# METHOD FOR THE DETERMINATION OF THE ROTAIONAL VARIABILITY OF CARDAN DRIVE

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***Abstract:*** *The paper justifies the importance of the experimental determination of rotational variability of cardan drives and couplings. The objective of the authors' team was to elaborate a new automated test machine for the determination of this variability. The principle design of this new automated test machine is described in details. The advantages of the application of electronic measuring equipment in combination with PC for the automation of the measuring and experimental data processing are pointed out. The test machine gives opportunities for changing of the angles between the driving and the driven shaft and for regulating the rotational speed of the driving shaft. The other functions of the electromechanical test machine are described in details in the paper. Conclusions are made: the methodology for experimental research of rotational variability of cardan drives is improved; the application of electronic test machine verifies the advantages of the usage of high sensitive and precise sensors of new generation; contemporary approaches are applied.*

**Keywords**: CARDAN DRIVE, ROTATIONAL VARIABILITY, AUTOMATED TEST MACHINE, ENCODERS, DATA PROCESSING

## *1. Introduction*

The cardan coupling is applied for transmitting torque between shafts with intersecting axes. The main disadvantage of the single cardan coupling (joint) is the fact that by constant angular velocity of the driving shaft ($\omega_1$=const), the driven shaft is rotating with periodically changing angular velocity $\omega_2$. This specific feature causes dynamic loadings, which have unfavorable impact upon the driving characteristics.

The relation between the angles of rotation of the driving shaft $\varphi_1$ and the driven shaft $\varphi_2$ can be observed through the angle $\gamma$ (the angle between the axes of both shafts) in the following way: $tg\varphi_2 = \frac{tg\varphi_1}{\cos\gamma}$

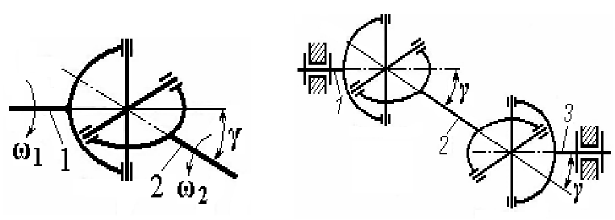


***Fig. 1*** *Scheme of a single and a duplicate cardan coupling*

Differentiating the indicated analytical expression concerning the time ***t***, the following relation between the angular velocities of the shafts: $\omega_1$ (for the driving shaft) and $\omega_2$ (for the driven shaft) is obtained:

$$\omega_2 = \frac{\cos\gamma}{1-\sin^2\gamma\cos^2\varphi_1}\omega_1$$

The variable angular velocity $\omega_2$ leads to changes of the torque $T_2$ (torque of the driven shaft) within one full rotational movement. These changes cause dynamic loadings which do not have positive influence upon the exploitation characteristics of the driven machine. The irregularity $\delta$ depends upon the value of the angle $\gamma$ (the angle between the axes of both shafts) and it is to be determined by the analytic expressions: $\delta = \sin\gamma.\ tg\,\gamma$.

The influence of this irregularity is not a positive phenomenon. Therefore, this specific parameter has to be investigated more thoroughly.

## *2. Prerequisites and Means for Solving the Problem*

Different methods and test devices for the determination of cardan drives' irregularity and variability are described in [1], [2] and [3]. The considered devices possess a variety of disadvantages: mechanical scales for reading data; not quite perfect coupling encampment; options for personal errors by reading the angular displacement, etc. Aiming to avoid errors and to ensure precise results, a new method for automated measuring the variability and irregularity of cardan drives is elaborated.

It is envisaged that the experimental measuring is to be carried out with the help of experimental test machine, in which the cardan drive possess very good bearing system. Besides, a registering system is to be also a component of the test machine. In order to achieve this objective a new test machine is designed. It will give the opportunities to register and analyze the existing irregularity of a cardan drive.

Measuring of rotational angles for different values of the angle of the intersection between the driving and the intermediate shaft and the angle between the intermediate and the driven shaft is envisaged. The experimental measuring will also be done by different rotational speeds of the driving shaft.

One possible method for reading the results is the application of electronic encoder. The design layout includes the data processing to be done automatically, with the help of device for collecting data (USB produced by the company National instruments).

The practical solution of the problem was based upon the professional experience of the authors' team.

