

nCode GlyphWorks Software Use for Test Data Processing

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Abstract

Some technique and results of experimental data processing on the stress-and-strain state study of wide-spray field sprayer boom parts have been described in the paper under discussion. The test data have been corrected to remove the data drift effect. Two approaches have been applied to correct the test data, namely the use of high frequency filter and the removal of the data array average values. The results of test data correction by the above-mentioned methods have intercommunicated very well. The data have been processed by nCode GlyphWorks software aimed at preparation for the further use of the obtained results to estimate the structure durability.

Keywords ¹

Experiment, test data, signal, processing, software, glyph, data correction

1. Introduction

Measurement, i.e. experimental determination of the values of physical quantities by special hardware, namely measuring apparatuses, is the basic way to obtain some information about the environment and the processes occurring in it. The measurements are the only way to prove or reject any statements or conclusions of theoretical models describing the real objects behavior.

Any experimental research has always involved some complex and time-consuming procedures dealing with data collecting and processing, analysis of the obtained information and construction of processes models and fields of various nature. Two approaches have been known to provide the analogue measuring signals recording aimed at further processing by digital methods [1].

One of the approaches is based on specialized complex systems use involving the equipment of analogue-digital conversion, microprocessors of digital processing and devices of information transformation. Another approach is based on the use of interface devices of data collection and universal computer systems.

As for the advantages of the second approach, based on the use of some additional interface modules and signals digital processors as parts of a personal computer, we can list the following ones: flexibility of a measurement system regarding the implementation of different algorithms of processing; functional completeness of the system (the tasks of data input, processing, management, analysis, visualization, measurements data and analysis results storage are being solved); good metrological characteristics.

In various spheres of reality, in particular, in economics, biology, medicine, technology etc are widespread conditional cyclic random processes and phenomena. The study of cyclical processes involving modern information systems requires the preliminary development of adequate mathematical models for them. Many different mathematical models of cyclic processes are known today, including harmonic, periodic and almost periodic deterministic functions, periodically correlated and periodically distributed random processes, linear periodic random process, almost periodically correlated random process, cyclic random process [2-6].

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In particular, the work [7] is devoted to the development of mathematical modeling of digital cyclic signals with double stochasticity, namely, the construction of their mathematical model in the form of a conditional cyclic random process of discrete argument.

In the paper [8] considers the unified approach to the modeling and processing signals of electrical, magnetic and acoustic (mechanical) nature based on the model of the theory of cyclic random functions, namely, using cyclic random process and vector of cyclic rhythmically related random processes.

In the paper [9] the new methods of statistical analysis of heart rhythm based on its generalized mathematical model in a form of random rhythm function, that allows to increase the informativeness and detailed analysis of heart rhythm in cardiovascular information systems are offered.

Nowadays, there is a great number of hardware and software for signals obtaining, segmentation, statistical analysis, processing and modeling. Although, many scientists have developed their own software to solve certain problems. It can be either a single-purpose software [10, 11, 12] or the whole program complexes [13].

Among the whole range of various software for the work with experimental data the software nCode made by the company HBM Prenscia [14, 15] has been of great interest, which was designed to process the signals, to work with large volumes of test data and calculation of the fatigue durability of the products.

nCode GlyphWorks software has a convenient object-oriented graphical interface and it is optimized for the complex work with large volumes of multi-channel data. The software functional includes a wide range of tools for temporary, frequency and statistical analysis of signals. Moreover, some tools are available to assess both the resource and fatigue durability of the products and synchronized reproduction of GPS signals, video and other data obtained during the tests, and also a convenient mechanism for automated creation of reports has been implemented.

nCode GlyphWorks software has a module system which enables us to create the required feature set either by means of large embedded libraries or by the use of language Python. Working templates in nCode GlyphWorks can be prepared in advance and can be found in the specified library to provide reliability and high speed of calculation. Thus, the users do not need to create the required feature set by themselves.

For effective work with such software it is necessary to have large sets of experimental data. The formation of such test data sets is an important phase of any scientific research, especially in modeling the dynamic load of parts and components of large mobile agricultural machinery.

Carrying out full-scale field tests of agricultural machinery involves significant costs and certain organizational problems, especially during a COVID-19 pandemic.

One of the ways to solve this problem is to conduct laboratory tests. However, such studies do not allow for a full set dynamic loading research of the large mobile agricultural machinery bearing structures.

To solve this problem the authors [16] developed a test bed for stationary semi-natural studies of the dynamic loading of wide-spray field sprayer booms. The test bed design is protected by a utility model patent [16]. Description of the design of the test bed for the study of the wide-spray field sprayer booms load dynamics and methods of semi-natural research are presented in [17].

The results of any measurements, despite the accuracy of the procedure, are likely to have some errors. It may be caused by the impact of different external factors on the measurement process result in an offset on the sensor output. This effect should be taken onto account as it may cause some errors in the results. In this case, the analysis of obtained results and errors of measurement has been an essential part of any scientific experiment, so a researcher must be able to apply some methods of test data correction.

2. Test data obtaining and correcting

The results of digital processing of the test data obtained by the authors [17] whilst studying the stress-and-strain state of a wide-spray field sprayer boom on purpose designed and made test bed to study the dynamic loading of mobile machinery [16] by nCode GlyphWorks software tools [15] are presented in the paper under discussion.

nCode GlyphWorks is a data processing system that contains a comprehensive set of standard and specialized tools for performing durability analysis and other insightful tasks such as digital signal processing. Designed to handle huge amounts of data, GlyphWorks provides a graphical, process-oriented environment that contains leading analysis capabilities for research of various processes.

2.1. Means of obtaining test data

Test data of any change in stress-and-strain state of a sprayer boom parts have been obtained by tensometric method with incoming signals recorded by the developed universal measuring system (fig. 1) fitted with analogue-digital converter (ADC) with the total number of measuring channels – 8, where the number of universal measuring channels – 5; the number of vibro-measuring channels – 2; the number of channels for angular velocity measurement – 1.

Universal measuring channels have provided the work with different resistive sensors and sensors with an outgoing signal as direct current voltage. Some possible work with different connection diagrams of resistive sensors has been provided as well: bridge, half bridge, quarter bridge, potentiometric ones. Discretization frequency can be specified within the range from 1Hz to 2 kHz. The minimal value of discretization period is 500 μ s (the same for all channels).

