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RAIL VEHICLES WHEELS AND BRAKE BLOCKS WEAR LABORATORY TEST STAND UTILIZATION

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Abstract: The new RAILBCOT test stand building reasons explanation. A project features definition. Railway wheel tread profiles wear research under the rail vehicle in operation conditions simulation on the test bench and the equivalent conicity change. Stand operation principles outline. A main structure components design and components parameters specification. The tests control, data acquisition and data assessment.
Keywords: test stand, equivalent conicity, railway wheel tread wear, loading modulus design, structural analysis, SIMRAIL

1. INTRODUCTION

Reduction of noise due to rolling contact of wheel and rail for fright cars is one of the principal tasks of the European railways to be solved. Experts of railways, industries and universities were engaged during the last about ten years to search for technical solutions. An important noise reduction of fright cars can be achieved by replacing the cast iron brake shoes by composite brake shoes. Doing that, two directions have been taken into consideration. This is due to the fact, that at that time most composite brake shoes were based on friction coefficients were far away from that ones of the cast iron brake shoes. Applying such friction materials on existing vehicles would have as a consequence the change of braking forces acting on the wheels. These types of brake shoes (K-block) show a friction coefficient which is higher than that one of cast iron. As a consequence the application of the “silent” composite brake blocks of type K affords the adaptation of the braking system of the vehicle, what is cost intensive. For these reason, the application of K-brake block was proposed for new built vehicles. For existing vehicles solutions having the same friction coefficient as the cast iron brake shoes were requested (LL-Brake doing in this way, the modification of the braking equipment of existing fright cars could be avoided.

2. TESTS OF BRAKE COMPONENTS

For the development of the braking system on the basis of composite brake blocks a lot of researches in different areas were afforded:

- Tests on test rigs to improve the friction characteristics dry, wet and hot conditions including stop breakings and breakings in severe downhill conditions.
- Tests to inhibit negative influences on the shunting circuits in railway lines.
- Tests under heavy winter conditions to avoid exceeding breaking distances of trains due to the influence of snow.
- Thermo mechanical test to avoid high residual stresses in the wheel rigs and important plastic lateral deformations of the wheels.
- Tests to avoid material inclusions into the brake shoes.
- In line test to prove the braking power.
- Downhill test under severe load conditions.
- Test to prove the whole system behaviour under real service conditions including all the seasons (winter, summer, etc.)
- Fuse tests (behaviour under failures in the braking system, handbrake not released, etc)
- As it can be seen from the above, a lot of tests had to be carried out. They were partly based on a long experience, especially based on the application of cast iron brake shoes. Some of them had to be newly developed due to the different behaviour of composite brake shoes in comparison to cast iron brake blocks (for example winter tests, tests concerning the shunting behaviour, fuse tests). With growing experience it was possible to develop tests on test rigs instead of expensive tests on lines. During the service tests it was observed, that under certain conditions and configurations an unfavourable wear especially concerning the treads of the wheels arises. As a consequence high equivalent conicities were reached partly after low in service time. As these parameters concerns dynamic vehicle behaviour it is completely understood only by experts of running dynamics.

3. EQUIVALENT CONICITY

What is equivalent conicity? The wheel and the rail have a particular surface geometry in their contact area. In a first approximation the wheel can be described as a cone rolling on a pointed edge. Conicity describes the angle (tangent) of this cone. Equivalent conicity is a measure comparing real geometries with this theoretical model. This makes it possible to compare different wheel geometries in terms of running behaviour [2, 3, 4, 5].

Importance of equivalent conicity: In order to sustain a good running behaviour of the vehicle on the track, to prevent wheel, rail and track damage and in the worst case the risk of a derailment the equivalent conicity must remain within given limits. The geometry of the wheel profile is designed in such a way that during operation, equivalent conicity does not exceed these limits due to wheel wear. The values are defined in EN 14363, stating that equivalent conicity in service may not deviate more than 50 % or a maximum of 0.05 from original values.

Different behaviour of cast-iron brake blocks and composite brake blocks: Cast iron brake blocks adapt their contact geometry to the wheel, so that there is no influence on the equivalent conicity of the wheels. This is not the case with composite brake blocks. Here the brake bocks influence the geometry of the wheel profile and therefore also equivalent conicity. Therefore a new element is introduced into the wheel – rail system. It is important that the new system is at least equal to the old one with respect to the wheel/rail contact conditions (compare Fig. 1).

