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Analysis and Calculation of Stresses, Strains and Displacements in the Cardanic Cross Joint of Vehicles

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Abstract: ***The present paper identifies the stresses and the strains in the cross joint of the cardanic transmission of motor vehicles. It is a research on the cardanic transmissions which shows that this component, the cardanic cross joint, is most often replaced due to the stresses occurring during operation.***

Keywords: stresses, strains, finite elements.

1. Introduction

The cardanictransmission of motor vehicles and various industrial machines are part of the driveline for transmitting the rotational motion from an engine to the drive wheels or the moving subassemblies [4].

A cardanic*transmission* is a set of machine parts (joints, shafts, intermediate bearings, etc.) that serves to remotely transmit the mechanical energy through rotational motion without increasing the *torque* between units, having a variable or invariable position in space. The judicious design of these machine parts and the execution technology ensure an increased reliability in operation and a low metal consumption [4].

The constructive design of the cardanic transmissions must also meet the design requirements of the technological manufacturing processes, thus excludingany problems regarding the construction of the transmission components.
In this regard, it is advisable to develop a flexible information system that would connectunder a unitary structure the constructive design with the technological design of the cardanic transmissions. Due to the diversity of types and dimensions of the cardanic transmissions, in the design and manufacturing phase, the different components have been typified for a certain field of use (agricultural machines, lifting and transporting machines, etc.).

Figure 1: Types of cardanic transmissions made by the Eurocardan company [6]

From a constructive point of view, the cardanic transmissions are mechanisms consisting of a set of machine parts - shafts, joints, safety couplings, shock absorbers, intermediate bearings, etc., which form an independent functional unit and serve for remotely transmitting torque, without amplification, between different parts of the same machine or between different machines located at a variable relative position.

2. The Current State of Research in the Field

After analyzing the first set of cardanic transmissions, a preliminary estimate of theirdurability was developed by plotting the Wöhler curve of the cardanic shafts and by performing an endurance teston DACIA 1304 motor vehicles equipped with such shafts. Also in this set of cardanic transmissions, the value of the torquewas determined at the transmission level in the phases: at startup, at sudden engine brake and during shift shock.

The malfunctions occurringwhile testing the first set of cardanic transmissions mounted on DACIA 1304 passenger vehicle, were the following:

a) The caps of the cardanic cross joint bearing fractured;
b) The deflector for the protection of the intermediate bearing in the elastic element and in the bearing frame showed signs of friction;
c) The deflector detached from the section.

The recommendations made in the test bulletins for the above mentioned test were as follows:

a) It is necessary to modify the extreme connecting flanges in the car transmission;
b) The radial flexibility of the elastic element of the intermediate bearing needs to be improved.

As the tests on the testing machine proved that the durability of the tested cardanic shafts was satisfactory, it was required to confirm it by conducting tests on the car, on a new set of cardanic transmissions where the necessary modifications have been performedin order to eliminate the deficiencies reported in the first set.

The tests were conducted in the mechanical testing laboratory on a stand specially built for this test (subjecting parts at high torque).

Figure 2: Cardanic transmission testing stand [5]

This stand consists of two props on which two base plates are rigidly assembled. Two connecting flanges are mounted on these two plates, by means of two radial bearings (so that the torque is not transmitted to these plates), each having an actuator. The cardanic shaft to be tested is rigidly mounted between these flanges, by means of the cardanic transmission fixing screws, tightened to a torque of 35 [Nm]. The two arms of the connecting flanges are set on the crosshead of the power transducers mounted on two hydraulic cylinders (one on each side of the cardan shaft). Knowing that the length of the arm (force) is 800 [mm], a cylinder was forced to act with a predetermined force, calculated according to the required torque, and transmittedto the second cylinder by an arm which isas long as the first one.

This solution was chosen so that the active cylinder could be controlled by the reaction force measured on the force transducer of the second cylinder, thus avoiding the measurement and conduction errors due to the inertia of the moving transducer. Therefore, the force transducer remains motionless, and the inertial forces are zero, making possible to control the torque in the cardanic shaft. The accuracy of the sinusoidal driving and respectively response signal of the actuator was highlighted on the oscilloscope. The ETS ROZARY testing machine set at 50 Hzfrequency was used for testing the cardanic shafts at low torque (300 and 500 [Nm] respectively).

