the lateral force, or when it encounters a kink in the track alignment.

According to [10] lateral force from the wheel on the straight line track is 20-40 kN, since locomotive speeds are very low on the turntable we will take the lowest value from the interval:

- $N = 20\ \mathrm{kN}$.

Because the2 locomotive is moving on the turntable's platform we need to estimate dynamic load as well. To reduce the dynamic loads on the turntable speed is limited to 3 km/h. According to A. N. Talbot [3] dynamic factor could be calculated by using formula (3):

$$\Phi = 1 + \frac{33v}{100D}. \tag{3.1.}$$

Where: Φ – dynamic factor; v – speed; D – diameter of the wheel.

We know that the diameter of locomotive TEM-2 wheel is 1014 mm, then dynamic factor is:

- $\Phi = 1 + \frac{33 \cdot 0{,}83}{100 \cdot 1{,}014} = 1{,}27$.

By having this data and the CAD model of the turntable's platform we can now start to evaluate effects the narrower gauge track will have on the construction.

3.1.3. 1508 mm gauge effect on the turntable's girders

As we mentioned earlier, full CAD model of the turntable's platform is too complicated for evaluation of strength. Therefore, simpler model of the turntable's section of girder is created (see Fig. 3.5.).

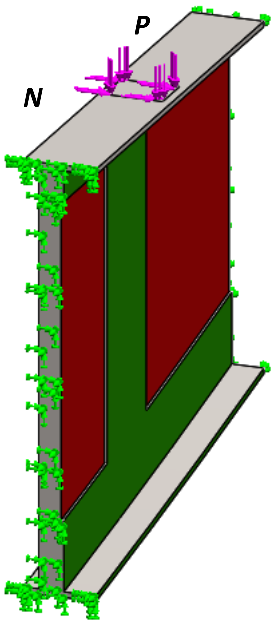
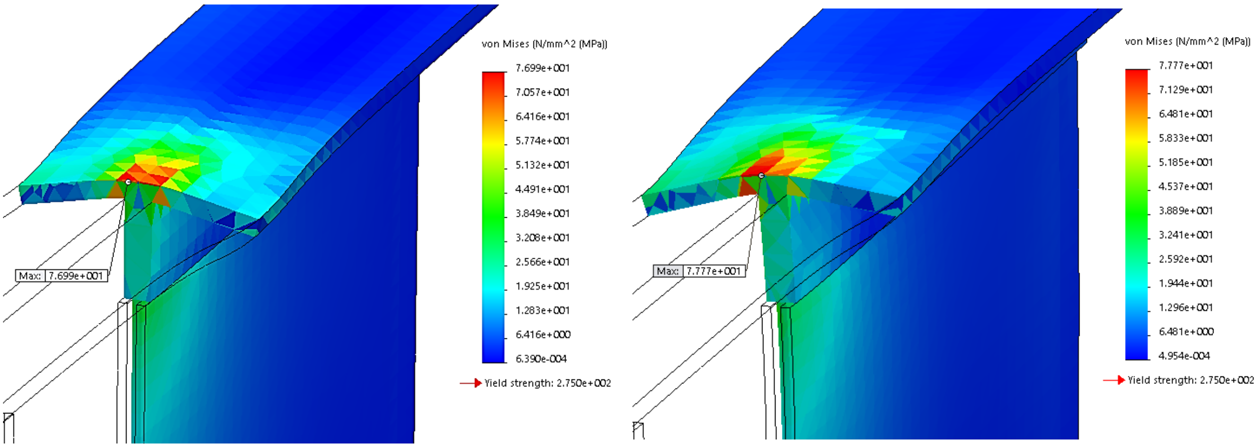


Fig. 3.3. CAD model for girder's strength analysis

For testing we have chosen one girder's section near the platforms end. The worst case is when the axle rolls over the tie plate positioned in the middle of two bulkheads, therefore in the model we do not have any braces. The girder itself is treated as a simple rack beam. It is fixed solid in one end replicating the situation, when locomotive stops in the position when its centre of gravity crosses the pivot point of the turntable. Theoretically neither support wheel should be loaded. One degree of freedom is removed from other end. In this way the far end in the picture cannot move lengthwise mimicking much longer solid beam.