LL-brake block homologation: In the operational tests of LL-blocks the equivalent conicity was not measured systematically except in Switzerland. Here it was shown that the equivalent conicity values increased too rapidly. If this proves to be the case in other situations, a monitoring system would be required and wheels would have to be re-profiled more often than with cast-iron brake blocks. This would increase the life-cycle-costs, which runs counter to the idea of having a low cost retrofitting possibility.

What are possible reasons for the increase in equivalent conicity? A UIC study showed that the increase in equivalent conicity is probably due to the geometry of the friction surface of the brake block. There are guidelines on the geometry of brake blocks; however it is unclear how they emerged. It is likely that the contact geometry of the brake block has not been adapted to the geometry of the wheel profile.

Possible approach: The issue of equivalent conicity can be approached in two ways:

- Determine if higher deviations from original equivalent conicity are possible: This work would define a new limit value for equivalent conicity. Added on to this approach a system for monitoring equivalent conicity during operation must be developed and implemented.
- Determine if changes in brake block geometry can reduce high increases in equivalent conicity. The change of geometries during operation must be studied and new brake block geometry must be developed and tested. Ideally brake block geometry is chosen in such a way that there is no influence on the equivalent conicity of the wheel during operation.
- Determine if brake shoes can be developed with properties similar to cast iron brake shoes concerning wheel wear.

Opportunities:

- Pursuing the suggested steps gives an opportunity to homologate an economically satisfying LL-brake block because wheel wear questions may be solved.
- Insights from this work will also help design an optimal K-block which may reduce observed high wheel wear that is observed in certain cases, thus reducing life cycle costs.
- Having optimal brake block wear, improves the wheel wear which in turn optimises rail wear: Finding an optimal solution reduces costs both in operations and in infrastructure.

Influence on regular homologation: This work can be done in parallel to the regular homologation and can be considered to be an economic optimisation. It is suggested, however, that operational tests include measurements of equivalent conicity.

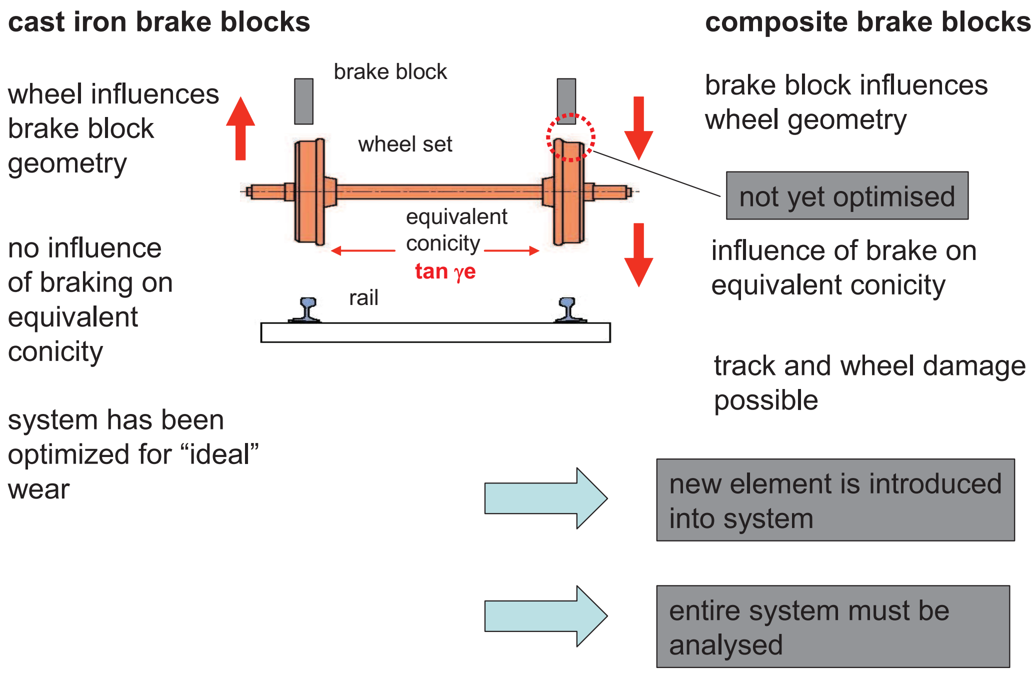

Fig. 1. Wheel wear and equivalent conicity for cast-iron brake blocks and for composite brake blocks

The problems concerning wear on wheels an wear on brake blocks have been found out during services tests. As services test are very cost full and time consuming, there exists a need to prove, if at minimum some aspects of such test in the future could be fulfilled by tests on a test rig. For these reasons the University of Žilina proposes a research project with the scope of optimisation of the interaction between brake shoes and wheels.

