U.P.B. Sci. Bull., Series D, Vol. 72, Iss. 3, 2010 ISSN 1454-2358

ASSISTED RESEARCH OF THE FOURIER SPECTRUM OF THE ROBOTS WITH MAGNETORHEOLOGICAL DAMPER

Şerban OLARU[1], Aurel OPREAN[2], Adrian OLARU[3]

În lucrare este prezentată o metodă nouă pentru determinarea funcţiei de transfer a vibraţiilor, complianţa dinamică globală şi transmisibilitatea la un robot de tip braţ articulat cu amortizor magnetoreologic. Prin utilizarea metodei comparative şi propriul analizor virtual Fourier, a fost posibilă alegerea valorii optime a domeniului de vibraţie pentru ocolirea anumitor rezonanţe din spectru.

The paper presents one new method of the assisted determination of the transfer function of the vibrations, global dynamic compliance and of the transmissibility of one didactical robot with magnetorheological damper. By using the comparative method and the proper virtual Fourier analyzer, we were possible to choose the optimal value of the vibration field to avoid some spectrum resonances.

Key words: transfer function, dynamic compliance, transmisibility, Fourier analyzer, assisted research, LabVIEW instrumentation

1. Introduction

In the world, researche of the dynamic behavior of the robots is made without virtual instrumentation and without developing some new dynamic behavior parameters strictly necessary for a complete research of the field [1, 2, 3]. All research is experimental and the results are specific for one pointed application [3]. The research shown in the paper introduce new terms and tries to solve the dynamic behavior in two ways: the research of the dynamic behavior of the magnetorheological damper, (MRD), and the research of the damped mechanical structure (one didactical arm type robot) [4]. All research activities have been made with the virtual LabVIEW instrumentation [4, 5]. In all mechanical systems, one of the most important things is to know the vibration behavior, the viscose global dynamic damper coefficient, (VGDDC), of its structure and how the dynamic variation of acceleration determine the mechanical vibrations, finally to avoid the resonance frequency of the spectrum [6, 7, 8].

[1]Ph.D.Eng., Romsys Company, Bucharest, Romania, e-mail: serban1978@yahoo.com
[2] Professor, Department of Machines and Manufacturing Systems, University POLITEHNICA of Bucharest, Romania, e-mail: oprean.aurel@yahoo.com
[3] Professor, Department of Machines and Manufacturing Systems, University POLITEHNICA of Bucharest, Romania, , aolaru_51@yahoo.com

Moreover, in the paper are studied some influences of the magnetorheological damper parameters on the equivalent coefficient value of the viscous global dynamic damper equivalent coefficient, (VGDDEC). The paper presents a new assisted method using virtual LabVIEW instruments for the assisted research of the VGDDEC. The virtual instruments achieved in the LabVIEW soft 8.2.0 from National Instruments, USA, assures the experimental results concerning the global transfer function, (GTF), the transmissibility and the global dynamic compliance, (GDC) for the mechanical structure of the didactical robot with rheological damper. In the world, all determinations of the dynamic compliance and of the damper influences were made without the modern virtual LabVIEW instrumentation preseted in this paper, which is special for such determinations and assures a small cost and a short research time.

2. Experimental setup

The research was made by exciting, with the electromagnetic exciter, the robot base modulus in the low frequency domain and by data acquisition of the exciting and damper force, displacement and velocity of the structure in the tool center point, (TCP), acceleration of the stimulus base modulus and of the TCP. The research was made in three cases: without damper, with aero damper and with magnetorheological damper. In all three cases, the damper was mounted between the base and the end effector of the didactical robot.

The experimental setup contains the following components: didactical arm type robot; the electromagnetic exciter type 11075 from RFT Germany; connector type CB-68 LP from National Instruments USA; acquisition board type PCI 6024E from National Instruments USA; function generator type POF-1 from KABID Poland; amplifier type LV 102 from MMF Germany for the generator of the force stimulus; personal computer from Taiwan; inductive displacement traducer type 16.1 IAUC Romania; inductive force transducer; Hottinger apparatus type KWS/T5 from Germany and one new MRD.

3. Mathematical model of the researched functions

For a global definition of the dynamic behavior of the robot with magnetorheological damper, it is necessary to know the global dynamic compliance, (GDC), the transmissibility between the base and the end effector of the robot and the global transfer function, (GTF). All these three dynamic parameters have been studied and compared in three cases: with/without MRD and with aero damper. If the dynamic impact with a periodical force on the base of the robot structure is $F_s(t)$, the displacement response of the TCP is $x(t)$, then the GDC of the TCP is:

$$GDC = \frac{1}{k(j\omega)} = \frac{\int_0^T x(t)e^{-j\omega t}dt}{\int_0^T F_s(t)e^{-j\omega t}dt} = \frac{FFT(x)}{FFT(F)} = \frac{E_x(j\omega)}{E_F(j\omega)}. \tag{1}$$

where $E_F(j\omega)$ and $E_x(j\omega)$ are complex spectrum of energy.