Power supply to the apparatuses has been provided by the alternative current mains of voltage 220 V 50 Hz or by the direct current mains of voltage 12 V.

The universal measuring system (UMS) has operating properly under the following environmental conditions: temperature of operation – from + 5 to + 55° C; storage temperature – from -10 to + 55° C; relative humidity – from 5 to 90 %.



Figure 1: Recording block of universal measuring system (UMS)

Whilst operating with an external computer a crate-controller is connected to a free port of a computer by a standard cable. Whilst operating in autonomous mode a crate-controller is connected to a parallel port plug-and-socket of a microcomputer by a bridge cable (fig. 1). The apparatuses are controlled in autonomous mode by a set of functional buttons.

The preset operation parameters of the universal measuring system include: gain ratio, cutoff frequency of low frequency, a mode of measurement, connection diagram of the channel, power supply voltage of sensors, values of zero shift (by default equals to 2048), a period of discretization (is set the same for all channels) and a kind of separating characters between the recorded data. These parameters are prescribed before the start of the measurements by means of MODE.DAT file formation and bringing it into the system memory where the codes of the system operation parameters values are recorded in columns for all eight channels of the system (a separate column corresponds to each channel). MODE.DAT file view illustration of universal measuring system settings to test the sprayer boom is shown on fig. 2.

Row	1	2	3	4	5	6	7	8	9
1	32	0	0	0	0	2048	2048	500	2
2	32	0	0	0	0	2048	2048	500	2
3	32	0	0	0	0	2048	2048	500	2
4	32	0	0	0	0	2048	2048	500	2
5	16	0	0	2	0	2048	2048	500	2
6	4	0	0	2	1	2048	2048	500	2
7	4	0	0	2	1	2048	2048	500	2
8	32	0	0	2	1	2048	2048	500	2
9									

Figure 2: Universal measuring system (UMS) settings file to test the sprayer boom

The results of measurements are recorded as a 12-bit code and are given by the universal measuring system as DATA.DAT file where the data of each channel is recorded in a row as digital codes separated by a separating character whose form is prescribed in previous settings of the system in MODE.DAT file. Thus, in the obtained data array the information from each specific channel of the universal measuring system is recorded in every eighth log. These data flow is a set of different digital codes which should be given in more convenient for calculations form. To achieve this goal there is a special technique of preliminary processing of test data prior to their possible use in further calculations.

A special software providing the data sorting of the obtained array to certain channels and reducing the digital codes of each channel to the real physical quantities with dimensional units (such as, for example, deformation (*mm*) or stress (*MPa*)) has been developed [12] for test data preliminary processing. The program interface view illustration (interface is in Ukrainian) is shown on fig. 3.

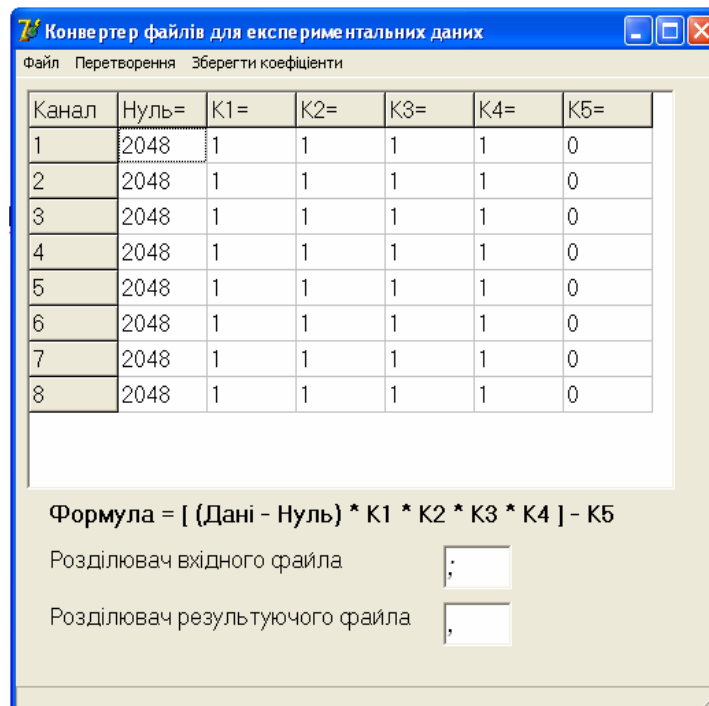


Figure 3: Program interface to converting test data array obtained from UMS

Converting of the digital codes of data array to the real physical quantities with dimensional units has been provided by formula (see the program interface on fig. 3) by means of taking into account a number of coefficients: zero level of data (Нуль =); tensosensors calibration test coefficient, amplification factor, and others (K1–K4); coefficient of static stress level (K5). The level of static stress should be taken into account when tensosensors are installed on preliminary loaded parts of a bearing structure. For analytical determination of static stress level in the components of the boom

structure under discussion a mathematical model has been developed which describes the distribution of internal efforts in the sprayer boom parts on the basis of the potential energy of deformation minimizing method [18].

Due to the test data array processing by the developed program [12] we have obtained eight files *ChannelN.txt* (where $N = 1 - 8$ matches the channel order number) with the data prepared for the signal processing from each channel. The data from the first four separate tensometric channels of the universal measuring system (fig. 4) is a function of time, their amplitude and level are constantly varying.

