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TESTING AND SIMULATION OF FRACTIONARY ELECTROMECHANICAL ROTATIVE DRIVES

D. B. Pimentel
C.A. Martin
Universidade Federal de Santa Catarina, Departamento de Mecânica
Laboraratório de Hardware – GRUCON
Cx. P. 476 88040-900 Florianópolis, SC, Brasil

Abstract. *This paper concerns about the development of drive systems that applies electromechanical rotative motor systems through the utilisation of a specially developed drive test system linked to simulation softwares. The objective of this paper is to show that a precision data acquisition, well tuned with state-of-the-art system model simulation packages, together, allow the affordable model validation procedure. This is required for fitting, in the best way, a drive to its load or also inversely, to adapt loads to given drive characteristics.*

Key words: *Test bench, Simulation, Fractional electrical drives, Automatic test and measurement, System dynamics analysis.*

1. FRACTIONARY ELECTROMECHANICAL ROTATIVE DRIVES AND ITS APPLICATIONS

Fractionary electromechanical rotative drives are already applied in truly uncommon quantities and even though, the tendency of new applications remains strongly growing. It is also observable that nowadays fractionary electromechanical rotative drives are available in a great variety of conceptions and designs.

The market branches that apply huge quantities of fractionary electromechanical rotative drives are widely varied. Main examples are the vehicles industry (automotive, aerospace, etc.), appliances (especially audio, video, home), computers (especially in peripherals as printers, disc and tape drives, image plotters and scanners, fans, etc.), in industrial automation (measurement and registration instrumentation), machines and manipulators of small to medium size, etc. (Bahniok, 1989) (Pimentel, D., 1996)

Similarly it is observed that the users are increasingly demanding in terms of the best dynamic performance of drive systems (high acceleration; high rotation speed; smooth motion even at very low rotation), low friction, light weight, etc. and also high reliability and durability, and, of course, it all must become available at low costs, each day more pressed by an extremely competitive global supplying market. (ELECTRO-CRAFT, 1989)

The user’s demands in part force an accelerated development of new and specific drive systems, at each one more sophisticated; and in another part, considering that, in present days, the drives and their specific applications form a tight integrated motion system, the application project requires the perfect knowledge of the drives itself, in order to match them correctly with the loads into the integrated solutions, specific to each host equipment framed in the various, above mentioned, particular application fields.

2. ANALYSIS OF FRACTIONARY ELECTROMECHANICAL ROTATIVE DRIVE SYSTEMS

The behaviour of fractionary electromechanical rotative drives can be described by means of their characteristic information (parameters, curves) that are brought in tests firstly performed at the manufacturers. With these data and with the help of product register files and computer aided evaluation and also with model simulation softwares, a good applications project is feasible.

It is able then, e.g., to choose to proceed the drive system development directly on one given specific application, which is undoubtedly a valid solution; however, as it is a specific solution, the results are restricted to the given application; further, this method obviously presupposes the availability of all the drive data.

However, the information is not always conveniently set in the products data sheets, thus creating insurmountable difficulties, especially in the case of matching components of distinct sources and that may be supported by different local standards. Besides this, many tests carried out show that there is also the problem that some products are simply not able to reach (and hold) the specifications presented in their respective data sheets.

Because of that the proposal presented here is, that for an effective solution development two steps are required: First, a kind of test system that can physically simulate all the conditions under which the drive system is going to be used and generate the needed reliable drive data, in a manner that will allow the best matching of the drive characteristics to that of the load, so that its further operation in the applications itself will be perfect; second, a linked drive model simulation system aiming the validation of the model needed e.g. for drive controller development.

3. TEST SYSTEMS FOR FRACTIONARY ELECTRO-MECHANICAL ROTATIVE DRIVES

With the purpose of realising tests to obtain reliable data for the development of motion systems with fractionary electromechanical rotative drives in the power level bands corresponding to torques of 5 Ncm to 2 Nm and also for didactic presentations and quality control in the production of drive components and systems, it is indispensable to have a test system, that, by the means of loading and measuring/instrumentation devices, allows the determination of the dynamic behaviour of the drives under test, in the form of its frequency response and its time response at acceleration/deceleration and at coupling / uncoupling of mechanical loads and also by obtaining static parameters and characteristic curves, all depending on the kind of loading applied, e.g. inertial loads without friction, viscous friction loads with negligible inertia and/or any of these combinations. This test system is broadly presented in (Pimentel, D., 1996). It follows only highlights of it.

