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VOLTAGE INDUCED EFFECT FOR VIBRATION SUPPRESSION USING EDDY CURRENT ON POWER STEERING SYSTEM

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ABSTRACT

This paper describes the study of vibration suppression by using eddy current as a suppression agent on a power steering system. Vibration occurs due to some factors such as engine vibration, road surfaces, vibration direction, tire characteristics, suspension design and steering devices. The objective of this study is to investigate the voltage induced effect on vibration suppression occurred at power steering system using eddy current braking. Equipments involve are accelerometer, data acquisition (DAQ), electric motor, transformer, aluminium disc and Voltage regulator. Position of the accelerometer was placed at the steering wheel and aluminium disc. Based on the result for frequency domain, in a normal condition, the level of vibration amplitude produce is 0.2348mvolt. while, after voltage was apply to power steering system lowest vibration suppression at steering column (aluminium disc) is 0.166mvolt with 2mm air gap opening using 48 volt power supply. For steering wheel, in a normal condition is the level of vibration is 0.2251mVolt. After voltage was applied to power steering system, the lowest vibration suppression at steering wheel is 0.1836mVolt using 96 Volt of voltage induced. Based on the experimental result, increasing voltage induced managed to reduce vibration on power steering system since the electromagnetic braking force using eddy current increase which act as the vibration suppression agent.

Keywords: vibration suppression, power steering, eddy current.

INTRODUCTION

Some of noise and vibration on a vehicle is caused by power steering system. Excitation vibration of power steering is affected by the engine itself and it will transfer pass through along steering shaft toward steering wheel [1-3]. The vibration in motor usually in periodic and simultaneously toward the shaft rotation which occurred at low hand wheel velocity and low frequency level [4-6]. Steering system usually involved of a steering wheel handle and a steering shaft column. Both of these main components are disposed to vibration that produced from road condition and engine excitation itself. The most important purposes of the power steering system that needs to transfer the static loads from driver toward the system, therefore leading to a series of problem. Power Steering is an important subsystem in automobiles system. The function of power steering is to rotate the front wheel tire in the required direction through the input force from steering wheel. Power steering consists of two types which are hydraulic power steering and electronic power steering. The hydraulic power steering is control by hydraulic pump while electronic power steering was controlled by electric actuator. When the steering was steered, response torque tend to return the wheel sequence to the apply force. If more torque apply to steering wheel, than more fluid allow by the valve to cylinder and more force was applied to moving the wheel. Frequency level of excitation energy at the steering wheel can reach up to 300 Hz [7], steering shaft and steering wheel vibration mode can generate high resonance peaks in the steering wheel at frequencies in range of 20 until 50 Hz [8]. The previous research from [9] has studied about the mechanical response toward the steering wheel system to sinusoidal translational vibration in frequency range of 20 until 500 Hz when holding a steering wheel. From the research Reynolds et al concluded that the position of arm only give a slightly reaction on the impedance of the hand opposite with tested frequency limitation. However grip tightness and hand pressure affected the excitation vibration at higher frequencies that exceed 60 Hz. So once grip technique was applied, a linear system could be considered by the hand–arm system.

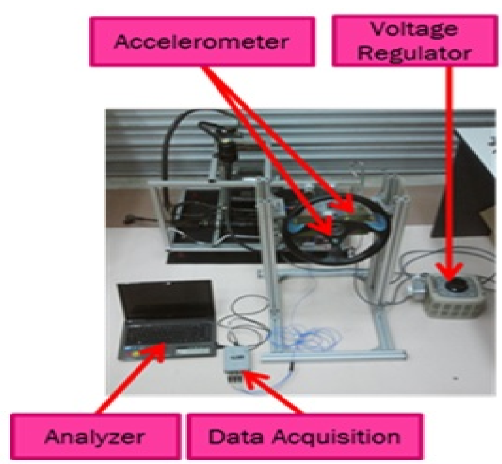
Electromagnetic braking force that come from the relations between magnetic flux and eddy current. While the movement of conducting material through a stationary magnet, the motion had been slow down by magnetic drag force. Changing in magnetic field will induce eddy current in the conductive material. This current will eliminate energy in the conductor and produce drag force [10]. These electromagnetic resistances for steering system will increase the steering feel and vibration by creating a braking effect resistance or drag force to oppose the rotational direction while torque is apply to the steering wheel [11]. Based on early research of electromagnetic braking system, it was founded that aluminum is the best conductor material to use as the conductor brake disc compared with copper and zinc [11]. The reactions and eddy current effect on aluminum are more effective than copper and zinc. The motion had been decelerating by a magnetic drag force produced during a moving conducting material pass through a permanent magnet or vice versa. So that to decrease the excitation vibration and increase the steering controlled performance comfort on hydraulic power steering system, electromagnetic eddy current braking system can be apply. As the speed of vehicle increase, more efficient power steering system required to ensure safety and reliability of vehicles. When the contact friction of the tire is reduced with high velocity driving, the steering effort is weak and the steering stability becomes worse. To prevent this, either the assisted steering effort should be reduced or the steering wheel should be held tight [12].

