THE LMS VIRTUAL.LAB APPLICATION
IN MACHINES TECHNICAL STATE ANALYSIS

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Abstract

The proper work of turbocharger has a very important aspect for vehicles combustion engines charging, it directly influence on: the vitality of the engine, the issues of harmful substances to surroundings and safety, the turbocharger damage could be dangerous and causes to the vehicle passage in the emergency mode or finally brought to the road incident. This paper introduces an example of way of machine engines chosen units modelling and simulation analysis on the introduced example of LMS Virtual.Lab application usage. The LMS Virtual.Lab was used for strain and deformation analysis of KKK BV39B-0050 turbocharger.

Keywords: turbocharger simulation, degradation processes analysis, vehicle, Computer Aided Design

1. Introduction

Development of three-dimensional modelling together with computers computational possibilities spread influence on significant growth of engineering software to assist in the creation, modification, analysis, or optimization of a design. Applying this software to designing process helps engineers fully replaced and accelerated work in the comparison with traditional drawing technics. The traditional methods of projecting required from the engineers huge precision while sketching. Thanks to virtual sketching process we could faster plotting possible changes and correction in design projects.

Computer – Aided Design (CAD) is an important design software that gives engineers the direct access to the set of engineering standards, codes of practise or actually instructions for given industrial branch of production which in the considerable way accelerate designing process with support of newest legal requirements [1,3].

The first version of CAD systems allows only the replacement of traditional ways of sketching and in significant way lowering the number of sketch mistakes during designing process. Introduction of three-dimensional objects (3D) during sketching to systems CAD just made possible of projecting the machine engines and devices units and their spatial visualization. The improvement of CAD systems in 3D technics facilitated many actions during designing process and also allowed to the correct understanding of technical drawings by non-engineer persons (e.g. management) [1,3,4].

The next step of design development of new objects was CAD systems improvement by implementation to software new modules that will realize simulations of sketched objects in different conditions. Thanks to these solutions we could reduce the costs of new prototypes

creation, costs of their investigations and also have an influence on new laboratory positions creation used for experimental audits. The computer programmes allowing to the simulations of the objects behaviours saves many time additionally and make possible the quick referral to the production of projected units [1,3,4].

In this paper authors introduced the simulation investigation realised with usage of LMS Virtual.Lab used for strain and deformation analysis of chosen elements of KKK BV39B-0050 turbocharger, which were realised basis on real object modelling and simulations.

2. The LMS Virtual.Lab system

One of the CAD software that helping designing process is the LMS International system called LMS Virtual.Lab. The LMS Virtual.Lab is an integrated suite of 3D finite elements and multibody simulation software which simulates and optimizes the performance of mechanical systems for structural integrity, noise and vibration, system dynamics and durability for real objects. This software offers a unique approach to simulations – input data that are given from real object measures are connecting with virtual data of simulated object.

The samples of virtual simulation of technical object behaviour that are realized in the Virtual.Lab software were introduced on figure 1.
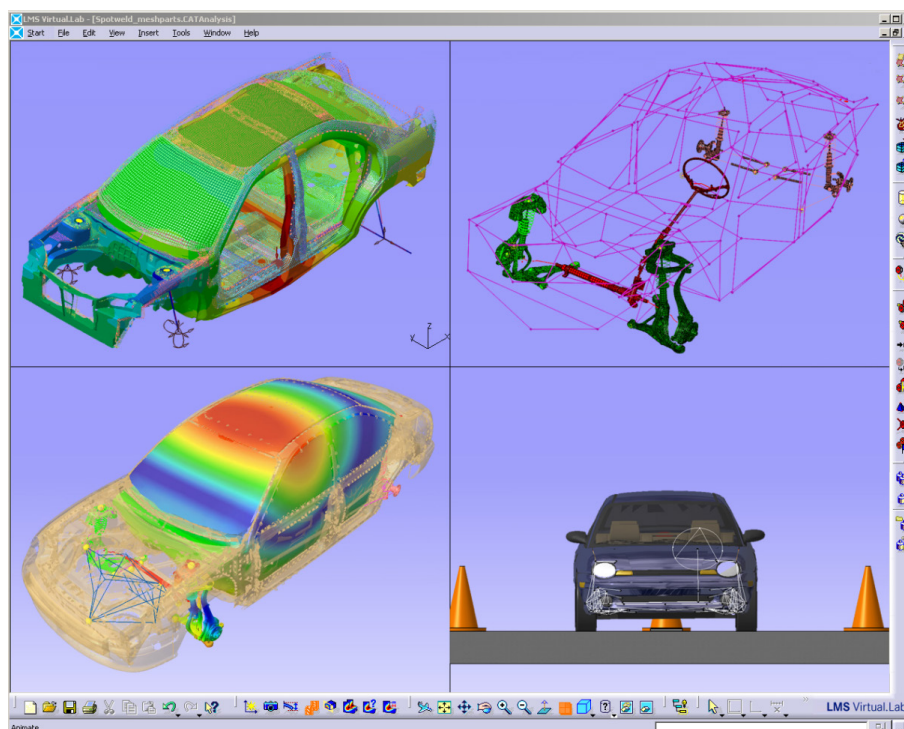