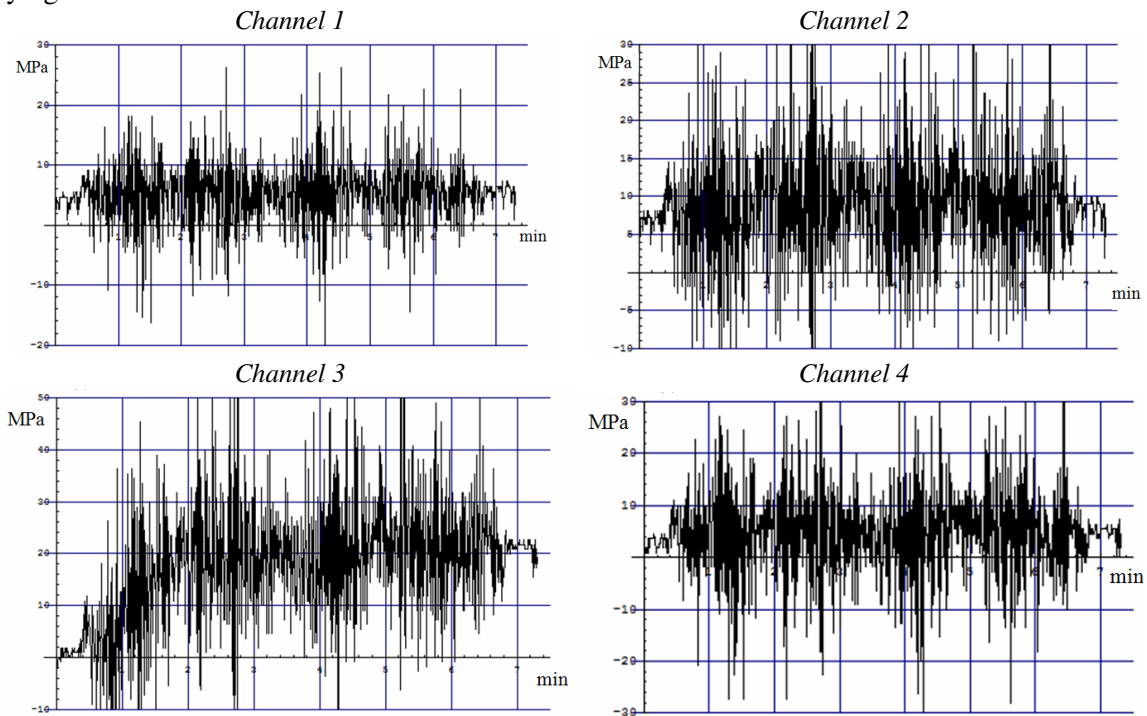


Figure 4: Test data of tensometric channels of UMS at test of the sprayer boom

Despite the curves start from the nominal zero, a so-called drift (offset) can be observed here which varies between the channels and non-linearly over time. It has been caused by the impact of different external factors (change in temperature, screen grid guidance, contacts reduction due to the vibration action, humidity etc.) on the measurement process resulted in an offset on the sensor output.

This caused a final value displacement at the end of the test that is no longer the expected zero value. This effect should be taken onto account as it may cause some errors in the results which are important in assessment of the structure fatigue durability.

2.2. Test data correction

Under test data digital processing conditions by specialized software tools the data drift effect has been corrected by the use of various linear filters with maximal flat amplitude-frequency characteristic in the range of transmission.

A method of test data correction has been used to remove the drift effect in the paper under discussion. The above-mentioned method consists in separation of average values from the data array so that to reduce the curves to the nominal zero level. Data correction will be provided by software tools nCode GlyphWorks aimed at their preparation for further use in the structure durability assessment by software tools nCode DesignLife.

GlyphWorks is a multi-file, multi-channel, multi-format environment for processing large amounts of data. GlyphWorks represents data analysis processes graphically. It lets drag and drop graphical representations of interactive data analysis processes that allow create and save sophisticated working projects for later re-use.

The basic analysis building blocks used in GlyphWorks are termed glyphs. Glyphs are connected by pipes, which contain the data that passes between glyphs and attach at the glyph's pads (different types of I/O pads are marked with different colors).

In fact, Glyph is a calculation module (template) with specified algorithms of certain functions performance and with possible setting of different parameters of its properties. A set of glyphs with functional connections is the detailed design of the research.

The general view of Interface nCode GlyphWorks is shown on fig. 5. These are the main windows of the GlyphWorks interface (there are several other windows that can be turned on using the View menu):

1. Analysis Workspace — Where the process is created
2. Available Data — Data that can be analyzed
3. Diagnostics — List of process, error messages, etc.
4. Glyph Palette — Glyphs available for processing

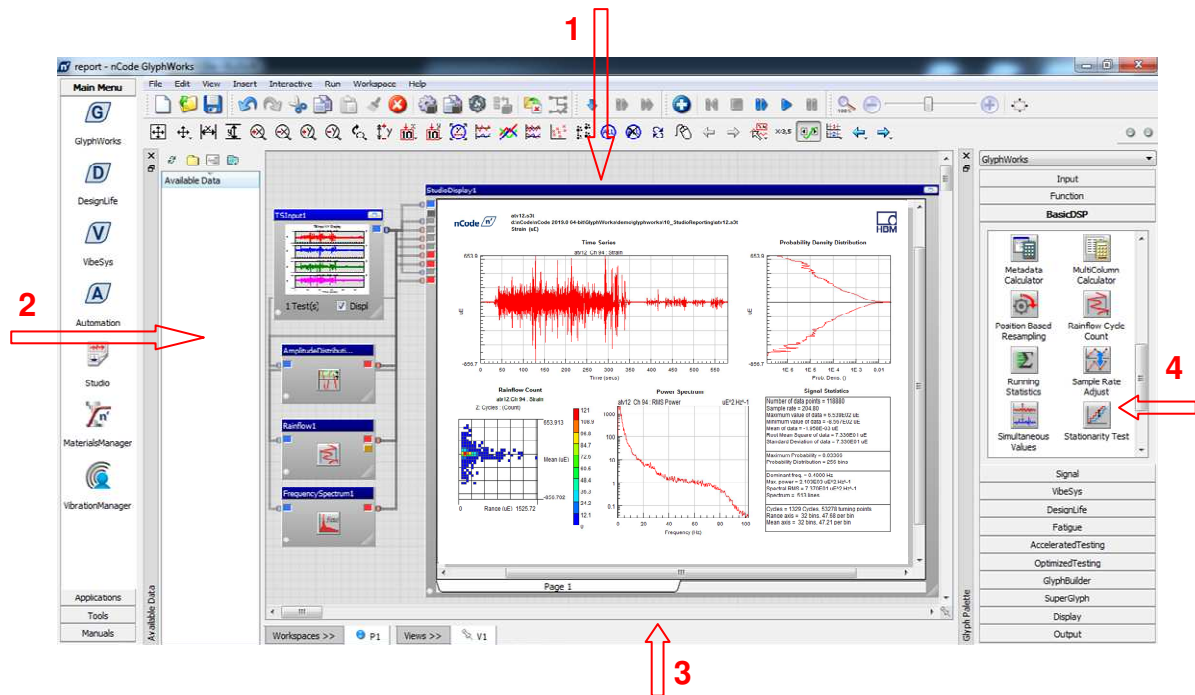


Figure 5: The main windows of the GlyphWorks interface

GlyphWorks glyphs are classified according to their functionality. The glyphs are available in the glyph palette (the window on the right side на рис. 5). There are sections in the glyph palette for glyphs that input data, perform basic digital signal processing (DSP), display results, and so on.

