

## THE PROCESS OF STUDY IN THE FIELD OF TRAMS' MODERNIZATION

Основна мета даної статті – показати прийняті допущення і процес проведення досліджень, необхідних для модернізації трамвая типу 805Na. Проект модернізації є одним з елементів стратегії відновлення трамваїв у Польщі [1]. Через складність задачі дослідження почалися, коли був обраний трамвай для модернізації, і закінчилися, коли трамвай після модернізації був пущений в експлуатацію. Згадана модернізація відноситься до «закінченої модернізації» і має на увазі створення відповідного сучасного пристрою трамваїв типу 805Na, що задовольняє поточним вимогам як служби зв'язку, так і пасажирів.

Основная цель данной статьи – показать принятые допущения и процесс проведения исследований, необходимых для модернизации трамвая типа 805Na. Проект модернизации является одним из элементов стратегии обновления трамваев в Польше [1]. Из-за сложности задачи исследования начались, когда был выбран трамвай для модернизации, и закончились, когда трамвай после модернизации был пущен в эксплуатацию. Упомянутая модернизация относится к «законченной модернизации» и подразумевает создание соответствующего современного устройства трамваев типа 805Na, которое удовлетворяет текущим требованиям как службы связи, так и пассажиров.

The main purpose of the article is to show the accepted assumptions and the investigation process necessary to modernize the tram of type 805Na. The modernization process is one of the elements of the tram renovation strategy in Poland [1]. One to the complexity of the task the investigation started after the tram to be modernized had been chosen and finished when the modernized tram went into operation. The above mentioned modernization concerns the complete modernization and means the creation of a modern design tram of type 805Na, that meets the current requirements of both the transportation service and passengers.

### 1. Introduction

The question concerning the modernization of rail vehicles is a vital subject in the last few years, when it comes to discussions and actions aimed at improvement of the rolling stock's present state, not only in Poland. The modernization of rail vehicles produced on the turn of the 80's and the 90's, take place mostly in the countries that have initiated economic and social transitions at the end of the 20th century. It is also connected with their financial abilities concerning the purchase of the new rolling stock. According to the investigations carried out in Poland [1], the modernization that practically allows creating an "almost new vehicle", costs nearly 70...80% of the value of the same type vehicle. Furthermore, social aspects of such actions are as well crucial, when we take into account the struggle against high unemployment rates, which is harassing those countries. The modernization means the production inside the country, by which we understand launching local producers and cooperatives. The effect is that new production lines are being opened and the level of unemployment decreases. In general, the aim of the modernization is to create a product, on the grounds of an already existing one, which shall

fulfill the present demand of the market as well as keep the technical parameters of the products offered by the competition, taking the same type and model.

The fundamental goals to be achieved in the process of modernization when we talk about rail vehicles are: improving the functionality, lowering the costs of exploitation as well as increasing the comfort of the passengers with simultaneous minimization of the modernization costs. Moreover, the user is interested in such qualities as the emitted noise, vibrations and the durability of the vehicle, having in mind the degree of the disposal the vehicle is at. Using traditional methods and tools in the process of designing the prototype of a modernized construction, it would be difficult to achieve the above mentioned goals and the expectations of the user within a given time of the project's realization. That is why it is indispensable to take advantage, in this kind of projects, of new approaches as well as techniques and computer tools [2]. Those techniques and tools allow using the modeling methods and simulation techniques that adjust the vehicle, in the course of designing, to the existing conditions in the precise surroundings of its exploitation.

Those conditions are, among others, the quality of the railroads, their geometry, the conditions of servicing etc. Additionally, in the case of modernization, its main objective is the existing rail vehicle under exploitation, which must fulfill certain technical parameters in order to subject it to the process of modernization in the first place. The correct choice of such vehicle requires conducting certain preliminary investigations in order to evaluate the level and state of wear, being the result of exploitation. The outcome of such studies is decisive in the moment of choosing the object of modernization and it later delimits the range of the modernization works.

The purpose of the present article is to show the process of studies conducted in the course of the modernization works over the construction of a rail vehicle. The exemplary results will regard the modernization of the 805Na tram.