4. RAILBCOT – RAIL VEHICLES BRAKE PARTS TEST STAND

The up – to date being built Railway vehicles brake components test stand RAILBCOT, [1] (see Fig. 2) is the facility, where the core consists of an electromotor position **1** with the power of 440 kW. The motor power is led via a transmission (position **2** - conical gearbox) UNIMEC500 to the discs of rotational rails position **3**. The railway wheelset (position **4**) is via a cable stayed transmission (position **7**) pressed to these discs with the force of 225.000 N. The wheelset is integrated into movable frame (position **5**) that enables rotating of wheelset about the angle of attack and the lateral movement in the acceptable limits.

There are known other active wheelset steering stands in Europe, mainly based on model size [7].

During the facility design and conception specification was badly needed to resolve several functional nodes, which are necessary for the simulated drive ability wheelset as on the railway.

Such nodes are:
- change of track gauge possibility,
- change of strike angle possibility,
- lateral forces loading solution,
- axle loading solution.

5. RAILBCOT – OPERATION PRINCIPLE

Electromotor (1) will through gearbox (2) which has one input and three output shafts transmit the torque and rotate the rotating rails.

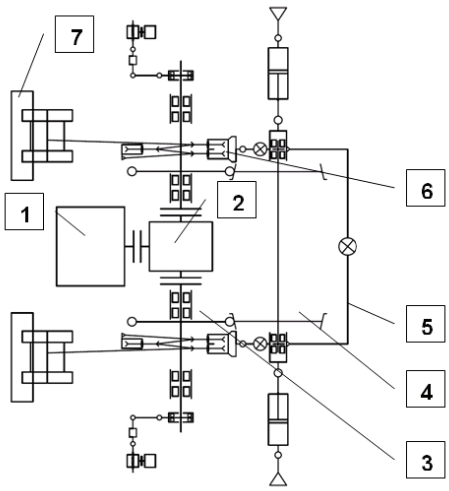

Fig. 2. Schema of the test stand functionality top view

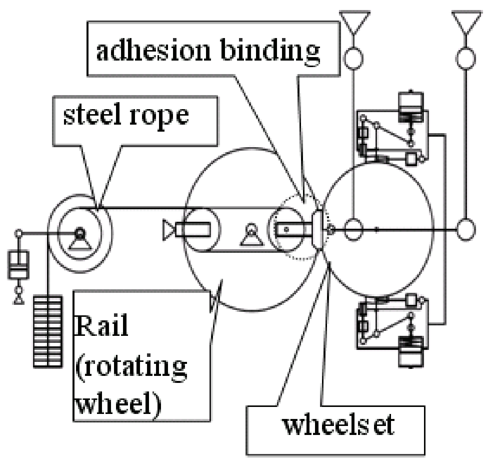

Fig. 3. Schema of the test stand functionality side view

1 – motor, 2 – conical gearbox, 3 – rotating rail, 4 – tested wheelset, 5 – moving frame
6 – rear hanging, 7 - weights

These ones are mounted in bearing housings which are connected with the frame. The supporting frame will hang on two hinges. Rear hinge is of a more simple design and its duty is to hold the support frame in the requested position. Four locomotive brake units are implemented in the support frame. Axle boxes are mounted on the wheelsets, they are attached with screw binding to the support frame. A pneumatic cylinder creates the necessary axial force. The front hinge is attached with a tilting lever wheelset. With pull rod is connected with axle box - with a supporting frame.