Glyphs are organized into the following categories (palettes), according to their functionality: Input; Function; BasicDSP; Signal; DesignLife; Frequency; Fatigue; AcceleratedTesting; Optimized Testing; GlyphBuilder; SuperGlyph; Display and Output.

Glyphs and input files, etc., can be dragged onto the workspace from their respective palettes.

In GlyphWorks, a process is defined as a combination of glyphs that define a data flow. A process typically starts with an input glyph to define the data to be processed. Additional glyphs define subsequent steps in the process for calculation, display, or writing output.

To implement the procedure of test data correction a detailed design has been developed (fig. 6) containing the following structural elements (glyphs): Exel Input, Multi-Column To Time Series, Running Statistics, Arithmetic, Time Series Output, XY Display. Functional purpose, parameters settings of these glyphs and structural relations between glyphs are described lower.

Structural elements (glyphs) with relations can be combined conditionally into functional blocks (fig.6) where the successive steps of test data correction procedure are taking place and the obtained results are represented as curves:

- I – a block of incoming data input,
- II – a block of incoming data statistical processing,
- III – a block of mathematical operations on incoming data,
- IV – a block of results analysis and comparison,
- V – a block of results saving.

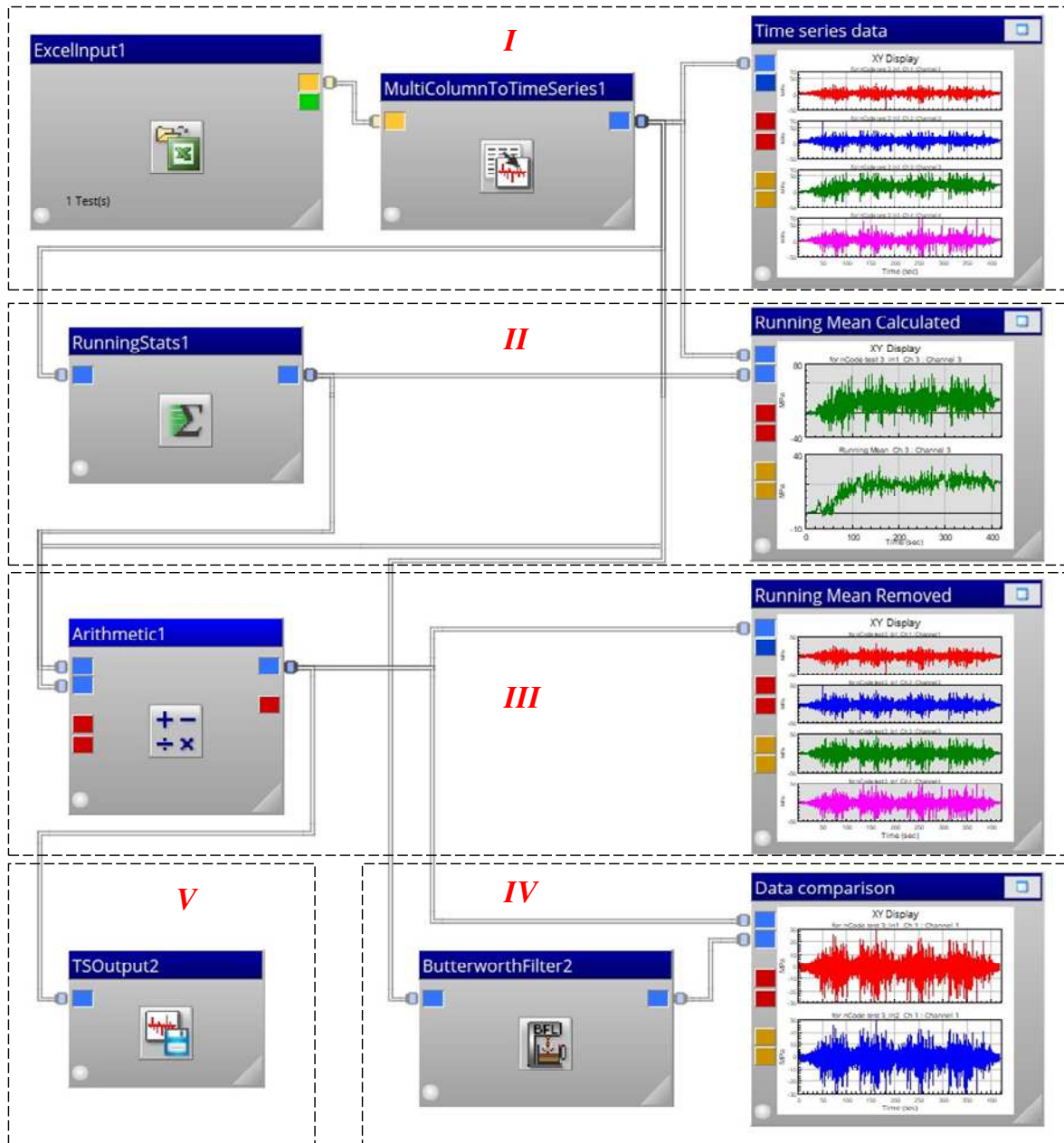


Figure 6: The process flow that removes running mean of the sprayer boom test data (completed)

To input some test data into the detailed design an executable file *.xls* has been formed where the data columns from binary files were added including the results of primary processing of four tensometric channels (fig.4). Above each data column the lines are located with channel name (*Channel1- Channel4*) and units of measurements (*MPa*).

The obtained executable file *.xls* was uploaded to the glyph of multicolumn data ExelInput1 (fig.6, block I). For correct representation of the uploaded data in glyph ExelInput1 settings it is necessary (fig. 7):

- in section Column Title Cells the tape cells with channels name should be specified;
- in section Column Units Cells the tape cells with dimensional values should be specified;
- in section Value Cells the tape cells with the initial data of the columns should be specified;
- Process rows up to first empty row should be specified.

