Materials and Design 66 (2015) 587–595

Contents lists available at ScienceDirect

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Damage prediction for un-coated and coated aluminum alloys under thermal and mechanical fatigue loadings based on a modified plastic strain energy approach

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ARTICLE INFO

Article history:
Available online 18 April 2014

Keywords:
Aluminum alloy
Low cycle fatigue
Thermo-mechanical fatigue
Thermal barrier coating
Energy-based model

ABSTRACT

In this article, a novel energy-based lifetime prediction model has been presented for uncoated and coated aluminum alloys, subjected to thermal and mechanical fatigue loadings. For this objective, isothermal and thermo-mechanical fatigue tests were performed on the A356.0 alloy, with and without thermal barrier coating systems. This model, which was based on the plastic strain energy, had three correction factors including temperature, strain and mean stress effects. The predicted lifetime showed a proper agreement with experimental data. By the present model, higher accuracy was obtained in comparison to other existed approaches. Besides, the present model had lower number of material constants.

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1. Introduction

Thermal barrier coating (TBC) systems have been applied to components of the gas turbine in order to increase the performance. Recently, TBC systems have applications in diesel engines to increase the fatigue lifetime, enhance the thermal efficiency and reduce the fuel consumption and pollutions [1–5]. In mentioned applications, TBC systems are exposed to thermal and mechanical cyclic loadings. Therefore, due to high importance of their service lifetime, scientists have presented different fatigue lifetime prediction models [6–8]. To find advantages and disadvantages of all these models, besides their formulations, a literature review has been mentioned in following paragraphs.

1.1. Sehitoglu's model

As one of famous criteria, the lifetime prediction methodology, proposed by Neu and Sehitoglu [6,7], contains a damage rate model including fatigue, creep and oxidation damages. The pure fatigue mechanism controls the lifetime at low temperatures such as the room temperature (RT). In high-temperatures (HT) low cycle fatigue (LCF) and in-phase (IP) thermo-mechanical fatigue (TMF) loadings, all three damage mechanisms operate. However, during the out-of-phase (OP) TMF test, the oxidation damage becomes significant, whereas the creep mechanism can be negligible [9].

As mentioned, in the Sehitoglu's damage rate model, the total damage (D_{tot}) is considered as the summation of fatigue (D_{fat}), creep (D_{cr}) and oxidation (D_{ox}) damages. The formulation of this model is shown as follows [8],

$$D_{tot} = D_{fat} + D_{ox} + D_{cr} \quad (1)$$

$$\frac{1}{N_{tot}} = \frac{1}{N_{fat}} + \frac{1}{N_{ox}} + \frac{1}{N_{cr}} \quad (2)$$

In which, N_{tot}, N_{fat}, N_{cr} and N_{ox} are total, fatigue, creep and oxidation lifetimes, respectively. When the total damage is equal to unity, the failure occurs. The fatigue damage is represented by fatigue mechanisms that occur at low temperatures.

The strain–lifetime relationship is utilized to estimate the pure fatigue damage component. This relation is written as follows [8],

$$\frac{\Delta\varepsilon_{mech}}{2} = \frac{\sigma'_f}{E}(2N_{fat})^b + \varepsilon'_f(2N_{fat})^c \quad (3)$$

In which, $\sigma'_f, E, b, \varepsilon'_f, c$ are material constants. These material constants can be determined from low-temperature isothermal fatigue tests.

The oxidation damage in the material is defined as follows [8],

$$\frac{1}{N_{ox}} = \left[\frac{h_1\delta_0}{B\beta^{0.5}K_{pz}t}\right]^{-1/\theta}\frac{2(\Delta\varepsilon_{mech})^{1+1/\theta}}{(\dot{\varepsilon}_{mech})^{1-n/\theta}} \quad (4)$$

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http://dx.doi.org/10.1016/j.matdes.2014.04.022
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FOLLOWING

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Fatigue Nanocomposite Coating Additive Manufacturing Design of Experiments

