Assisted Research of some Dynamic Behavior Robot's Parameters

Adrian D. Olaru, Serban A. Olaru, Niculae C. Mihai, and Natalia M. Smidova

***Abstract*—Optimization in Robotics is one of the most important problem to be solved because for that will be possible to obtain the best results to control the space trajectory, to control the vibration with final goal to obtain the extreme precision and stability. In the paper are shown the research of some dynamic behavior parameters like global dynamic transmissibility (*GDT*), global dynamic compliance (*GDC*) and damper's transfer function (*DTF*). All the assisted research were made by using the virtual LabVIEW data acquisition instrumentation and the acquisition board from National Instruments, USA. The applied method solves one small part of the complex problems of the optimisation in robotics.**

***Index Terms*—Assisted research, virtual instrumentation, dynamic behavior parameters, global dynamic compliance, global dynamic transmissibility, damper's transfer function.**

I. Introduction

The optimizing of the dynamic behavior in Robotics is one of the most important problem to be solved. Without the assisted research isn't possible to study the dynamic behavior because will be necessary to show the variation of the dynamic parameters vs. frequency, to identify some new dynamic behavior parameters, to construct some Fourier spectrum for him, to assisted study of him and establishing the frequency domain where: the damper is efficiently; the transfer function of the damper is maximum; the transmissibility of the vibration between the robot's base and the end-effecter is decreased; the compliance is minimum to be obtained the maximum of the stiffness.

The assisted research was made by using the proper virtual LabVIEW instrumentation and the acquisition board from National Instruments, USA. The stand used for the research is shown in fig.1, for the assisted dynamic behavior parameters of one didactical arm type robot.

The basic concept of the transmissibility, compliance and damper transfer function can be found in almost every vibration fundamentals manual. The definition of the concept of transmissibility rarely was presented, being widely accepted the following formulation [Tustin 2005] [1]: ‘’Transmissibility: In steady-state vibration, transmissibility is the non-dimensional ratio of response motion / input motion: two displacements, two velocities or two accelerations...". Another more complete formulation of the concept, can be found in [Licker 2003][2]: "Mechanical Transmissibility: A measure of the ability of a system either to amplify or to suppress an input vibration, equal to the ratio of the response amplitude of the system in steady-state forced vibration to the excitation amplitude; the ratio may be in force, displacements, velocities, or accelerations". The reviewed literature use the transmissibility function term to define the functions that correspond to the above definitions. There are some exceptions, like in [Pietrzko 1991][3] paper, who introduced the transmissibility in place of the Frequency Response Function (*FRF*) term, a special case of a function for an un-damped vibratory system.

Precision and stability of all dynamic systems is one of the more important contradictory problem what must be solved by assisted research. This problem is contradictory because if we try to increase the precision imposed from the application, the stability decrease and will be possible to touch or to be closer to the limit of stability, when the element or system couldn’t be controlling more, otherwise if we try to increase the stability, the precision will decrease and the element or system will be very slow and will not be able to respect the minimal limit of the desired promptitude [4]-[11]. The other more important thing in the optimization field of the robots' is the global dynamic compliance (*GDC*) that influences the robot's behavior. In the paper is shown the assisted method with the proper virtual LabVIEW instruments (*VI*) for the theoretical and experimental assisted research of one didactical arm type robot with DC motors. The virtual instruments were achieved in the LabVIEW^{TM} soft 8.2 from National Instruments, USA. By data acquisition of the velocities, accelerations, damper force, excitation force and after generating the Fourier spectrum for them will be possible to choose the optimal frequency field for all dynamic behavior researched parameters [10]-[15]. This method will be possible to be used in the assisted research of the many other mechanical applications where it is necessary to know the dynamic behavior, the vibration spectrum and how the constructive and functional parameters of the DC servo systems and the robot's movements in up or down directions (the equilibrium of the robot’s arm) determine the major changes of the spectrum and of the dynamic behavior. Now, in the world, all of the dynamic behavior parameters, or the vibration spectrum are made with some complex apparatus with the expensive cost, not by using the LabVIEW instrumentation. This paper tries to develop one general assisted methodology of some dynamic behavior parameters in the real and frequency domain of the articulated arm type robot. In the paper were solved the following problems: (i)the