State-of-the-art drive systems for fine mechanics and precision mechanics, e.g. drives using transmission by synchronising belt or direct drives, powered by DC or AC servomotors or also by stepping motors, can be tested reliably by reproducing the real conditions of the applications operation. Modes of operation in open loop or closed loop control systems, e.g. to control position, velocity and/or torque, can be outlined, while the data acquisition operates in a analogic way or totally digital.

In the conception of the mechanical structure of the corresponding test bench performed for the system (it itself classifies as equipment of fine mechanics) it was tried to guarantee the maximum operational flexibility and simplicity at mounting each of the many variants of test configurations that result from the combination of bench elements such as the drive under test, the mechanical load elements and the transducers for the various mechanical, electrical and thermal variables and parameters. For this purpose those elements are mounted on devices especially projected for frequent test configuration changes, while otherwise the coupling of the respective axles are fast and safe. A strong mechanical base structure construction guarantees the effective damping of the vibrations induced by drives of the expected power band. Moreover, it was guaranteed especially that, for example, parasitic moments of inertia, friction and elasticity was made negligible, in order to achieve an uncomplicated modelling of the system and to get a very good conformity in the further comparison between the measurement results and the results of the mathematical simulation of the model of the drive system under test.

4. INSTRUMENTATION OF THE TEST BENCH FOR THE VARIOUS MEASUREMENTS

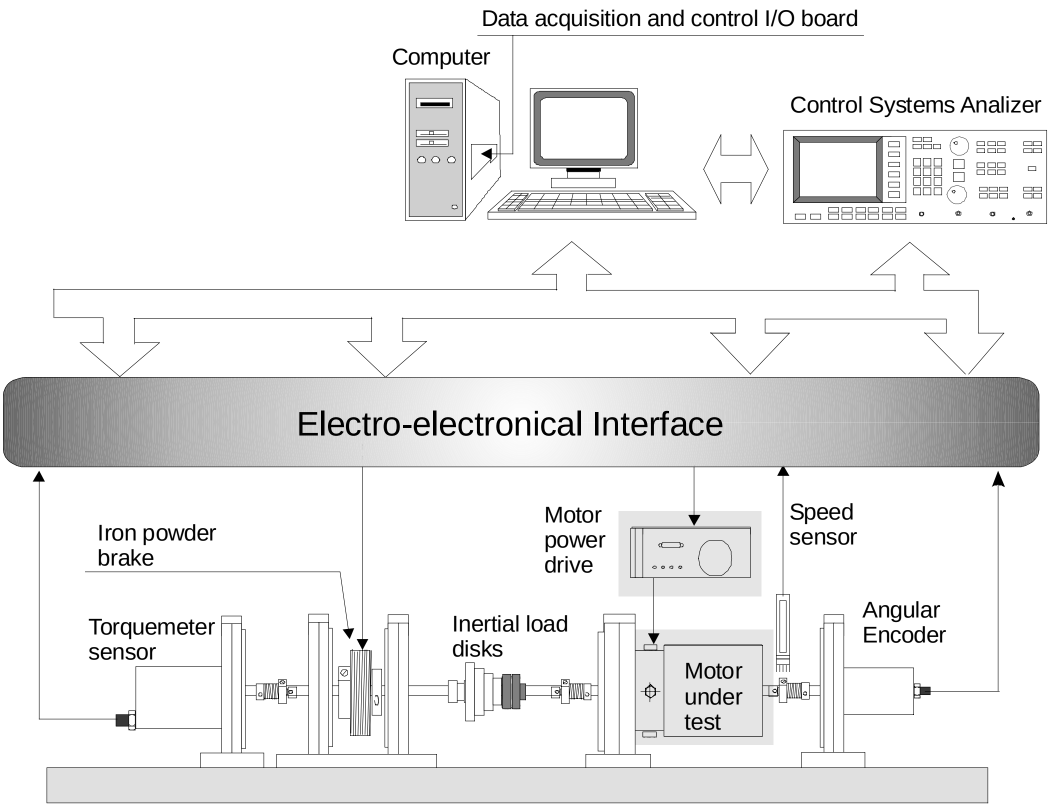

Figure 1- Test System Structure

On a test system for fractionary electromechanical rotative drives like that shown in Fig. 1, the necessary instrumentation must be available to obtain: The static rotation x torque curves, which requires the utilization of a torque sensor and a tachometer; the time response of position, velocity, acceleration parameters that must be acquired fast and precisely; this is done by the use of a computer interface for the communication with an encoder, that delivers the position directly by up-down counting the number of its output pulses; through the correspondingly pulse rate, the angular velocity can be derived; from the variation of pulse width the acceleration can be get, and from its two quadrature pulse channels also the rotation sense can be detected.