## 2. The process of study and analyses

The general targets of modernization can be formulated as below:

- ◆ Increasing the comfort and safety of the passengers and of the operator,
- ◆ Lowering the costs of exploitation and servicing (LCC costs),
- ◆ Improving the outside and inside looks,
- ◆ Increasing the durability of the vehicle,
- ◆ Lowering the noise level.

It is quite easy to notice that these targets are linked to the assumptions of a new vehicle's constructor when he begins working over a new vehicle's prototype. However, in case of the modernization, as mentioned above, the object already exists and it must meet certain requirements.

For this reason, the process of study and analyses in case of modernization, can be divided into three stages:

- research before the modernization,
- study and development works while the prototype project is being elaborated,
- study over the prototype.

The research before the modernization shall allow choosing the proper object of modernization. Regarding the detailed program of modernization, the research can be composed of such elements as:

1. Inspection and examinations research.
2. Research on endurance of the material samples taken from various elements of the vehicle.
3. Metallographic research.
4. Vibroacoustic research.

The aim of the inspections and examination research is to state the quality of the vehicle under

examination.

The research on endurance as well as the metallographic research is to evaluate the endurance properties of those elements or sub-assemblies of the vehicle, which will be used in the modernized construction.

The vibroacoustic analyses are conducted in order to obtain research material for further, post-modernization, comparisons of the dynamic properties of the vehicle as well as of the traveling comfort. This type of research may cover with its range the measurement of the vibration and noise level in selected parts of the vehicle, for example the driver's cabin or areas particularly in danger of increased noise level because of closeness to its sources, the outside surrounding of the tram etc.

The analysis of the obtained results shall help in making the decision as to choosing the wagon to be modernized. The year of production, the established criteria and the evaluation of the proposed modernization changes are to be taken into account.

In the course of the works over the prototype of a modernized vehicle, the simulation-type research and analyses have the purpose of evaluating the influence of the static and dynamic load on the behavior of the vehicle's construction [3]. These kinds of research are carried out on discrete or continuous models. The procedure of the research at this stage has been shown on the figure 1. In consideration of the static load, the elements of the vehicle's construction are being tested with specific regard as to the maximum permissible loading of passengers as well as possible breakdowns that may happen in the course of exploitation, such as derailing and lifting of the vehicle.

Whereas, the dynamic load, which frequently exceeds the statistic values of endurance, leads to the wear of the construction and, through the strains accumulation, is the cause of fractures and, finally, of the construction damage. The discrete model, which describes the dynamic of movement, allows to obtain the maximum values of the forces and displacements that are to occur in the modeled elements of the vehicle during a simulation of movement in real conditions. The question of vital importance is to consider in that model the area of rail and wheel contact as well as the real rail geometry. In the process of the endurance, safety and the construction durability evaluation the model of finite elements. From the conducted computer simulations, the values of deformations and strains are being estimated and the critical points of the construction are located. This phase

of the research allows to early detect the construction failures and to correct them without having to examine the prototype [4]. This can considerably lower the costs of the whole process of the prototype construction.

The phase of research performed on the vehicle's prototype has the purpose of verifying and controlling the accordance of the vehicle after the modernization and its properties with its assumptions. At this stage, studies over the homology of the vehicle, or the permission for exploitation, are also performed.

### 3. Examples of research

The realization of a research program, carried out in the process of modernization, shown on the figure 1, will be presented on the example of the 105/805Na tram. This type of vehicles makes nearly 85% of the rolling stock in Poland, and 65% out of these vehicles are 15 years old. The profile of this vehicle, together with its elementary size, is shown on the figure 2.

The performed modernization is reckoned to be one of the so-called big modernizations, where the cost should not exceed 60% of the purchasing price of a new unit with similar parameters.

