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Command Structure Design of a Robot for the Vibro-Acoustic with Scanning Testing

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Abstract. This paper is presenting the command system improvement of a scanning robot for acoustical testing. The evaluation of noise emitted by an object by measuring the acoustic intensity according with the ISO 9614-3:2002 international standard requires displacement of the probe on spatial trajectories with constant speed and maintaining the spatial orientation of the probe. In a previous work a robot was design by the authors for performing this task, including a unit with 3 translations and an orientation unit with 2 rotations.The practical tests of the first system shown high difficulties in maintaining the constant speed due to the robot dimensions and inertia. Also the noise produced by the translational units during scanning was too high. The system is improved by adding 1 degree of freedom at the orientation unit, reduction of noise and new software version. The new mechanical structure is the subject of another paper. This article is presenting the control system of the robot based on Festo controllers, DSP board and programs derived using LabVIEW. The new version is based on a positioning of the scanning unit in the vicinity of the scanning plane, using translation axis, and then the displacement of the acoustic probe for scanning using only the orientation unit, having DC motors, much lower inertia. This allowed a better control of scanning and lower noise.

The command structure of the robot

According to the stipulations of the ISO 9614-3:2002 standard [1], the robot to be designed, manufactured and used within the anechoic room for displacement of an intensity proble must fulfill two technical conditions of great difficulty:

• the designing of a minimum 6 mobility degrees robot, who must generate scanning spatial trajectories (parallel, go and back, passing over) while it is moving with constant, programming speed, regardless the lateral surfaces types of the scanned volumes: prismatic, cylindrical or spherical. This is enforcing a very complex control program with movements and speeds interpolation, which in order to impose a constant speed on the trajectory, it must guarantee almost permanently continuous variable speeds on the coordinates axis;

• a robot whose own noise level during operation must be 20 dB smaller than the one of the testing source/product.

In a previous work a robot was design by the authors for performing this task, including a unit with 3 translations and an orientation unit with 2 rotations [2]. Such robots used for testing automation in acoustics and vibration are produced by only two companies in the world [3], [4]. The practical tests of the first system shown high difficulties in maintaining the constant speed due to the robot dimensions and inertia. Also the noise produced by the translational units during scanning was too high. The system is improved by adding 1 degree of freedom at the orientation unit, reduction of noise and new software version. The new mechanical structure is the subject of another paper [5]. The robot has 7 DOF and is designed for controlling the positioning and orientation in space of a intensity probe or a microphone array.

– The resultant structure is composed by 2 assemblies:
– one positioning sub-system with 3 translations, using FESTO motors;

– one orientation sub-system with 3 rotations (there is also a translation but redundant to the ones from the first subsystem), using DC servo motors from Maxon.

The positioning assembly with 3 translations is comprising 3 positioning sub-systems (Fig. 1):

– an assembly with 2 translation units DGE-40-1600-ZR-GF-GK-LB-RK-KG FESTO type; the 2 units shafts are connected with a transmission unit and are driven simultaneous by a single motor Festo MTR-AC-100-3S-GA;

– a positioning unit DGE-63-1600-ZR-GF- GK-LV-RK-KG FESTO type, driven by a Festo MTR-AC-100-3S-GA motor;

– a positioning unit DGE-25-1425-ZR-GF- GK-LV-RK-KG FESTO type, driven by a Festo MTR-AC-55-3S-AB motor with internal brake.