Load is added to the area of tie plate's footprint. The vertical load is multiplied by the dynamic factor and is equal to 140 kN. Lateral load is 5,5 kN. Since actual mechanical properties of the steel used to build the platform are unknown, we assume that yield strength is 275 MPa and we will run a direct comparison between wider gauge layout and the 1508 mm layout to spot any potential problems.



1520 mm gauge layout **1508 mm** gauge layout

Fig. 3.4. Comparison of the effects of two gauge layouts

As you can see in Fig. 3.6. the nature of fixing railway tracks really helping here. Since the load of the wheel-set is spread by both the rail foot and the tie plate the effect of centreless load (1508mm gauge rail is 6mm closer to the centre of the turntable's platform) is rather minimal. Numerical values of the test you can compare in the Table. 3.1.

Table 3.1.

Comparison of the effects to the girder of two gauge layouts

Layout	**1520 mm**	**1508 mm**
***Max Stress*, MPa**	76,99	77,78
***Max. displacement*, mm**	0,36	0,49

Now we can finally state that there is no practical difference of the effect on the main girder and we can carry on to the mounting of check rails.

3.1.4. Design of the check rail mounts

Similarly to the previous case simplified CAD model is created. Although this time we are dealing with a greater transversal load, not to mention, because of the nature of the check rail, load is also acting in an opposite direction. Therefore (see Fig. 3.5.) we have two segments of the main girders as well as some transverse and diagonal braces.

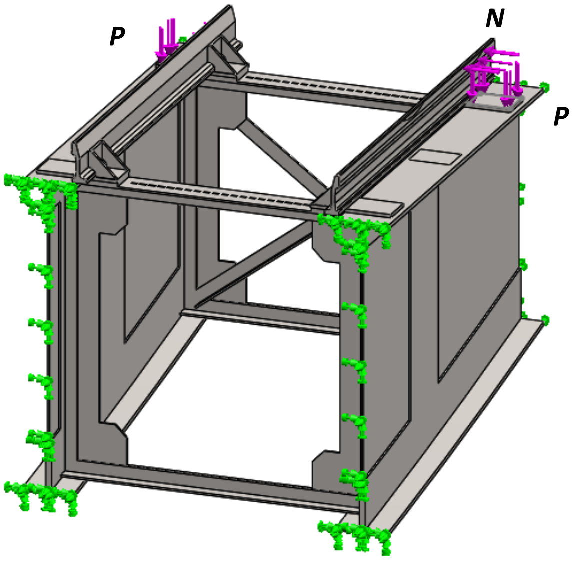


Fig. 3.5. CAD model for check rail mounts strength analysis

The model is fixed, again, in a similar fashion as in a previous test. This time vertical load on the both girders on a bulkhead where the supports for the check rail are planned to be fixed. Transverse load *N* equal to 20 kN is placed to the wheel's footprint on the check rail.

Check rail is mounted in the same way as described in previous chapter. Since tie plates have to be lifted 17,5 mm above girders, 429x180 mm plate is used to form a base on top of which both rail and check rail could be laid. To the same plate check rail mounts could be welded, but in this case in need to be additionally supported from the middle part of the turntable, because girder tops and transverse braces are not level.

Early tests showed weak points just below top rectangle plates to support diagonal braces of the bulkhead. These elements were strengthen by adding additional 100 mm wide and 10 mm thick vertical strips and 50x50 angle sections to prevent them from buckling. Distribution of stresses you cans see in Fig. 3.6.