TITLE	CITED BY	YEAR
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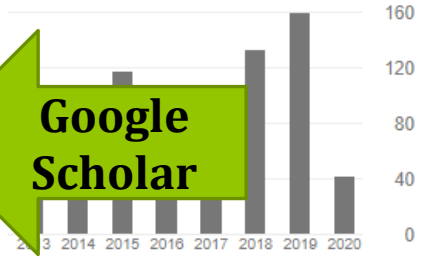

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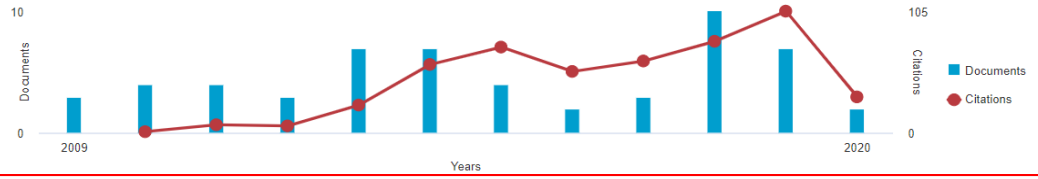

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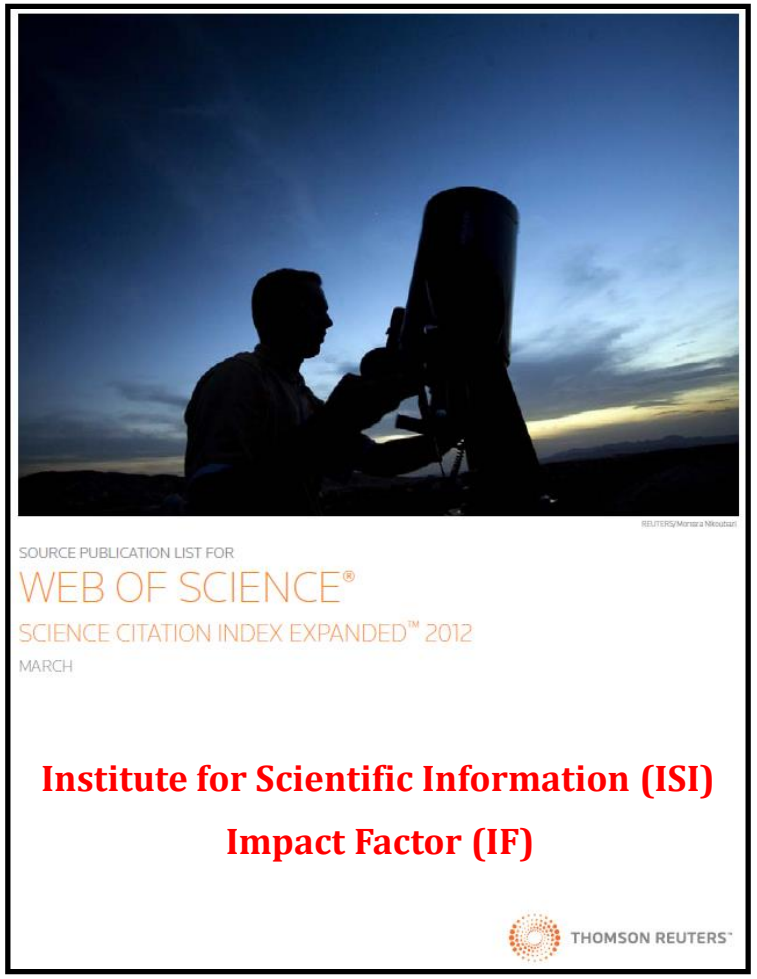