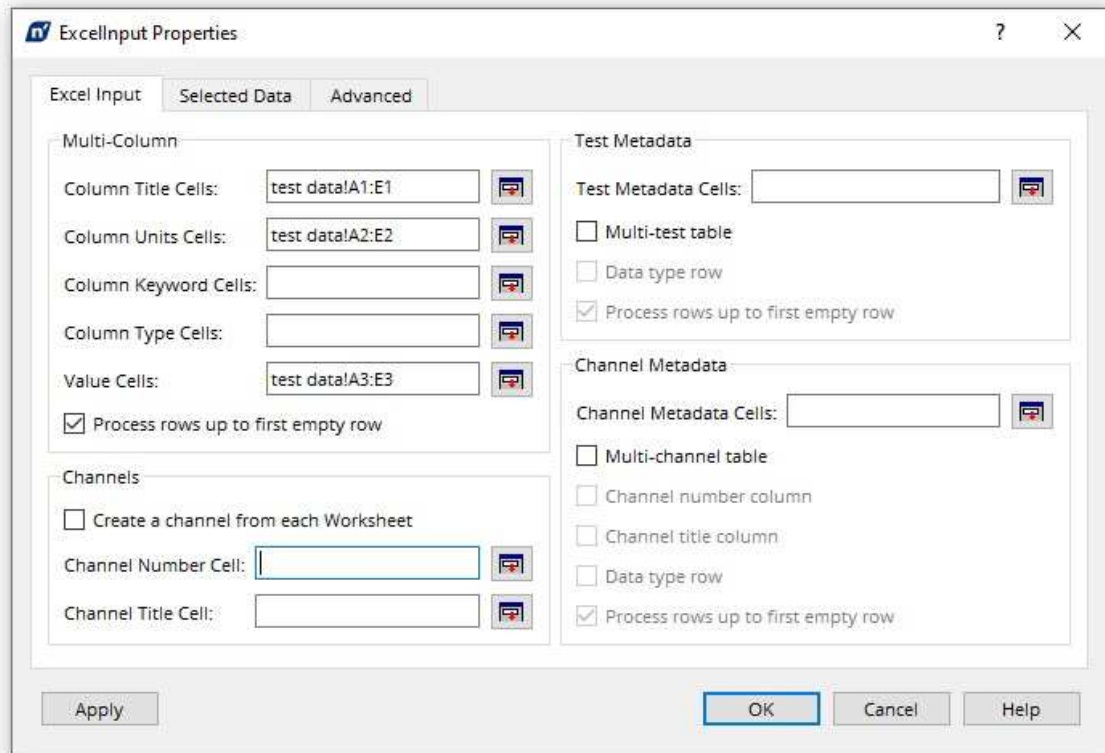


Figure 7: ExelInput1 glyph properties

MultiColumnToTimeSeries glyph (fig.6, block I) is used for the conversion of multi-column data into the data of temporal series. The glyph is connected to the orange output pad on ExcelInput1.

The following parameters should be specified in the properties of this glyph (fig. 8):

- Method → Resample;
- SampleRate → 500 (fig. 2);
- Interpolation → Linear.

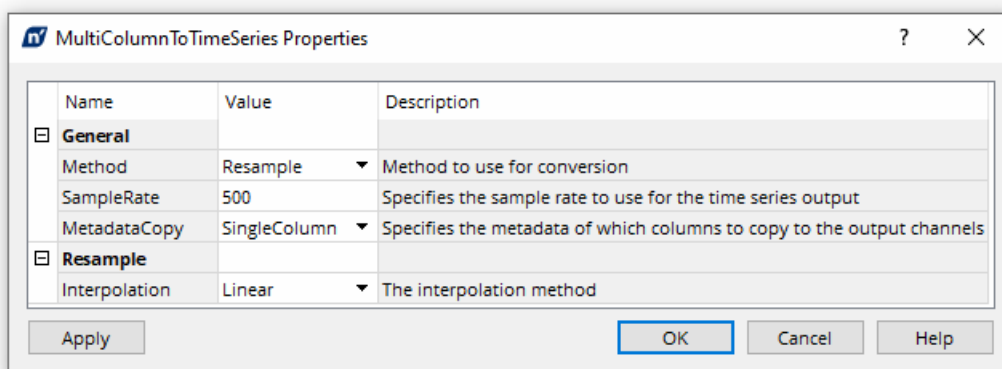


Figure 8: MultiColumn to Time Series glyph properties

XY Display glyph has been used to show the incoming data. On fig. 6 it is renamed as Time Series Data. This glyph input is connected with the glyph MultiColumnToTimeSeries output. The incoming data representation results of are shown on fig. 9.