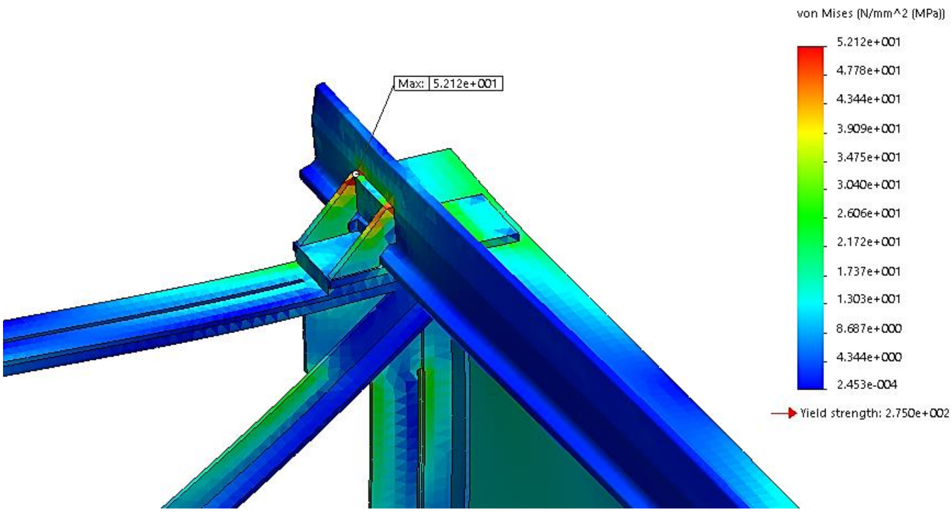


Fig. 3.6. Distribution of stresses in the check rail mounts

As you might noticed the stresses (the maximum reading is 52,1 MPa) in the construction are in the same level as in the main girder's analysis which (if we assume that the yield strength is 275 MPa) guarantees the factor of safety in the region of 5 which is exactly what we need for the structure like this.

In order to understand whether intervals between check rail mounts, equal to the gaps between turntable's platform bulkheads (1600 mm), are enough to ensure check rail's stability, the loads were transferred in between the two mounts.

Tests showed that due to excessive displacement of the check rail stress concentration points appeared at check rail mounts edges. Solution to this would be additional supports in the gaps between already existing ones.

The upper part of additional support is identical. Since it is only additional measure we might not need the same construction from underneath. A couple of triangular supports from the 10 mm steel plate might do the job. We just need to make sure that wherever it rests against a single layer of the main girder's web, there is at least 100 mm wide strip to reinforce it.

The stresses after modifications you can see in Fig. 3.7. There are no concentrations of stresses, all values are within the region of factor of safety – construction is strong enough.

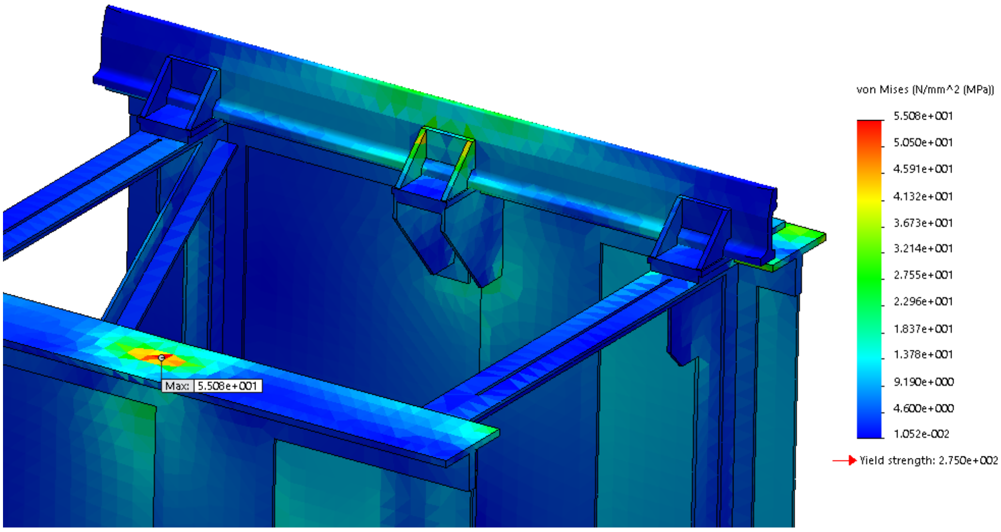


Fig. 3.7. Distribution of stresses in the additional support for a check rail

So, here you go, with this we are finishing all necessary modifications for the turntable's platform. Now not only wider gauge locomotives could roll onto it but with combination of special 1508mm track and check rails standard gauge locomotives could be serviced as well.

