Prof. dr hab. inż. Tadeusz Łagoda
Katedra Mechaniki i Podstaw Konstrukcji Maszyn
Wydział Mechaniczny
Politechnika Opolska

Opole, 2025-08-29

Review

Thesis of M.Sc. Eng. Benard Kiptoo Kipsang entitled - „Assessment of fracture development in thick-walled elements of power boiler after long-time operation"

The thesis review was commissioned by the Chairman of the Discipline Council of "Materials Engineering" of the Silesian University of Technology, Prof. Adam Grajcar, PhD, DSc, Eng, from 1 July 2025. The supervisor of the reviewed doctoral dissertation is Dr. Krzysztof Wacławiak, DSc, Eng, and the co-supervisor is Prof. Wim De Waele, PhD, ir.

1. Characteristics of work

Energy generation is a significant problem in the modern world. The amount of energy consumed is increasing. Therefore, the durability of structures operating in the power industry is crucial. The goal is to maximize the lifespan of structures while maintaining adequate reliability. To this end, research and analysis of materials used in the power industry, namely boiler steel, are necessary. Therefore, addressing the behavior of these materials under various loads perfectly fits into contemporary problems of strength and material analysis of steels used in the power industry. The reviewed work perfectly fits this issue and allows for a better understanding of the problem. Therefore, the task undertaken by PhD candidate Benard Kiptoo Kipsang, MSc. Eng., is ideally suited to such research and analysis. The title of the work accurately reflects the scope of the doctoral dissertation.

Unfortunately, the entire doctoral thesis contains numerous editorial errors, as described in more detail in the special notes. This makes the work difficult to read at times.

The reviewed doctoral thesis consists of seven numbered chapters. The beginning includes a list of key symbols and acronyms, an abstract in English and Polish (but without the

title), translated into Polish, and an untitled abstract in Dutch. A bibliography and appendices follow the numbered chapters.

The first chapter is an introduction to the work, including a brief description of the origins of the work, as well as the thesis, purpose, and scope. The second chapter is a literature review, outlining the state of knowledge on the doctoral dissertation topic. The reviewer believed it would be better if the work's thesis, purpose, and scope were derived from the literature review and served as a conclusion and culmination of this chapter. The purpose of the work should stem from the conclusions drawn from the literature review, or more precisely, it should supplement the completed literature review. This review should identify gaps, and the tasks set should address these gaps at least partially. Reading the first chapter, it is unclear where the stated goals and scope of the work originate.

Chapter three presents experimental and numerical studies on the fracture toughness of materials used in steam boiler components operating for 100,000 hours. These studies involved 13HMF steel and L17HMF cast steel. The studies demonstrated the homogeneity of the materials used in the boiler components. Chapter 4, in turn, presents experimental studies on fracture toughness in mixed modes. These studies involved samples made of 16MoV6-3 steel. The second part of this chapter compares the obtained numerical results with the experimental ones. The results were found to be in good agreement. The analyses demonstrated a strong influence of the notch angle on the fracture behavior of the analyzed material. The next chapter analyzes the effect of short-term creep on the CTOD parameter. The tests were performed for three test times at a temperature of 540°C and a stress of 169 MPa. The tested material's impact tests and microstructure analyses were also performed for various states. As creep progresses, the CTOD value decreases, with degraded samples exhibiting a decrease of approximately 40%. The final, substantive chapter, Chapter 6, addresses the analysis of fracture toughness related to thermal degradation of the creep-associated material. The work provides a relatively thorough description of all the research methods analyzed. The only area of concern is digital image correlation analysis, which has recently become increasingly common in research analyses but is not yet fully understood and is still developing. The work is very well edited regarding the presentation of individual information. All chapters 2-6 conclude with conclusions drawn from each chapter. This makes it easy for the reader to familiarize themselves with the author's achievements and simultaneously navigate to the last, numbered chapter, which contains conclusions concerning the entire doctoral dissertation. The bibliography includes a total of 183 entries. However, this list contains numerous errors, which

I have detailed in the special notes to the work. However, there is a lack of standards and references to them throughout the work.

2. Opinion on the work regarding compliance with statutory requirements

2.1. Assessment of general theoretical knowledge

The state-of-the-art review in Chapter 2 confirms the doctoral student's understanding of the fracture toughness of materials used in thermal power plant boilers. The literature review presented in these papers is sufficient, although not very extensive, covering only 28 pages.

2.2. Assessment of the ability to conduct independent scientific work

The doctoral student demonstrated independence in both the preparation and execution of the experimental and numerical studies. The analyses performed demonstrate his independence.

2.3. Evaluation of an original solution to a scientific problem

The achievements presented within the individual chapters demonstrate, as demonstrated in the thesis characteristics, the scientific contribution of this doctoral dissertation, its innovative nature, and the topic's relevance. The doctoral student was able to resolve cracking in heat-resistant materials. Analyses were conducted for samples of materials prepared differently and subjected to monotonic and impact loads. The reviewer will consider what fracture results would be obtained for fatigue tests of the analyzed material, despite the positive review of the doctoral dissertation by Benard Kiptoo Kipsang, M.Sc. Eng., as noted in the thesis characteristics and the doctoral student's most important achievements, I have included several concerns in the thesis characteristics, as well as in the comments and questions regarding the work.

3. Uwagi i pytania szczegółowe dotyczące pracy

I've included some of my comments in the previous sections. Below are other errors or questions I've noticed:

- not all symbols in the list of symbols and agronomists are listed in alphabetical order,
- he stress symbol is incorrect; it is delta δ, and it should be sigma σ.
- On pages 2, 11-12, the bottom row is later repeated on page 3, 1-2 rows from the top.
- p. 4, Figure 2 is missing units.
- Figure 3. – The graphs should be based on a circle.