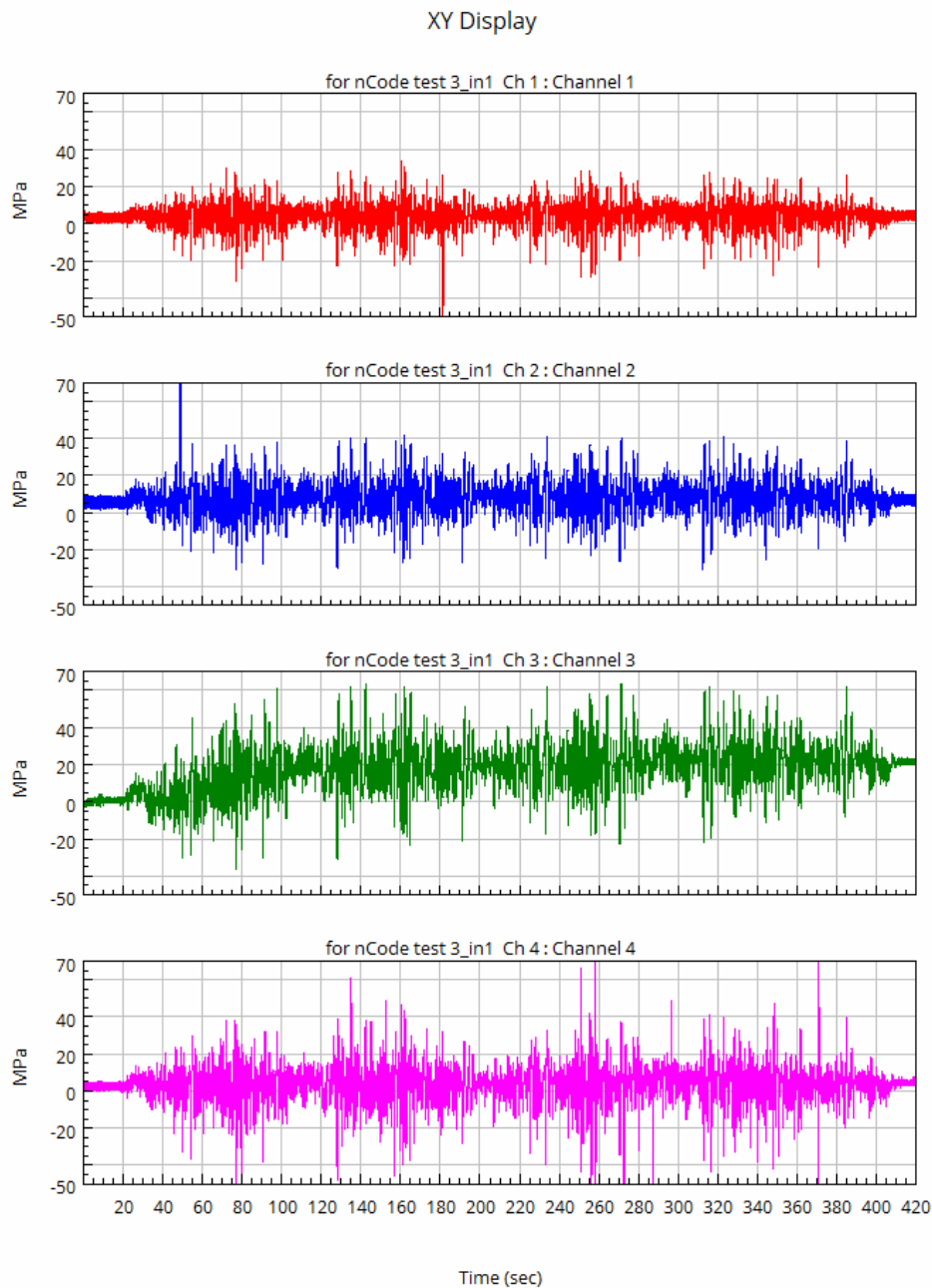


Figure 9: Incoming data curves

A special glyph Running Statistics has been used for incoming data statistical processing enabling us to process the data by methods of mathematical statistics using the special methods nCode. This glyph input is connected with the glyph MultiColumnToTimeSeries output.

In the settings of calculation template RunningStats1 in Tab General (fig. 10) we have chosen a type of data statistical processing Mean (by average value). The parameter ProcessingMethod determines how the current data will be processed. We have chosen the method PointByPoint where each value of test data will be processed in a series resulted in a set of sequential measurements and the general statistics of the experiment will be formed on their basis. Such method guarantees that the source file with processed data will have the same amount of data that the initial original file contains.

In the tab WindowLength we have specified the number of displayed points in the parameters of visualization – 1000.

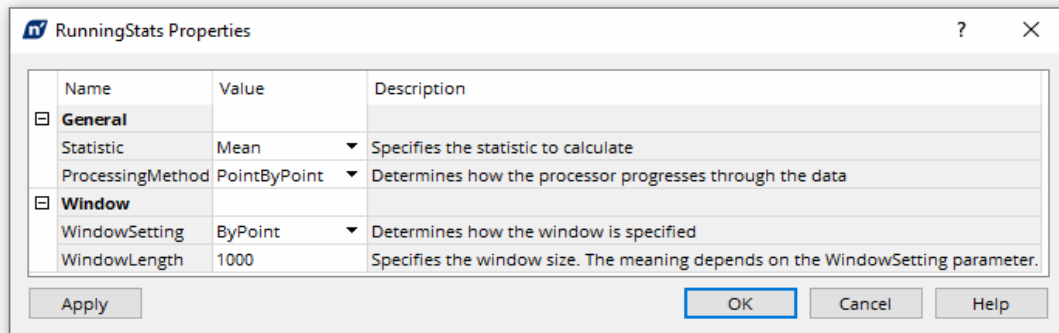


Figure 10: Running Statistics glyph properties

The results of statistical processing of test data from *Channel 3* by their average value are shown on fig. 11. On fig. 6 this glyph is renamed as Running Mean Calculated. The first input of this glyph is connected with the output of MultiColumnToTimeSeries and the second input is connected with RunningStats1. Thus, the upper curve shows the data incoming array from *Channel 3*, and the lower one represents their average values. It has made possible to follow the data offset on the curves and to estimate the drift of the most important values of the results.

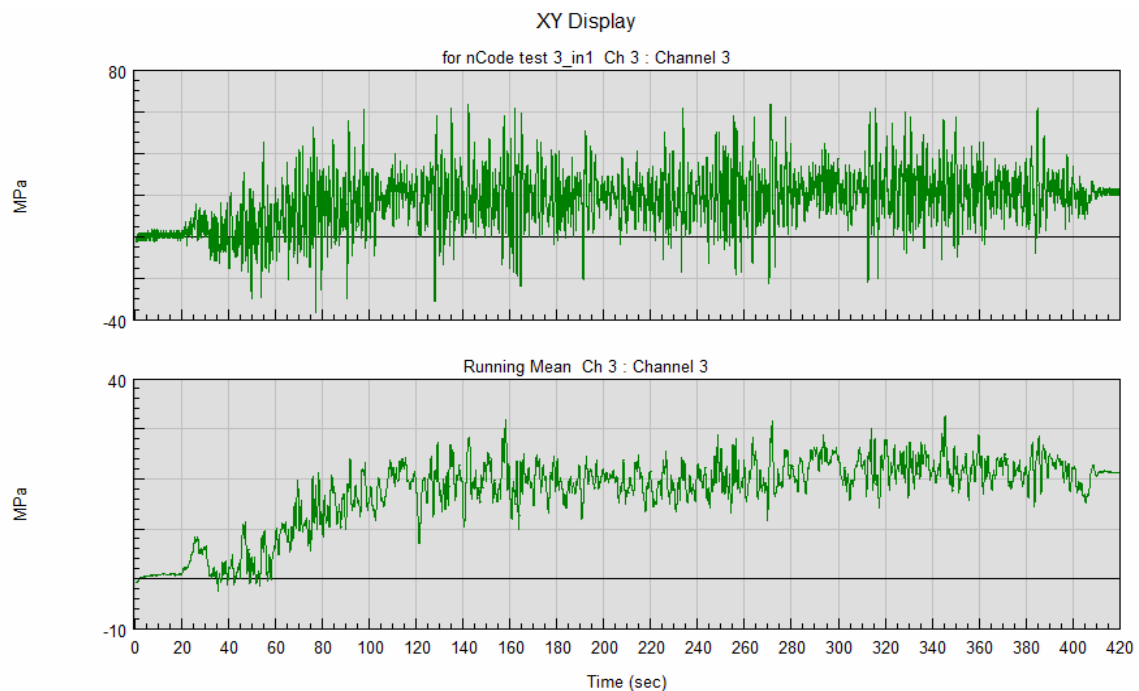


Figure 11: Running Mean Calculated glyph

Glyph Arithmetic1 makes possible to perform mathematical operations on the data prepared in advance. The first stroke of this glyph is connected with the output MultiColumnToTimeSeries and the second output is connected with RunningStats1.