A force sensor is placed on pull rod which measures the longitudinal forces arising during braking. The adapter is attached to the bearing box in which is a force sensor that is connected to the rope fairlead. A vertical wheel force is evoked by weights and each wheel is loaded with one weights. For simulation of the vehicle running arc track are rotating rails moving in a horizontal direction for max. 16 mm. For this change the rotating rail mechanism of transverse displacement is used. This enables a track gauge change passing vehicles arc. The test bench is placed on two bases.
Scheme of the brake test stand RAILBCOT consists from electromotor, gearbox, rotating rails, brake units, rear hinge, front hinge, support frame, railway wheelset, base, weight units)

Wheel is braked with two locomotive brake units (four units per wheelset). The test stand will be not included into the brake stands branch but ride stands. The utilization of the stand, operation and scientific investigation direction is different from Flywheel test stand UIC.

6. TEST STAND DESIGN MODEL

Three dimensional model of test stand was created in CATIA system. In Fig. 4 is a central executive part of a device. Left side represents the driving part and constitutes the rail the right side (separated by dash dot line) represents a vehicle and constitutes a bogie with railway wheelset.

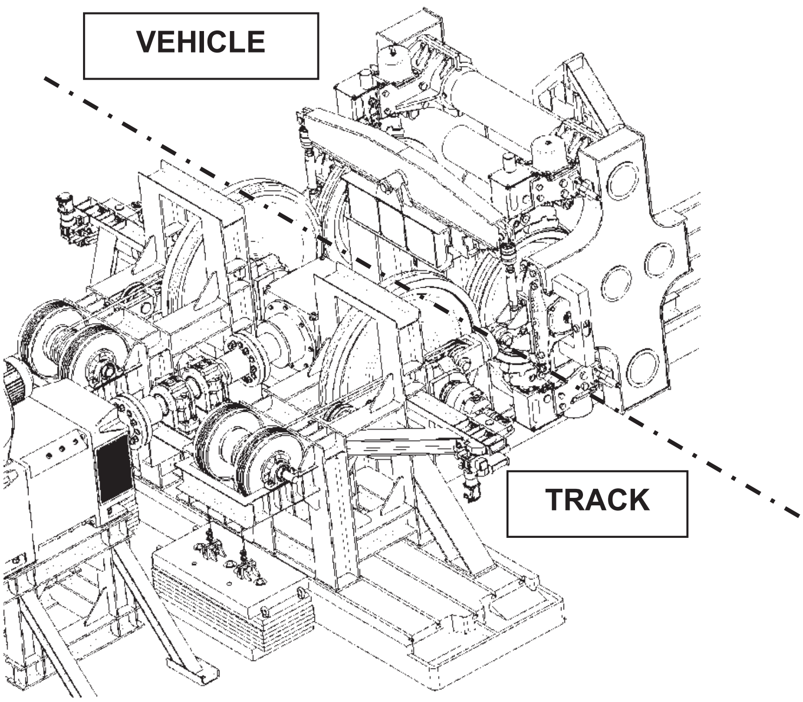

Fig. 4. 3D projection of the test stand model

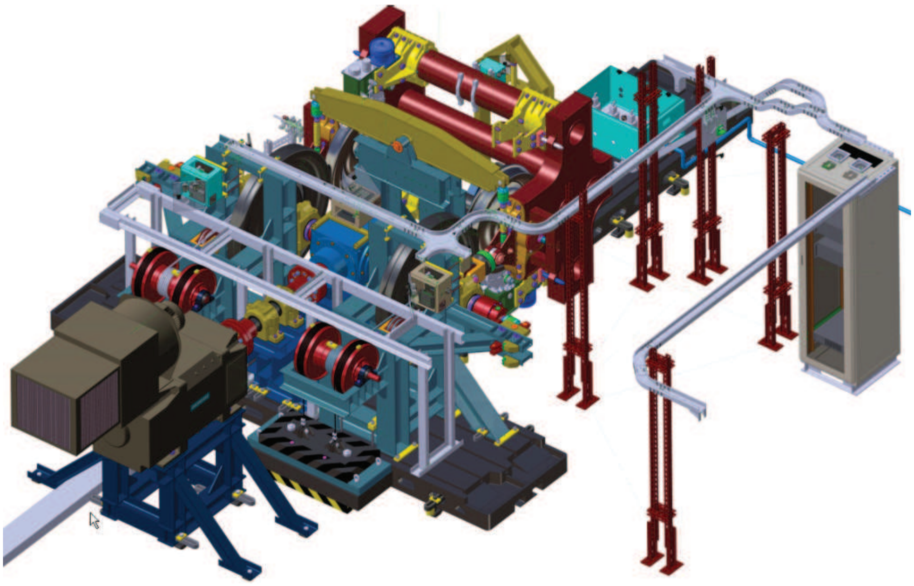

Fig. 5. Test stand virtual computer model

The test stand is in the basic version equipped by force sensors (2x wheel forces, 2x forces in the ride direction, 2x frame lateral forces, 4x normal brake forces a 4x tangential brake forces) as well as the wheel revolution sensors and sensors of rail discs. The ground of technical support of data acquisition and data processing are two stations HBM MGC Plus.

Data acquisition, data processing and data assessment is performed by our own development environment and all the test stand control will be guarantee by software LaGer.

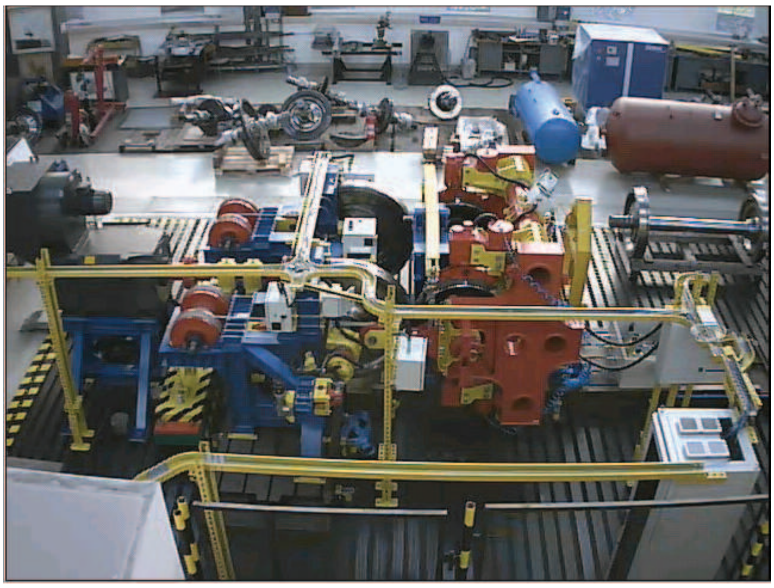

Fig. 6. Test stand real building in the laboratory

7. TEST STAND LOAD MODULUS CONSTRUCTION PROPOSAL FOR THE REALISTIC SIMULATION OF RAILWAY OPERATION