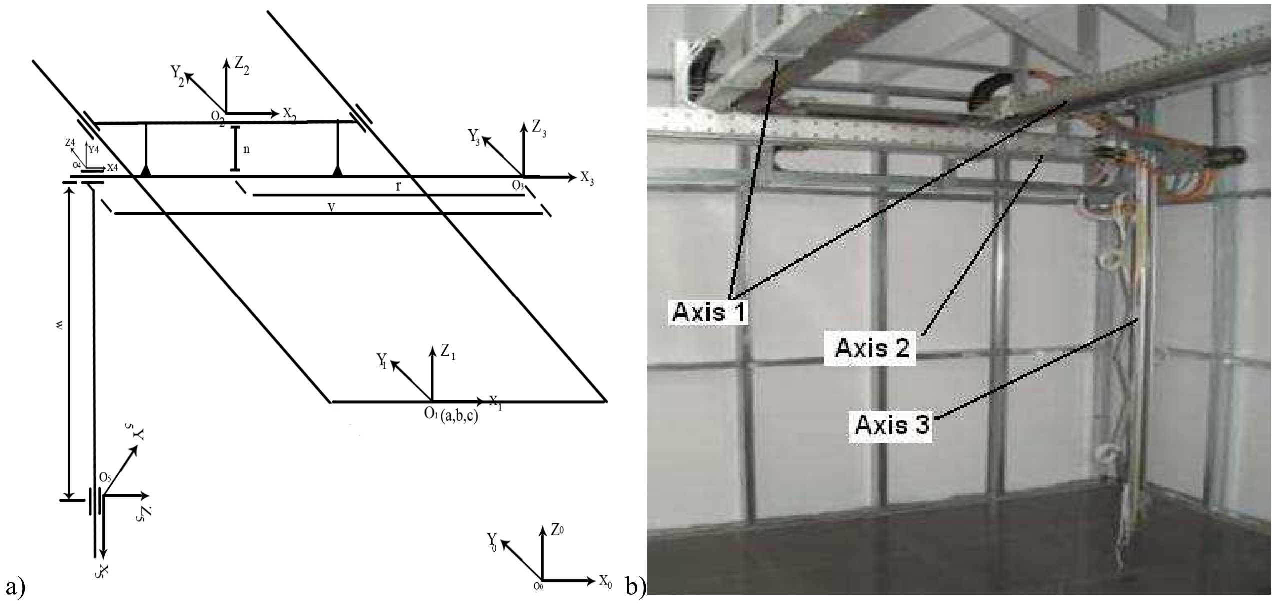

Fig. 1 Positioning assembly with 3 translation: (a) Kinematic structure and assembling between units; (b) Practical design

The command of the system is done using two subsystems: a system based on SEC-AC 305 FESTO controllers for the translation units with FESTO AC motors (Figure 2) and a system with a PCI-7344 National Instruments, DSP controller for the orientation unit (Figure 3).

The Festo controllers includes the power stage for converting the control voltage from 220V to 380V, the analog input stage for acquiring the signals from the rotation encoder included in the motor structure and also for measuring the motor temperature. There are also provided digital inputs and outputs used in this case for acquiring signals from the switches. For limiting the displacement are used Reed effect switches. One of the limiting switches is used also as a home reference. The controller implements few possible feedback rules: position control; velocity control; torque control and also combination of them. The communication between the controller and PC can be done using RS -232 bus or CAN bus for improving communication speed (Figure 3). The device integrate all filters required by the EMC rules (electromagnetic compatibility - EMC), such as network filters out the motor, power and inputs/outputs filters. Integrated braking module allows the braking energy to be dissipated by the internal braking resistor. It is also possible to connect external resistors with a power of a few kW to improve braking energy. The central component of the control unit is a microcontroller 32-bit RISC type HITACHI SH 7032. Communicating with other controllers, PLCs or computers is done using CAN interface type or serial interface and via digital inputs and outputs. Ten external digital inputs and five digital inputs are completely electrically isolated. Digital analog converter controller is integrated in SEC-AC and facilitate the digitization of analog variables (eg currents engine or motor temperature set-points and analog output stage final). Digital to analog converter is used to display on a monitor control analog variables. This feature helps to optimize the controller SEC-AC.