The measurement of the characteristic constants of the drives such as torque constant, voltage constant, electrical and mechanical time constants, requires additionally an ammeter and a voltmeter; the power for the drive system under test is supplied by a regulated power supply; to obtain the frequency response of the drive and its components a Control Systems Analyser - CSA (HP Application Note, 1990) is interfaced with the host computer.

5. MANAGEMENT OF THE TEST BENCH

In order to make the tests totally automatized, it was elaborated a managing software in a Windows environment, formerly with the programming language "*Borland C*" © and now, applying "*Delphi 3*" ©, that offers a better and easy graphics programming interface.

This program consists basically of the following modules:

"Main", which presents the basic options of the manager, the most important begin the *test* option, which allows to set the commands individually and visualise the aquisitions, Fig. 2.

Figure 2- Main menu screen, Input and Output test.

"Parameters", which allows to specify the operating parameters of the drive system under test and the various signal conditioners of the bench (screen "*hardware*", Fig. 3) and another screen "*torquemeter*" for setting its electronics.

Figure 3- Defining parameters menu screen.

"Tests", which allows to set the parameters for the various programable tests with the test system (e.g. for the torque vs. speed characteristic, Fig. 4); after performing the test, the results are presented graphically.

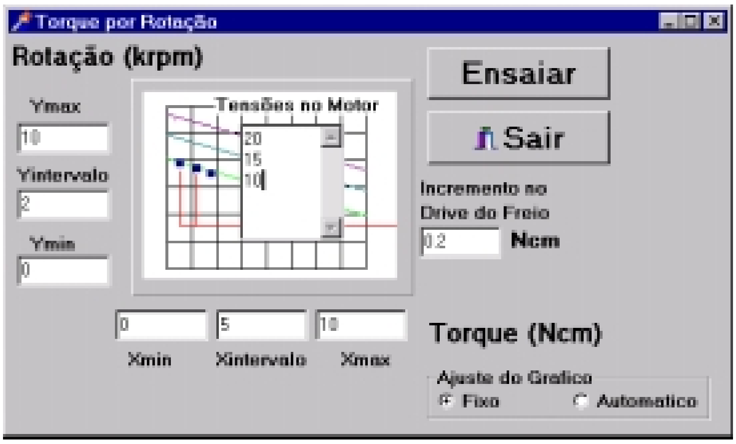

Figure 4- Screen of the "*test*" menu, for obtaining the "*torque vs. speed*" characteristic curve.

Furthermore, the software also offers the option of choosing the user interface language, that at this time are, English, German, Portuguese and Spanish. It also offers the option of keeping in a motion products data base, the data of different motors already tested, aiming later comparisons with the results of new test. A new option that is in implementation will allow the setting of data tolerance ranges in order to enable the classification of the tested drives..

6. NUMERICAL SIMULATION OF FRACTIONARY ELECTROMECHANICAL ROTATIVE DRIVES

In the teaching and development work on motion drives, apart of the testing itself, it is very important, for various reasons, to perform mathematical simulations of the behaviour of the drive system. The simulation allows the validation of the acquired data and the model by comparing the measurement results with those of the simulation. The simulation also can show how the drive behaves when parameters of the system change, here including the boundary cases that lye outside the physically safe operating range of the equipment. In such cases, of course, the mathematical simulation model should have previously been fully validated. The model must be obtained or developed before. This may be a time domain or frequency domain model, since data obtained with the test system supports both options. In order to start the simulation, a very simple frequency domain model – transfer function – of the system is presented. Its parameters are exchanged with the measured data. Then these equations are implemented to a simulation software package, like *Vissim* ©, *Simnon* ©, etc. For the present work the powerful *Matlab* © package was applied. The results are presented as graphics outputs of the frequency behavior and time response. After the first validation is completed by having a good matching between measured data and simulation output, the simulation model is ready for the execution of runs with model parameters freely changed by the user, with the aim of observing the response of the drive when applied in a system subject to alterations. Obviously, a lot of parameters can be altered also physically in the test bench for matching the corresponding alterations introduced in the model, so that it is now possible to once more compare the measured results with those of the simulation when both, the physical system and its model, are simultaneously altered.