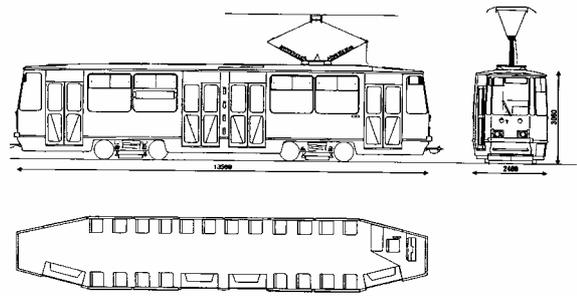


Fig.2. The 105/805 Na-type wagon produced in the 1983-1990

For the purpose of modernization, the 805Na wagon produced in the 1980, has been chosen. The whole process has embodied all the vehicle's elements. The new, modernized 805Na tram was equipped with a modern body, made in the interlocking technology, used for years in the aerial industry, assuring the next 15-20 years of exploitation. The walls, both frontal and back, made of plastic materials and equipped with a safety cage, have significantly increased the level of the passengers and driver's safety. Introducing a new, energy absorber bumper permitted to lower the costs of exploitation and improved the practical properties of the vehicle. The driver's cabin has been enriched with an ergonomic control desk, air conditioning system, manual track controller and an electronic diagnostic and controlling system, which provided very comfortable working conditions for the driver. The installation of an inside camera system as well as an incident registration system has considerably increased the level of safety. A higher level of traveling comfort has been achieved also by creating an air conditioning system in the compartments, connected to a ventilation system and a heating system, using the outside air, has created very comfortable traveling conditions. The vehicle has been also furnished with convenient, soft and vandal-proof seats, anti-slipping floor lining and a visual and sound information system for the passengers. This assured freedom and culture of traveling. The carriage has also been modernized by adding a second degree of de-springing, in form of a rubber-metal MEGI type system. The vibrations transmitted onto the wagon body have thus been reduced and the standard of traveling has risen. A new drive steering system, produced by the Polish company WOLTAN from Łódź, reduced energy spending up to 20%. Furthermore, a new possibility of recuperating the energy was created during brakes applying and stopping of the tram. By reducing the number of contact bondings in the drive system, their work without cutting off

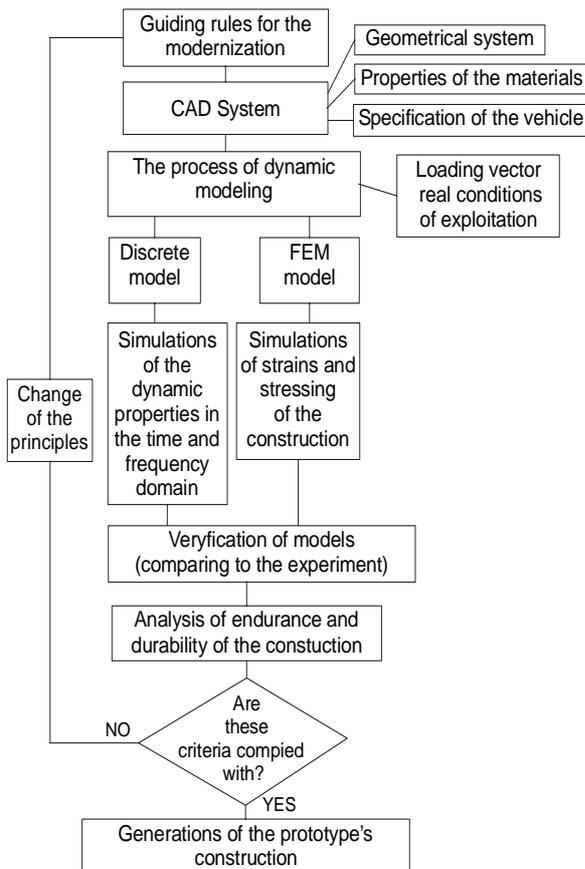


Fig. 1. The research procedure at the stage of working over the prototype



elements of the construction have been modeled by covering. The geometrical model has the ability of easy modification of the material properties and of the thickness.

This model has been elaborated in the *MSC/PATRAN* environment, which is a pre and post processor of the *MSC/NASTRAN* program. The following simulation tests have been conducted:

- ◆ Compression test,
- ◆ Stretching test,
- ◆ Research on the construction endurance with exploitation loading,
- ◆ Wagon body lifting test,
- ◆ One-side wagon lifting test
- ◆ Evaluation of the transposition and acceleration process in chosen points of the vehicle,
- ◆ Evaluation of the wagon body vibrations (frequencies and natural forms).