The magnitude of the GDC is calculated by:

$$\frac{1}{k(\omega)} = \sqrt{(\mathrm{Re}\{\frac{1}{k(j\omega)}\})^2 + (\mathrm{Im}\{\frac{1}{k(j\omega)}\})^2}. \tag{2}$$

The VGDDC, c without magnetorheological damper for each resonance frequency can be obtained with:

$$c_i = 2\xi_i \frac{k_i(\omega)}{\nu_{ni}}, \tag{3}$$

where ν_{ni} is the natural frequency .

The damping ratio for each resonance frequencies ξ_i can be determined from Fourier vibration spectrum by:

$$\xi_i = \frac{\nu_{i1} - \nu_{i2}}{2\nu_{iR}}, \tag{4}$$

where ν_{1i} and ν_{2i} are the frequencies obtained by the $\sqrt{2}$ method [2] for each resonance frequency.

The viscose dynamic damper equivalent coefficient of the magnetorheological damper c_{eq} can be obtained as:

$$c_{eq} = \frac{E}{\pi\omega x^2}, \tag{5}$$

where: E is the damper energy over a cycle, [J]; ω - response pulsation of the robot arm [rad/s]; x- magnitude displacement in each resonance frequencies, [m]. The damper energy can be calculate with:

$$E = \int_0^{2\pi/\omega} F(t)x'(t)dt, \tag{6}$$

where: $F(t)$ is the damping variable force determined experimentally, [N]; $x'(t)$ - velocity of the response determined by derivation of the displacement characteristic, [m/s].

The VGDDEC after application of the MRD is:

$$c_f = c + c_{eq}. \tag{7}$$

4. Experimental results and discussion

The experimental research was made in the Laboratory for Dynamic Behavior of Industrial Robots from MSP Department, IMST Faculty, University Politehnica of Bucharest, Romania, on a didactical arm type robot with magnetorheological damper MRD jointed between the base and end-effector of the robot, and with some proper virtual LabVIEW instrumentation. The method of research included the exciting the base of the didactical robot with a periodical force with different frequencies and by simultaneously acquisition of the results by five acquisition channels of the different physical terms, in excitation point, and in effector point. For that, virtual LabVIEW instruments for the movement command and for acquisition was created. All instruments were achieved in 8.2.0 LabVIEW version. The results of the assisted research contain the real and frequencies characteristics. The special created instrument have the possibility to command a movement in up or down, to achieve some data and to show on-line some damper real and frequency characteristics. The achieved data were: acceleration on the base modulus of the robot, acceleration on the end-effector, damper force, velocity of the end- effector and excitation force. Some of these characteristics and those of the front panel of the virtual instrument are shown in the Figures 1- 8.

The synthetic presentation of the assisted data acquisition results is shown in Tables 1-3. After analyzing the table data and the characteristics from Figures 1- 8, we can do the following remarks: the virtual LabVIEW instrumentation in the data acquisition of the experimental values and their interpretation is extremely necessary; the applying of MRD assures the transfer of the frequencies from the low to the high frequency field of the spectrum, see Fig. 8; the transmissibility with aero damper is maximum when the excitation frequencies are 20, 50, 70 Hz, see Table 1; GDC is maximum when the excitation frequencies are 10, 25, 35, 50 Hz. These determine a small global dynamic stiffness; the damper force is maximum when the excitation frequencies are 10, 30, 35, 50 Hz; damper energy is maximum at the excitation frequencies 10, 20, 35 Hz (see the maximum coefficient from Table 1); the transmissibility is small in the case with MRD in comparison with the cases without MRD or with aero damper (see Table 2); in this case, the transmissibility is maximum when the frequencies from the Fourier spectrum are 10, 14, 20 Hz; GDC is maximum in the case with MRD when the frequencies from the Fourier spectrum are 10, 40, 60, 80, 110 Hz and in the case without MRD, when the frequencies from the Fourier spectrum are 5, 25, 45, 72, 90 Hz (see Table 3); GDC is bigger (that means the rigidity is smaller) in the case without MRD and have the maximum values when the frequencies from the