In settings of the glyph Arithmetic1 (fig. 12) in the tab General in section Operator we have chosen the type of arithmetical operation Equation. In section EquationDefinition we write the parameter Equation as «Test 1 – Test 2» (difference in incoming and processed in the module RunningStats1 data array).

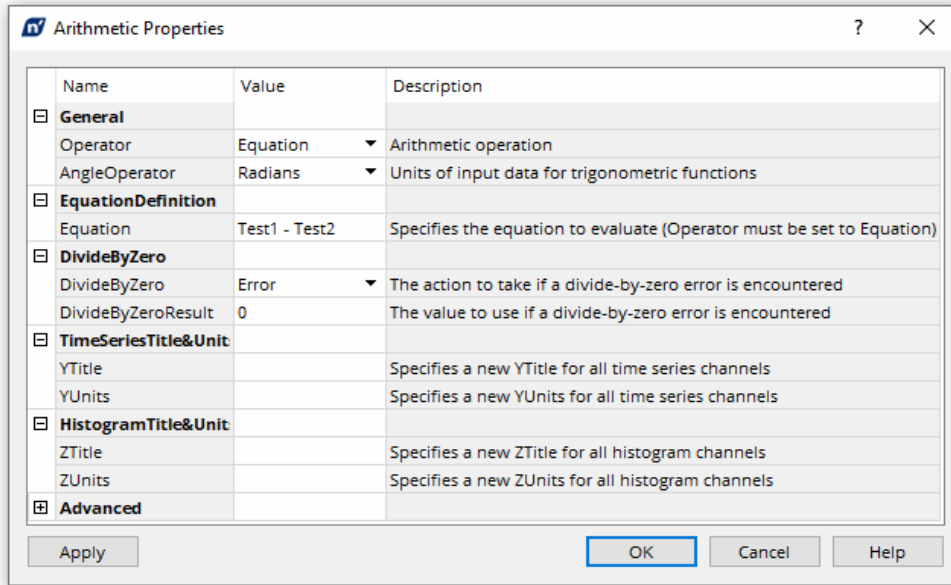


Figure 12: Arithmetic glyph properties

The results of test data processing by glyph Arithmetic are shown on fig. 13. On fig. 6 this glyph is renamed as Running Mean Removed. This glyph input is connected with the glyph Arithmetic1 output. The obtained data have not included “spurious” current data yet which can alter the general operating characteristics of the unit under discussion.

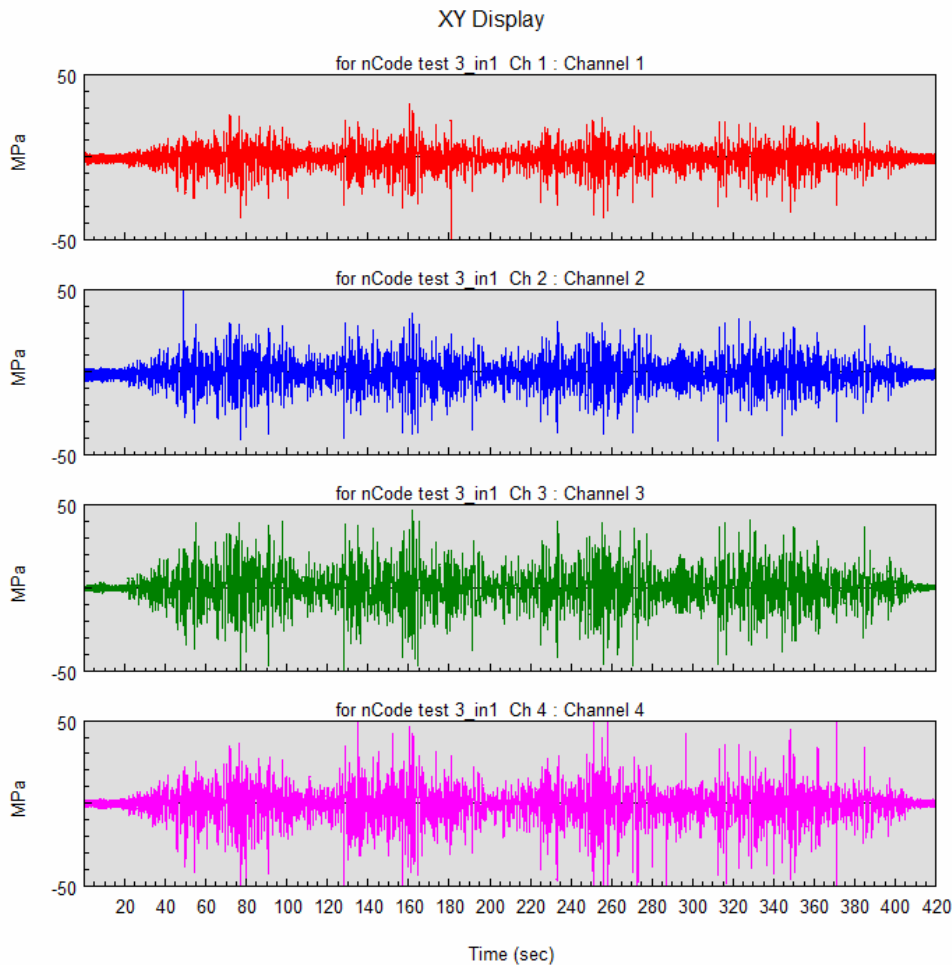


Figure 13: Resulting data with running mean removed

In practice one should always be careful while using such techniques and manipulations with the data arrays as a share of valid data can be lost after some mathematical operations resulted in the distortion of the real process description. It is necessary to check and analyze the obtained results.