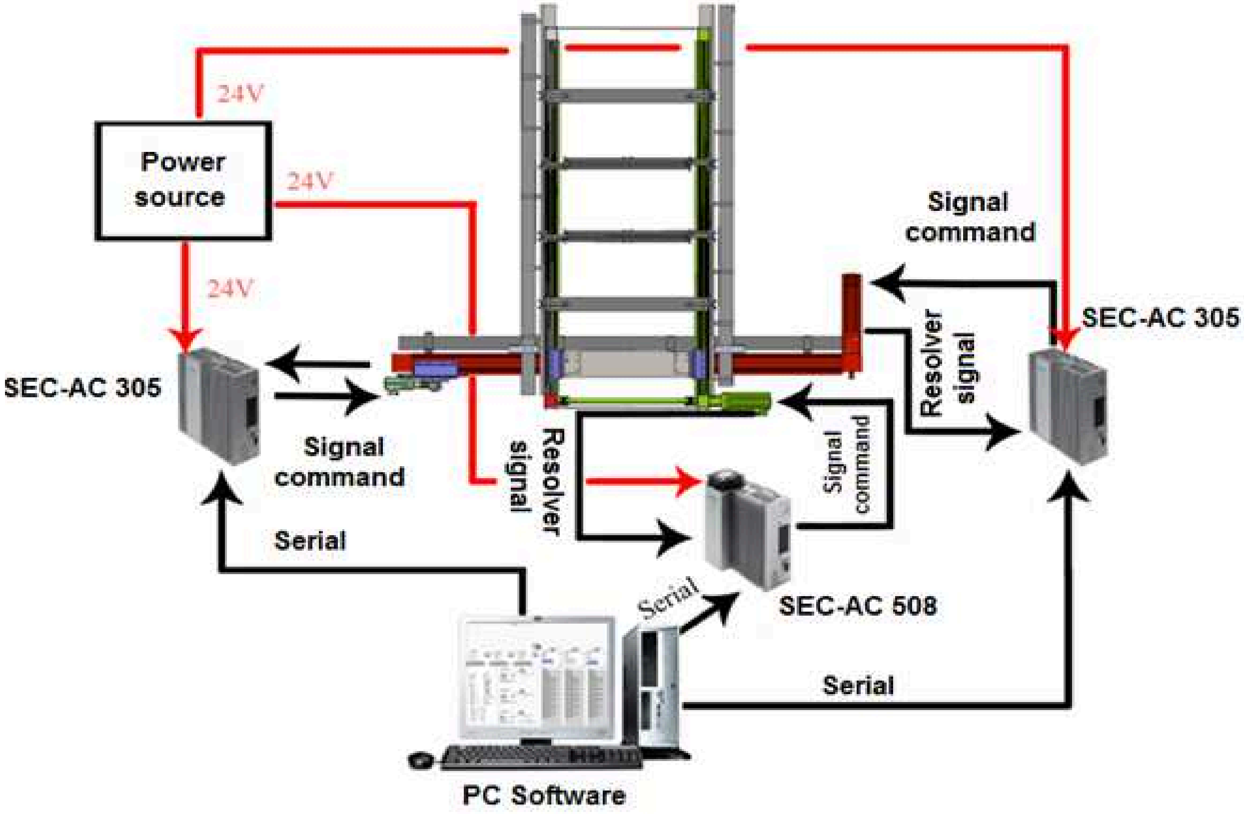

Fig. 2 Control of the translation axes

The final output stage is designed in three phases. The motors must be connected in a star mode. Operation in low or intermediate circuit voltage is also possible. A brake relay is integrated into the final output stage. There are an extensive number of arrangements of sensors and monitoring functions to ensure operational safety: motor temperature measurement, temperature measurement final stage, recognizing the connection between the phases of two engines, recognition of internal power voltage falls. During operation, the SEC-AC controller can display different monitoring parameters. These parameters are communicated to the user via software. Rotary encoder evaluation unit is incorporated into a plug-in board as standard SEC-AC operates with a resolver signal. It also has an incrementally sensor input.

The controller has an internal memory with 10 „states" in the destination table. The „states" are programmed using RS 232/CAN bus (speed, position, final speed, etc.). The „state" is selected by software or by using 4 digital inputs of controller. It is possible to start the movement by software or by using another digital input line. For this robot was chosen the RS-232 communication because the translation subsystem has only the role of positioning the orientation unit in certain positions then the movement is blocked, the FESTO motors stop for reducing noise, and scanning is done using only the orientation unit. The scanning time is high allowing reprogramming for the states in the interval memory. The controller can also work without using the interval memory, by receiving the destination and movement parameters from software and also the start/stop command.

The orientation unit has 4 DC brushed motors, with internal incremental encoders. The motors has external amplifiers working as power-stage having also the role to power the encoders. These amplifiers receives control voltage from the DSP board. The DSP is acquiring the encoder quadrature signals and also the digital outputs of the limit switches (mechanical and optical). The DSP board has 2 microcontrollers allowing synchronizing movement of up to 4 axes using a trapezoidal or arbitrary velocity profile.

