40th Danubia-Adria Symposium on Advances in Experimental Mechanics

BOOK of ABSTRACTS

GDAŃSK, POLAND

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Edited by:
Zbigniew L. Kowalewski
Mateusz Kopec
Dariusz Rudnik
Jacek Widłaszewski

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INSTITUTE OF FUNDAMENTAL TECHNOLOGICAL RESEARCH
POLISH ACADEMY OF SCIENCES

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PREFACE

There is a long tradition to organize Danubia Adria Symposia on Advances in Experimental Mechanics in different locations in Europe to cover all areas of experimental research in mechanics of materials and structures, including interactive fields.

Symposia of the DAS series have been initiated in 1984 in Stubicke-Toplice, Croatia, and further successfully continued in: 1985 – Graz, Austria, 1986 – Budapest, Hungary, 1987 – Plzen, Czech Republic, 1988 – Udine, Italy; 1989 – Mösern-Seefeld, Austria; 1990 – Pula, Croatia; 1991 – Gödöllö, Hungary; 1992 – Trieste, Italy; 1993 – Merin, Czech Republic; 1994 – Baden, Austria; 1995 – Sopron, Hungary; 1996 – Rajecké Teplice, Slovak Republic; 1997 – Porec, Croatia; 1998 – Bertinoro, Italy; 1999 – Cluj Napoca, Romania; 2000 – Prague, Czech Republic; 2001 – Steyr, Austria; 2002 – Polanica Zdroj, Poland; 2003 – Györ, Hungary; 2004 – Brijuni/Pula, Croatia; 2005 – Parma, Italy; 2006 – Zilina, Slovak Republic; 2007 – Sibiu, Romania; 2008 – Ceske Budejovice/Budweis, Czech Republic; 2009 – Leoben, Austria; 2010 – Wroclaw, Poland; 2011 – Siofok, Hungary; 2012 – Belgrade, Serbia; 2013 – Primosten, Croatia; 2014 – Kempten, Germany; 2015 – Stary Smokovec, High Tatras, Slovak Republic; 2016 – Portoroz, Slovenia; 2017 – Triest, Italy; 2018 – Sinaia, Romania; 2019 – Pilsen, Czech Republic; 2021 – Linz, Austria; 2022 – Poros, Greece and 2023 – Siofok, Hungary. The DAS Symposia are organized under the auspices of the Danubia Adria Society.

The Danubia Adria Symposia bring together internationally recognized experts and young researchers in an effort to exchange ideas on different topics of „Experimental Mechanics“. The conferences serve also a platform for establishing connections between different research teams and development of future scientific collaboration.

Based on the papers included in the Book of Abstracts one can conclude, that the engineering community is constantly moving towards a more globalized and digitalized world in which, thanks to the increased computational resources, problems of high complexity can be analyzed. Nevertheless, the relevance of Experimental Mechanics remains indisputable. Experimental Mechanics with the increased interest in reliable design, durability analysis, lifetime prediction, etc. unquestionably stays the ultimate source of information on the real behaviour of materials and structures. At the macro-, micro- and nano-scale, the broad discipline of Experimental Mechanics provides more and more advanced techniques to study the influence of defects such as inclusions, cracks, voids and/or inherent manufacturing defects on the nucleation and growth of failure mechanisms.

Besides of the basic problems usually studied in the framework of Experimental Mechanics, the symposium covers experimental, theoretical and numerical aspects of the mechanical behaviour of solids at high strain rates. The lack of knowledge on the behaviour and performance of structures/components against hazardous dynamic loads of human or nature origin, may result in catastrophic consequences for human life and structural systems. The experience and knowledge from extensive research, experimental testing and advanced computational techniques can provide feasible solutions to diminish these catastrophic effects.

Therefore, the present 40th DAS is focused not only on fundamental topics of Experimental Mechanics, but also aims to provide a forum for participants from around the world to show, review and discuss the latest developments in it.

This volume of the 40th DAS Book of Abstracts contains 97 extended abstracts of papers out of 102 papers that were accepted for presentation. The program of the conference includes 1 Plenary Lecture, 25 Keynote Presentations and 72 poster presentations.

Danubia Adria Symposia on Advances in Experimental Mechanics have maintained throughout the last 40 years high scientific standards and served as a forum for the exchange of new ideas and research information. A considerable number of participants from different countries delivered here fascinating lectures not a single time and certainly remember the period when they came for the first time as young, beginning researchers, while now they are presenting lectures as eminent scientists. It is my great satisfaction to see again old friends to whom we shared our ideas and enthusiasm to Experimental Mechanics. It is especially a great pleasure to meet here the young generation of researchers working in emerging fields and contributing new important results.