Fig.1. The sample of simulation realised in LMS Virtual.Lab [5]

LMS Virtual.Lab allows tracing all critical steps of designing process. It offer special tools and technologies that will allow to assess the whole designing process of technical unit with analysis of all key aspects long before accession to expensive creation and prototype testing process [3,4].

In the aim of the created patternel analysis execution and his individual working unit's dependence audits is the necessity of model virtual geometry creation. The virtual patternel should have some parameters – the degrees of freedom should be defined or the places and values of external forces should be estimated. Finally we receive the ready virtual prototype which we could thanks to the suitable possibilities of the programme examine under various regards after creating patternel e.g. strain and deformation analysis for chosen unit, the virtual analysis of cooperating

units, the comparison of work parameters of the same mechanical unit made by different structural materials [3,4].

The software has a large base of finished elements that improve modelling and designing process in many range of knowledge. In range of motor industry, the LMS Virtual.Lab offer a ready-made libraries of the chosen units and aggregates of vehicles which include: suspension, drive transmission arrangements, combustion engines units, tooth gear transmission which are ready to implementation by engineer to created patternel and analysis of virtual model on this stage of mechanical unit creation [3,4].

3. MODELLING OF TURBOCHARGER

The motorization is the one of disciplines that using modern systems of virtual modelling and simulations. In vehicles exists many parts and components which are put forward in various kinds of burdens. Thanks to integrated virtual systems that aided design we could very strictly define and examine the work parameters of chosen technical objects before they will be produced.one of those elements is turbocharger aggregate, which during his normal exploitation is put forward of high and changing value of burdens booth thermal and mechanical.

Designing the turbocharger assembly if we know the work conditions we could use the LMS Virtual.Lab to analysis and simulations of behaviour of turbocharger during exploitation. As an effect of this simulation we could model simulate and analysis parameters as e.g.:
- deformation schedule,
- strain schedule,
- critical velocity,
- thermal influence on partial elements of investigated combustion engine turbocharger unit.

In this paper authors conducted the computer simulations of chosen burdens for chosen elements of turbocharger aggregate no KKK BV39B-0050, which were used in diesel combustion engines by Ford and Volkswagen AG. The simulations were conducted for combustion idle run (800 rpm) and full speed of diesel engine (4500 rpm) [2].