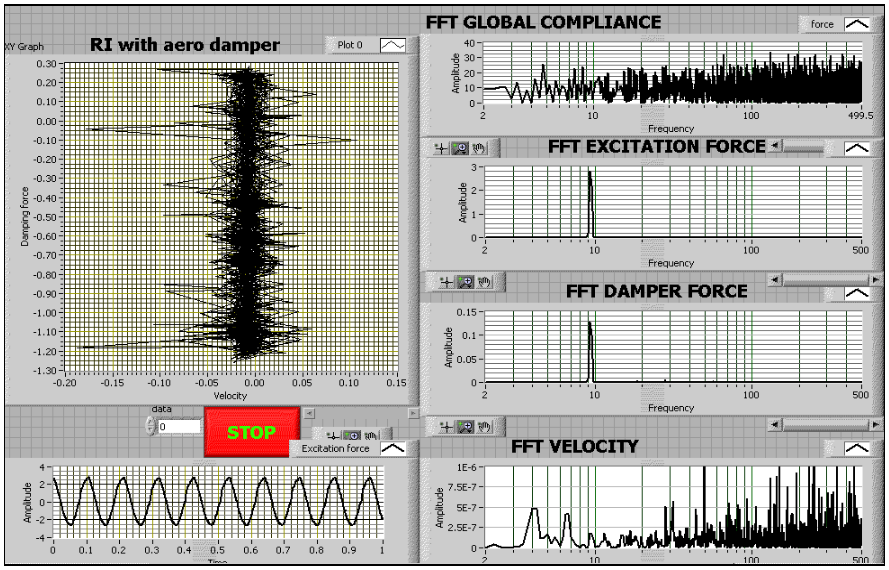


Fig. 1. The real and frequencies characteristics with 10 Hz stimulus: excitation force vs. time, damper force, excitation force, GDC vs. frequency.

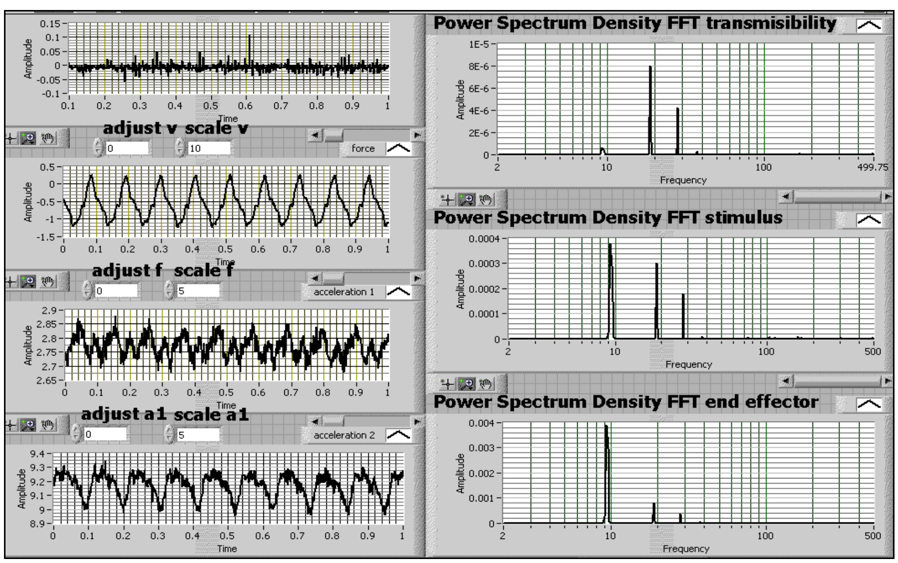


Fig. 2. The real and frequencies characteristics: excitation force, damper force, acceleration on the base, acceleration on the end- effector vs. time, FFT acceleration vs. frequency

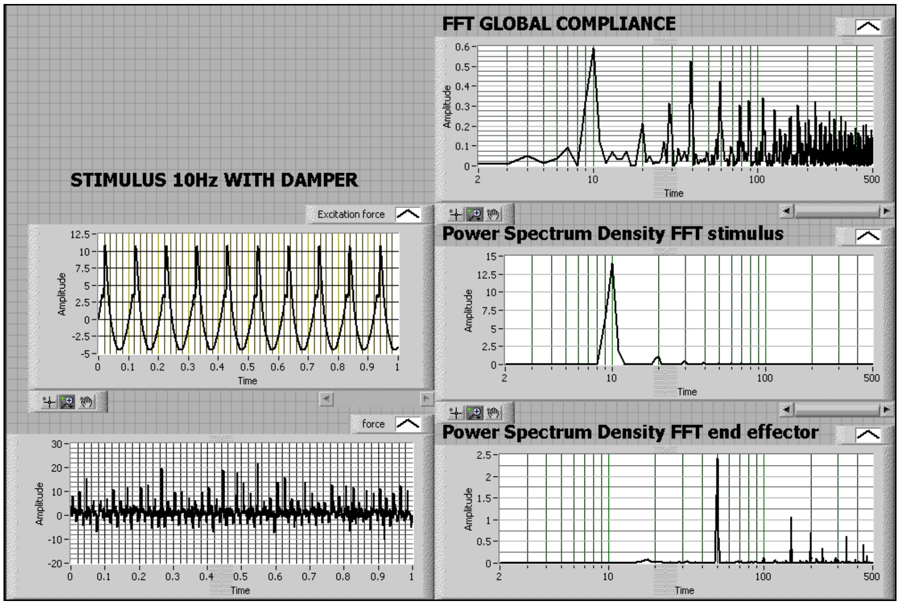


Fig. 3. The real and frequency characteristics with 10 Hz stimulus and with MRD: excitation force and damper force vs.time, FFT stimulus, FFT end effector, GDC vs. frequency