Besides the scientific program, the 40th DAS participants will have an opportunity to explore and discover the city of Gdańsk. Gdańsk is one of the most beautiful Polish cities with a tradition dating back over 1000 years. Everyone who was at least once in this city will not forget the impression left by the local atmosphere of the Main Town, the most famous, historic part of Gdańsk. The multilingual crowd admires the iconic view of the Motława River, where tourist ships moor, surrounded by tenement houses on the waterfront and the rebuilt Granary Island. It is place where groups admire one of the icons of Gdańsk - the Crane, which is the largest medieval port crane in Europe, now part of the museum. Tourists who pass through the Green Gate to Długi Targ can admire the Royal Route, which consists of several dozen tenement houses, carefully rebuilt after the war. The tower of the Main Town Hall rises majestically above the Route - it always arouses admiration. Just like the Neptune Fountain, the Golden Tenement House and the Artus Court located right next to it. It is worth adding that the latter facility is the place where the first Gdańsk beer was served, masquerades took place, various brotherhoods and court hearings were held, and where monarchs were received. The Artus Court is an integral part of the previously mentioned Royal Road. It began with the Upland and Golden Gates, through which triumphal entries into the city took place. Then the processions crossed Długa Street to reach Długi Targ. Today, this entire section is a beautiful, colorful and lively promenade. Let me acknowledge here, the great support of the Gdańsk Convention Bureau in organizing the event, giving you a great opportunity to travel around the city using local transportation for free.

I wish all participants a fruitful and enjoyable conference time in beautiful Gdańsk and look forward to the 40th DAS, hoping that it will pave new ways for the development of Experimental Mechanics.

On behalf of the organizers, I would like to express our gratitude to all who showed their interest and actively helped us in preparing the event.

Finally, it is a great pleasure to express my cordial thanks to all members of the Scientific Committee, to all members of the Local Organizing Committee, to all supporting institutions (all names enclosed separately), and to the Jordan Group – the official Conference Partner - for their help which cannot be overestimated.

September, 2024
Gdańsk, Poland

Zbigniew L. Kowalewski
Chairman of the 40th DAS 2024

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DEGRADATION OF ELASTIC MODULUS IN STEEL DURING FATIGUE TESTING

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1. Introduction

Elastic modulus is one of the most important parameters of metallic materials. It determines the total amount of the elastic deformation of a metallic sheet during plastic deformation. Elastic modulus is the measure of the stiffness of the material when subjected to alternating stress. In most fatigue simulations, the elastic modulus of steels has been regarded as a constant during the plastic deformation. However, the elastic modulus does change with plastic deformation, and this change does affect the mechanical properties of steel [1].

The fatigue life is estimated as the relationship between cyclic stress or strain range and the number of cycles. In high-cycle fatigue (HCF), the material is subjected to low-stress amplitude in an elastic regime, leading to many fracture cycles. In low-cycle fatigue (LCF), the material is subjected to high-stress amplitude in a plastic regime, leading to fewer cycles until fracture. Measuring the elastic modulus during the testing of metal specimens is a difficult task when the specimen undergoes plastic strains [2].

The main idea of this paper is to introduce a damage variable D as the representation of an elastic modulus change during the fatigue testing of metal specimens.

2. Elastic modulus degradation

Many publications have been produced on introducing a damage variable D, as the measure of elastic modulus degradation for the load case loading/unloading [3]. For the case of isotropic and homogeneous materials, the damage variable D is related to the surface density of micro-defects in the material [4].

It is of great interest to define the methodology for formulation relationship between the stress-strain history and the damage variable, based on the theory of damage mechanics. The constitutive equation for damaged material can be obtained by degradation of the material stiffness as:

$$E = (1 - D) E_0 \,. \tag{1}$$

Thus, damage variable D may be represented by elastic modulus change

$$D = 1 - \frac{E}{E_0} \,, \tag{2}$$

where E is the elastic modulus of damaged material and E_0 is the elastic modulus of virgin material [5].

Uniaxial tension–compression strain-controlled fatigue test is performed to measure damage variable D through the degradation of the elastic modulus due to fatigue testing of round specimens. Uniaxial tension–compression fatigue tests were performed by applying a sinusoidal wave in a universal servo-hydraulic machine. The tests were strain controlled using a SHIMADZU DYNASTRAIN TCK-1-LH dynamic extensometer (Fig. 1.). The uniaxial tension-compression test was performed as: loading ratio R=-1 i.e., mean strain amplitude ε_m=0% and strain amplitude 0.20%.

