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Geometrically Non-linear Vibrations of Structures

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STUDY OF EXPERIMENTAL SIGNALS DURING IMPACTS AND VIBRATIONS OF A ROBOTIC MANIPULATOR

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1 INTRODUCTION

In practice the robotic manipulators present some degree of unwanted vibrations. In fact, the advent of lightweight arm manipulators, mainly in the aerospace industry, where weight is an important issue, leads to the problem of intense vibrations. On the other hand, robots interacting with the environment often generate impacts that propagate through the mechanical structure and produce vibrations. Reference [1] mentions several techniques for reducing vibrations and its implementation either at the robot manufacturing stage or at the operational stage. One of the techniques, that has been receiving considerable attention, consists on the use of a micromanipulator [2], with a higher frequency response than the main manipulator, mounted at the end-effector and actively counter-acting the undesirable dynamics.

In order to analyze the phenomena of vibrations an acquisition system was developed. The manipulator motion produces vibrations, either from the structural modes or from end-effector impacts. The instrumentation system acquires signals from multiple sensors that capture the joint positions, mass accelerations, forces and moments and electrical currents in the motors. Afterwards, an analysis package, running off-line, reads the data recorded by the acquisition system and extracts the signal characteristics.

This extended abstract is organized as follows. Section 2 describes briefly the robotic system enhanced with the instrumentation setup. Section 3 presents the experimental results. Finally, section 4 draws the main conclusions and points out future work.

2 EXPERIMENTAL PLATFORM

The developed experimental platform has two main parts: the hardware and the software components [3]. The hardware architecture is shown in Figure 1. Essentially it is made up of a robot manipulator, a Personal Computer (PC) and an interface electronic system.

The interface box is inserted between the robot arm and the robot controller, in order to acquire the internal robot signals; nevertheless, the interface captures also external signals, such as those arising from accelerometers and force/torque sensors. The modules are made up of electronic cards specifically designed for this work. The function of the modules is to adapt the signals and to isolate

galvanically the robot's electronic equipment from the rest of the hardware required by the experiments. The software package runs in a Pentium 4, 3.0 GHz PC and, from the user's point of view, consists on two applications: the acquisition application and the analysis package.

The acquisition application is a real time program for acquiring and recording the robot signals.

After the real time acquisition, the analysis package processes the data off-line in two phases, namely, pre-processing and processing. The preprocessing phase consists on the signal selection in time, and their synchronization and truncation. The processing stage implements several algorithms for signal processing such as the auto and cross correlation, Fourier transform (FT), and window Fourier transform.

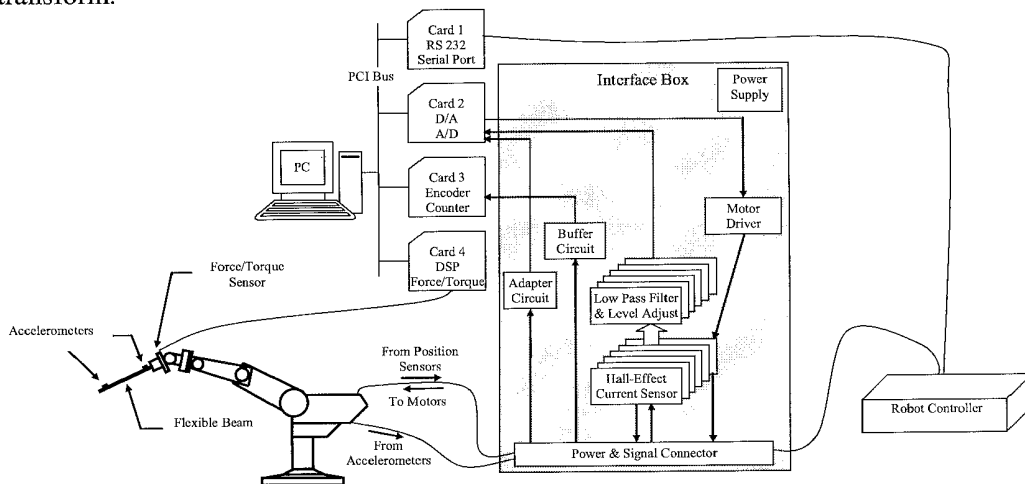


Figure 1. Block diagram of the hardware architecture.

3 EXPERIMENTAL RESULTS

In the experiments is used a flexible link that consists on a long and round flexible steel rod clamped to the end-effector of the manipulator. In order to analyze the impact phenomena in different situations two types of beams are used. Their physical properties are shown in Table 1. The robot motion is programmed in a way such that the rods move against a rigid surface. Figure 2 depicts the robot with the flexible link and the impact surface.