## *3. Solution of the Examined Problem*

Fig. 2 shows the scheme of the test machine for automated data acquisition and for analysing the irregularity of cardan drives by transmitting motion.

The electronic encoders, item 1 on Fig. 2, are intended for measuring the rotational angle of the relevant shaft. The compensating couplings, item 2 on Fig. 2, form the connection between the driving and the driven shafts and the relevant electronic encoder.

The angular rotation $\varphi_1$ (of the driving shaft) and $\varphi_2$ (of the driven shaft) is to be converted by the corresponding electronic encoder in a signal sequence $N_1$ and $N_2$. The number of the signals in the relevant sequence is a function of the angular rotation: $N_1=f(\varphi_1)$; $N_2=f(\varphi_2)$.

The exact expression of the function is to be determined by the characteristics of the electronic encoders. Particularly, this function depends on the resolution capacity: number of signals per rpm (revolutions per minute) – [i/R].

The electronic encoders used in the test machine possess resolution capacity 1024 i/R. This kind of encoders ensures the necessary preciseness of the experimental research. Besides, if changes are to be envisaged these encoders can be replaced with other devices – from a higher class. It is especially important the parameter resolution capacity to be included in the software programme. Taking into account that the design of the applied encoders makes possible to realize and to convert a certain position, then the full resolution capacity is to be multiplied by four. The existence of zero pulse/signal (zero position of the shaft of the encoder) is to be used for starting the measuring.

The circular scales, item 4 on Fig. 2, ensure the opportunity for direct visualization of the shafts' rotation.

The generated signal sequence by the electronic encoders is designated respectively: **INPUT DATA** $(\varphi_1, \omega_1)$ and **INPUT DATA** $(\varphi_2, \omega_2)$. The signals enter the USB devices, item 6 on Fig. 2. Then, the number of signals gives information about the rotational angle $\varphi_i$ and the frequency of the signals carries data about the angular velocity $\omega_i$. After registering these parameters in the relevant USB device, they are to be transmitted to a personal computer PC, item 7 of Fig. 2.

The created files and records are to be processed by specialized programs. The USB modules are also special and they are used to convert the measure parameters and to read them. Their function includes also assigning control commands and modes to all other units in the program environment LabVIEW, which is installed on the PC – item 7.

The results' visualization in real time is displayed on the monitor of the PC, item 7, with the help of special software of the programme system LabVIEW.

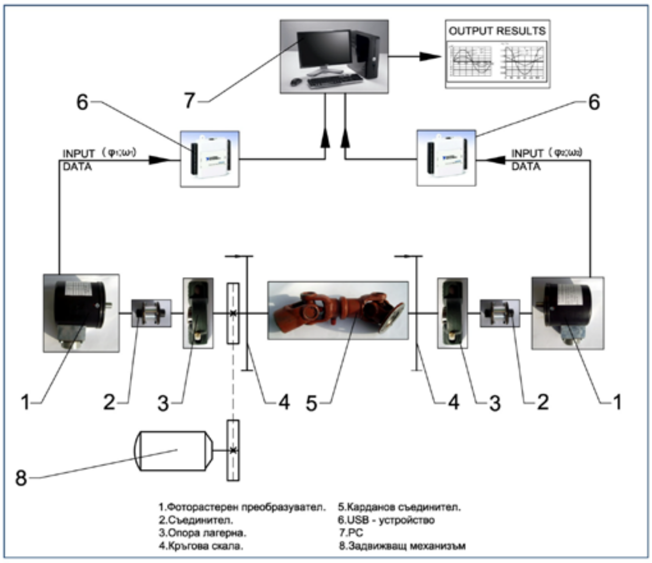


***Fig. 2** Scheme of the test machine for the experimental research of cardan drive*

The following methods for experimental research with the system are possible:

1. The experiment is started by manual driving of the input shaft, through crossing the zero position by the electronic encoder. The number of the signals (which is generated by the electronic encoder of the driving shaft) is reported through the **N** signal of the driving shaft.

Based upon this working approach, the relationship $\varphi_2=f(\varphi_1)$ is recorded over the angular interval $\Delta\varphi$. Such method of working with the system requires the opportunity for setting the parameter $\Delta\varphi$ and its relevant transformation in a number of impulses **N**.