7. RESULTS

The presented results cover only few of the possible tests performed at the bench with fractionary high dynamics motors. All the tests herein presented refer to the dynamic behaviour of the drives. More about tests, mainly static ones is present in (Pimentel, D., 1996).

7.1 Test for obtaining the mechanical time constant

The mechanical time constant, τ_m, is a dynamic mechanical characteristic of the drive system. Applied a step function input voltage (Fig. 5), the mechanical time constant is defined as the time delay for reaching 63.3 % of the final speed value (ELECTRO-CRAFT, 1989). The value and time delay of the step function input applied on the motor is generated by a CSA (Control System Analyser).

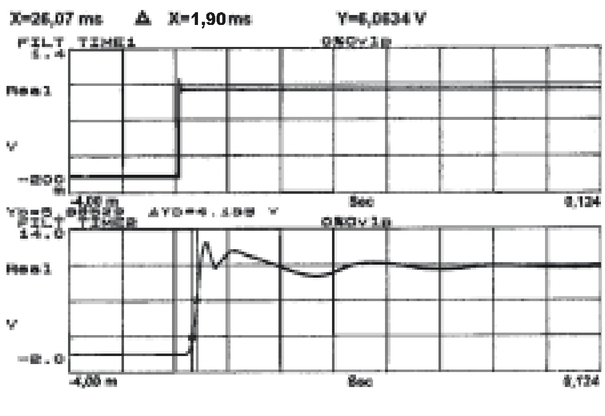

Figure 5- Speed step response of the driving tested, obtained by CSA.

The mechanical time constant is a parameter through which one can classify whether or not a drive system is of high dynamic (The current value of τ_m for high dynamic fractionary drives is under 1 ms, (Bahniok, 1989))

7.2 Test for getting the Frequency Response

To obtain this plot, it is applied to the drive input an harmonic signal of variable frequency, and the amplitude ("*dB*") and the "*Phase*" responses are obtained (HP Application Note, 1990), Fig. 6. Also this plot allows the evaluation of the dynamic response of the drive under test. In this plot the drive resonance frequencies can be observed, what is useful when designing the drive system.

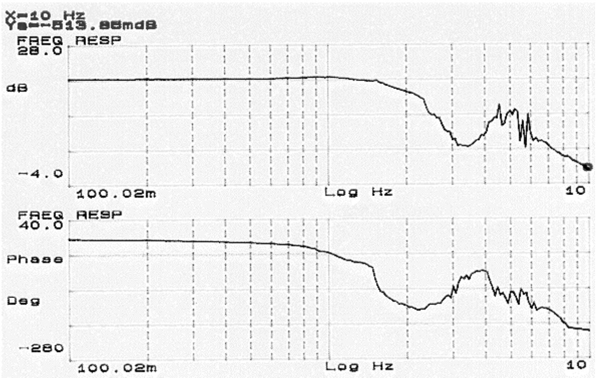

Figure 6- Frequency Response of the tested drive.

Figure 7 presents the test system structure for torque-frequency response measurement.

Figure 8-left shows the output data of the obtained torque-frequency response (amplitude (dB) and PHASE) in the form of Bode plots together with the fitted amplitude response curve (CURVE FIT), and the corresponding numerical data in the pole, zero and gain table (Fig. 8-right, S Curve Fit).