The design process of turbocharger elements enclose given steps:
a) in the first step during modelling - virtual creation of turbocharger all elements and then their assembly in the general patternel of turbocharger. The example of virtual design of compressor wheel were introduced on figure 2;
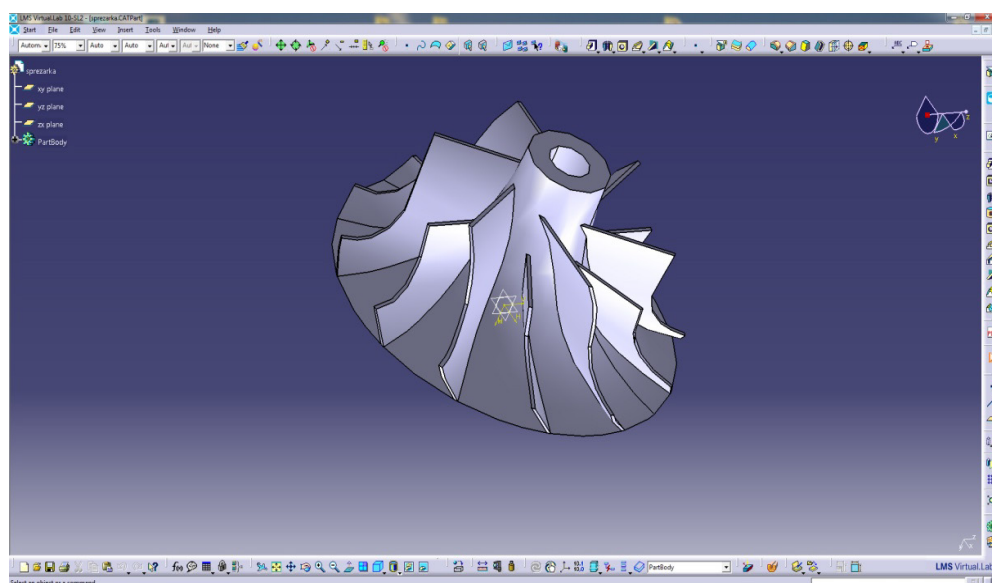

Fig.2. Virtual model of compressor wheel [own source]

b) in the second stage of work in LMS Virtual.Lab was proper attributing of turbocharger chosen units the material properties;

c) in the third stage of work designer put on the elements: compressor and turbine wheel, turbocharger shaft virtual mesh of finite elements (MESH). This mesh will allow defining burdens and conducting rotor simulations in chosen points of the structure. The virtual model of turbocharger rotor was introduced on figure 3.
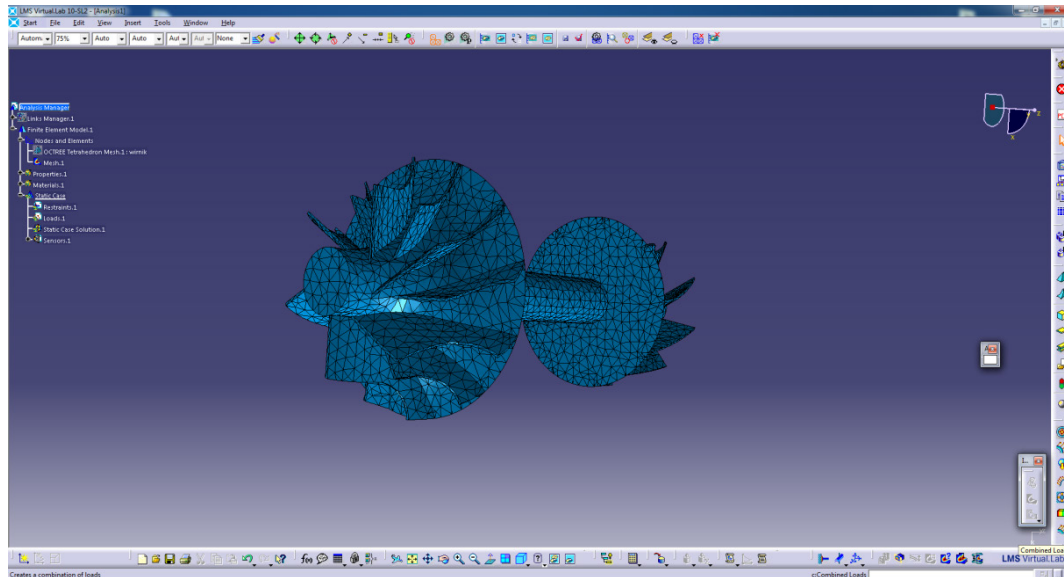

Fig.3. Virtual model of turbocharger rotor with MESH [own source]

4. THE ANALYSIS OF CHOSEN TURBOCHARGER BURDENS

After design of turbocharger virtual patternel in the next stage of investigations was simulated the pressure influence in turbine and compressor chambers on the turbocharger rotor. During investigations authors establish pressure for idle run of engine: 0,1 MPa for compressor and 0,115 MPa for turbine chambers. For maximum speed of engine authors establish pressure: 0,210 MPa for compressor and 0,255 MPa for turbine [2].