The impulses, which are generated by the rotation in a reverse direction, are not to be reported by the designed system. In this case, the angular velocity $\omega_1$ is not constant.

2. Rotating the input shaft with constant angular velocity $\omega_1$, it is possible to carry out the measurements over a time interval $\Delta t$. This parameter has to be considered together with the magnitude of the angular velocity $\omega_1$ in order to reach the necessary preciseness.

In this way of working with the system, the relation: $\omega_2=f(\omega_1)$, is determined.

The application of the described methods and the designed test machine makes possible the achieving of the following positive results:

- The personal errors by recording the data during the implementation of the experimental measuring are avoided;

- Special registering system is applied aiming to increase the measuring preciseness;

- The registering system reports the values of the rotation of the driving and driven shaft with high accuracy in real time;

- The applied specialized software processes the results and gives the opportunity for their graphical visualization.

## *4. Results and Discussion*

In order to ensure the successful functioning of the test machine, special software product has been elaborated. This application converts data and makes possible the results' visualization in the environments of LabVIEW. The special features of this software application are described in details in [4].

The front panel of the developed (in the environment of LabVIEW) virtual instrument is shown on Fig. 3. It presents in a graphical way the relation between the ratio of the angular velocities and the values of the rotation of the driving shaft. Besides, the dependency between the difference of the rotational angles $\Delta\varphi$ and the same parameter: rotation of the driving shaft is also visualized. The obtained graphical functions, Fig. 3, correspond to 2 different values for the angle between the driving and the driven shaft of the cardan coupling: $\gamma$ = 15° and $\gamma$ = 30°.

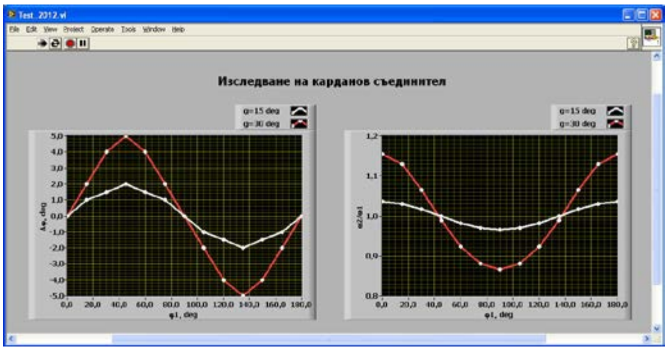


***Fig. 3** Front panel of the virtual instrument with visualization of the results from the experimental research*

The structure of the software application of the virtual instrument is presented through the block diagram, Fig. 4. This product has been developed especially for the designed automated test machine.

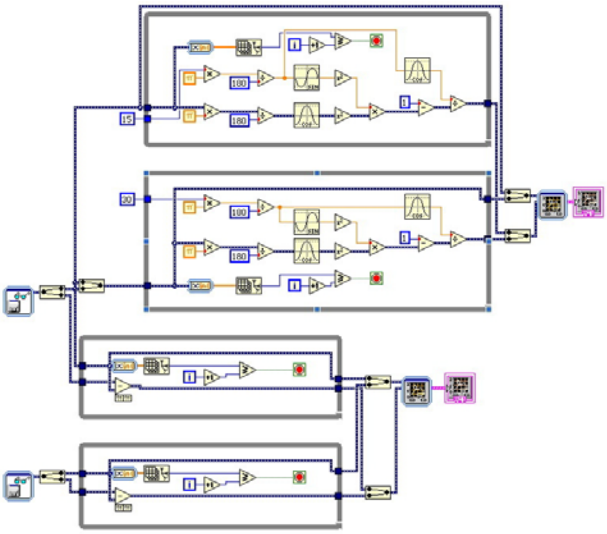

***Fig. 4*** *Block diagram of the virtual instrument, [4]*

The product LabVIEW has been selected due to the following reasons:

- The programmes, which are developed with the help of LabVIEW, can be regarded as virtual instruments. Their way of functioning is comparable to real devices;

- The virtual instruments consist of interactive user interface, diagram of data flow (program code – block diagram) and icons with links, which gives the opportunity to the virtual instruments to be accessed as a subprogram from other software instruments;

- The interactive user interface of the virtual instruments is characterized by a front panel, which can include (Fig. 5 and Fig. 6) keys, sliders, graphical display and other input areas and indicators.