Vehicle stability control systems that sustain the stability of the vehicle in order to maintain a dynamic safety protection system [6, 13, 14]. The achievement of electromagnetic brakes much more reasonable for other equipment compared with other retarders [15, 16]. The conventional brakes can be used less often and hence practically certainly not grasp high temperatures. In addition, electromagnetic brake can avoid the unsaved situation that can occur from the sustained used exceed its ability to dissipate heat. It does not need to use cooling system. The eddy current braking system does not influence the engine component efficiency, such as exhaust and hydraulic brakes. The electromagnetic brakes also provide good control assist. One of the uses could be effective when change the magnetic relative toward the moving conductor, to increase the net rate between both devices and instigate a higher damping force [17]. Another active control approaches can use electromagnets to suppress vibrations. If a number of researches continue to develop towards eddy current damping, this kind of damper for sure will find a way of typical applications and will change the commercial market of automotive industry. The advantages of using electromagnetic braking system because it is non-mechanical, no moving parts that will not produce friction energy. The research from SAE the Engineering Society for Advancing Mobility Land Sea Air and Space said that vibration can felt at the steering wheel. The source of steering excitation vibration was generated by fluid pump and engine transferred pass through steering shaft toward the steering wheel. Therefore, the idea of this project will use the application of drag force or resistance generated by electromagnetic braking of eddy current to suppress vibration on current power steering system. The non-contact braking and resistance generated will reduce vibration, increase the handling and control stability, and improve the driving comfort. It will become another solution in order to overcome the problem occurred in most low and medium cost segment vehicles.

EXPERIMENTAL SETUP

This experimental setup involves the hardware measurement device such as accelerometer. The test was done to get the acceleration signal from power steering system at different part. A National Instrument DAQ measurement device was used to change analogue input into the signal input to the computer. The accelerometer sensor was located at a critical point of vibration excitation level. In addition, to obtain maximum accuracy of accelerometer reading, the sticky or grease gum for accelerometer was used to attach the accelerometer to the steering shaft. The steering shafts are divided into several points to get the different reading at different points. For preliminary study, the impact hammer was used to produce excitation force toward the steering shaft column. The force sensor provides to produce a measurement of the frequency and amplitude content of the energy content stimulus that is transmitted to a test object. In order to maintain a measurement of the object's structural response due to the hammer blow, an accelerometer is used together with the impact hammer. To suit the condition of the item in testing, a variety of tips outfitted with each hammer allow the energy content of the force impulse to be tailored. National instrument DAQmx is used with multi-channel and analysis software, it is able to resolve a variety of mechanical properties that related to an understanding on structural behavioural of an object characteristic. Items analysed including mode shape, transfer characteristics, resonance detection and beam structural health.

The steering shaft vibration is then suppressed by using eddy current braking system. Steering shaft is placed between eddy current poles (eddy current pole place right and left side of steering shaft). Another test rig is used for eddy current system to suppress excitation vibration of steering shaft. Figure-1 shows the overview experiment setups of main equipments are computer, accelerometer and National Instrument Data Acquisition. The data acquisition system of National Instrument (NI) has been used. NI-cDAQ 9171 which is a 1 slot USB consist of four input channel been connected to the tri axial accelerometer of (number series 3 axis). This data acquisition system and accelerometer will be configured using Measurement and Automation Explorer (MAX) software of National Instrument (NI). Then the Dasylab will synchronize the measurement setup with the MAX itself. The rest are ware, electric motor and power steering system to test power steering vibration which can refer Table-1 for specification of electric motor for experiment parameter. For the preliminary study the sensor was placed to the steering shaft and test rig. After determine the highest location of vibration, this experiment continues to focus on steering wheel and aluminium disc representing the steering column. The aluminium disc is placed in between of four eddy current laminated steel facing each other. The holder is used to hold the eddy current in a fixed position when conducting the experiment. The position of accelerometer need to place at fixed position on steering wheel and aluminium disc to get better signal result.