The pressure force was introduced on the virtual models as yellow arrows on the compressor and turbine wheels. The sample of virtual burdens was introduced on figure 4.
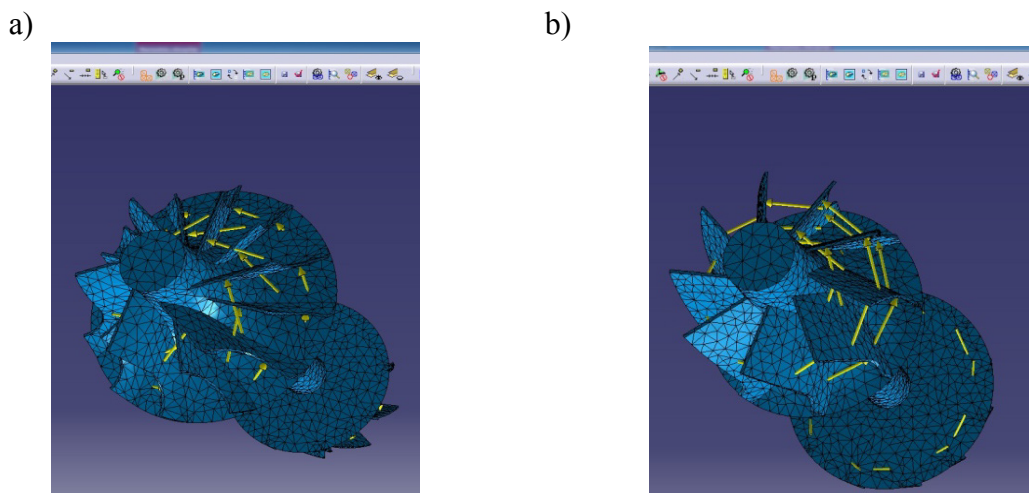
a)

b)

Fig.4. Virtual model of wheels with pressure force a) compression wheel, b) turbine wheel [own source]

The final stage of the simulation depended on the calculation and the visualization for so the received burdens of turbocharger assembly wheels and shaft the values of strain and deformation for given engine speed.

5. RESULTS OF SIMULATIONS

The results of simulations in LMS Virtual.Lab were received in the graphics figure. As a results system puts on the mesh fields of colours – each colour has an estimated value of studied quantity. During simulation process of strain schedule their highest value for compressor and turbine wheels were placed at the basis of blades, were step out stress concentration called out the notch, meanwhile the farther part of blade come under to the insignificant values of strains. The similar phenomena stepped out in case of the rotor shaft, where the largest vales of strain step out in place of the shaft diameter change. The results of virtual simulations of strain schedule were introduced in table 1.

Table 1. The strain schedule of turbocharger elements [2]

Unit	Rotation speed	Minimum strain value [N/mm^2]	Maximum strain value [N/mm^2]
Compressor	800 rpm	3	46
	4500 rpm	5	101
Turbine	800 rpm	7	106
	4500 rpm	15	276
Shaft	800 rpm	4	119
	4500 rpm	10	263

In case of deformation simulations the highest values step out on the end of compressor and turbine blades, because the forces coming from the gases pressure in turbine and compressor chambers worked out on the longest arm of a force. The similar phenomena stepped out in case of the rotor shaft, where the highest values of deformations were placed on the shaft ending points. The results of virtual simulations of deformation schedule were introduced in table 2.

Table 2. The deformation schedule of turbocharger elements [2]

Unit	Rotation speed	Minimum deformation [mm]	Maximum deformation [mm]
Compressor	800 rpm	0,002 mm	0,029 mm
	4500 rpm	0,005 mm	0,074 mm
Turbine	800 rpm	0,002 mm	0,072 mm
	4500 rpm	0,005 mm	0,157 mm
Shaft	800 rpm	0,001 mm	0,013 mm
	4500 rpm	0,001 mm	0,029 mm