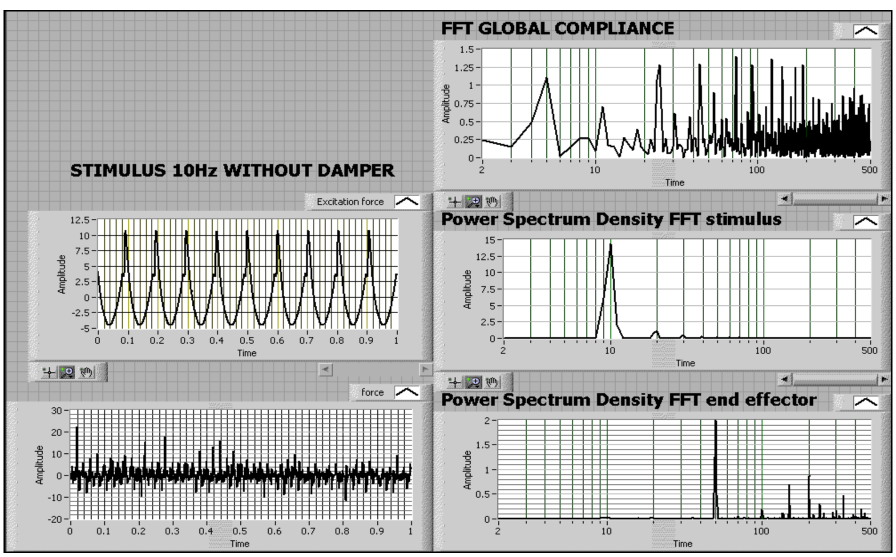


Fig. 4. The real and frequency characteristics with 10 Hz stimulus and without MRD: excitation force and damper force vs. time, FFT stimulus, FFT end effector, GDC vs. frequency

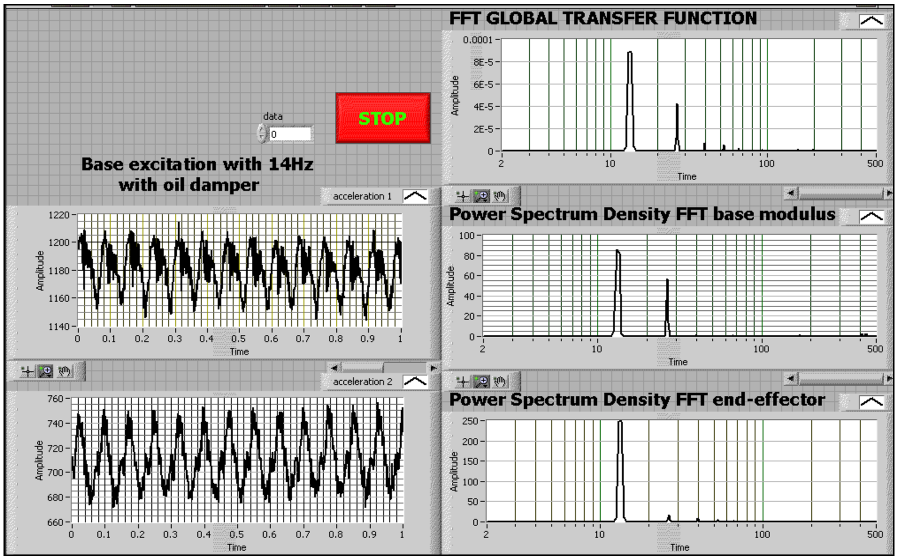


Fig. 5. The real and frequency characteristics with 14 Hz stimulus and with MRD: acceleration on the base and acceleration on the end-effector vs. time, FFT stimulus, FFT end effector, GDTF vs. frequency

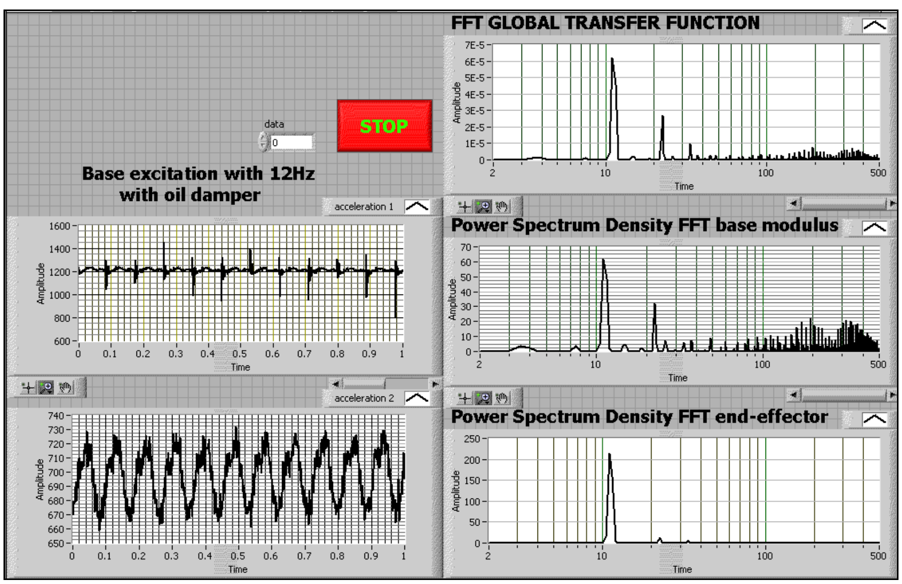


Fig. 6. The real and frequency characteristics with 12 Hz stimulus and MRD: acceleration on the base and acceleration on the end-effector vs. time, FFT stimulus, FFT end effector, GDTF vs. frequency