- Inconsistency and errors in defining some quantities. After formula (2.4) are the Poisson's ratio and Young's Elastic Modulus, and after formula (2.13) are the Poisson's ratio and Young's Modulus.

- In formulas (2.4) and (2.5), the el and pl symbols should be subscripted, as in formula (2.3).

- missing subscripts in formulas (2.6), (2.7), (2.8),

- incorrect stress symbol in formula (2.9),

- page 16, 1st line from the bottom, p should be subscripted,

- page 22 – Kowalski's paper [21] is cited. This paper is not listed under this heading.

- page 23, 15th- 16th lines. What do the expressions σ0 mean?

- page 25 – written "Boroski." It should be "Boronski" (Boroński),

- page 35 – what does "So2" mean?

- The caption of Table 7 is written "l17HMF." It should be "L17HMF,"

- p. 44 – min and max should be written as subscripts,

- Tables 9 and 21 have the same values, although different notations and numerical notation methods are used. How was the tensile strength variation (490-690 MPa) numerically modeled (Table 9)? If it wasn't modeled, the caption in Table 9 is incorrect.

- The KIC unit is miswritten in the paper. It says MPa.m1/2, it should be MPa m1/2,

- Table 13's last column contains an incorrect unit, kNs. It should be kN,

- (3.3) – this is not a formula. The quantity being entered must be defined first and then applied. Besides, it's not a formula; the work becomes unreadable later. For example, the last row of Table 17 is illegible.

- In formula (4.2), the Von Mises deformation appears, and later in the caption of Figure 48, it should be Huber-Mises-Hencky. Moreover, in the extended summary in Polish, HMH appears without defining what it is. One can only guess that it is Huber-Mises-Hencky

- Similarly to (3.3), (4.4) is not a formula. Moreover, expression (4.4) is miswritten because it reduces to $[K_I^{DIC}-1] \times 100$. Furthermore, this quantity should be defined in %.

- On page 84, "Energy steel" is written. This is a jargon term. It should be "heat-resistant steel" or "boiler steel."

- In Fig. 59, the ordinate scale does not start at 0 kN. The graph would be more complete if the value were 0, because in this case, it looks as if the force were starting from 0 kN.

- In Table 31, it is unclear what errors are presented in the last two lines and how they are calculated.

- The caption in Fig. 68 states that these are maps. This is a geographical term. It should be in layers,

- the bibliography is written carelessly, in particular: a) the titles of works [2, 13, 19, 22, 35, 50, 57, 58, 60, 71, 74, 76, 84, 110, 115, 117, 137, 162] appear in capital letters for some unknown reason, b) errors in first names, last names, and journal titles, [19, 52, 110], c) no journal title [93, 99, 100], item [170] – N.G.B, M.R.C, Z.C.C, and K.G.D – why were such abbreviations used?

4. General comments and conclusions

The presented characteristics of the thesis, as well as comments and supplementary questions regarding the thesis, indicate that the dissertation demonstrates the doctoral student's understanding of the problem posed in the thesis, concerning the cracking of power boiler components. It is particularly noteworthy that the doctoral student utilized the acquired knowledge and experience to apply it to the analysis and testing of the samples. It is imperative to emphasize that the doctoral student was able to combine knowledge in the field of Materials Science and Materials Strength Analysis as part of another scientific discipline, Mechanical Engineering. The few comments in the review may be the subject of analysis in the doctoral student's further research and publication activities. They may also help write subsequent scientific papers. It should be noted that a significant portion of the comments are questions and suggestions for future use, rather than a direct critique of the reviewed thesis. The most important advantage of the research and analyses conducted is the practical applicability of the analyses in commercial power plants to safely extend the life of power equipment operating under difficult operating conditions, considering the impact of high temperatures on the materials used.

After analyzing the thesis, the work can be positively assessed in terms of general theoretical knowledge, the ability to independently conduct research, and the ability to find an original solution to a scientific problem. Furthermore, it should be noted that the reviewed doctoral thesis is interdisciplinary and could be placed within three currently existing disciplines: Materials Science and Engineering, Mechanical Engineering, and Energy and Environmental Engineering. Given that energy and environmental engineering are treated as secondary in the thesis, the thesis could be presented within the other two disciplines. However, it is best placed within the discipline of Materials Science and Engineering, where the primary emphasis is on materials issues. The scope could be broadly defined as the mechanics of materials. Therefore, the thesis was correctly assigned to the discipline of Materials Science and was submitted for review.

5. Final conclusion

The entire evaluation of the doctoral dissertation enables the formulation of an application for sufficient fulfillment of the conditions specified in the Law on Higher Education and Science of July 20, 2018, as amended, and for admission of the dissertation by Benard Kiptoo Kipsang, M.Sc. Eng., entitled "Assessment of fracture development in thick-walled elements of power boilers after long-time operation" to the public defense of the doctoral dissertation at the Silesian University of Technology in the Discipline of Materials Engineering.

Z poważaniem

prof. Tadeusz Łagoda

/podpis odręczny/

*wyłączenie jawności w zakresie danych osobowych oraz ochrony prywatności osoby fizycznej na podstawie art. 5 ust. 2 ustawy z dnia 6 września 2001 r. o dostępie do informacji publicznej (tj. Dz.U. z 2016 r., poz. 1764)