DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 36TH CYCLE

Title of the research activity:	Applications of Nonlinear Systems Modeling techniques
State of the Art:	Most of the techniques for system modeling and, in particular, in flaws detection and evaluation applications, usually rely on linear models. In the reality of the applications it is frequent that non-linear phenomena are generated: in order to have efficient models in the different operating situations it is of fundamental importance to have system functioning models able to take into account the possible non-linearities that can be generated in some operating situations. In the case of, for example, non-destructive ultrasonic diagnostic inspection and evaluation techniques (NDT&E ultrasonic techniques), high mechanical stress generates non-linear phenomena. Models suited to fit the input-output characteristics and the existence of non-linear behaviors, if any, allow improved sensitivity and early detection of the onset of cracks. We propose a technique of nonlinear characterization of the response, adequate for a real time industrial implementation. A different case of considerable application interest arises in the design of power electronic devices. The volume and weight of the systems can be considerably reduced, with the same performance, by using non-linear inductor behaviour modelling techniques. The practical usefulness of such modelling techniques is linked to the complexity of non-linear model identification techniques: if the computational cost associated with identification, and/or the amount of measured data required to define a reliable model of the non-linear system is high, the advantage of having a model that takes account of non-linearities becomes not easily feasible. Recently, highly efficient techniques have been developed to identify the Hammerstein model of a nonlinear structure. These techniques, based on a variant of impulse
Short description and objectives of the research activity:	The aim of this research topics to apply the modeling technique in the case of ultrasonic (US) inspection and to the design of power electronic devices. In particular US techniques are among the most widely used to highlight manufacturing flaws or fatigue damage in safety- critical structures. Fundamental properties of the propagation of ultrasonic waves, such as their propagation velocity or attenuation, are linked to the structural characteristics of the object being analyzed. These techniques, although widely used, are based on

	linear models and do not take into account possible nonlinear dependencies of the sample response with respect to the amplitude of the excitation to which it is subjected. On the other hand, recent studies have shown that the excitement of cracks, grain boundaries and interfaces due to large mechanical deformations can generate nonlinear elastic waves that propagate through the damaged object. Effects are produced such as a shift in the resonance frequency as the amplitude of the stress increases, or the generation of higher- order harmonics. Therefore, the onset of these phenomena provides an indication of a strong interaction between the high intensity stresses and the irregularities (cracks, grain boundaries and interfaces) present in the structure under test (SUT). These nonlinear effects are related to the irregularities/defects of the part to a greater extent than the parameters of the linear model, as, for instance, linear elastic modules. Because of this high sensitivity to degradation of material and/or structural properties, which is even evident at early stages of damage, nonlinear ultrasonic diagnostics techniques are becoming increasingly important in the field of non-destructive diagnostics and evaluation (NDT&E) of materials and structures. For the aforementioned reasons, is of utmost importance the faithful estimation of the degree of non-linearity that may be present in the response to a given stress. The use of nonlinear techniques for aerospace applications must be possible in extensive tests on the entire production of critical parts, or for the periodic testing of structures subjected to high mechanical stress; it must therefore be possible to carry out these analyses with relatively simple algorithms that can be used in an industrial environment for real time inspection. To this end, in this paper we propose a technique for estimating the insurgence of harmonic distortion, in the case it is present in the response to an excitation of given amplitude; the technique is based on the use of a single chirp signal of short duration: it derives from a methodology for identifying the Hammerstein model of a non-linear system based on Pulse Compression of an exponential chirp signal. A modified version of the technique is proposed here for an NDT application. In the case of the design of power electronic devices the identification of the Hammerstein model has been successfully applied to a variety of real world inductors. The aim of the second phase of the research activity will be to relate the identification tecniche not only to the characteristics of the inductor as measured by other techniques, but directly apply the chirp signal to the real world device and obtain the model directly from the measurement.
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