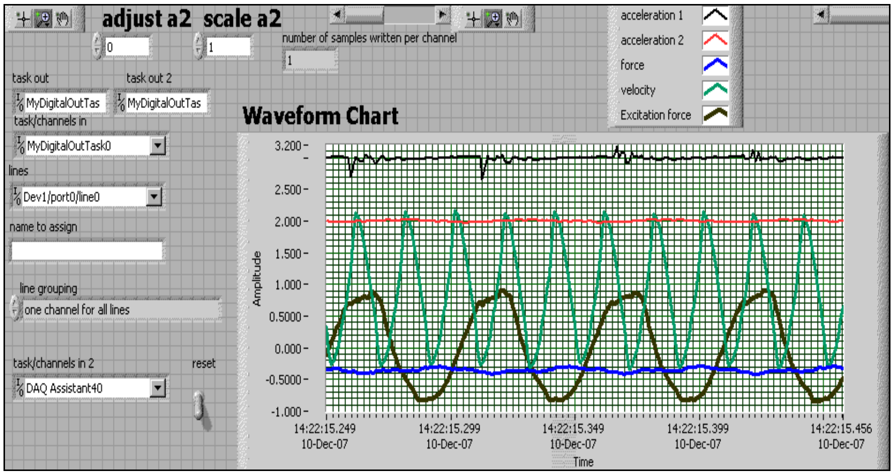
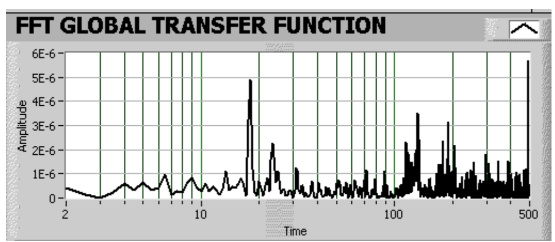
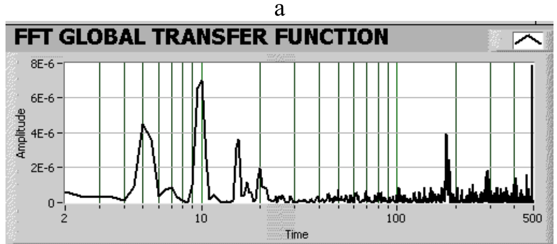


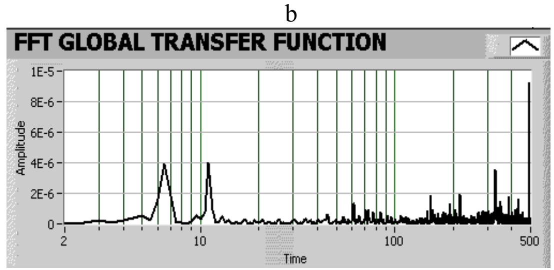
Fig. 7. The front panel of the LabVIEW virtual instrument for the data simultaneous acquisition on five channels



a



b



c

Fig. 8. The comparative results of the global dynamic transfer function, GDTF in an up movement, in three different cases: a- with MRD; b- with aero damper; c- without damper

Fourier spectrum are in the low frequency field (ex.: 5 Hz in comparison with 10 Hz; 25 Hz in comparison with 40 Hz and so on).

Table 1

Variation of Transmissibility and GDC in the movement with aero damper (simultaneously acquisition with 5 channels)