The front panels, shown on Fig. 5 and Fig. 6, include a “button” for starting the program and another “button” for ending it.

One of the main advantages of the innovative test machine is that the experimental research can be implemented for different angles γ between the driving and the driven shaft.

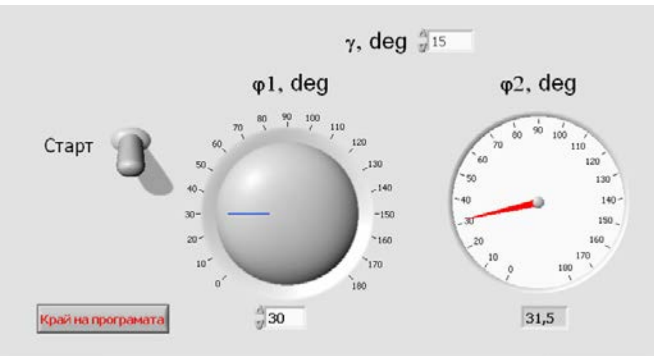


***Fig. 5*** *Front panel showing measuring results by* $\gamma = 15°$

Fig. 5 shows a front panel, which visualize in real time the experimental values of the investigated parameters for angle γ (between the driving and the driven shaft), equal to 15°.

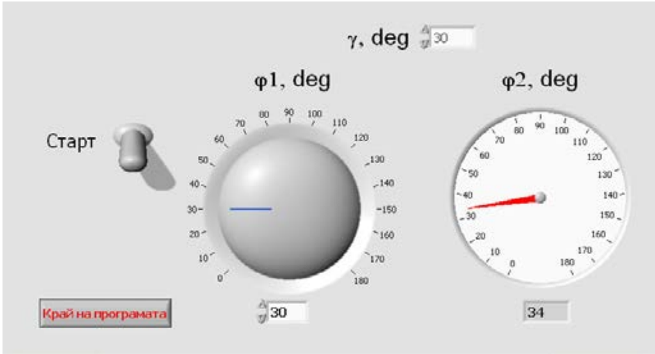


***Fig. 6*** *Front panel showing measuring results by* $\gamma = 30°$

Fig. 6 shows a front panel, which visualize in real time the experimental values of the investigated parameters for angle γ (between the driving and the driven shaft), equal to 30°.