Table 1 Physical properties of the flexible beams.

Characteristics	Thin rod	Gross rod
Material	Steel	Steel
Density [kg m^{-3}]	4.34×10^3	4.19×10^3
Mass [kg]	107×10^{-3}	195×10^{-3}
Length [m]	475×10^{-3}	475×10^{-3}
Diameter [m]	5.75×10^{-3}	7.9×10^{-3}

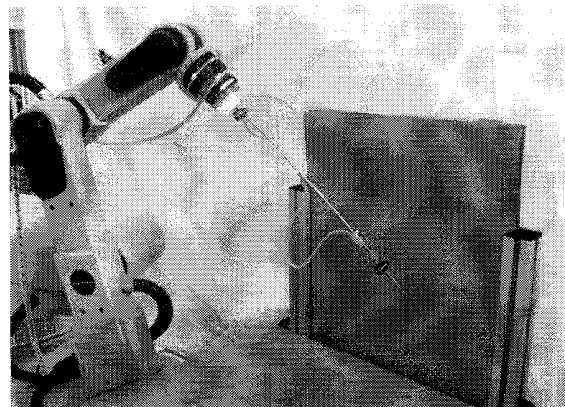


Figure 2. The steel rod impact against a rigid surface.

During the motion of the manipulator the clamped rod is moved by the robot against a rigid surface. An impact occurs and several signals are recorded with a sampling frequency of $f_s = 500$ Hz. The signals come from different sensors, such as accelerometers, force and torque sensor, position encoders and current sensors.

Figures 3 to 5 depict some of the signals corresponding to the cases: (i) without impact, (ii) the impact of the rod on a gross screen and (iii) the impact of the rod on a thin screen using either the thin or the gross rod.

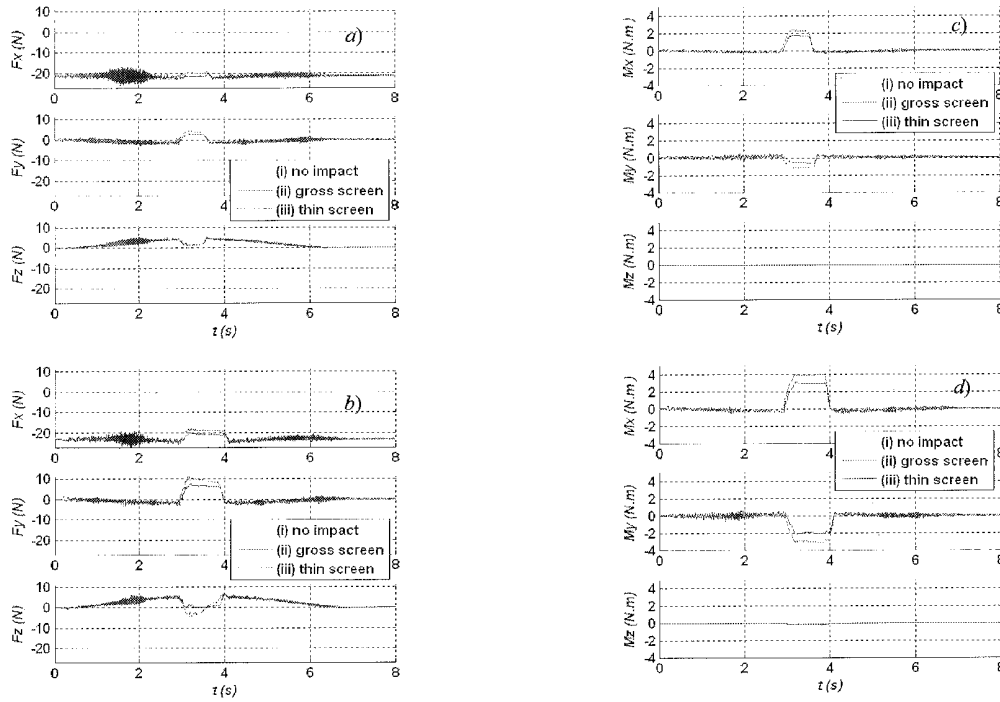


Figure 3. Forces (left) at the gripper sensor for the: a) thin rod; b) gross rod; and moments (right) at the gripper sensor for the: c) thin rod; d) gross rod.