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theoretical and the experimental assisted research with data acquisition by using the proper theoretical and experimental LabVIEW *VI*; (ii)the optimization of the dynamic behavior with the virtual proper *VI*-s, by establishing the frequency field of the maximum of the damper force (*DTF*), the minimum of the global dynamic compliance (*GDC*), the minimum of the global dynamic transmissibility in the frequency field (*GDT*).

The Global Dynamic Compliance (*GDC*), the Global Dynamic Transmisibility (*GDT*), the Damper Transfer Function (*DTF*) [16]-[20] are some of the most important parameters of the dynamic behavior of the industrial robot. In the manufacturing systems is necessary to know the vibration behavior of the maschine where will be put the robot, the Viscose Global Dynamic Damper Coefficient (*VGDDC*), or the Viscose Global Dynamic Damper Equivalent Coefficient (*VGDDEC*) of his structure and how the variation of accelerations determines the damped mechanical vibrations of the application, to avoid the resonance frequencies from the Fourier spectrum. The paper shows for the first time one assisted research method with proper virtual LabVIEW™ instruments for determining the *GDC, GDT, DTF* of the stationary robots. These virtual apparatus that were designed are generally and they can be used in many others mechanical researches and applications. Now, in the world, the *GDC, GDT* and *DTF* are not determined for the robots in this maner and for that this paper presents a novelty in the Robotics field [21]-[54].

II. The Assisted Research

A. Stand Used in the Assisted Research

In all assisted research study cases, the design, modeling and simulation offer some on-line results what can be used to choose some optimal values of the constructive and functional parameters to obtain one required dynamic behavior: without vibration components in the resonance field, without vibration with large amplitudes, one short acceleration time in concordance with the accepted vibration field, minimal stationary errors of the space trajectory of the end-effecter, one bigger Bode frequency to assure one minimum acceleration time, one higher cutting Bode frequency, one higher proper and natural frequencies. In the proper assisted research papers [9]-[11], [15] were shown some results that can be used by the researchers in the robot design activities.

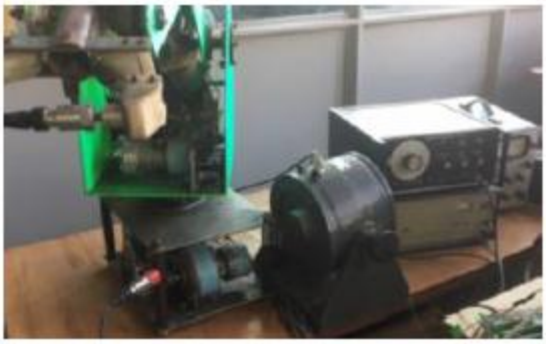

Fig. 1. Research setup of the *GDC, GDT, DTF*.

The experimental setup contents the followings: - the didactical arm type robot that used for the research;- the exciter systems with the following components: frequency generator to assure the periodical sinusoidal signal with different frequencies and amplitudes; the amplifier to increase the applied electrical tension to the exciter; the electro dynamic exciter that transform the electrical exciter tension in the exciter force with different magnitude and frequencies; - the measure system with the following components: the inductive transducer to determine the damper force; the air damper; the inductive Hottinger bridge to measure the damper force; the tacho to determine by integration the displacement of the robot's arm; the electrical resistance positioned on the excitation electrical wire to measure the tension loss and convert them in to the excitation force; two accelerometers to measure the acceleration on the robot's base and end-effecter; the connector of the acquisition board; the acquisition board from National Instruments, USA; the LabVIEW soft and the acquisition virtual instrument *VI* for the 5 channels- robot's base acceleration, end-effecter robot's acceleration, excitation force, velocity of the robot's arm and damper force.