The graphical results of strain schedule simulations of turbocharger aggregate chosen elements were introduced on figure 5, where as an example of strain schedule were introduced course of strain along the line between point A and B. AB line is placed on the turbine blade and simulations results are conducted for maximum rotation speed of engine. The graphical results of strain

schedule simulations for compressor blade along the line between point A and B conducted for engine maximum rotation speed were introduced on figure 6. The graphical results of strain schedule simulations for rotor shaft along the line between point A and D conducted for engine maximum rotation speed were introduced on figure 7.
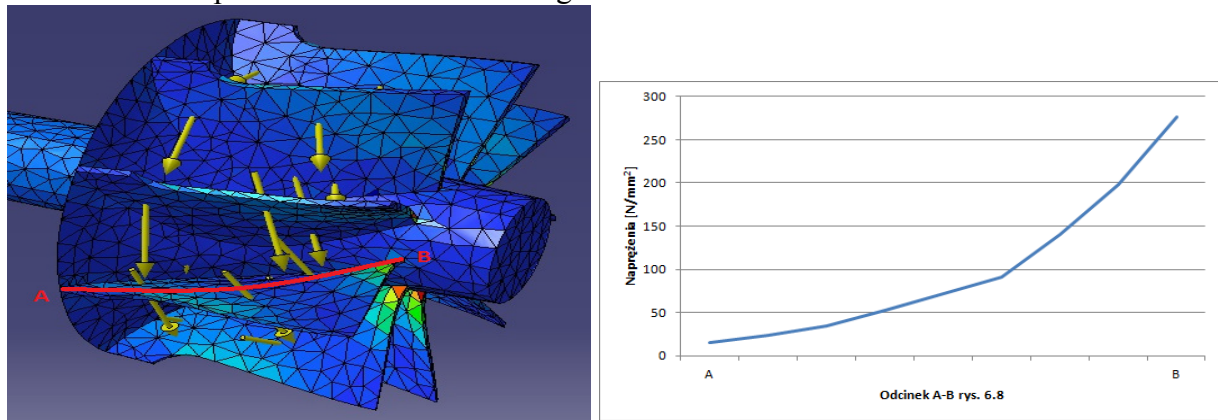

Fig.5. Strain schedule course on the turbine blade along line A-B for maximum rotation speed of engine [own source]
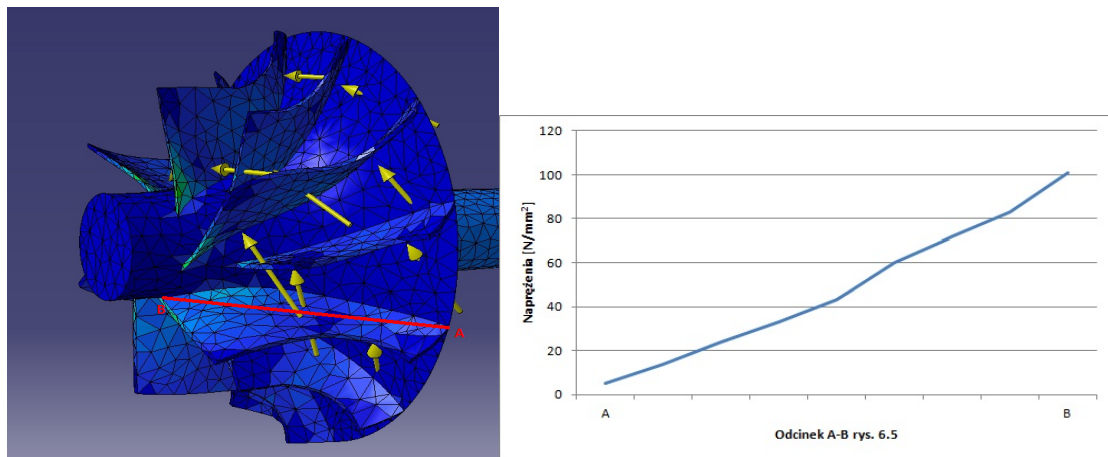