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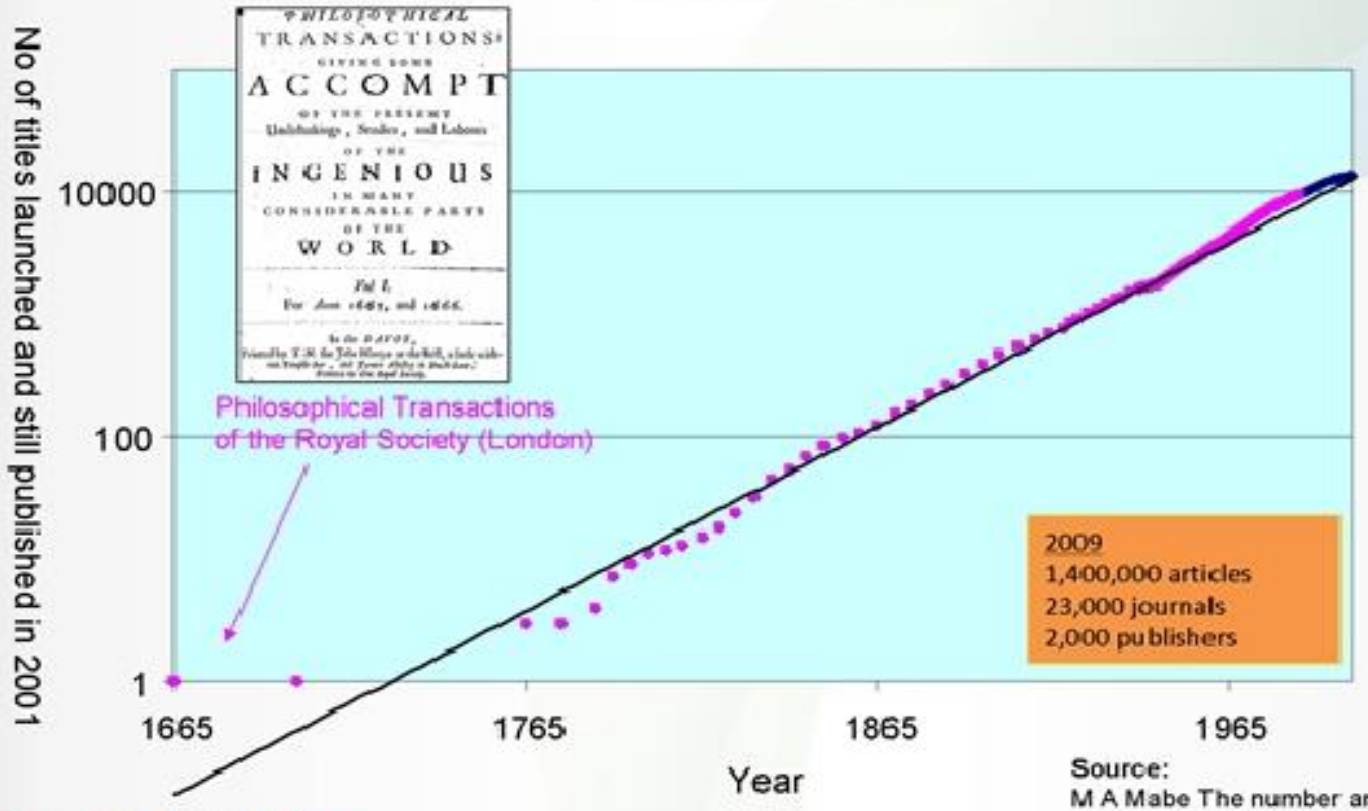