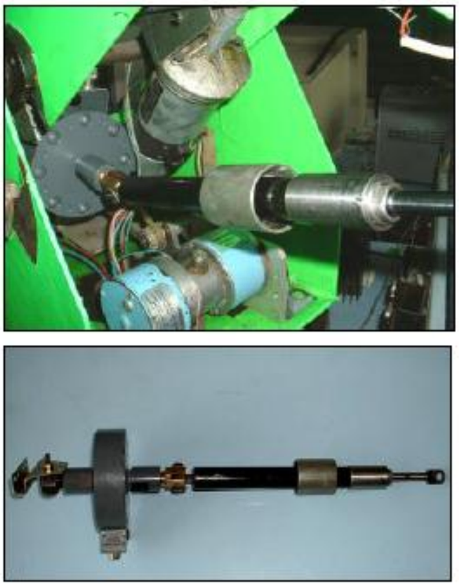

Fig. 2. The part of the setup: a) air damper; b) air damper with inductive traducer.

B. The Research Method

The assisted method for the research of the *GDC, GDT, DTF* used the acquisition data from the traducers and used the following mathematical forms:

$$GDC = \frac{FFT(x)}{FFT(F_{ex})} \quad (1)$$

$$GDT = \frac{FFT(a_{end})}{FFT(a_{base})} \quad (2)$$

$$DTF = \frac{FFT(F_d)}{FFT(F_{ex})} \quad (3)$$

where: *GDC*- global dynamic compliance; *FFT*(x)- fast Fourier transform of the displacement of the robot's arm; *FFT*(F_{ex})- fast Fourier transform of the excitation force on the robot's base; *GDT*- global dynamic transmissibility; *FFT*(a_{end})- fast Fourier transform of the robot's end-effecter acceleration; *FFT*(a_{base})- fast Fourier transform of the robot's base acceleration; *DTF*- dynamic transfer function; *FFT*(F_d)-

fast Fourier transform of the damper force; *FFT*(F_{ex})- fast Fourier transform of the excitation force.

For determine the *GDC*, was measured the displacement of the robot's arm and the excitation force on the robot's base, during the variation of the excitation force frequency, between 5-500Hz. Using the LabVIEW *VI* will be determine the frequency Fourier spectrum. Will be shown the minimum values of the magnitude of the *GDC* vs. the frequency field. To determine the minimum values of the *GDC* vs. excitation frequency is necessary to know how the robot structure change his stiffness vs. frequency, finally to avoid the frequency field what determine the increasing the compliance, increasing the displacement of the end-effecter at the external perturbation forces what could transform the robot's structure in to one un controlling robot.

The variation of the *GDT* vs. frequency is necessary to know to avoid the frequency field where the *GDT* increase.

DTF is the dynamic parameter that confirm the frequency field where the damper force is active and it is possible to use them. Where the *DTF* is minimum vs. frequency it means that the damper is unusual. His effect is decreased and it is not efficient. Finally the needed the frequency field (*Optimal Field*) must be:

$$OF \in \{\min(GDC)\} \wedge \{\min(GDT)\} \wedge \{\max(DTF)\} \quad (4)$$

C. *Proper Virtual LabVIEW Instrumentation*

The front panel of the used LabVIEW *VI* is shown in Fig.3.

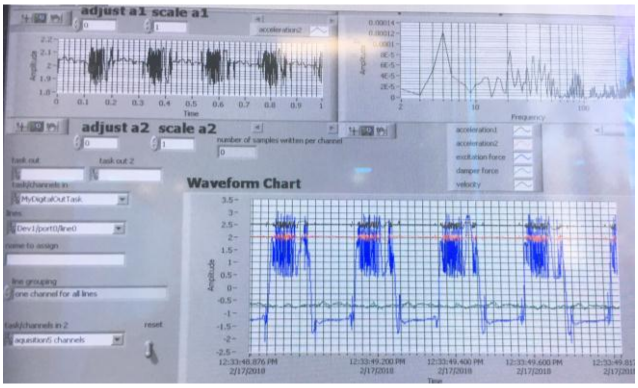

Fig. 3. The front panel of the LabVIEW *VI* of the aquisition data.