Fig.6. Strain schedule course on the compressor blade along line A-B for maximum rotation speed of engine [own source]
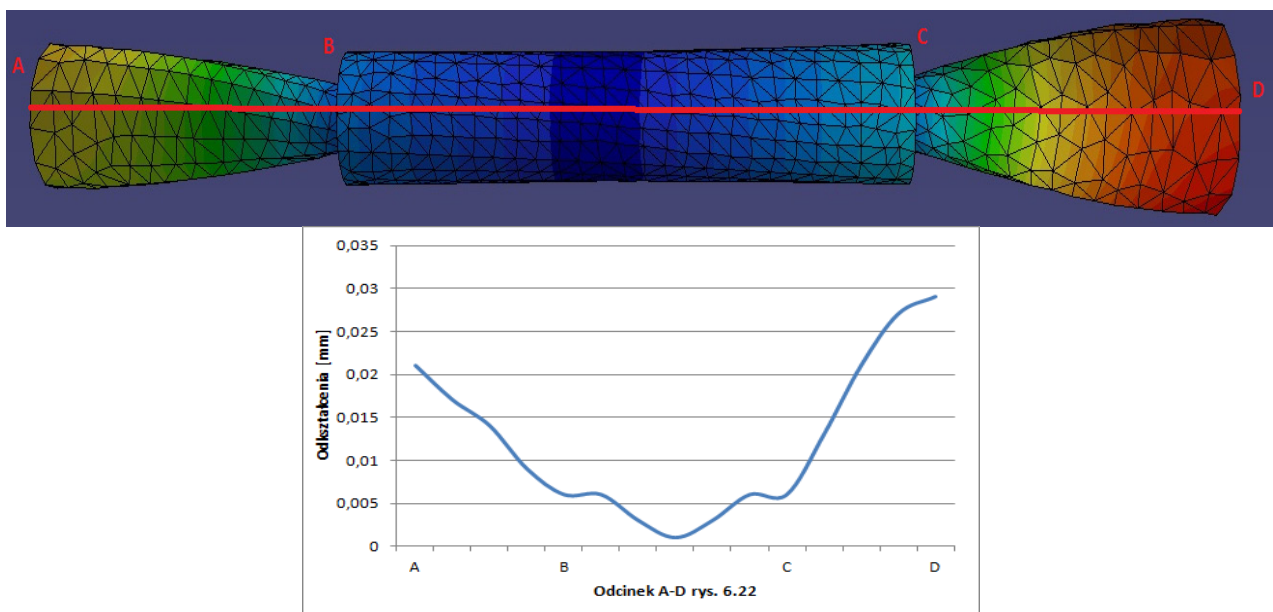

Fig.7. Strain schedule course on the rotor shaft along line A-D for maximum rotation speed of engine [own source]

6. CONCLUSIONS

In this paper were introduced the possibilities of usage the LMS Virtual.Lab design application in virtual modelling process of strain and deformation schedule on the example of real technical object – turbocharger aggregate. Basis on the virtual patternel were marked out the dangerous work states and precisely define the conditions which should be fulfilled for real object so that turbocharger worked out unfailingly according his destination. The investigations were conducted to mark out the analysis of changes course for chosen parts of turbocharger on the results of strain and deformations influence.

Marked out during simulation values of turbine and compressor blades strain raised up together with the distance decreasing to the centre of the rotor turn. However the largest values of strains achieved at the basis of the blade. During designing process of these elements we should pay a special attention into appointed critical places and we should to conduct suitable constructional materials selection, geometrical dimensions and pay attention on the ways of rotor processing.

The highest values of blades deformations marked out in the terminal point of blade and lowering in direction of rotor rotation centre. The critical blades deflection of rotor wheels is very dangerous because the turbocharger aggregate are designed and produced with very small value of linear tolerance. Each deformation could case to whirling units point of the contact with casing and finally damage and immobilize the turbocharger assembly.

The highest values of rotor shaft strain were marked out in points B and C (fig. 7) – places where the shaft diameter value changes. Such strain schedule in these points forces on the designers to put special attention during designing process of these elements. Designers should choose suitable constructional materials, proper shape of rotor shaft and predict suitable shaft processing to this unit damage avoidance.

The highest values of rotor shaft deformation were marked out in shaft pins where the rotors wheel is placed. Such phenomena could be predicted early on the shaft projecting stage, because these places are deformation susceptible – the places with the smallest geometrical value. Similarly as in rotor wheels for shaft, to high value of deformation could damage and immobilize the turbocharger assembly. The main reason of rotor shaft deformation was caused his bending and torsion. It was caused by unequal schedule of forces on the rotors wheel circuit. The inequalities of forces reigning in the turbine and compressor chambers are called out by reducing chambers diameter what causes gases pressure increasing and also from the angular frequency of the admission expiratory gases.

The most important parameter during exploitation on turbocharger assembly in vehicles is the value of combustion engine rotation speed. During simulations estimated strain and deformations values depend on engine rotation speed. During exploitation of turbocharger assembly, the violent change of combustion engine rotation speed influence on estimated values of strain and deformations growth twice what was introduced in this studies.

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