Excit. Freq. [Hz]	Type of damp.	Transmisibility freq./magnit. [Hz]/[mm/daN]	GDC freq./magn. [Hz]/[mm/daN]	Damp. Force [daN]	Damp.force - velocity
		[v] /[A]	[v] /[A]	[v] /[A]	[$F_{min-max}$]/ [$v_{min-max}$]
10	Aero damp.	10/0.5 10^{-6}; 19/8 10^{-6}; 28/4 10^{-6}	4/20; 7/19; 8/19; 12/18; 14/18; 18/18; 19/18; 20/19; 21/19; 25/18; 28/19; 32/17	9/0.12; 18/0.01; 28/0.01	-1.3 to 0.2/ -0.05 to 0.05 (1.5/0.1) **15**
20	Aero damp.	20/1.5 10^{-5}; 190/3 10^{-6}; 210/1 10^{-6}	20/0.6; 28/0.14; 40/0.14; 150/0.15	20/0.04	-0.9 to -0.2/ -0.04 to 0.04 (0.7/0.08) **8.75**
25	Aero damp.	25/9 10^{-6}; 75/4 10^{-6}; 130/0.5 10^{-6}; 180/5 10^{-6}; 220/1.5 10^{-6}; 420/0.5 10^{-6}	25/1.8; 50/1; 75/0.4; 100/0.2; 150/0.2; 250/0.1	25/0.04; 50/0.002; 75/0.001	-0.8 to -0.1/ -0.04 to 0.02 (0.7/0.06) **11.66**
30	Aero damp.	30/1 10^{-6}; 88/7 10^{-6}; 120/1.4 10^{-6}; 180/3.8 10^{-6}; 200/9 10^{-6}; 220/1.2 10^{-6}	21/0.1; 30/1; 50/0.4; 80/0.1; 88/0.25; 120/0.1; 150/0.3; 250/0.1	30/0.07; 88/0.005	-1 to -0.15/ -0.06 to 0.04 (0.85/0.1) **8.5**
35	Aero damp.	38/1 10^{-6}; 90/7 10^{-6}; 130/1.4 10^{-6}; 190/3.8 10^{-6}; 210/8 10^{-6}; 240/1.2 10^{-6}	35/4.2; 50/0.5; 70/2; 80/0.1; 100/2; 140/1; 150/0.5; 180/0.5; 250/0.5	35/0.05; 70/0.025; 100/0.05	-0.9 to - 0.05/ -0.05 to 0.03 (0.85/0.08) **10.625**
50	Aero damp.	50/1.2 10^{-5}; 150/0.00025 10^{-6}; 200/5 10^{-6}; 250/0.002 10^{-6}	4/120; 7/150; 12/120; 15/120; 18/110; 22/140; 26/130; 30/100; 32/110; 34/110; 40/180; 45/120; 50/120;	50/0.08;	-1 to 0/ -0.05 to 0.04 (1/0.09) **11.11**

			52/120; 55/150; 60/140; 63/110; 70/150; 80/90; 85/110; 90/180; 95/110; 100/160; 110/160; 120/150; 130/90; 140/150; 150/150; 200/150		
60	Aero damp.	60/0.8 10^{-6}; 180/3.8 10^{-6}	4/0.02; 50/0.05; 60/0.18; 150/0.05; 170/0.04; 230/0.03; 250/0.05; 400/0.05	60/0.014	-0.8 to -0.25/ -0.04 to 0.04 (0.55/0.08) **6.875**
70	Aero damp.	70/2.8 10^{-5}; 150/1 10^{-6}; 200/2.5 10^{-5}; 400/1 10^{-6}	25/0.02; 30/0.02; 32/0.03; 40/0.01; 50/0.15; 58/0.03; 68/0.02; 70/0.01; 150/0.08; 250/0.07; 350/0.07	70/0.0035	-0.66 to -0.36/ -0.05 to 0.04 (0.3/0.09) **3.33**
80	Aero damp.	40/0.2 10^{-6}'; 80/3.5 10^{-6}; 120/0.4 10^{-6}; 160/0.5 10^{-6}; 190/0.55 10^{-6}; 220/0.1 10^{-6}	4/0.01; 20/0.01; 32/0.01; 50/0.13; 90/0.01; 100/0.01; 120/0.04; 150/0.075; 220/0.06; 250/0.07; 280/0.02; 320/0.075; 350/0.025; 400/0.06	40/0.00025; 80/0.001; 120/0.00025	-0.62 to -0.42/ -0.04 to 0.04 (0.2/0.08) **2.5**
90	Aero damp.	90/5.5 10^{-6}; 180/0.8 10^{-6}; 220/0.2 10^{-6}	3/0.005; 5/0.005; 8/0.005; 11/0.005; 13/0.005; 15/0.005; 18/0.018; 30/0.01; 43/0.01; 50/0.05; 53/0.005; 80/0.008; 100/0.005; 160/0.04; 200/0.01; 220/0.01; 250/0.03; 280/0.015; 320/0.01; 400/0.03	45/0.0002; 90/5 10^{-5}; 100/2.5 10^{-5}; 120/2.5 10^{-5}; 180/2.5 10^{-5}; 200/1 10^{-5}; 300/1 10^{-5}	-0.58 to -0.42/ -0.04 to 0.04 (0.16/0.08) **2**
100	Aero damp.	100/5 10^{-7}; 120/1 10^{-7}; 200/2.3 10^{-6}; 300/1 10^{-7}; 400/1 10^{-7}; 450/2 10^{-7};	3/0.01; 50/0.12; 60/0.01; 70/0.01; 80/0.01; 90/0.01; 100/0.01; 110/0.01; 130/0.015; 200/0.02; 250/0.05; 270/0.02; 300/0.03; 320/0.01; 350/0.05; 400/0.03; 450/0.04	12/1.25 10^{-5}; 15/2.5 10^{-5} ; 50/2 10^{-5}; 100/8 10^{-5} ; 110/2 10^{-5}; 150/1 10^{-5}; 200/1 10^{-5}; 300/1.8 10^{-5}; 400/1 10^{-5};	-0.62 to -0.38/ -0.05 to 0.04 (0.24/0.09) **2.66**
150	Aero damp.	72/0.8 10^{-7}; 95/0.8 10^{-7}; 150/2.2 10^{-7}; 170/0.2 10^{-7};	4/0.01; 5.5/0.01; 15/0.015; 18/0.012; 28/0.01; 30/0.015; 38/0.008; 50/0.05;	4.8/0.5 10^{-5}; 5.5/0.8 10^{-5}; 13/0.2 10^{-5}; 72/1.3 10^{-5};	-0.56 to -0.46/ -0.05 to 0.03 (0.1/0.08)