Frecvența	TDG
5	1.00E-06
6	2.50E-06
7	2.50E-05
8	4.00E-05
9	1.00E-04
10	1.50E-04
20	3.50E-03
30	8.00E-04
40	1.00E-04
50	1.00E-04
60	6.00E-04
70	2.00E-03
80	3.00E-03
90	2.00E-03
100	1.50E-02
200	1.80E-01
300	2.4
400	1.50E+01
500	1.2

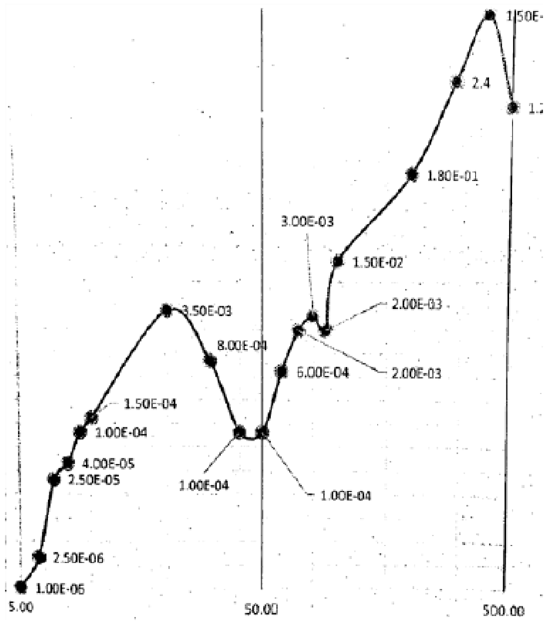

Fig. 4. The GDT vs. frequency.

GDC- global dynamic compliance;

Frecventa	Fa[N]	Fex[N]	FT
5	1.2	0.0013	923.0769
6	1.2	0.001	1200
7	1	0.0014	714.2857
8	1	0.0005	2000
9	0.8	0.0004	2000
10	0.7	0.0005	1400
20	2	0.008	250
30	1.8	0.007	257.1429
40	2.2	0.006	366.6667
50	1.8	0.001	1800
60	2.9	0.0065	446.1538
70	3	0.0004	7500
80	2.8	0.0005	5600
90	2.8	0.0001	28000
100	2	0.00001	200000
200	2.8	0.0001	28000
300	2.6	0.00008	32500
400	3.2	0.0001	32000
500	2.6	0.00008	32500

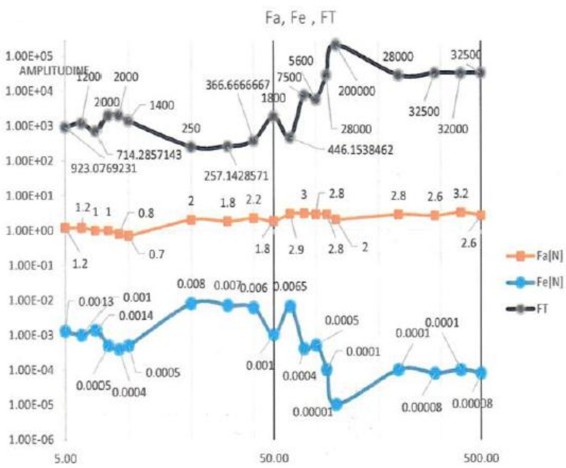

Fig.5 The GDC vs. frequency.

DTF- damper transfer function.