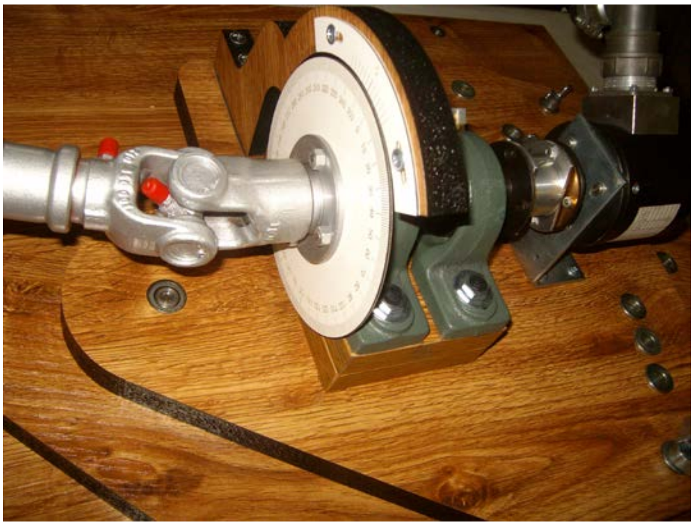

***Fig. 7*** *Photograph of the designed and produced test machine*

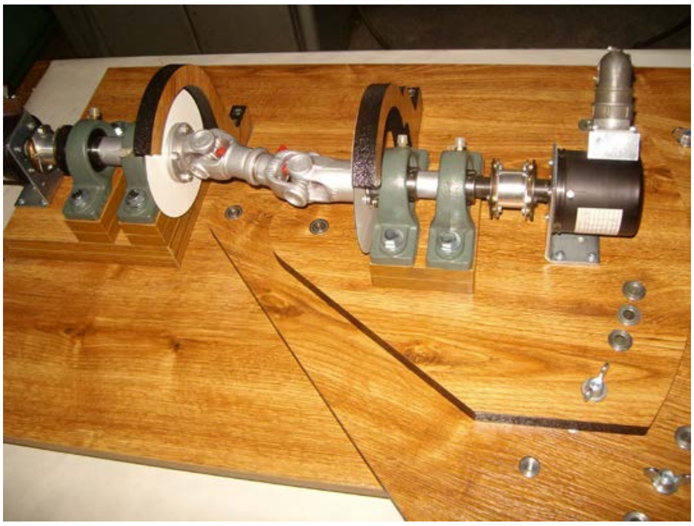

***Fig. 8*** *Photograph of the designed and produced test machine*

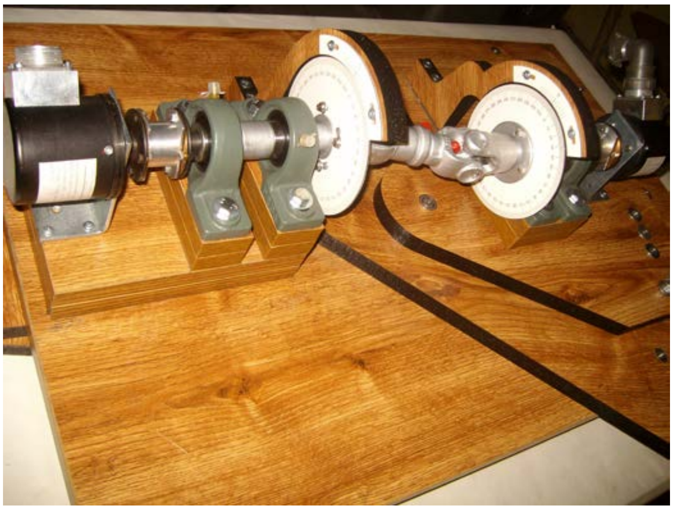

*Fig. 9 Photograph of the designed and produced test machine*

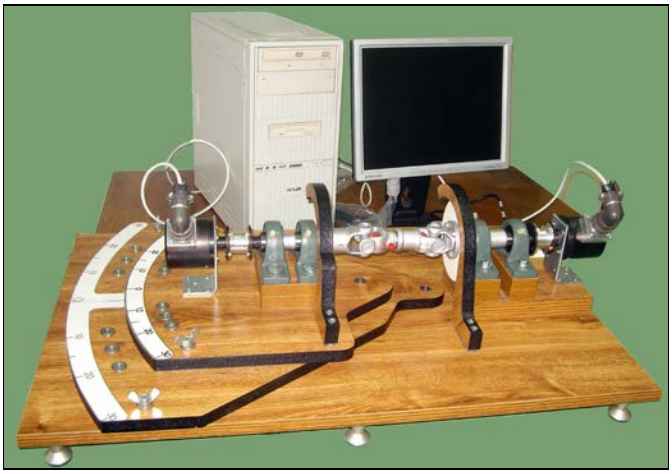

*Fig. 10 General view of the innovative test machine*

Several photographs of the innovative test machine for cardan drives are shown on Fig. 7, Fig. 8, Fig. 9 and Fig. 10.

## 5. Conclusions

1. The determination of the irregularity during the transmitting of motion in cardan drives is carried out through an innovative method. It has been developed by the authors' team based upon improved methodology for the investigation of the variability and the loading during the process of motion transmittion by cardan drives;

2. The processing of the input and output parameters is carried out automatically. The designed and produced mobile automated test machine with electronic measuring equipment works in the environment of LabVIEW. Special software for converting and controlling of signals and a program application for the obtained results' visualization has been developed;

3. The measuring of the rotational angles is implemented directly with electronic encoders;

4. The obtained results are visualized in real time on a monitor. This feature of the innovative test machine presents one of the main advantages of the developed method for the determination of the variability of the cardan drive based upon contemporary tools;

5. Significantly greater accuracy by the processing of the experimental data has been achieved.

The designed and produced automated test machine for cardan drives applies a new way of processing input and output parameters. Besides, it is able to work in the environment of LabVIEW and with the corresponding to this product specific hardware.

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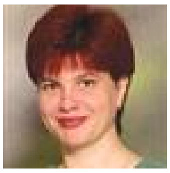

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