		180/1.5 10^{-7}; 220/0.5 10^{-7}; 250/0.2 10^{-7}; 270/0.6 10^{-7}; 300/0.5 10^{-7}; 420/5.8 10^{-7};	100/0.01; 120/0.012; 130/0.015; 150/0.04; 170/0.01; 180/0.01; 190/0.01; 230/0.015; 250/0.03; 260/0.015; 300/0.015; 350/0.025; 360/0.018; 400/0.01; 420/0.045;	98/0.5 10^{-5}; 100/1.8 10^{-5}; 150/2.5 10^{-5}; 160/0.6 10^{-5}; 200/0.6 10^{-5} 250/0.1 10^{-5}; 300/1.8 10^{-5}; 370/0.1 10^{-5}; 400/0.5 10^{-5};	**1.25**
200	Aero damp.	190/6 10^{-6}	50/0.06; 150/0.04; 230/0.01; 250/0.03; 270/0.025; 330/0.018; 350/0.02; 420/0.018; 450/0.03;	12/0.00025; 100/0.00001; 300/0.00001;	-0.57 to -0.45/-0.05 to 0.04 (0.12/0.09) **1.33**
300	Aero damp.	4/5 10^{-8}; 100/3 10^{-8}; 180/4 10^{-8}; 190/2 10^{-8}; 200/2 10^{-8}; 270/3.5 10^{-8}; 290/4 10^{-8}; 300/2 10^{-8}; 370/2 10^{-8}; 400/3 10^{-8}; 450/1.7 10^{-7}	50/0.15; 150/0.1; 220/0.02; 250/0.1; 320/0.02; 350/0.08; 450/0.08;	15/8 10^{-5}; 100/2 10^{-5}; 150/1 10^{-5}; 200/1 10^{-5}; 300/1.8 10^{-5}; 400/0.5 10^{-5};	-0.56 to -0.46/ -0.05 to 0.04 (0.1/0.09) **1.11**
400	Aero damp.	45/4 10^{-8}; 100/3 10^{-8}; 180/3.5 10^{-8}; 300/4 10^{-8}; 350/2 10^{-8}; 400/4 10^{-8}; 450/2 10^{-8};	3/0.04; 50/0.2; 130/0.05; 150/0.15; 220/0.02; 250/0.05; 320/0.01; 330/0.02; 360/0.04; 430/0.05;	6/5 10^{-6}; 13/1.5 10^{-6}; 100/2.5 10^{-6}; 110/2.3 10^{-5}; 150/8 10^{-6}; 210/1 10^{-5}; 320/1.5 10^{-5}; 400/3 10^{-6}	-0.55 to -0.47/ -0.04 to 0.03 (0.08/0.07) **1.14**
500	Aero damp.	25/2 10^{-8}; 50/3 10^{-8}; 100/2 10^{-8}; 180/2 10^{-8}; 200/2 10^{-8}; 300/3 10^{-8}; 320/3 10^{-8}; 400/5 10^{-8}; 500/2 10^{-7};	50/0.13; 120/0.03; 150/0.075; 220/0.03; 240/0.04; 280/0.03; 350/0.03; 400/0.02; 450/0.02; 490/0.03;	100/2 10^{-6}; 110/1.8 10^{-5}; 150/5 10^{-6}; 210/7 10^{-6}; 250/1 10^{-6}; 310/1.8 10^{-5}; 350/1 10^{-6}; 400/2 10^{-6}; 480/1 10^{-6};	-0.55 to -0.47/ -0.04 to 0.03 (0.08/0.07) **1.14**

Table 2

Transmissibility between the base and end-effector in the cases with base excitation with/without damper

