Kraków, 11 September 2025

OPINION

on PhD Thesis entitled „*Yield Surface Identification of Functional Materials and its Evolution Reflecting Deformation History Under Complex Loadings*" by Mr. **Ved Prakash Dubey** representing Department of Experimental Mechanics, Institute of Fundamental Technological Research, Polish Academy of Sciences.

1. Scope of Thesis

Thesis under consideration comprises 189 pages of text, including over 100 figures, 26 tables and 272 references. Author distinguished 9 chapters of the Thesis.

Chapter 1, entitled Framework of the Thesis, comprises motivation and main objectives. The scientific background and methodological approach are broadly described. Also, an overview of the Thesis, original contributions as well as possible applications of anisotropic yield criteria are described in it.

In Chapter 2, entitled Literature review, Author presents historical review of experimental techniques used for characterization of yield surfaces applied to engineering materials. In order to illustrate possible applicability of pre-deformation effects several pre-deformation processes together with their influence on material properties are demonstrated by Author. Special attention is paid to pre-tension, pre-compression, pre-torsion and combinations of them. Moreover, Author provides a literature overview of mechanical properties frequently used in functional materials.

Subsequent Chapter 3, entitled Experimental techniques and their methodology, comprises general summary of the experimental techniques used for material characterization under quasi-static conditions. Experimental methods of pre-deformation concern uniaxial tension and complex, biaxial loading conditions. Discussed methods serve to precise determination of yield locus.

Chapter 4, entitled Yield criteria, is a study on yield and failure criteria applied in solid mechanics. Author presents an overview of yield criteria starting from the Tresca–Guest criterion, then subsequently the Mohr–Coulomb, the Huber–Mises–Hencky, the anisotropic Mises, the Drucker–Pager, the Hill and others so that finally focus attention at the Szczepiński riterion, which plays main role in further investigations.

Subsequent Chapters 5, 6, 7 and 8 comprise yield surface identifications of CP-Ti (Commercially Pure Titanium), CP-Cu (Commercially Pure Copper), Ti-Cu bimetal and AM SS316L (Additive Manufacturing Stainless Steel), respectively. In each of them Author presents his original experimental results comprising identification of fundamental material parameters (yield stress, tensile strength, elongation and Young's modulus) accompanying combined loading conditions (monotonic tension and cyclic torsion, monotonic tension and cyclic torsion-reverse torsion etc.). Next step of analysis is associated with determination of yield surfaces, according to the Szczepiński criterion, in case of: initial and pre-deformed states (CP-Ti and CP-Cu), initial and tensile pre-deformed states (Ti-Cu bimetal and SS316L), and finally microstructural characteristics of materials (CP-Ti and Ti-Cu).

In the last one, Chapter 9, Author presents overview of his key findings and achievements, giving simultaneously directions of future works.

2. Meritorious judgment of Thesis

Problematics of the judged Thesis comprising yield surface identification of functional materials and its evolution reflecting deformation history under complex loadings is simultaneously difficult, novel and actual. Difficulty of problematics is strictly associated with a fact that the Thesis deals with phenomena requiring series of combined experiments, on one hand, but these phenomena are described by formalism of anisotropic plasticity, on the other hand.

Author correctly focuses his attention at four materials (CP-Ti, CP-Cu, Ti-Cu and SS316L) since these are materials widely used in medicine, aerospace, marine engineering etc.

Author attains goal carrying out series of experimental tests upon aforementioned selected materials. The experimental methodology applied by Author is based on the single specimen approach combined with the sequential probing technique. The yield surfaces are identified at various plastic offset and the Szczepiński yield criterion serves for their approximation. Both the initial and subsequent yield surfaces result from pre-deformation caused by uniaxial tension and combined tension-cyclic torsion loading. The findings reveals anisotropic nature of yield surfaces resulting from manufacturing processes like conventional forging or Laser Powder Bed Fusion printing along different printing orientations, this effect is additionally confirmed by use of Electron Backscatter Diffraction technique. Presented outcomes may successfully serve as valuable hints in design, manufacturing and structural optimization of materials under consideration in aerospace, automotive or biomedical applications.

All original results are honestly presented in figures and tables. Author is well prepared to: carry out experimental tests, identify anisotropic materials parameters, model and analyze yield surfaces as well as very well oriented in current scientific literature.