These endurance tests led to the following conclusions:

- The clamping flanges on the gearbox are different from the ones used so far and create interchangeability problems;
- For the mounting assembly on the gearbox flange, four more holes were drilled and a centering ring was inserted, and the flange of the bevel gear (the differential on the drive axle) has been replaced with a new one to ensure the correct fixing on the cardanic shaft;
- After driving about 120 km on the endurance testing ground, a bearing cap of the cardanic cross towards the drive axle fractured. The incident is similar to the one reported on the testingstand, and the respective part was taken over by SC COMPA - S.A. SIBIU for detailed analysis.
- The bearing-relay protection deflector rubs into the rubber support producing noise. The incident was observed on all three cardanic transmissions tested, and the cut is located at the bottom of the rubber socket, therefore occurring atmaximumtransmission speed, when the angle between the shafts is wide;
- There has been no freedom of movement noticed inside the joints so far.

Also, these endurance tests have proven that the level of vibrations transmitted to the structure of the truck is slightly higher in the case of the tested transmissions, probably due to the higher transmissibility of the intermediate bearing, due to lower radial flexibility than in the case of standard equipment.

It is required to continue the endurance tests on the vehicle according to the testing program (80,000 km) "customer type" and (20,000 km) in the testing ground.

Other conclusions worth mentioning from these tests are the following:

- The outer flanges of the cardanic transmission (towards the gearbox and towards the bevel gear) must be compatible with the current flanges of the gearbox and of the bevel gear in order to avoid the interchangeability inadequacies;
- It is necessary to increase the radial flexibility of the intermediate bearing;
- The caps of the cross joint bearing fracture during operation;
- The tests on the testing stand show a sufficient durability, but the tests will have to be confirmed based on recordings under real road conditions;
- There have been no incidents in operation except for the fracture of the cap on the cross joint bearing.

3. Intended Objectives

The study of the literature led to the conclusion that the cardanic cross joint was a part that must be studied and optimized by taking into account the new analysis and calculating software.

Figure 3: Cardanic cross joint.

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4. Elements for the Calculation of the Cardanic Cross Joint

The cardanic cross joint is subjected to bending, shearing and crushingstrength stresses by force F_1 (fig. 4).

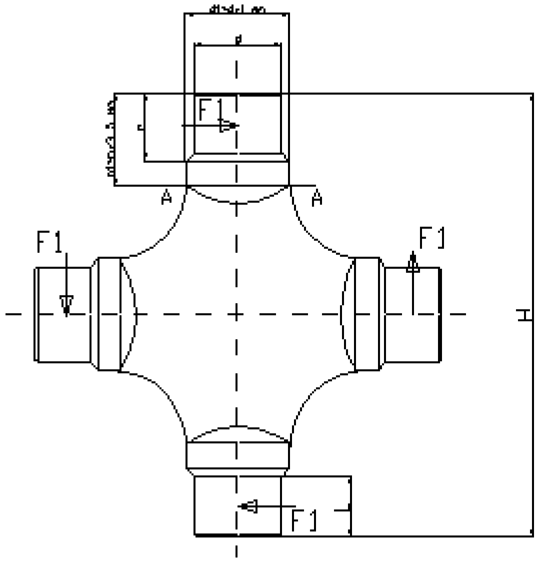

Figure 4: Cardanic cross joint calculation scheme

Force F_1 is calculated with the relation:

$$F_1 = \frac{F}{\cos\gamma} = \frac{5.42}{\cos 20} = 5.76\ kN,$$

whereγ is the angle between the axes of the shafts.

$$F = \frac{M_c}{2 \cdot R} = \frac{300 \cdot 10^3}{2 \cdot 27.7} = 5.42\ \ kN \cdot$$

The normal bending stress in section A-A is calculated by the relation:

$$\sigma_i = \frac{M_i}{W_i} = \frac{F_1 \cdot \left(h_1 - \frac{L}{2}\right)}{0{,}1 \cdot d_1^3},$$

$$\sigma_i = \frac{15.37 \cdot 10^3 \cdot \left(15 - \frac{10.5}{2}\right)}{0{,}1 \cdot 18.65^3} = 231\ MPa \cdot$$

The allowable bending stress σ_{ai}=750 N/mm^2 is taken into account.

The shear stress at the base of the spindle is determined by the relation:

$$\tau_f = \frac{4F'}{3 \cdot A} = \frac{4 \cdot 7{,}19 \cdot 10^3}{3 \cdot 262{,}32} = 36{,}57\ MPa,$$

where force F’ is calculated with the following relation:

$$F' = \frac{M_c}{2(R - 0.5h) \cdot \cos\gamma} = \frac{300 \cdot 10^3}{2(27.7 - 0.5 \cdot 11) \cdot \cos 20} = 7.19\ kN.$$

It is recommended to have τ_{af}=80-120N/mm^2.