Exemplary results of the stretching test and the transposition simulations are shown on pictures 4 and 5.

Those test have allowed to formulate conclusions as follows:

- the construction meets the requirements of the UIC card, the strains are smaller than the plasticity limits for each of the tests,
- as a result of the exploitation cases' analysis, the sheets that strengthen the linking of the cross-bars with the back beam have been suggested. Taking into account, that the underframe is exploited for about 15 years and there are no signs of fracture, this change is recommended but not obligatory and the only purpose of its implementation is to increase the construction endurance.

Moreover, the modernization of the carriage has been performed. The basic characteristics of the modernized construction are:

- ◆ guiding the lubricating-box by means of rubber and metal shade MEGI-type springs ,
- ◆ open frame of the H shape,
- ◆ cross-bar,
- ◆ two-degree springing,
- ◆ lateral placing of the body on the rubber and steal springs of the second degree springing/de-springing (by using a cross-bar),
- ◆ pivot linking of the body and carriage,
- ◆ axial transmission,
- ◆ vibration suppression:
  - in the joint of the 1<sup>st</sup> degree springing, using a dynamic suppression loop of rubber and metal shade springs,

- in the joint of 2<sup>nd</sup> degree springing, using two vertical hydraulic shock-absorbers.
- ◆ standstill brake – shoe brake with self-regulation of the neutral gears, steered in an electro mechanical way and working on all axes,
- ◆ electromagnetic rail brake,
- ◆ covering the rolling surface of the wheels with HPF agent, in order to increase the factor/coefficient of the wheel on rail friction, lubricating the wheel flange with a CENTRAC LCF set grease, in order to decrease the factor of the flange on rail friction.

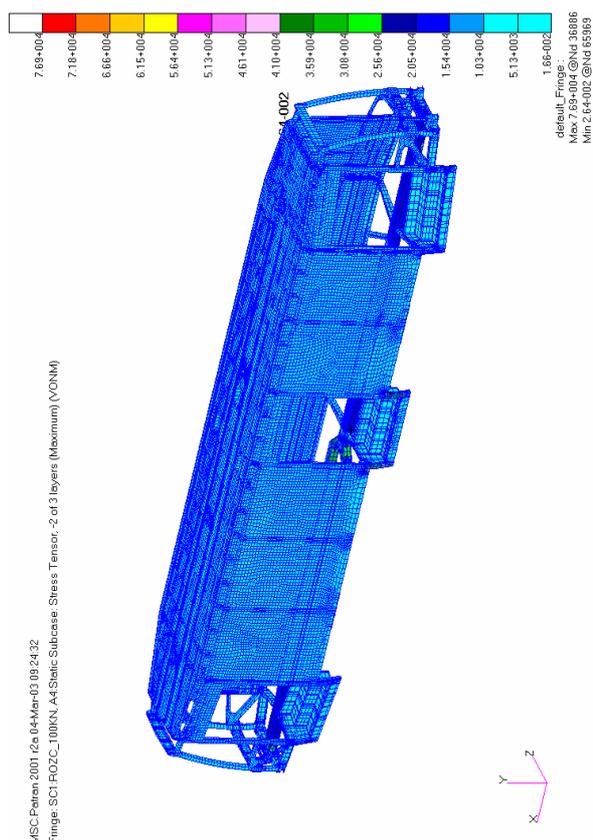


Fig. 4. A Result of the stretching test

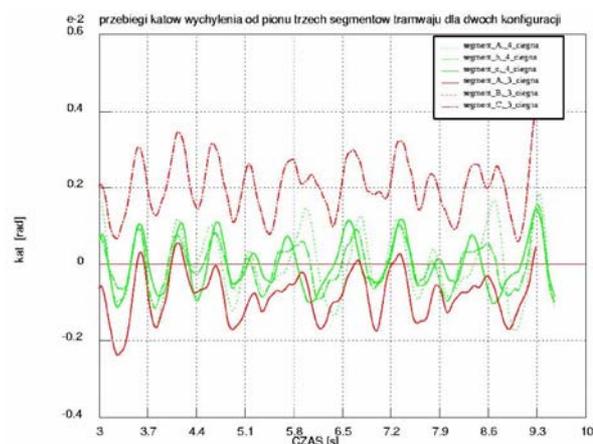


Fig. 5. A results of simulation study; angular displacements

The calculations of the frame's endurance were made using the method of finite elements.