Type of damp.	Excit.Freq. [Hz]	Transmissibility		Type of damp.	Transmissibility	
		Freq. of spectrum [Hz]	Magnitude of spectrum		Freq. of spectrum [Hz]	Magnitude of spectrum
MRD	10	10	$3.5\ 10^{-6}$	Without MRD	10	$5.5\ 10^{-6}$
		20	$2.8\ 10^{-6}$		20	$4.5\ 10^{-6}$
		30	$0.2\ 10^{-6}$		30	$0.3\ 10^{-6}$
		50	$0.15\ 10^{-6}$		50	$0.2\ 10^{-6}$
MRD	10	130	$0.15\ 10^{-6}$	Without MRD	130	$0.2\ 10^{-6}$
		220	$0.8\ 10^{-6}$		220	$0.8\ 10^{-6}$
		320	$0.9\ 10^{-6}$		320	$0.9\ 10^{-6}$
		420	$0.8\ 10^{-6}$		420	$0.8\ 10^{-6}$
MRD	14	14	$3.8\ 10^{-6}$	Aero Damp.	6.5	$1.1\ 10^{-5}$
		20	$6.5\ 10^{-6}$		15	$0.25\ 10^{-5}$
		180	$0.5\ 10^{-6}$		20	$1.5\ 10^{-5}$
		220	$0.1\ 10^{-6}$		26	$0.18\ 10^{-5}$
		340	$0.2\ 10^{-6}$		50	$0.18\ 10^{-5}$

Table 3

GDC in cases with/without damper

Excit. Freq. [Hz]	Type of damper	GDC		Type of damper	GDC	
		Freq. of spectrum [Hz]	Magnitude [mm/N]		Freq. of spectrum [Hz]	Magnitude [mm/N]
7	MRD	6.5	0.55	Without damper	2	1.2
		14	0.65		8	0.98
		20	0.05		14	0.8
		38	0.18		21	0.9
		42	0.1		32	1.1
		50	0.8		40	0.9
		55	0.1		41	0.98
		61	0.18		52	0.4
		150	0.1		100	0.5
10	MRD	10	0.6	Without damper	5	1
		20	0.2		11	0.75
		30	0.32		15	0.25
		40	0.52		18	0.37
		60	0.4		25	1.25
		70	0.08		30	0.6
		80	0.3		40	0.55
		90	0.32		45	1.25
		110	0.33		55	0.85
		130	0.28		60	0.5
		140	0.18		62	0.5

		150	0.15		72	1.4
		160	0.22		80	0.4
		180	0.25		90	1.25
		200	0.2		100	0.6
		220	0.28		110	0.35
		10	0.02		6.5	0.05
		33	0.01	With aero damper	14	0.025
14	MRD	45	0.01		20	0.005
		95	0.072		50	0.1
		180	0.06		100	0.1
14	MRD	200	0.03	With aero damper	160	0.1
		220	0.02		200	0.02
		12	0.04		5	0.1
		19	0.02		7	0.03
		21	0.04		9	0.04
		35	0.02		12	0.11
		48	0.07		18	0.12
20	MRD	57	0.03	With aero damper	22	0.13
		70	0.02		28	0.12
		73	0.04		30	0.08
		80	0.04		33	0.09
		98	0.05		40	0.09
		110	0.02		50	0.09

5. Conclusions

The method, the virtual instrumentation and some of the results can be used for optimization of the dynamic behavior of this field. Introducing the magnetorheological damper in the construction of the robot, determines the transfer of some low frequencies to the high field, reduces the GDC with the increase of the stiffness and decrease of the transmissibility. The research assures the future way to the intelligent damper system of the robot with the goals to reduce and optimize the robot spectrum of the vibrations. The virtual instruments and the method can be applied in many other mechanical applications.

R E F E R E N C E S

[1] *S.-B Choi & S.-K Lee,* A Hysteresis Model for the Field-Dependent Damping Force of a Magnetorheological Damper, Journal of Sound and Vibration, 245, 2, 2001, pp. 375-383.

[2] *S.J. Dyke, B.F. Jr Spencer, M.K Sain & J.D. Carlson,* An experimental study of MR dampers for seismic protection, Smart Mateials and Structures 7, 1998, pp. 693-703.

[3] *T. Sireteanu, D. Stancioiu, Gh. Ghita, C.W, Stammers,* Semi-active vibration control by use of magnetorheological dampers, Proceedings of the Romanian Academy, 2000, pp.195-199.

[4] *S .Olaru,* Experimental research of the optimization of the dynamic behavior of the industrial robots by using the intelligent dampers, research second report, Ph.D. thesis, University “Politehnica” of Bucharest, 2009.

[5] *A. Olaru,* Virtual LabVIEW instrumentation in the technical research of the industrial robots elements and the systems, Bren Publishing House, 2002.
[6] *S. Olaru, A. Olaru,* Contribution of the modeling and simulation of the rheological damper, DECOM2007, Turcia, 2007.
[7] *S. Olaru, A. Oprean, A. Olaru,* Assisted research of the rheological dampers with LabVIEW instrumentation, The 1-st European DAAAM International Young Researchers and Scientists Conference, 24-27 October, University of Zadar, Zadar, Croatie, 2007.
[8] *Olaru, A., Olaru, S.,* Assisted dynamic behavior optimization of the robots elements and systems with LabVIEW instrumentation, 15th International Mechanical Engineering Conference, May 2007, Amirkabir University of Technology, Teheran, Iran, 2007.