The crushing strength test is done by determining the specific load applied on the spindle of the cross joint, subjected to force F_1, with the relation:

$$\sigma_s = \frac{F_1}{d \cdot h} = \frac{5.76 \cdot 10^3}{18.28 \cdot 11.08} = 28.44\ MPa \cdot$$

It is recommended to have: σ_{sa}=75-100 N/mm^2.

5. Numerical Analysis of the Cardanic Transmission Component – the Cardanic Cross Joint

The CAE Module (Computer Aided Engineering) was introduced in the composition of CIM systems (Computer Integrated Manufacturing) after the development of the CAD module (Computer Aided Design); it actually appeared with the emergence of the finite element method. The method was originally used in the mechanical calculation of the aircraft structures but later it expanded widely to all the material continuum problems. These problems seek to determine, in a considered area, the values of one or more unknown functions such as: displacements, velocities, temperatures, stresses, strains, etc., depending on the nature of the tackled problem. In the chapter covering the numerical simulations with the finite element method of the behavior of the cardanic transmissions we will refer only to those problems related to the structural behavior, i.e. to analyses that study the behavior in terms of strength. These analyses try to determine certain measurements (nodal displacements, stresses, strains) when different types of loads are applied. The loads that can be applied are forces, pressures or torque.

The natural phenomena of this kind are described by differential equations, which, when integrated under given limiting conditions, lead to the exact solution. In this way we can calculate the value of the unknown function or functions in any point in the studied area. This is the analytical, classical solving method, which is applicable only to the simple problems. However, the problems that arise in the practical engineering activity are not simple but rather complex, both in terms of physical geometrical construction of the part, and in terms of the loading boundary conditions. In this situation solving the differential equations is no longer possible. At this point, there are two solving options:

- Creating a simplified model of the real one and solving the differential equations on the former, thus obtaining the exact solution on a simplified model;
- Obtaining an approximate solution to a real problem.

The approximate solutions obtained by numerical methods more often reflect reality better than the exact solutions on simplified models. The applications of the finite element method can be grouped according to the type of the applied loads, as follows:

- Problems of balance or stationary state, where the unknown function or functions are not time dependent. The study of the elastic behavior of bodies under a static state is included into this category.
- Problems of eigenvalue where the unknown functions do not depend on time either and where someof their critical values are determined by respecting the equilibrium configuration. Included here are the modal analyses, namely the calculation of the natural frequencies of the bodies;
- Problems of propagation or transient state, where the unknown functions are time-dependent. This category

includes the dynamic study of the elastic or the non-elastic behavior.

According to this classification, this chapter will cover the static and dynamic analyses, fatigue analysis and a constructive optimization analysis applied to the cardanic cross joint.

The cardanic cross joint was modeled with the assisted design and numerical analysis software Catia v5 at scale 1:1 (figure 5)

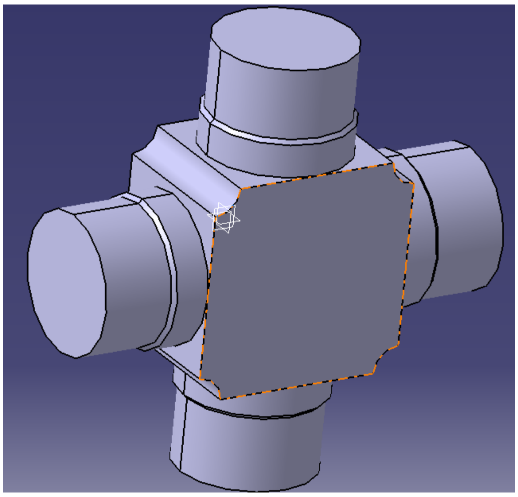

Figure 5: 3D model of the cardanic cross joint

Loadsat values observed in practice were applied on the arms of the cardanic cross joint (figure 6), resulting in the stresses and strainsshown in figures 7 and 8.