The construction works were carried out within the CAD-CATIA environment. In the same time, a research work has been conducted in order to modernize the electric system of the tram. The most essential conclusions that were drawn from this research allowed indicating the subassemblies that shall undergo a major repair and be reinstalled. The fundamental subassemblies in this case were the engines as well as the subassemblies of the auxiliary/subsidiary circuits have not been changed. In the starter box, two IGBT choppers have been placed. Furthermore, a microprocessor drivers were installed, which allowed the difference in the tram's steering (a manual track controller was installed and a screen with basic movement parameters).

### 3.3 Research after the prototype's construction

After the prototype has been put in motion, another series of research has been performed. It regarded the evaluation of its properties and allowed for the permission for exploitation (homologation research).

The object of the studies over the prototype was the estimation of the dynamic behaviour of the vehicle's construction in the environment of experimental exploitation.

During the passage the following factors were registered:

1. Construction strains in three chosen points and in three directions (every 120°) on one plane using a 2NW driving carriage.
2. Speeding of vibration in three reciprocally perpendicular directions (horizontally longitudinally X, horizontally transversally Y and vertically Z) in chosen 9 points: inside the tram, on the floor level – 5 points, in the tram driver's cabin – 3 points and on the 2NW driver carriage – 1 point.
3. The level of the acoustic pressure inside the tram in 4 chosen points: on a hypothetical level of the passengers' heads – 3 points and in the tram driver's cabin – 1 point.
4. The level of electromagnetic disturbance emitted by the vehicle.

The exemplary results of those analyses are shown on figure 6 and 7.

Before the tram has been fully exploited, some test exploitation studies have been conducted in order to verify the modernization assumptions and to repair all the faults or clear mistakes.

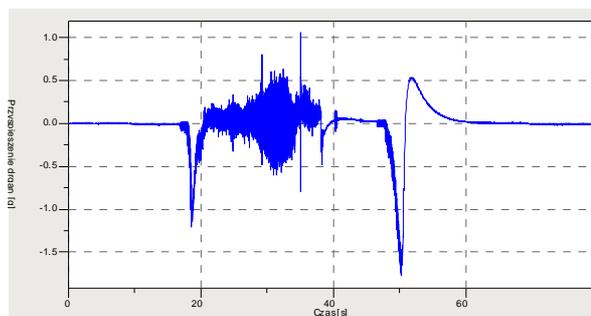


Fig. 6. A result measurements of a acceleration

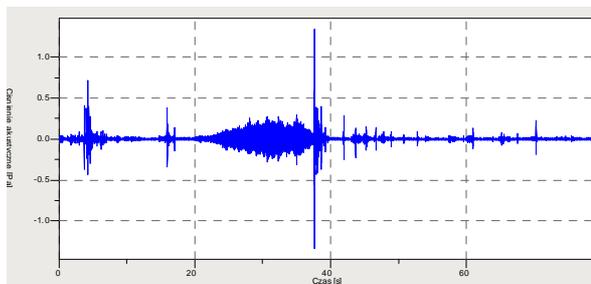


Fig. 7. A result measurements of acoustic pressure

The next step was the homologation research, which allows for the vehicle to get the permission for exploitation. The Institute of Spatial Economy and Municipal Housing, in accordance with the requirements stated in appropriate Polish regulations carried these analyses.

The main conclusion from this research is:

- ◆ Those vehicles meet all the requirements valid at the present in the range of movement parameters, safety and comfort of the passengers as well as the ecology. They can be allowed for exploitation with the passengers.

The results of the carried research, at every stage, were presented during seminars and conferences [5].

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