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:	Development of procedures for fatigue-based design and vibration qualification of mechanical components
State of the Art:	Structures and mechanical systems are often exposed to complex vibratory excitations. Examples are vehicles excited by road irregularity and engine vibrations, off-shore platforms and wind turbines exposed to waves or wind, aeronautical and aerospace components subjected to vibrations arising from aerodynamics and engine (cf. reference [11]). In such examples, the complex excitation and the resulting timevarying stresses are stochastic and multiaxial, which means that there are multiple signals taking on random values at each time instant. A wing, for example, may be subjected simultaneously to longitudinal, vertical and lateral excitations coming from the aerodynamic forces. In most critical parts, such excitations and stresses may cause a progressive fatigue damage possibly leading to unexpected failures [3, 16]. A comprehensive design procedure requires that: i) the service life of the system is preliminary estimated through virtual models implementing suitable criteria for estimating the amount of fatigue damage [18, 19, 25, 28]; ii) experimental tests are carried out on fullscale prototypes by accelerated vibration tests (on ground or in laboratory), which accurately replicate in a shorter time the same fatigue damage caused by actual excitations [2, 17]. The design by numerical modeling and fatigue criteria can profitably exploit a frequency-domain approach based on 'spectral methods', in which the service life is directly estimated from the frequency spectrum (Power Spectral Density, PSD) characterizing the excitation or the stress signal [5, 6, 8, 12, 14]. The advantage of using a PSD, which can be calculated by a frequency-domain structural dynamic analysis, is to avoid time-consuming transient dynamic simulations and direct processing of long time-histories. Not only does the design need to apply spectral methods suitable for uniaxial stress, but it also requires those for multiaxial stress [22, 27]. One limitation, however, is that the amount of published experimental data for calibrating existing, or newly-developed, fatigue criteria is often very limited. This emphasizes the need, from one hand, to gather additional experimental results carried out by shakers or slip-tables, with simple specimens and excitations. The improvement to the existing

	procedures is the main aim of the project. This improvement, partly already started by the project proposers [1, 7, 10, 24], will provide the manufacturing industry with more reliable methods for fatigue-based design.
Short description and objectives of the research activity:	The project is focused on the virtual design and experimental qualification of mechanical systems undergoing complex vibratory excitations, which may cause fatigue failures. These topics are very relevant for several industrial fields (aerospace, automotive, marine, automation). The design usually exploits theoretical/numerical models followed by accelerated vibration-based fatigue life tests. Standards make use of test tailoring procedures, in which field data are processed to synthesize excitations used in laboratory tests or to define on field accelerated tests. A critical issue is how to define a test excitation (experimental or virtual) which replicates - in a short duration - the fatigue damage experienced over the entire lifetime, while also accurately reproducing the frequency content of the real excitation. A careful literature survey allows to identify several aspects in the current procedures which can be improved, thus outlining the original contribution of the project. The project will overcome such limitations by developing a new vibration qualification procedure both numerical and experimental.
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