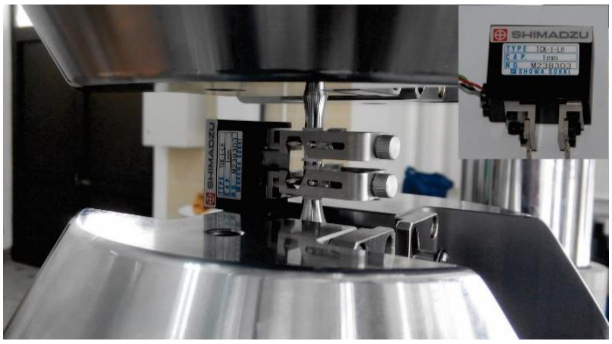

Fig. 1. Strain-controlled fatigue testing of round specimen.

The tested specimen was loaded in tension up to a value of total strain, recorded with the dynamic extensometer mounted on specimens. Then specimen is unloaded and elastic modulus is obtained from the slope of the unloading stress-strain curve. The specimen is loaded again to produce the same value of total strain and then unloaded to obtain a new value for the elastic modulus. This process is repeated until the crack detection.

3. Results and discussion

The experiment was simulated with a complete loading history respecting the real loading realized. The experimental and simulation results as stabilized cyclic stress–strain hysteresis loops for the tested specimen, are depicted in Fig. 2. Stress-strain hysteresis loops for the tested specimen show the effect of softening under strain-controlled fatigue test.

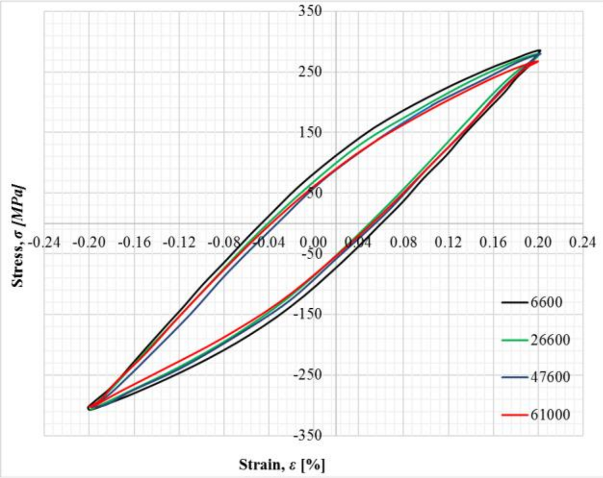

Fig. 2. Stabilized stress–strain hysteresis loops of tested specimen.

Fatigue testing results were used for quantitative analysis of the elastic modulus *E* that depends on loading conditions (cyclic variable), and number of cycles. Changes in the elastic modulus *E* during the fatigue tests have been observed and calculated for each recorded testing result.

The hysteresis loops recorded during the fatigue tests allowed one to determine the elastic modulus. Because the hysteresis loop branches (Fig. 2) do not possess the linear elastic part, the elastic modulus was decided to be described as the straight line between maximal/minimal stress and strain in each loading cycle.

During the research, variability of the elastic modulus *E* in the function of the number of the realized load cycles was observed as well. According to equation (2) for each recorded hysteresis loop and determined elastic modulus, damage variable D, as a measure of degradation of elastic modulus is calculated. A relation between damage variable D and the number of cycles during strain-controlled fatigue testing is shown in Fig. 3.

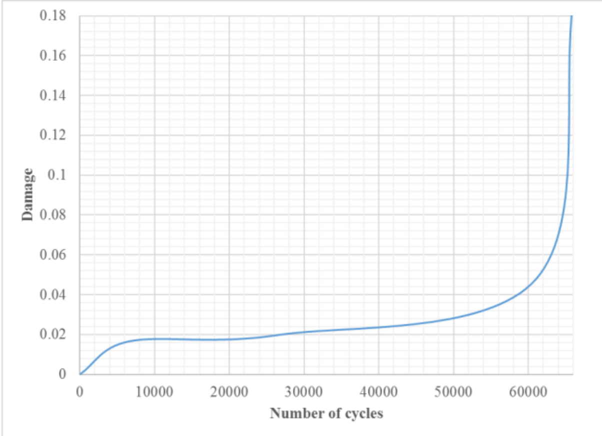

Fig. 3. Relation between damage variable D and number of cycles during strain-controlled fatigue testing.

4. Conclusions

This paper has presented an experimental investigation of the degradation of elastic modulus for metallic materials during strain-controlled fatigue testing. Fatigue loading in the range of loads producing plastic strains decreases elastic modulus; in the conducted test. The value of elastic modulus obtained by the linear approximation decreases with the number of cycles which, indicates the effect of softening and increasing damage variable D as a measure of degradation.

Acknowledgments

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