The aim of the article is to present the necessity of completion of the test stand of brake components of railway vehicles with the equivalent railway operation load simulator for the research of the wheel wear on it. The other aim of presented research needs is to perform the analysis of the equivalent conicity as a parameter for the rail vehicles in operation ride properties prediction. The sub aims are the change of frame, wheel, braking forces load via SIMRAIL simulator program load collection performance.

The project of test stand loading modulus should result to an original device. The test stand is being as prototype realized at the Faculty of Mechanical Engineering laboratory working place. The aim of the project solution is to create a brand new original load module for requested test type performance. The originality leads from the fact too, that the uneven wheel tread wear problem appeared after utilize of the up to date new brake blocks sintered composite materials in a goods transport. The brake blocks composite materials crucially decrease the noise level during braking, increase and keep the value of friction coefficient level, are more durable, but at the same time crucially increase the wheel tread surface wearing. Modified Wheel profile causes the non-stabile vehicle movement in a track, higher level of wheel /rail contact forces, lower safety against derailment and higher force influence on the track. The composite brake blocks are much more expensive than cast-iron brake blocks and the damaged profile must be re-profiled sooner, than before. The maintenance costs are getting high and the service life of wheels is getting down. The track must be under service more frequent too. Important contribution of the project realization will be the fact, that we will not investigate the contact phenomena only, but we will create the unique test conditions environment and the object of research can be modified in accordance of test requirements.

8. TEST STAND ENHANCED WITH THE OPERATIONAL LOAD MODULUS

Up – to date built Railway vehicles brake components test stand RAILBCOT, (where load element SIMRAIL is the aim of the project solution) is the facility, where the function core is created from an electromotor with the power of 440 kW. The motor power is led via a transmission (conical gearbox) UNIMEC500 to the discs of rotational rails. The railway wheelset is via a cable stayed transmission pressed to these discs with the force of 225.000 N. The wheelset is integrated into movable frame that enables rotating of wheelset about the angle of attack and the lateral movement in the acceptable limits.