(a)

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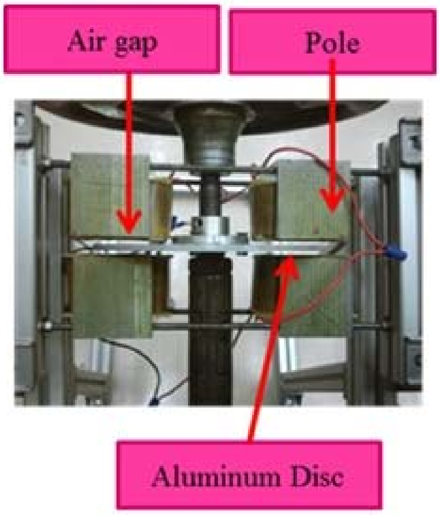

(b)

Figure-1. (a) and (b) Full view for experimental setup.

Table-1. Process parameters and their levels.

RPM	1400
Voltage regulator	0 V,48 V,72 V,96 V,120 V, 144 V
Frequency	50 Hz
Air gap	2 mm, 4 mm, 6 mm
Number of eddy current	4

As a safety precaution, check the voltage regulator controller before switch on the power supply, voltage regulator is limit until 144 volts to control voltage source of eddy current to avoid it from overheated. Make sure all of the wires connect properly to the eddy current and voltage regulator to avoid from short circuit. The accelerometer place perpendicular to steering shaft. Special wax is used on the accelerometer surface to assure the accelerometer does not move during system is running. The position of accelerometer is placed at the high vibration level to get the better signal input. The research from [18], they placed small accelerometers in their experiment at two different points along the steering shaft column and measured the value of mechanical response to handle that caused translational vibration. Vibration at frequencies above 100 Hz was limited to the fingers and hand.

EXPERIMENTAL PROCEDURE

The goal of this experiment is to measure the vibration suppression of hydraulic power steering by using eddy current and to improve the steering feel performance. The constant and variable parameters involve must to define first before run the experiment. The experiment parameter for this experiment is shown in Table-1. Normally, the purposes of using DASYLab software is to construct complex applications in minimal time without any programming, means that it does not involve coding code to make the application. However, build worksheets using graphical functions and implements real-time operations, including PID control can provide standard real-time displays for example display graph. With software can refer library that provided for computational functions including FFT analysis. Has a generator functions to simulate inputs. This is easy for users to test their blog diagram system. Firstly, connect DAQ with the computer, and then select synchronization with MAX Configuration in hardware setup. For this block diagram the sampling value block size is 2,048. The measurements are involving 3D axis, means that there are three channels involve. Regarding to the number of channels, channel zero refers to x-axis, channel one for y-axis and channel three for z-axis. Before run the experiment, change the unit scaling for accelerometer from mVolt/g using at linear function formula 9.81ms-2 of gravity acceleration. The new unit after scaling is mVolt. Connect with y/t chart for acceleration and write data to save the acceleration graph in ASCII format.

Use the data window module to multiply non-periodic signals with a window function. This module prepares data channels for Fast Fourier Transform. There are many types of window such as rectangle, flattop, Hanning, hamming, Poisson, turkey, and Blackman others type can refer in data window setting, can use any type of windowing but it depends on condition of experiments. For this experiment, recommend use flattop window type. This is because, flattop it is a cosine shaped weighting function that forces the beginning and its end of the sample interval to the zero. It is mostly as a bell shaped. The block size in data window must same as setting earlier. Convert time domain to the frequency domain by using FFT module. Select Real FFT of a real signal and unclick the FFT without the power of two at operation option. Block average was used to take the average reading for FFT graph to obtain the best FFT graph.