3.1.5. Design of the dive offs

We would not focus on the 1520 mm to 1508 mm transition because it is as simple as narrowing approaching to a turntable track to appropriate width. This is commonly used practice, because railway track width always alternates before tight turns and so on, so it should not cause any problems.

The only difficulty might be tracks leading to the roundhouse. There tracks are laid very close to each other and as a matter of fact they ending by crossings. Fortunately, gauge here could be adapted by tailoring assembly of the crossing which is again a common practice (see Fig. 3.8.).

Fig. 3.8. Railway crossing assembly

Now if we would talk about transition from standard to 1508 mm gauge there are slightly mode considerations. First of all 1435 mm gauge track cannot simply widen to 1508 mm. This transition must be backed up with check rails, because otherwise the risk for locomotive to derail significantly increases.

From this arises the next problem. The same as all wider gauge tracks rails leading to roundhouse standard gauge track would start with the railway crossing. Problem is that crossing would interfere with check rails. That means, that at least from the roundhouse side check rails cannot be installed.

After extensive wheel-set motion analysis the following solution is proposed. All approaching to the turntable standard gauge tracks could maintain the width of 1435 mm. However, the ends of these tracks needs some modification. The 3 mm chamfer (as showed in Fig. 3.9.) needs to be formed on each rail, from the middle side of the track, ensuring 1:100 slope.

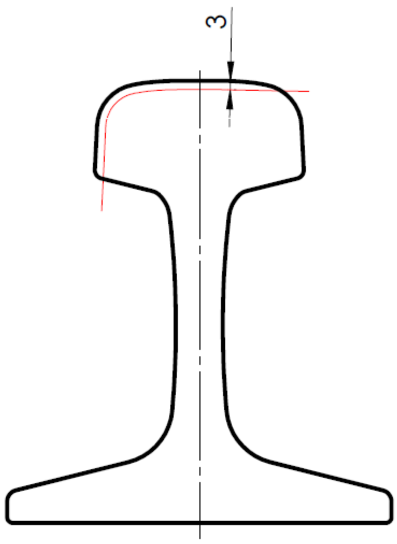


Fig. 3.9. Modification of *P50* rail

Because of the cone-shaped wheel-set surface it naturally sits deeper in the 1508 mm gauge track. This change is not essential but by implementing it the smooth transition from 1508 to 1435 mm gauge would be ensured.

On other hand, changes to turntables check rails are essential due to much higher risk to hit it with wheel-set flange. Testing situation when one flange is constantly touching the rail it was found that it is enough to bend each check rail end 15 mm inwards. However, it is not recommended to increase the bend because it could increase stresses in the ends of turntable's rails leading to premature fatigue.

3.2. Component Parts

3.2.1. Standard Elements

The whole project is based, as it is now, on Russian standard *P50* rail group, still commonly used in Lithuania. Main standard elements are given in Table 3.2. [16, 21, 13, 22]

Table 3.2.