To check the adequacy of the obtained results we have compared them with the results of incoming data processing by means of the standard procedure, such as, for example, the use of a filter of high frequency which enables to isolate the low frequency signals from the data array.

In nCode GlyphWorks this possibility can be implemented by frequency filter based on the tool ButterworthFilter. For this purpose, we have added the glyph ButterworthFilter from section BasicDSP (basic digital signal processing) to the temporary field of the project. For the correct connection of this filter to the detailed design we have connected the template MultiColumnToTimeSeries output with the template ButterworthFilter input and we have connected the template ButterworthFilter output with another input of the pattern Data Comparison. We have connected the first input of this pattern with the output of the glyph Arithmetic1.

To set the calculating pattern ButterworthFilter we choose the type of filtration HighPass in its characteristics, method of filtration – ForwardAndBackward, parameter Order (ranking) – 8, filtration frequency Frequency1 – 0,1 and parameter DCWarning (percentage of errors) is specified as 0,01.

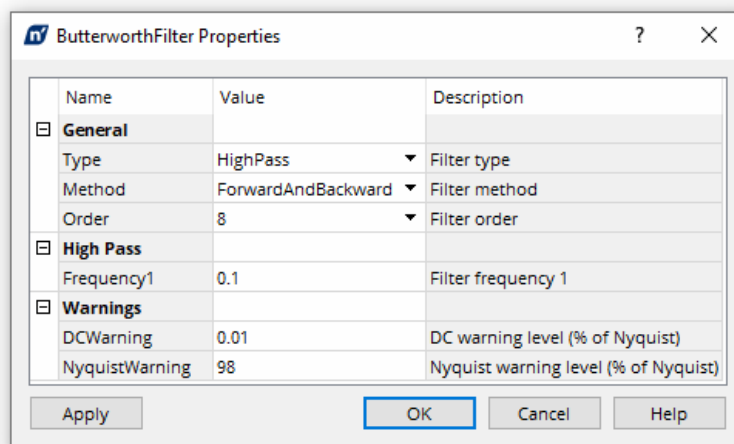


Figure 14: ButterworthFilter glyph properties

After calculations in the graphic glyph XY Display (entitled Data Comparison on fig. 6) two curves will be displayed (fig. 15, a) obtained due to the incoming data array processing by two different methods – by average values subtraction of the initial data array and using the filter of high frequencies (the curves only from the first channel are shown on the figure). To draw the curves the first input of the glyph Data Comparison was connected with the glyph Arithmetic1, the second one – with the glyph ButterworthFilter2 output.

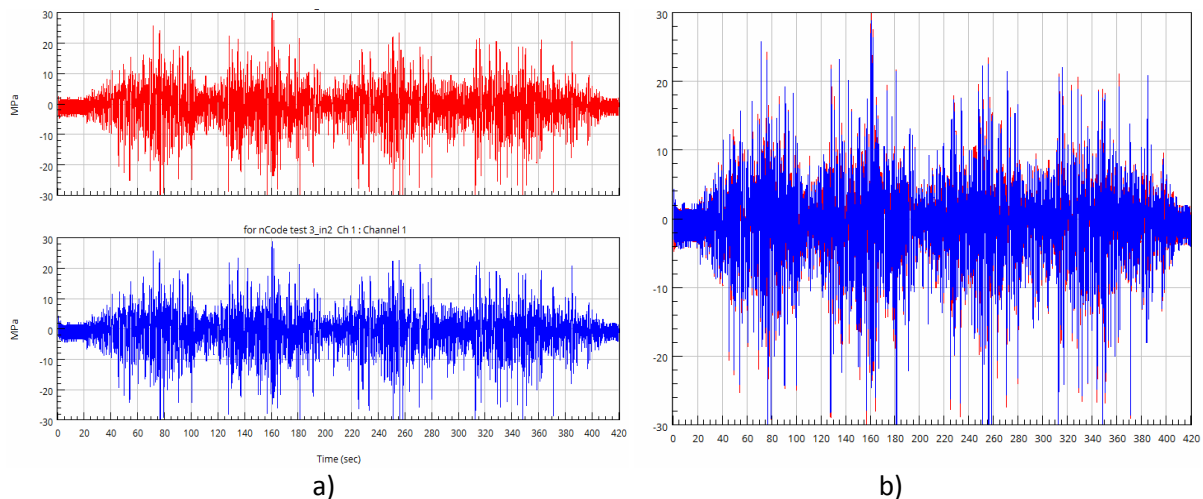


Figure 15: Comparison of test data array correction by two methods

To make the comparison more convenient these curves have been superimposed (fig. 15, b).

As we can see on fig. 15 the results of test data correction by two methods intercommunicate very well. Moreover, both methods from the engineering point of view correctly describe the conversion procedure of the results obtained by the method of signals digital capture from the tensosensors installed on the real structure. In these corrected data the drift of average values of the process indices has already taken into account and we can be sure that the amplitude will vary correctly enabling to determine the real number of cycles of the structure loading according to the techniques and theoretical substantiation of the above-mentioned results [19].

The following ways are mostly used in calculations: of maximums, of ranges (amplitudes), of augmented ranges, of complete cycles, "rain-flow" method. The main advantage of these ways is that they do not restrict the schematized process, i.e. any mode of loading can be processed by these methods [20].

By means of the glyph TSOOutput2 the obtained results, which are the function in time, are recorded in a separate file of the pattern **.s3t* with the prefix *_out*. The obtained file with the processed and prepared test data can be further used to calculate the fatigue durability of the structure.

3. Conclusion

The results of any experimental research dealing with data collecting and processing, are likely to have some errors. The analysis of obtained results and errors of measurement is an essential part of any scientific experiment, so a researcher must be able to apply some methods of test data correction.

At present, there is a great number of software for signals obtaining, segmentation, statistical analysis and processing. The software nCode, which was designed to work with large volumes of test data, makes possible to carry out processing of experimental signals, both by standard methods and by the developed alternative techniques of data processing.

In the paper under discussion the drift of experimental data has been corrected so that to reduce the test data curves to the nominal zero level. Two approaches have been applied to test data correction to remove the drift effect, namely the use of high frequency filter and the removal of the data array average values. The results of test data correction by two methods have intercommunicated very well.

Both methods from the engineering point of view correctly describe the conversion procedure of the results obtained by the method of signals digital capture from the tensosensors installed on the real structure. The obtained results can be used in carrying further out research of the structure durability.

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