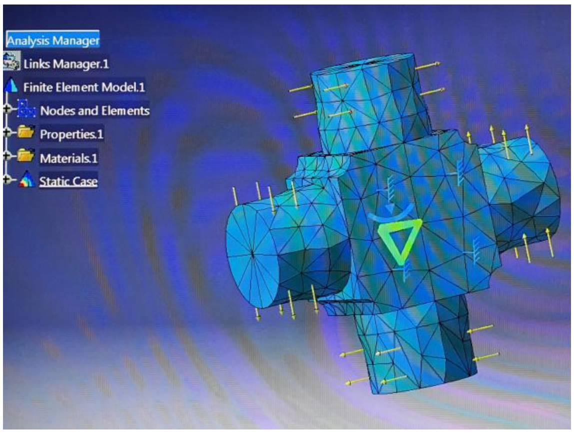

Figure 6: Constraints and loads positioned on the arms of the cardanic cross joint

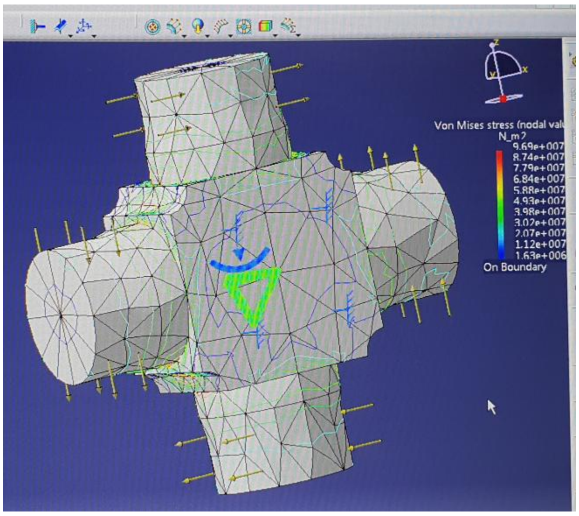

Figure 7: Von Mises Stress in the cardanic cross joint, MPa

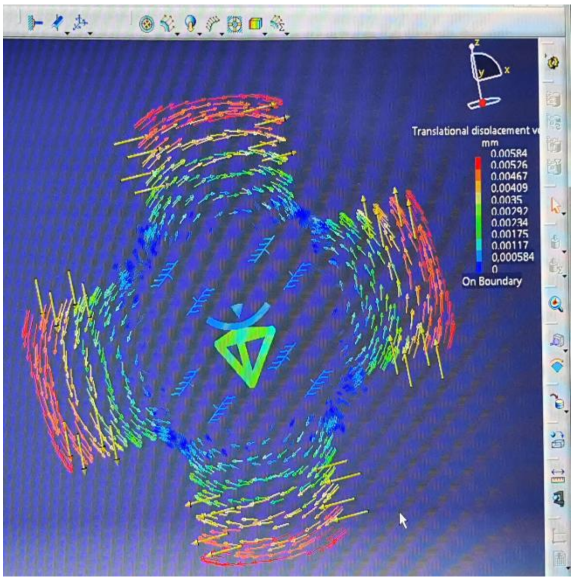

Figure 8: Maximum strains obtained in the cardanic cross joint, mm

6. Remarks and Conclusions

Following these studies, it was established that this element of the cardanic transmission, the cardanic cross joint, is an important element in the operation of the assembly. It has been proven that it is the part that yields first in operation and needs to be replaced most frequently.

The present study led to the conclusion that further research needs to focus on the cardanic cross joint. For this purpose, the part was three-dimensionally modeled using the Catia software, real-scale loads were applied and the numerical results were obtained using the finite element methods.

It is concluded that a dimensional optimization of the model taken into account can be achieved by modifying the non-functional dimensions, thus developing an optimal model.

References

[1] AVRIGEAN E. Studiuasuprastãrilor de tensiunisideformaţii din elementelecomponente ale

transmisiei cardanice cu ajutorul metodelor tensometrice. Research contract. Nr. 2541/2016. SC Compa SA Sibiu.
[2] CURTU, I., SPERCHEZ, Fl. Strength of Materials, vol. I and II. University of Brasov, 1998.
[3] DUŞE, C. DUSE, D.M. Studiiasupraprobleme - lorapăruteînpracticautilizăriitransmisiilorcardanicepebazachestionarului. Research contract. 2015.
[4] DUDIŢĂ, Fl. Transmisiicardanice. Technical Publishing House, Bucharest, 1966.
[5] www.eurocardan.it
[6] https://compa.ro/servicii/service-cardane-eds

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Avrigean Eugen - holder of a Ph.D. title in Mechanical Engineering, specialty Strength of Materials, higher education faculty member (Lucian Blaga University - Engineering Faculty) and researcher for 20 years. He has conducted work on numerous research books and articles, on laboratory studies, numerical analysis and computer aided design.