Wheelset is braked with two locomotive brake units. This test stand will be not included into the brake stands bur ride stands. The utilization of the stand, operation and scientific investigation direction is completely different from Flywheel test stand UIC. The aim of the work is to complete the test stand of brake components of railway vehicles with the equivalent railway operation load simulator and to research the wheel wear on it. The other aim is to perform the analysis of the equivalent conicity as a parameter for the rail vehicles in operation ride properties prediction.

A: SIMRAIL modulus implemented for the middle frame movement (lateral displacement of wheelset and angle of attack setting).
B: SIMRAIL modulus implemented for the wheel forces values modification.

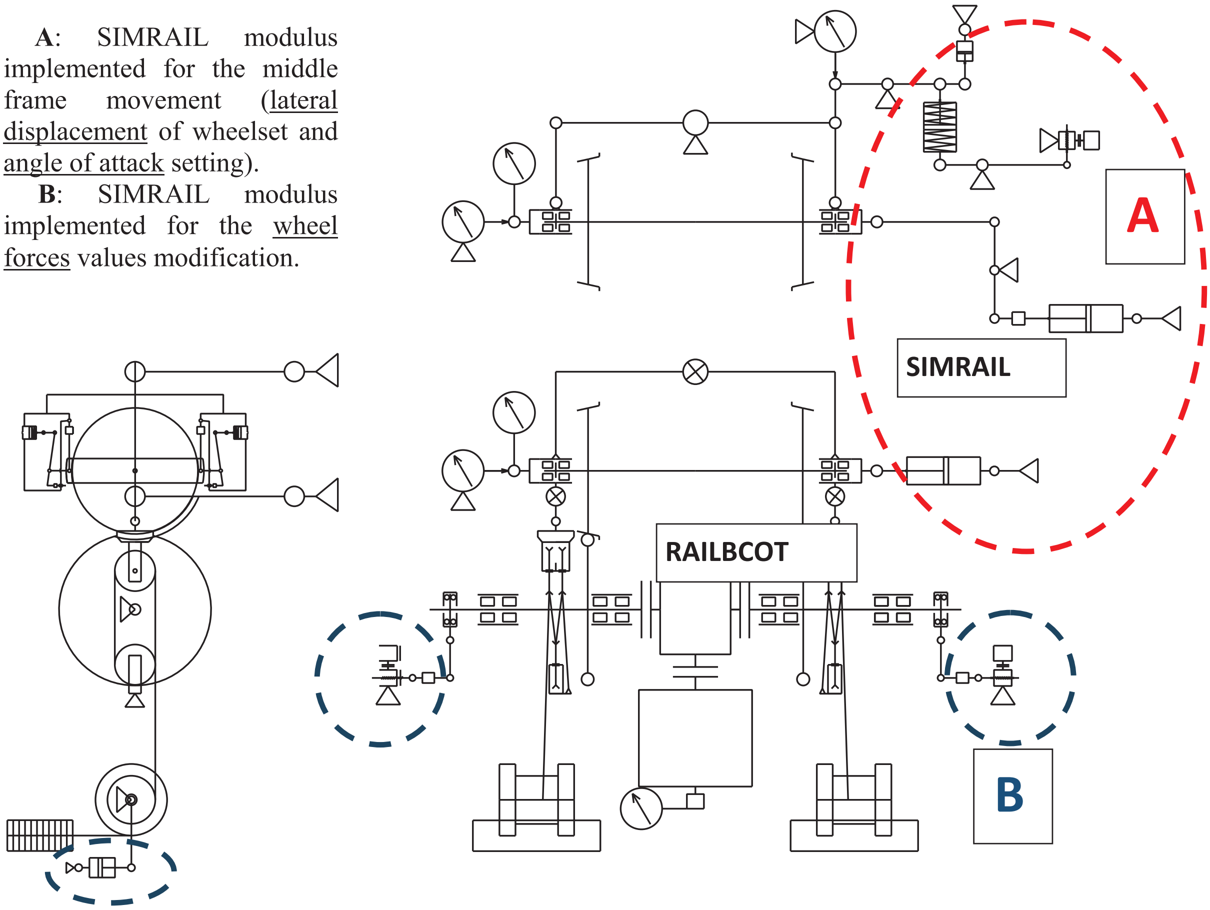

Fig. 7. The test stand enhanced version scheme