3. Detailed remarks

3.1 Meritorious and formal remarks

Reading carefully this Thesis I paid special attention to Chapters 3 and 4. In connection with that I formulate several critical remarks:

- temperature in Fig. 3.4 does not refer to the Kelvin scale but to the Celsius one,
- correctly transformed Drucker–Prager yield criterion Eq. (4.32) takes format

$$\sqrt{J_2} = -\alpha I_1 + k,$$

whereas its extended format Eq. (4.33) looks as follows

$$\sqrt{\frac{1}{2}[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2]} = -\alpha\frac{\sigma_1+\sigma_2+\sigma_3}{3}+k\ ,$$

- the generalized Hill criterion Eq. (4.35), or more precisely Hershey–Davies criterion, makes sense only for even powers of $m = 2, 4, 6$ etc.,
- Szczepiński's yield criterion Eq. (4.36) is not straightforward extension of von Mises' yield criterion Eq. (4.29) since it requires deviatoric format as well as involving of linear terms

$$S_{ij}K_{ijkl}S_{kl} + b_{ij}\sigma_{ij} = 1$$

hence such format is closer to the Tsai–Wu yield criterion,

- Szczepiński's yield criterion in full format Eq. (4.36) or in its plane stress format Eq. (4.37) comprises linear terms with respect to the shear stress component, which are sensitive to change of sign of shear stresses, e.g., $2\tau_{xy}k_{16}(\sigma_{zz}-\sigma_{xx})$ etc., this effect is physically questionable and, finally such terms are consequently omitted in some cases. In this Thesis aforementioned terms ply crucial role since they are directly responsible for the rotation angle ϕ, see Eq. (4.43).

3.2 Editorial remarks

Author did not check carefully the text with respect to editorial errors. Frequently, this is associated with omission of Polish or Slavic diacritic marks, particularly in family names:

- page 5, line 14 from bottom, instead of „Szczepinski" it should be written „Szczepiński",
- page 10, line 16 from above, instead of „Marjanovic" it should be written „Marjanović",
- page 17, line 6 from above, instead of „Mroz" it should be written „Mróz",
- page 186, reference [233], instead of „Uscinowicz" it should be written „Uścinowicz",

use of wrong word or format of verb:

- page 4, lines 1 and 7 form above, phrase „... stress ellipsoid ..." should be replaced by „... stress ellipse ...",
- page 10, line 12 from above, perhaps phrase „... von Mises circle ..." should be replaced by „... von Mises ellipse ...",
- page 32, line 13 from above, phrase „The aging kinetics were also ..." should be replace by „The aging kinetics was also ...",

use of wrong font:

- all mathematical symbols used in displayed formulas as well as in text should be written with use of Math Italic font, for instance: page 76, line 13 from bottom, instead of „... by coefficients A, B, C, D and F ..." it should be written „... by coefficients A, B, C, D and F ...",
- all subscripts and superscripts accompanying mechanical symbols, which are not indexes in the mathematical sense, should be written with use of Times Roman font, for instance:
  page 10, line 16 from bottom, instead of format „$(\varepsilon_p = 0.5\%)$" it should be used format „$(\varepsilon_{\mathrm{p}} = 0.5\%)$",
- all mathematical operators and functions, like: trace, max, atan, should be written with use of Times Roman font, see Eqs (4.6), (4.7) and (4.20), (4.22) as well (4.43), respectively,
- Eq. (2.1) should take proper format $\varepsilon_{\mathrm{f}}^{\mathrm{engg}}\big|_{\mathrm{axial}} = \dfrac{\Delta_{\mathrm{f}} - \Delta_{\mathrm{load}}}{l_0} = \dfrac{\Delta_{\mathrm{c}}}{l_0}$,
- page 172, reference [48], chemical symbol „ Ni□Ti□Nb" is unidentified.

4. Final conclusion

The present Thesis is original and individual study on the yield surface identification and its evolution in functional metallic materials under complex loading paths. In my opinion Thesis fulfils all requirements necessary for PhD Theses, hence I conclude to admit to the public discussion on Mr. Ved Prakash Dubey Thesis.

A. Ganczarski

prof. dr hab. inż. Artur Ganczarski