Average data block number for the FFT is 4. To display the frequency domain data, add Y-T chart module with the same setting at displaying time domain data. Then the graph will display amplitude versus frequency. For collecting the data of experiment add with write data module and connect with y/t chart. Use digital filter modules, whereby the filter type are high pass for velocity with limit frequency are 0.4 Hz and filter order are 8. All settings in digital filter must same value with three channels. Follow by high pass for displacement of 0.5 Hz for all channels. The graph will show amplitude versus time. Set auto scaling in Y-T chart setting to get automatic full data display. All the data for acceleration, frequency domain and displacement are saved in ASCII file format, tab application in ASC II sets to separate data in column.

RESULTS AND DISCUSSIONS

Table-2 shows the obtained results of mean amplitude value in mV for the amount of vibration occurred at aluminium disc and steering wheel based on different amount of voltage induced from 0V to 144V.

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Figure-2 and Figure-3 show the acceleration mean amplitude graph versus voltage increment for three different of air gap value at aluminium disc. While, Figure-4 and Figure-5 shows the acceleration mean amplitude graph versus voltage increment for three different of air gap value at steering wheel. The blue colour representing the 2 mm air gaps, red colour is 4 mm air gap and black colour is 6mm air gap opening.

Table-2. Mean amplitude valus in mV.

Voltage (V)	Mean amplitude (mV) at Aluminium Disc	Mean amplitude (mV) at Steering Wheel
0	0.2348	0.2251
48	0.166	0.1979
72	0.1841	0.1882
96	0.1959	0.1836
120	0.2344	0.1893
144	0.2437	0.2153

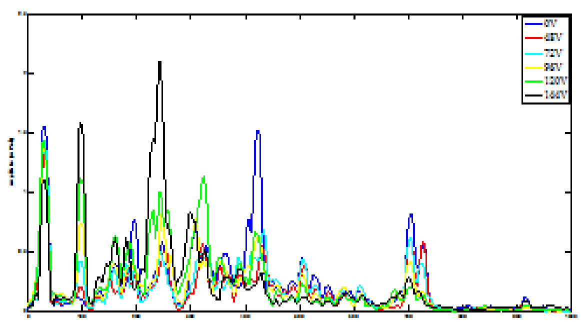

Figure-2. Aluminum disc 2 mm air gap using 2 poles at x-axis.

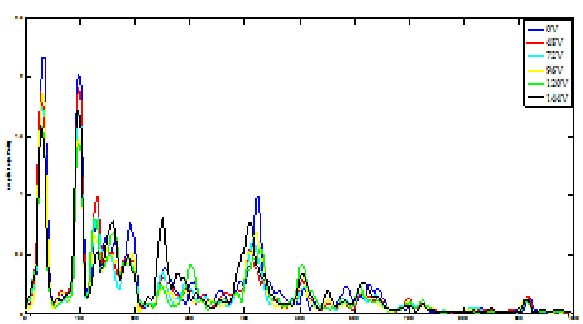

Figure-3. Steering wheel 2 mm air gaps using 2 pole at x-axis.

Figure-4 is the x-axis graph mean amplitude versus voltage increment using 2 pole of transformer. The mean amplitude value before apply pole is same for three air gaps opening which is 0.2348. The lowest vibration suppression was at 2 mm air gap opening with the mean amplitude of 0.166 mVolt using 48 Volt power supply. From the graph it shows that when the number of air gaps decrease, the level of vibration amplitude will decrease. This is because when the air-gaps decrease, magnetic flux density will increase. Air gap is inversely proportional with magnetic flux density. Figure-5 is the y-axis graph mean amplitude versus voltage increment using 2 poles of transformer. The mean amplitude value before apply pole is same for three air gaps opening which is 0.3139 mVolt. Lowest vibration suppression was at 2 mm air gap opening with the mean amplitude of 0.2782 mVolt with 48 Volt power supply. From the graph it shows that when the number of air gaps decrease, the level of vibration amplitude will decrease. This is because when the air-gaps decrease, magnetic flux density will increase. Air gap is inversely proportional with magnetic flux density.