The sub aims are the change of frame, wheel, braking forces load via SIMRAIL simulator program load collection performance. The particular aims for meeting the main aim are: change of frames forces apply, change of wheels forces apply, change of wheelset in frame lateral position in accordance the limit cycle, change of brake forces apply and finally the computer program controlling of the load collection on the test stand with the help of SIMRAIL module.

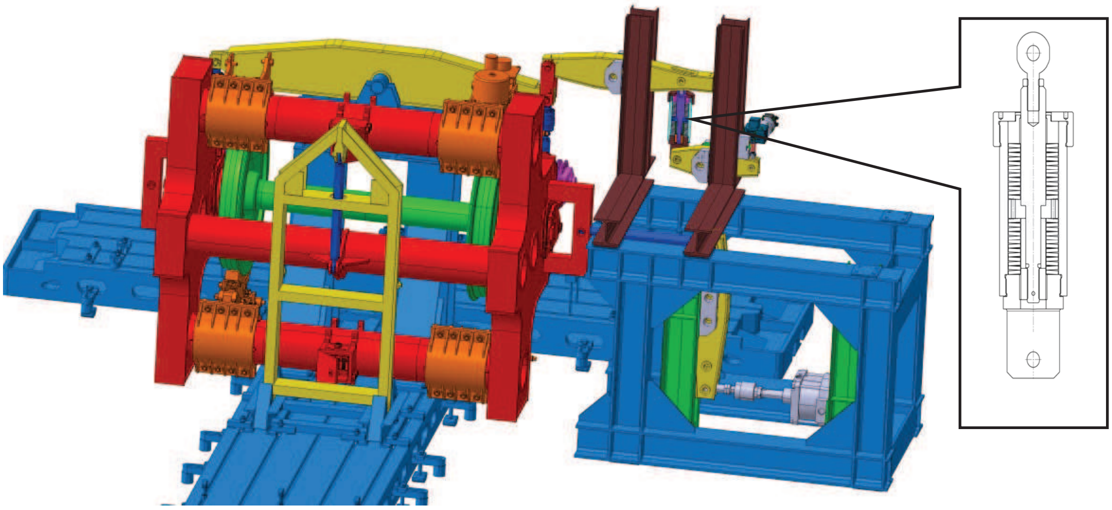

Fig. 8. 3D model of the test stand equipped by the loading modulus (a suspension member is drawn in frame separately)

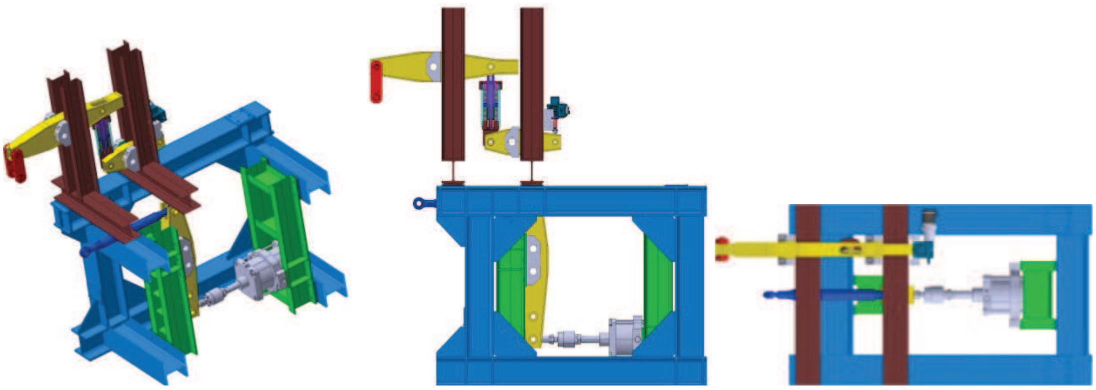

Fig. 9. Load modulus model: view on the function parts, side view and top view

9. METHODOLOGY OF THE LOAD MODULUS IMPLEMENTATION REQUIREMENTS

The work solution methodology is based on the in operation goods wagon bogie /track field mutual interaction detail analysis and will be defined in main points: The loading limit values analysis, applicable to the test stand. The limit values analysis that safely enables the construction are tested.