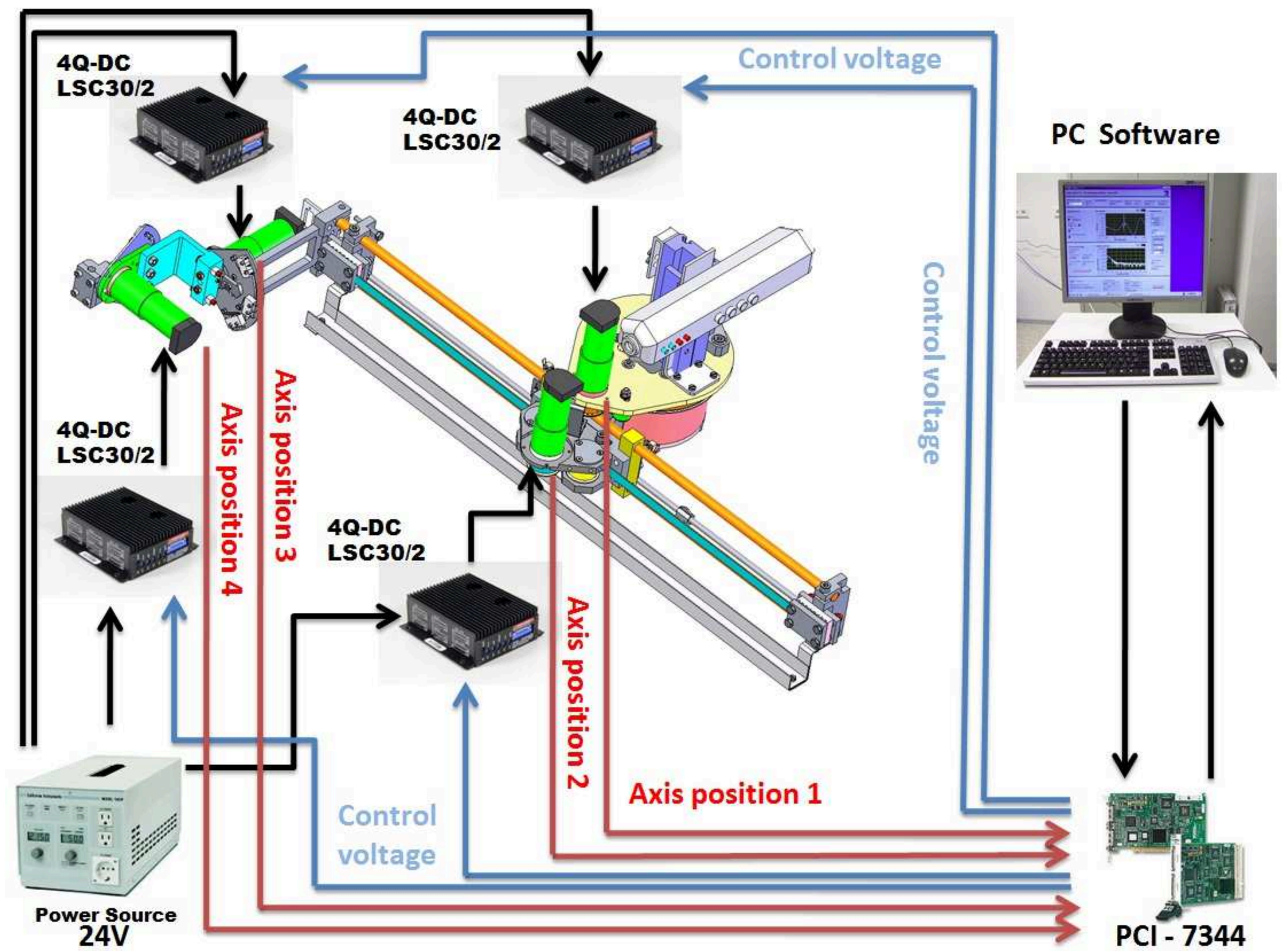

Fig. 3 Control for the orientation unit with 4 DOF

The software for controlling the robot was made using LabView graphical programming language and includes:

- using a front panel module for introducing the positions, orientations and dimensions of the scanning planes; the software is computing the scanning trajectories and the optimal positions of the orientation unit;
- module for communication with the FESTO controllers using RS-232 bus;
- module for control of the DSP board; this board is needed to control the motors to obtain scanning in a plane;
- module communicating with the PULSE module software. The PULSE software is controlling a data acquisition unit specialized in acquiring signals from the intensity probes. The communication with PULSE implies start of the acquisition and reading of the acoustic intensity values (the signal processing parameters are defined in PULSE interface). The communication between PULSE and LabView is based on ACTIVE X protocol.

The control panel of the virtual instrument for communicating with FESTO controllers is presented in Fig. 4 and is split in 3 area:

- programming the communication parameters (baud rate, number of data bits, parity, stop bits, flow control, XON/XOFF characters, etc.) and VISA names for the three axes;
- programming the movements (positions, speed), buttons for executing the next command; button for execution of the actual positioning command, button for emergency stop;
- input of different command, buttons for stop of the command in use;
- indicators for the messages send by the microcontrollers.

