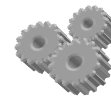# UNIVERSITY OF FORESTRY (LTU) – SOFIA

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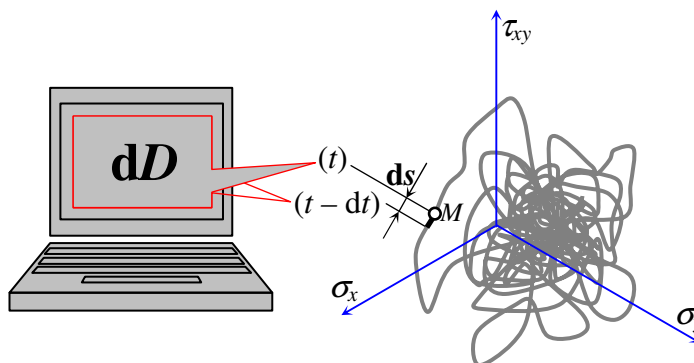
DEPARTMENT OF

MECHANICAL ENGINEERING AND AUTOMATION OF PRODUCTION

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INTEGRATION OF DAMAGE DIFFERENTIALS (IDD)
FOR FATIGUE LIFE ASSESSMENT UNDER ANY LOADING

THESIS

presented for conferring DSc degree on the author

Area of Higher Education: „5. Technical Sciences"

Professional Field: „5.13. General Engineering"

Scientific Speciality: „02.01.32 Machines and Technical Equipment for the Forestry, Wood Industry, Woodworking and Furniture Industry"

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The phrase "any loading" in the heading of this thesis means the following:

"variable (with respect to the time t) plane state of stress having components $\sigma_x(t)$, $\sigma_y(t)$ and $\tau_{xy}(t)$ that may vary in any way: cyclic or non-cyclic (in the second case, deterministic or random); one of the three components may remain constantly zero, or two of the three components may remain constantly zero (then the state of stress is uniaxial or pure shear); in the general case, the oscillograms of the stresses $\sigma_x(t)$, $\sigma_y(t)$ and $\tau_{xy}(t)$ are all of them non-zero and have non-cyclic, arbitrary (or random) and non-proportional variations".

In order to avoid such a long description, the short phrase „any loading" has been preferred. In fact, „any loading" means „any stressing" but the fatigue researchers say much oftener „loading" for "stressing". With that, it is expected to be understandable that „loading" does not mean loads like variable forces and/or moments but variable stresses causing fatigue of the material. Those stresses are caused by forces and/or moments that may even be constant (for example, constant forces on a carriage axle cause variable stresses due to the rotating bending).

The above text is in defense to an otherwise just remark of Professor L. Lazov he made during the preliminary counsel on this thesis on June 21, 2011: why "loading" after talking about stresses?

FOREWORD

The phenomenon of **fatigue of materials** due to variability of loading (of stresses) was realized in 19th century. Most of the fractures of engineering structures are due to fatigue and the consequences are disastrous. How to envisage in what operational lifetime fatigue failure would occur, i.e. how to assess the fatigue life, is one of the most important engineering problems for the last two centuries. *There was not any uniform and all-acknowledged solution under any loading including the general multiaxial case of non-proportional, non-cyclic and arbitrary wave-forms of the stress components.* According to this thesis, the lack of solution was since the fatigue life had not been searched by means of an integral of fatigue damage differentials. Such a possibility had not been revealed and exploited before but it can be practically implemented nowadays thanks to the computers.

This thesis opens a **new scientific research line** under the IDD abbreviation. The underlying statement is that only the universal mathematical way of the calculus from differentials to an integral can establish a uniform and all-acknowledged solution to the problem of fatigue life evaluation under any loading. *The new line proposed would re-direct a vast world-wide research experience, accumulated for nearly two centuries, into another course. The basic notion of this experience is loading cycle and therefore the hitherto existing approach is called Cycle Counting Approach (CCA). In this thesis, another, new and radically different IDD approach is proposed: the basic, general notion is loading differential, while loading cycle is a particular notion, and the damage differentials per the separate loading differentials are integrated (summed).*

That such differentials are introduced for fatigue life assessment may have the same importance which the differentials introduced in the mathematics and exact sciences generally have: decisive.

The development of the IDD approach and creating unique IDD software has been done by the author only what has inevitably engaged a lot of time: about 30 years. Since everything proposed here is entirely original and without any existing analog, the colleagues in the world and in Bulgaria have taken an explainable position of waiting for results. At the beginning (before 1980), the author, as a doctorand at the Technical University of Sofia, had a strong support of his director of studies: Professor Petar Levchev Ganev. However, he unexpectedly early passed away and the author went to work for the LTU University of Sofia. The IDD work continued most of the time without any collaborators, nor any financial or other support. Nevertheless, the IDD approach has become well-known and discussed in the world.

What is said above, as well as the necessity of juxtaposition to the nearly two-century CCA experience, explain the inevitable fact of a comparatively large volume of this thesis: 353 pages (with expanded line spacing and with an IDD-software manual included). But the colleagues that will study it, as well as the members of the scientific jury, will quickly orientate themselves to the main points. To help them, the Summary, this Foreword and an extended peculiar Preview serve. Then, the Conclusion and the Contributions (presented separately) can be read. Afterwards, the details can be entered: the new notions, the mathematical instruments, the software created for practical application of author's IDD method, the verifications carried out and their results, and so on. The volume of these details has been compressed to an acceptable minimum.

The IDD site cited above has been organized in a way as to also facilitate the study of this thesis. Besides, the site gives the IDD software as freeware. As well, the site gives the files involved in the sections of the thesis and in the verifications.

Eventually, this foreword hints that the thesis is expected to evoke great interest and opinions under considerable scientific responsibility on the part of the scientific jury members and the other colleagues. To all of them the author renders homage and his expectation of a just evaluation.