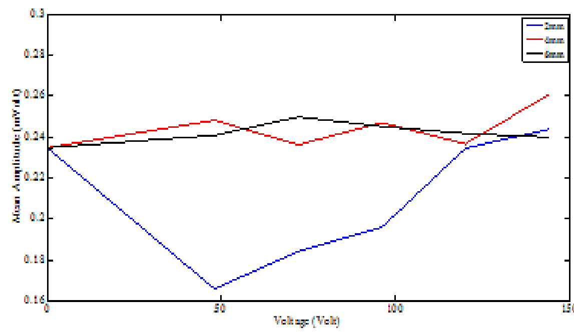

Figure-4. X-axis graph using 2 poles at aluminum disc.

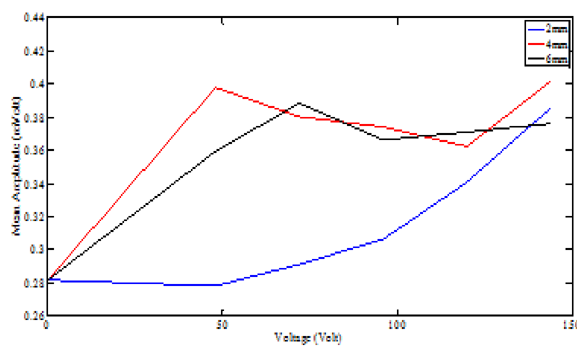

Figure-5. Y-axis graph using 2 poles at aluminum disc.

Figure-6 is the x-axis graph mean amplitude versus voltage increment using 4 poles of transformer. The mean amplitude value before apply pole is same for three air gaps opening which is 0.2348 mVolt. Lowest vibration suppression was at 6 mm air gap opening with the mean amplitude of 0.2016 mVolt with 96 Volt power supply. From the graph it shows that when the voltage is increase, the mean amplitude will decrease. It is because when the voltage increases, current will increase. Current is directly proportion with the eddy current damping force. The vibration does not suppress at 2 mm air gaps because poles are very close to the aluminium disc. As a result poles itself give the unstable force to the aluminium disc and will increase the vibration to the system.

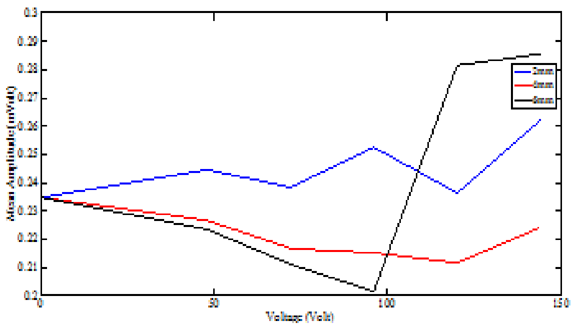

Figure-6. X-axis using 4 poles at aluminium disc.

Figure-7 shows the y-axis graph, mean amplitude versus voltage increment using 4 poles of transformer. The mean amplitude value before apply pole is same for three air gaps opening which is 0.3139 mVolt. Lowest vibration suppression after apply 4 poles transformer was at 4mm air gap opening with the mean amplitude of 0.3419 mVolt using 120 Volt power supply. From the graph it does not suppress at y-axis because of eddy current damping force produce more force to the aluminium disc and will increase the vibration to the system.

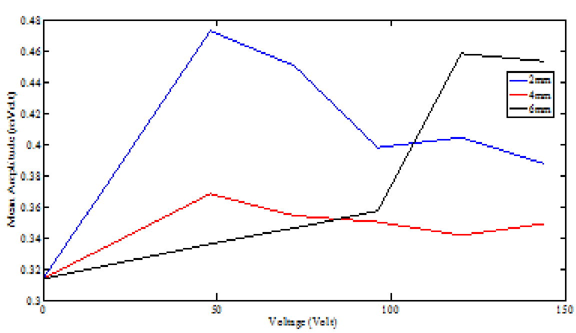

Figure-7. Y-axis using 4 poles at aluminium disc.

CONCLUSIONS

In this paper, it was attempted to visualize the effect of vibration suppression using eddy current braking effect on power steering system with different amount of voltage induced. It can be concluded that increasing the amount of voltage induced to the eddy current braking system has suppressed the vibration on aluminium disc and steering wheel. However, results shown that if the amount of voltage induced is too high, it also could increase back the amount of vibration. Therefore, future study could put more focus in finding the optimum range value for the voltage to be induced into the system with the combination behavior of other parameters such as air-gap used.