The virtual instrument is designed not only for position control, but also as a debugging tools having access to all the parameters of the microcontrollers. When is integrated as a sub VI in the overall software, the user has access only to the programming of the movement parameters.

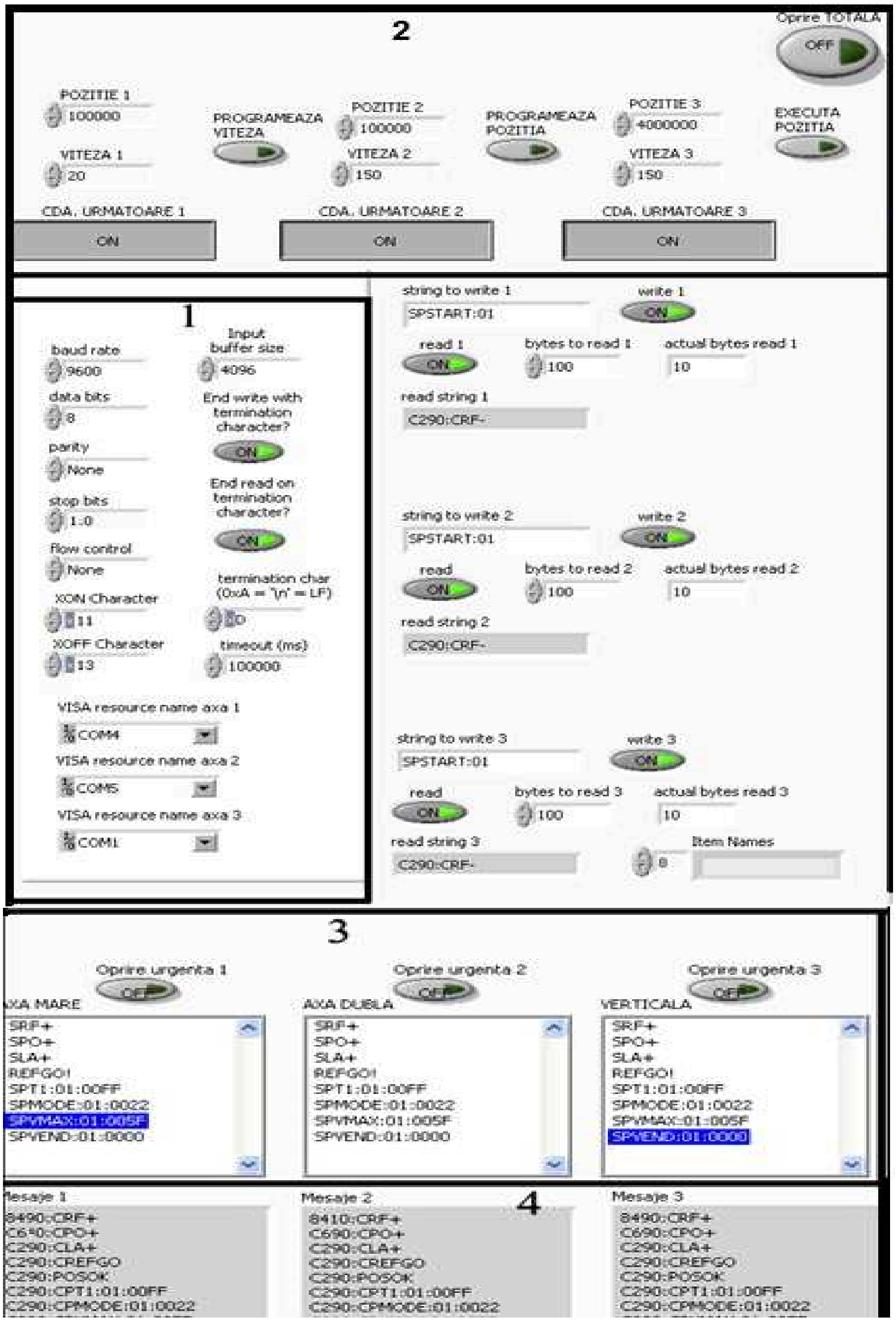

Fig. 4 The control panel of the translating system

The optimal movement parameters for the Festo axes were derived experimentally using the optimization interface provided by the company (Figure 5).