Maximum loading parameters increasing based on computer simulation computations analysis. Main simulator realization functional scheme is determined. Actual function load components definition on the base of feasibility and purposefulness. Specified frames design, 3D models creation, structural, stress and strain analysis. Construction design realization analysis on the base actual material accessibility, manufacturing manner and additional technologic modification of the stand.

Working drawings and technical documentation create, asking for manufacturing and purchase of function elements. Parts and substructures manufacture, substructures testing, creating of main assembly, simulator assembly testing. Tuning of the cooperation of test stand and SIMRAIL simulator (program computer setting), on the base of experimental Works and computer simulation analysis. Middle – time experimental tests performance. Project realization can help in crucial dimension to fulfill theoretical presuppositions for railway wheelset wear analysis in laboratory simulated operation. The qualitative and quantitative railway wheel and rail head profiles shapes change evolution will be analyzed, as well as the discs rims shapes (they represent the rails) change evolution will be analyzed too. The contact couple profile shapes modifications lead to the change of wheelset in track stabile motion tendency. It is reason of non-stabile vehicle in track motion. On the base of wear study the limit values of permissible deviation from ideal nominal shape will be specified.

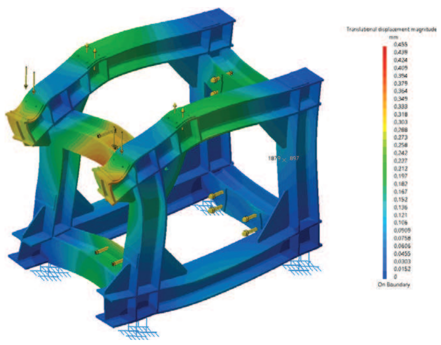

Fig. 10. Frame deformation (displacement) analysis

10. CONCLUSIONS

The project [1] aims for the railway research branch are very topical mainly from the international point of view. The results of an investigation are extremely interesting for European railway research, European operators of railway goods wagons with an impact to the vehicle producers and owners (operators) of the railway tracks. The project aims are topical for railway wheels /wheelset producers, railway vehicles brake systems and brake friction materials components (brake blocks) producers. The aims are topical for the interaction of vehicle and transport route analysis and in the environmental field for environmental loads, from the vehicles operational noise as well as from the brake system operation pollution particles released and emitted into the space, prediction.

The project implementation is aimed not only to the solution of one separated, even though very topical and important issue (wheel tread wear) but it enables to create presuppositions for performance of new projects aimed to the study of wear wheel/rail in contact, new wheel or rail profiles development [2, 3, 4, 5] wheel/rail couple adhesion phenomena, friction conditions of wheel tread / brake block, analysis of wear of rotating members of test stand, temperature and thermal fields spreading, initiation and disposition of stress fields in test specimens (wheelsets, surface stresses in wheels rims, and wheels bodies), wheel unroundness analysis [6], noise transmission and so on. All the tests will be supported by the possibility of active input into the realistic, operational loads of railway wheelset with the possibility of on-line test condition change influence in limits and braking through limits allowed in operation. A new testing device may be an excellent base tool for international scientific and research cooperation.

ACKNOWLEDGEMENT

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STANOWISKOWE BADANIA ZUŻYCIA KÓŁ ZESTAWÓW KOŁOWYCH WSPÓŁPRACUJĄCYCH Z KLOCKAMI HAMULCOWYMI

Streszczenie: W artykule przedstawiono nowe stanowisko badawcze RAILBCOT do badań laboratoryjnych zużycia profilu koła kolejowego współpracującego z klockami hamulcowymi. Artykuł omawia wykonywane badania symulujące zachowanie się układu koło/klocek hamulcowy przy zmiennych warunkach eksploatacyjnych, w tym zmiennej ekwiwalentnej stożkowatości koła. Zamieszczono również opis stanowiska oraz wyniki badań testowych.
Słowa kluczowe: stanowisko badawcze, ekwiwalentna stożkowatość, zużycie profile koła, RAILBCOT, SIMRAIL