Frecventa	X	F	CDG
5	4.00E-05	6.00E-04	6.67E-02
6	5.00E-05	6.00E-04	8.33E-02
7	3.00E-04	1.00E-04	3.00E+00
8	1.00E-04	2.00E-04	5.00E-01
9	2.00E-04	1.00E-04	2.00E+00
10	2.00E-04	3.00E-04	6.67E-01
20	2.20E-03	3.00E-03	7.33E-01
30	1.75E-03	3.00E-04	5.83E+00
40	1.60E-03	1.20E-03	1.33E+00
50	6.20E-04	4.00E-04	1.55E+00
60	1.50E-03	6.20E-04	2.42E+00
70	2.50E-04	1.50E-04	1.67E+00
80	7.00E-04	1.00E-04	7.00E+00
90	1.00E-04	8.00E-05	1.25E+00
100	5.00E-05	6.00E-05	8.33E-01
200	1.80E-04	5.00E-05	3.60E+00
300	3.00E-04	5.00E-05	6.00E+00
400	1.50E-04	5.00E-05	3.00E+00
500	2.00E-05	7.00E-05	2.86E-01

The *VI*-s contents the following modules: one module with input data contents the name of the acquisition devise, the command line, the output application name and acquisition application name; one module to establishing the scale of the characteristics; one module of the Fourier spectrum characteristics of all dynamic parameters *GDC*, *GDT* and *DTF*.

D. The Results of the Researched Dynamic Behavior Parameters and Discussion

This paper tries to develop one general assisted methodology of the dynamic behavior in the real and frequency domain of the articulated arm type didactical robot. In the paper were solved the following problems: the theoretical and the experimental assisted research with data acquisition by using the proper theoretical and experimental LabVIEW *VI*; the optimization of the dynamic behavior with the virtual proper *VI*-s; the choice of the optimal frequency field when all three dynamic behavior parameters are optimal. The actual research in the world does not approach the assisted virtual instrumentation for the optimization of the dynamic behavior parameters that were studied in this research [44]-[54].

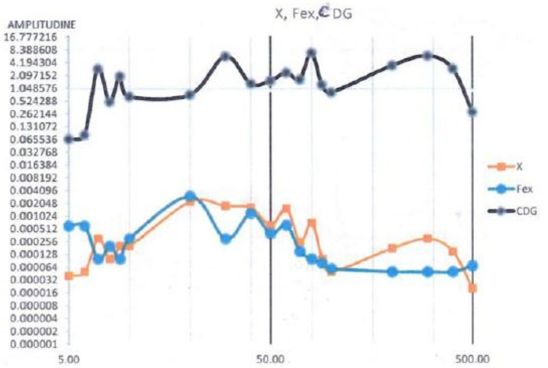

Fig.6. The characteristics of the DTF, damper force and excitation force.

III. Optimization of the Robot Dynamic Behavior by Using the Results

One way to optimize the dynamic behavior of the is to find the frequency field where all studied parameters are optimal: the *GDT* is minimum, the *GDC* is minimum and the *DTF* is maximum. In this frequency field the effect of the damper and the robot's stiffness will be maximum and the effect of the vibration to the end-effecter will be minimum. After calculate the relation (4) will obtain the following: *min*(*GDC*) ∈ [5,6] U [8,20] U [40,50] U [60,70] U [400,500]; *min*(*GDT*) ∈ [5,10]U[40,50]; *max*(*DTF*) ∈ [8,9]U{50}U[70,500];*O*∈*min*(*GD*∧*min*(*GDT*)∧*max*(*DTF*);

$$OF \in [8,9] \cup \{50\}; \tag{5}$$

We know that between the working frequency and the acceleration time of the movement is the relation:

$$t_a = \frac{1}{2\upsilon} \tag{6}$$

To obtain the function objective rel.(5), the field of the acceleration time in this condition, must be:

$$t_a \in \{0.01; 0.05; 0.0625\}. \tag{7}$$

IV. Conclusion

The results shown in the paper, the researched dynamic behavior parameters, the method and the LabVIEW*VI*-s can be used in many other research in the robotics field.

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