The steps are:

- input parameters for the x-axis (type of electric drive and linear motion in order to position the intensity probe in space, weight of moving mass eg. 17 kg. , maximum stroke is 1600 mm and the tolerance will be 0.10 mm for the OX axis);
- the introduction of speed and acceleration;
- at great length axes, the production company recommends placing a dead profile. Because space is limited in anechoic chamber, it was decided not to use the additional profile;
- introduction of feedback parameters;
- testing and optimization of feedback.

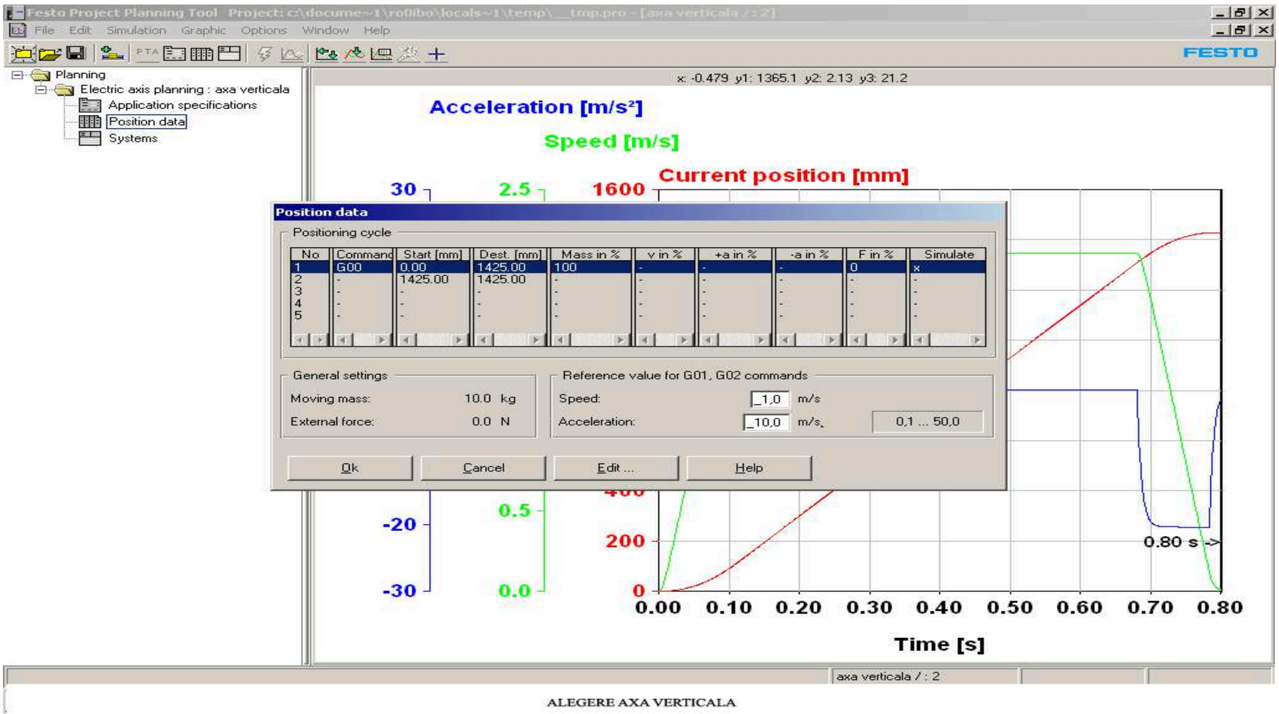

Fig. 5 The optimization interface

The robot is programmed to work in the next steps:

1. The user is introducing the dimensions of the scanning planes and the positions of the origin and axis orientations for the tri-orthogonal coordinate systems linked to each plane;

2. The user is defining the scanning lines density;

3. The software computes the positions of origin of coordinate system linked to the orientation unit, guided by the vertical axis, and commands necessary for the translational axis. This commands are sent to the FESTO controllers and the start command is send.

4. The trajectory of the end transducer is computed; applying an inverse calculation are computed the trajectories for the orientation unit degrees-of-freedom; the trajectories are send to the DSP board; the scanning time is computed and programmed to the PULSE unit; the start command for the DSP board is also applied to the PULSE unit.

Summary

A robot with scanning possibilities for vibration and acoustical testing was made. The control system is presented in this article together with the main functioning steps. Few of the virtual interfaces derived in LabVIEW are presented. The system allows control of external motor controllers, a DSP board and also a specialized acoustic data acquisition unit.

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