***P50* group**

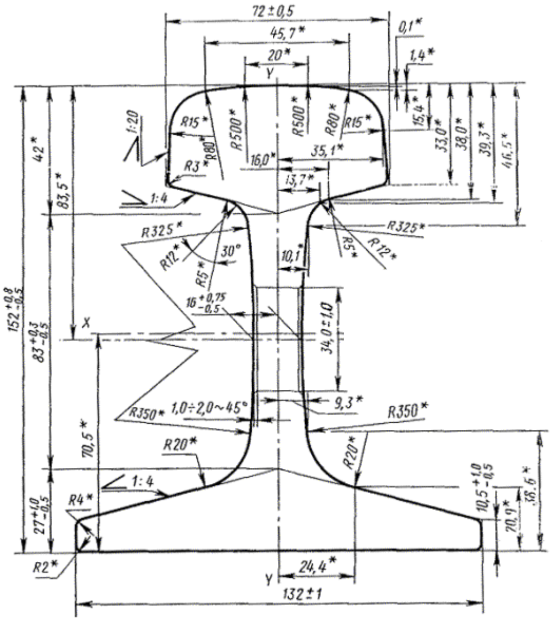
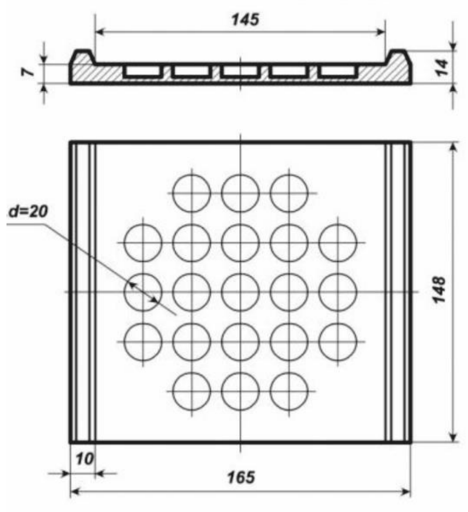
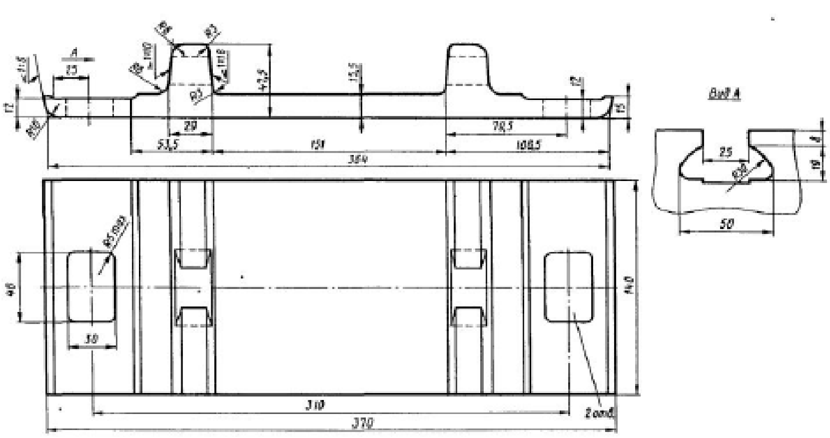
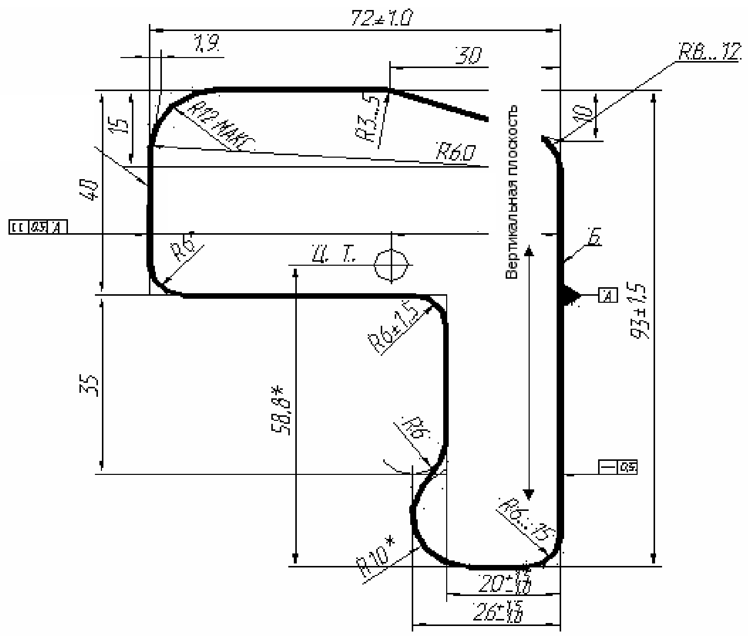
No	Element	Sketch
1.	**Rail *P50***	
2.	**Rubber tray *ЦП-318***	

Table 3.2. (Continued)

3.	**Tie plait *КБ-50*** (needs to be modified)	
4.	**Check rail *СП850***	

Tie plate *КБ-50* is usually used for concrete railway sleepers therefore it does not have that 1:20 slope built in and it suits well in our case. The ends of the tie plate need to be machined off since it will be welded rather than bolted. All standard fasteners are given in the appendix.

3.2.1. Assembly

Since the majority of parts are standard components, there is only minimal amount of fabrication work. The best part of it is the turntable's platform modifications. There are two major tasks: reinforcement of vertical parts of the bulkheads and supports for the base plates.