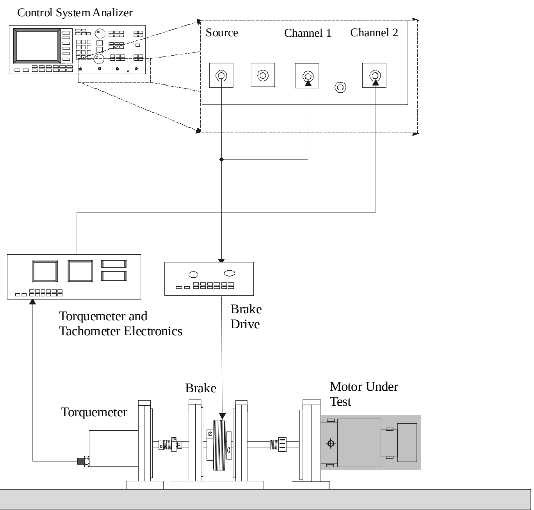

Figure 7- Disposition of equipment for drive torque frequency responce

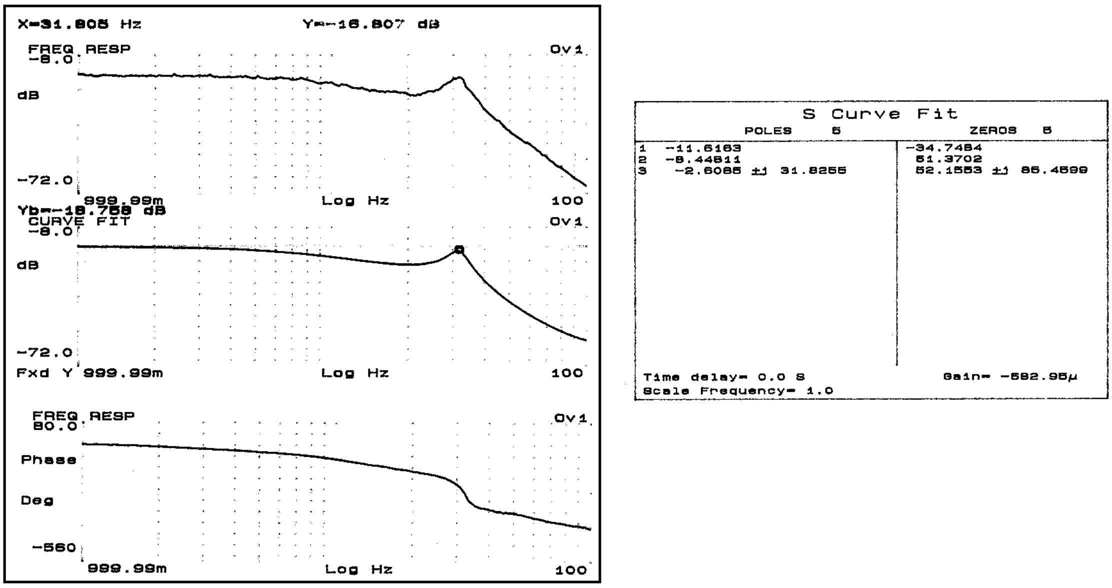

Figure 8- Measured drive torque frequency response.

Eq.1 shows the transfer function of the drive system under test, achieved by introducing the measured numerical data in the polinomial form.

$$H(s) = -(682{,}95E-6)\frac{(s+34{,}77)(s-61{,}37)[s-(52{,}15+j85{,}46)][s-(52{,}15-j85{,}46)]}{(s+11{,}62)(s+8{,}45)[s-(-2{,}61+j31{,}83)][s-(-2{,}61-j31{,}83)]} \qquad (1)$$

Figure 9 finally shows the resulting *Matlab* © amplitude and phase response output of the Transfer Function evaluated for the data obtained in the previous measurement.

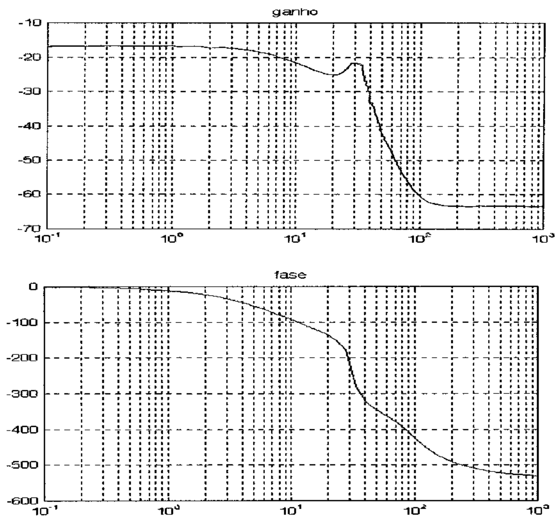

Figure 9- Simulation output: Amplitude and phase Response with *Matlab* ©.

8. COMMENTS, CONCLUSION

A comparison between the Bode plots generated by the CSA and those of the Matlab simulation shows the excellent matching already achieved.

The current development will allow a full linking between the bench instrumentation, its management system and the simulation softwares.

The results obtained for the tested motor, are presented similarly to the manufacturer's catalogs (HONEYWELL, 1985). However, it was noticed that some values determined at the system and shown in Table 1.

Table 1 Comparison between the values obtained at the system and the ones presented by the manufacturer.

TEST	Data from manufacturer	Values obtained by the system
Mechanical Time Constant	1,70 ms	1,90 ms
Torque Constant	4,00 Ncm/A	3,56 Ncm/A
Voltage Constant	4,22 V/krpm	4,22 V/krpm

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