REFERENCES

[1] N. Ab Latif and A. Z. M. Rus. 2014. Vibration transmissibility study of high density solid waste biopolymer foam. Journal of Mechanical Engineering and Sciences. Vol. 6, pp. 772-781.

[2] M. Balcı and Ö. Gündoğdu. 2013. Determination of physical properties of laminated composite beam via the inverse vibration problem method. Journal of Mechanical Engineering and Sciences. Vol. 5, pp. 611-622.

[3] P. S. Kachare and Bimleshkumar. 2013. Effect of particle size and packing ratio of PID on Vibration amplitude of beam. Journal of Mechanical Engineering and Sciences. Vol. 4, pp. 504-517.

[4] M. Balcı, M. O. Nalbant, E. Kara and Ö. Gündoğdu. 2014. Free vibration analysis of a laminated composite beam with various boundary conditions. International Journal of Automotive and Mechanical Engineering. Vol. 9, pp. 1734-1746.

[5] S. K. Jha and A. Sharma. 2013. Optimal automobile muffler vibration and noise analysis. International Journal of Automotive and Mechanical Engineering. Vol. 7, pp. 864-881.

[6] C. B. Patel, P. P. Gohil and B. Borhade. 2010. Modeling and vibration analysis of road profile measuring system. International Journal of Automotive and Mechanical Engineering. Vol. 1, pp. 13-28.

[7] J. Giacomin, M. Shayaa, E. Dormegnie and L. Richard. 2004. Frequency weighting for the evaluation of steering wheel rotational vibration. International Journal of Industrial Ergonomics. Vol. 33, pp. 527-541.

[8] M. G. Pottinger, K. D. Marshall, J. M. Lawther and D. B. Thrasher. 1986. A review of tire/pavement interaction induced noise and vibration. The Tire Pavement Interface. pp. 183-287.

[9] D. Reynolds and E. Angevine. 1977. Hand-arm vibration, part II: Vibration transmission characteristics of the hand and arm. Journal of sound and vibration. Vol. 51, pp. 255-265.

[10] Lee K. and K. Park. 1998. Environmental Optimal Robust Control of a Contactless Brake System Using an Eddy Current. Journal of Mechatronics.

[11] Baharom M., Nuawi M., Priyandoko G., Harris S. and Siow L. 2011. Eddy current braking study for brake disc of aluminium, copper and zinc. In: Proceedings of Regional Engineering Postgraduate Conference.

VOL. 10, NO. 17, SEPTEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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[12] Y. Shimizu and T. Kawai. 1991. Development of electric power steering. SAE Technical Paper.

[13] C. W. Shan, M. I. Ghazali and M. I. Idris. 2013. Improved vibration characteristics of flexible polyurethane foam via composite formation, International Journal of Automotive and Mechanical Engineering. Vol. 7, pp. 1031-1042.

[14] Z. M. Yusop, M. Z. Md. Zain, M. Hussein and A. R. Musa. 2013. As'arry, Evaluation on an Assistive device in suppressing hand tremor during writing. International Journal of Automotive and Mechanical Engineering. Vol. 8, pp. 1187-1196.

[15] N. Jamil, A. R. Yusoff and M. H. Mansor. 2012. Literature review of electromagnetic actuator force generation for dynamic modal testing applications. Journal of Mechanical Engineering and Sciences. Vol. 3, pp. 311-319.

[16] A. R. Yusoff, M. R. Z. Mohamed Suffian and M. Y. Taib,. 2011. Literature review of optimization technique for chatter suppression in machining. Journal of Mechanical Engineering and Sciences. Vol. 1, pp. 47-61.

[17] H. Tamaki, Z. J. Zhong, N. Matsumoto, S. Kida, M. Koikawa, N. Achiwa, Y. Hashimoto and H. Okawa. 1992. Design of metal-complex magnets. Syntheses and magnetic properties of mixed-metal assemblies {NBu4 [MCr (ox) 3]} x (NBu4+= tetra (n-butyl) ammonium ion; ox2-= oxalate ion; M= Mn2+, Fe2+, Co2+, Ni2+, Cu2+, Zn2+). Journal of the American Chemical Society. Vol. 114, pp. 6974-6979.

[18] D. Reynolds and W. Soedel. 1972. Dynamic response of the hand-arm system to a sinusoidal input. Journal of Sound and Vibration. Vol. 21, pp. 339-353.