We have already spoken about what it takes to prepare the turntable for 1508 mm gauge, so we will just run through the sequence of the operations:

01 Dismantling of the deck of the turntable platform;

02 Taylor fitting and installing of 100 mm wide, 10 mm thick vertical steel strips to the bulkheads;

03 Reinforcement of the strips by 50x50 mm angle section steel bars;

04 Preparation of the rests for additional supports in between the bulkheads, by adding 100 mm wide and 10 mm thick strips to the single layer parts of the main girder's web;

05 Installation of the additional triangular supports;

06 Installation of spacers for the support of the base plates on top of the bulkheads;

07 Installation of the baseplates;

08 Installation of the tracks.

All the supports and reinforcements are welded in. Material is a basic structural steel with the yield strength no less than 275 MPa. Keeping that in mind it is recommended to provide some protective coating after the modifications. Base plate thickness is 17,5 mm, so it will require some machining operations in preparation. More detailed parameters are given in the appendices.

The upper part of the platform is mostly standard components. The standard *КБ-50* tie plates need their ends to machine off. Those are then welded precisely on top of the base plates. Check rail mounts are built from blanks of steel plates and need to be welded to the base plates as well. Again, more detailed parameters are given in the appendices.

3.3. Economic Evaluation

This project is a result of changes in the Lithuanian and indeed Baltic State railway market due-to influences of political-legal environment. Therefore it could be referred to as a necessity rather than a need, because, with the help of "Rail Baltica" project, European standard gauge railway vehicles now will be able to reach Kaunas. Ability to provide full maintenance services not only increase the competitiveness of the region, moreover it will help to ensure continuous and timely movement of both passenger and cargo trains.

This project will not add any additional value to the company's range of products or services. Therefore, it is essential to keep the costs down. 1508 mm gauge turntable layout scheme enables the wide use of standard components. This is one of the greatest advantages over traditional layout schemes where, in our case, the machining of twenty-two plus meter long rail through the length of it would be required. The amount of resources and time, not to mention the need for special equipment required makes this alternative far more attractive.

Project costs include:

- Raw materials;
- Standard elements;
- Labour;
- Equipment
- Energy consumption;
- Turntable down-time;
- Upgrade of Russian standard drive-offs.

As a result of a simplicity of the turntable upgrade project it will make up only a very small part of the total resources needed to adapt the whole infrastructure of the depot to serve both Russian and European standard railway rolling stock.

CONCLUSIONS AND RECOMENDATIONS

1. For successful development of the company in current political-legal environment it is necessary to upgrade depot turntable to serve both Russian and European standard gauges;

2. For this case both traditional turntable layout schemes proved inadequate not only physically but economically as well. They compromise the balance of the turntable and require manufacturing of large scale precision parts;

3. 1508 mm gauge track is selected for turntable upgrade. The biggest advantages: it is compatible with both Russian and European gauge wheel-sets; turntable remains perfectly balanced;

4. Slightly narrower layout of 1508 mm gauge track proved not to have any negative effect on main girders. Max stress: 77,78 MPa and it is only 1 % higher than current layout;

5. Proposed check-rail construction is strong enough. Max stress 52,12 MPa. That guarantees factor of safety equal to 5, for general purpose structural steel S275;

6. For the safe transition 1520 mm tracks should narrow to 1508 mm gauge before turntable. For the 1435 mm to 1508 mm transition, each check rail end should be bent 15 mm inward;

7. Drawbacks of the selected turntable layout scheme: all existing Russian gauge tracks leading to the turntable need to be modified; European gauge drive-offs are compromised by the crossings of the tracks leading to the roundhouse;

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FIGURES

19. KAUNO DEPO STATINIŲ KOMPLEKSAS [watched 2014-12] Website address: http://kvr.kpd.lt/heritage/Pages/KVRDetail.aspx?MC=29952&lang=lt;
20. НАПРАВЛЕНИЯ ДЕЯТЕЛЬНОСТИ [watched 2015-05] Website address: http://www.kontrrels.ru/ ;
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APPENDICES