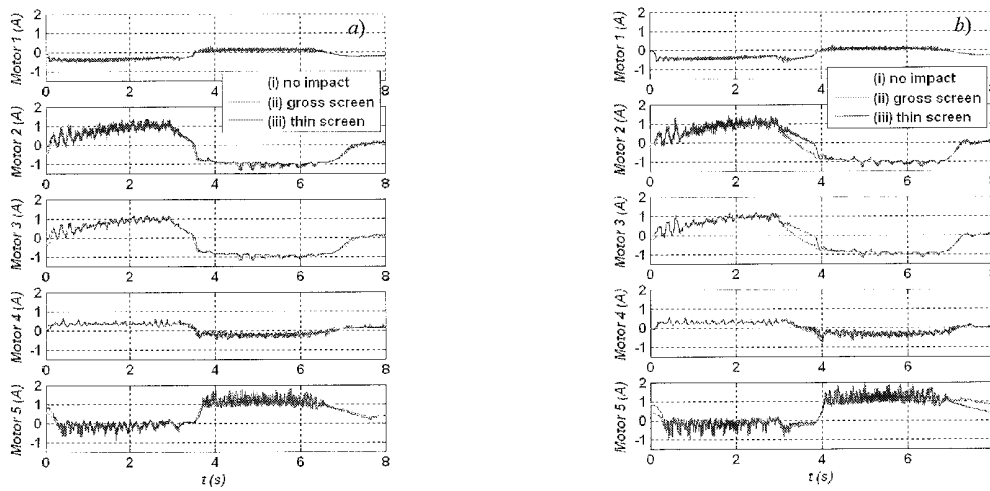


Figure 4. Electrical currents of robot axis motors for the: a) thin rod; b) gross rod.

Due to space limitations only the most relevant signals in time domain are depicted. In this example, the signals present clearly a strong variation at the instant of the impact that occurs, approximately, at $t = 3$ s. Consequently, the effect of the impact forces (Figure 3 left) and moments (Figure 3 right) is reflected in the current required by the robot motors (Figure 4). Moreover, as would be expected, the amplitudes of forces due to the gross screen (case ii) are higher than those corresponding to the thin screen (case iii). On the other hand, the forces with the gross rod (Figure 3

left *b*) are higher than those that occur with the thin rod (Figure 3 left *a*). The torques present also an identical behavior in terms of its amplitude variation for the tested conditions (see Figure 3 right).

Figure 5 presents the accelerations at the rod free-end (accelerometer 1), where the impact occurs, and at the rod clamped-end (accelerometer 2). The amplitudes of the accelerometers signals are higher near the rod impact side. Furthermore, the values of the accelerations obtained for the thin rod (Figure 7 *a*) are higher than those for the gross rod (Figure 7 *b*), because the thin rod is more flexible.

The use of mathematical tools for the motion analysis [4] as, for example, the spectrum analysis [5] of the signals helps us further understand the dynamics of the variables.

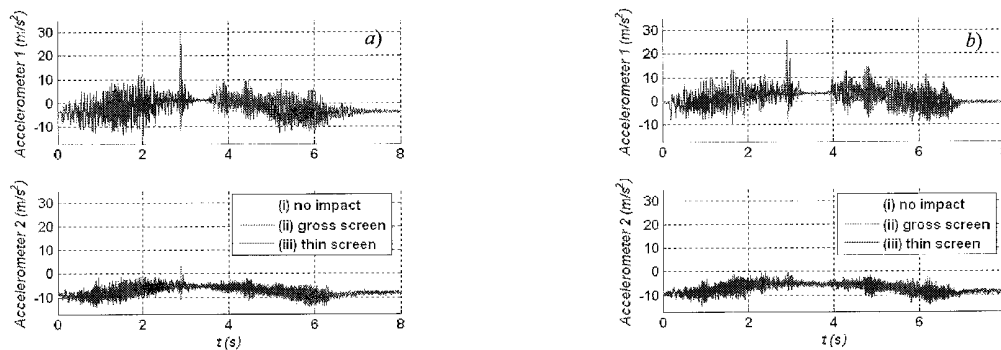


Figure 5. Rod accelerations for the: a) thin rod; b) gross rod.

4 CONCLUSIONS

In this paper an experimental study was conducted to investigate several robot signals during impacts and vibrations of a mechanical manipulator. In this set of experiments we show the relationship between the variables. To gain further insight into the variables dynamics several distinct experiments are conducted, in order to obtain valuable results that can assist in the design of a control system to be used in eliminating or reducing the effect of vibrations. These strategies include the use of a multiwindow algorithm applied to the scattered spectra, the study of the non linearities and others approaches.

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