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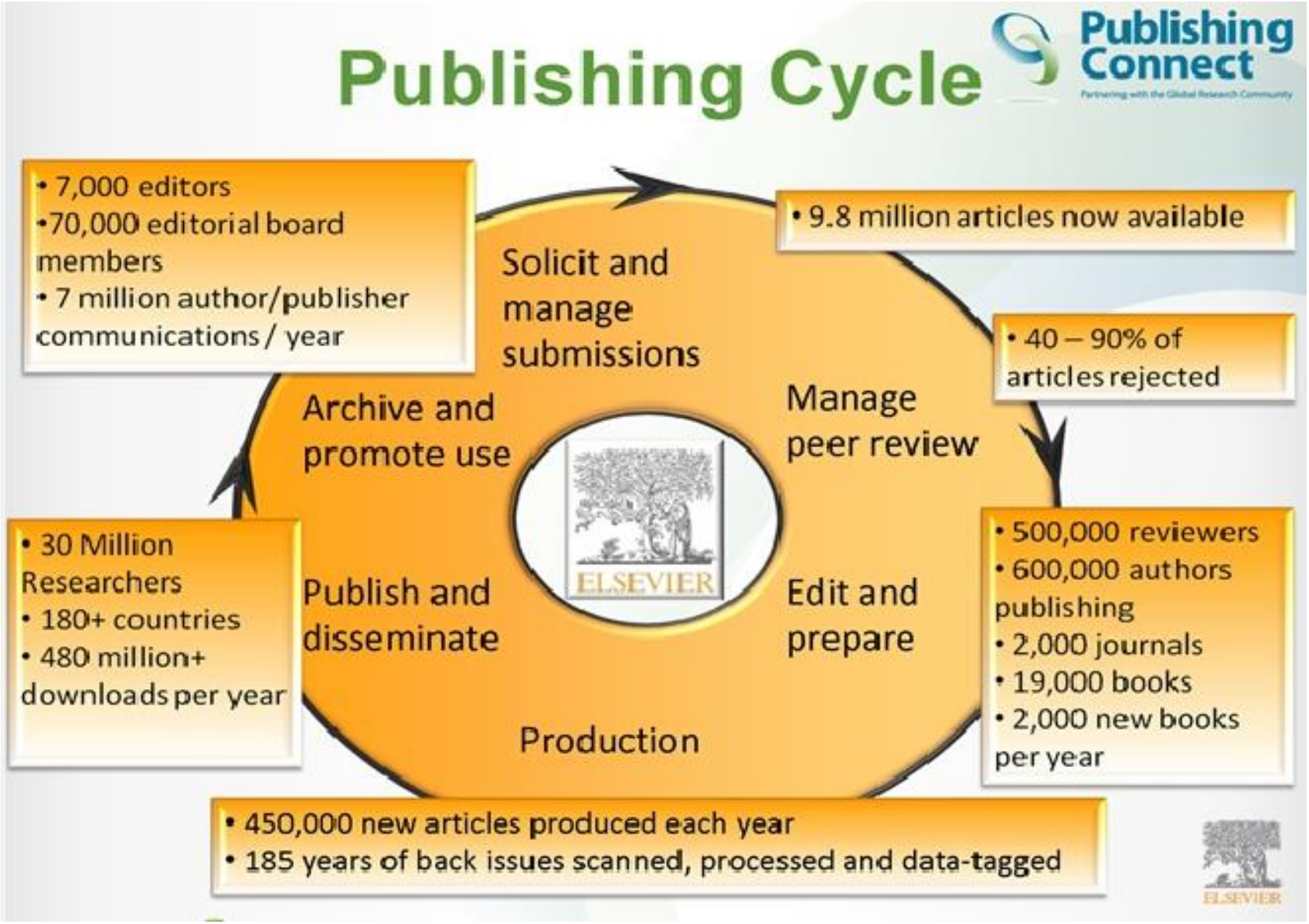

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Determine if you are ready to publish

You should consider publishing if you have information that advances understanding in a specific research field

This could be in the form of:

- Presenting new, original results or methods
- Rationalizing, refining, or reinterpreting published results
- Reviewing or summarizing a particular subject or field

If you are ready to publish, a strong manuscript is what is needed next

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What is a strong manuscript?

- Has a clear, useful, and exciting message
- Presented and constructed in a logical manner
- Reviewers and editors can grasp the significance easily

Editors and reviewers are all busy people – make things easy to save their time

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Types of manuscripts

- Full articles/Original articles
- Short communications/letters
- Review papers/perspectives
  - Self-evaluate your work: Is it sufficient for a full article? Or are your results so thrilling that they need to be shown as soon as possible?
  - Ask your supervisor and colleagues for advice on manuscript type. Sometimes outsiders see things more clearly than you.

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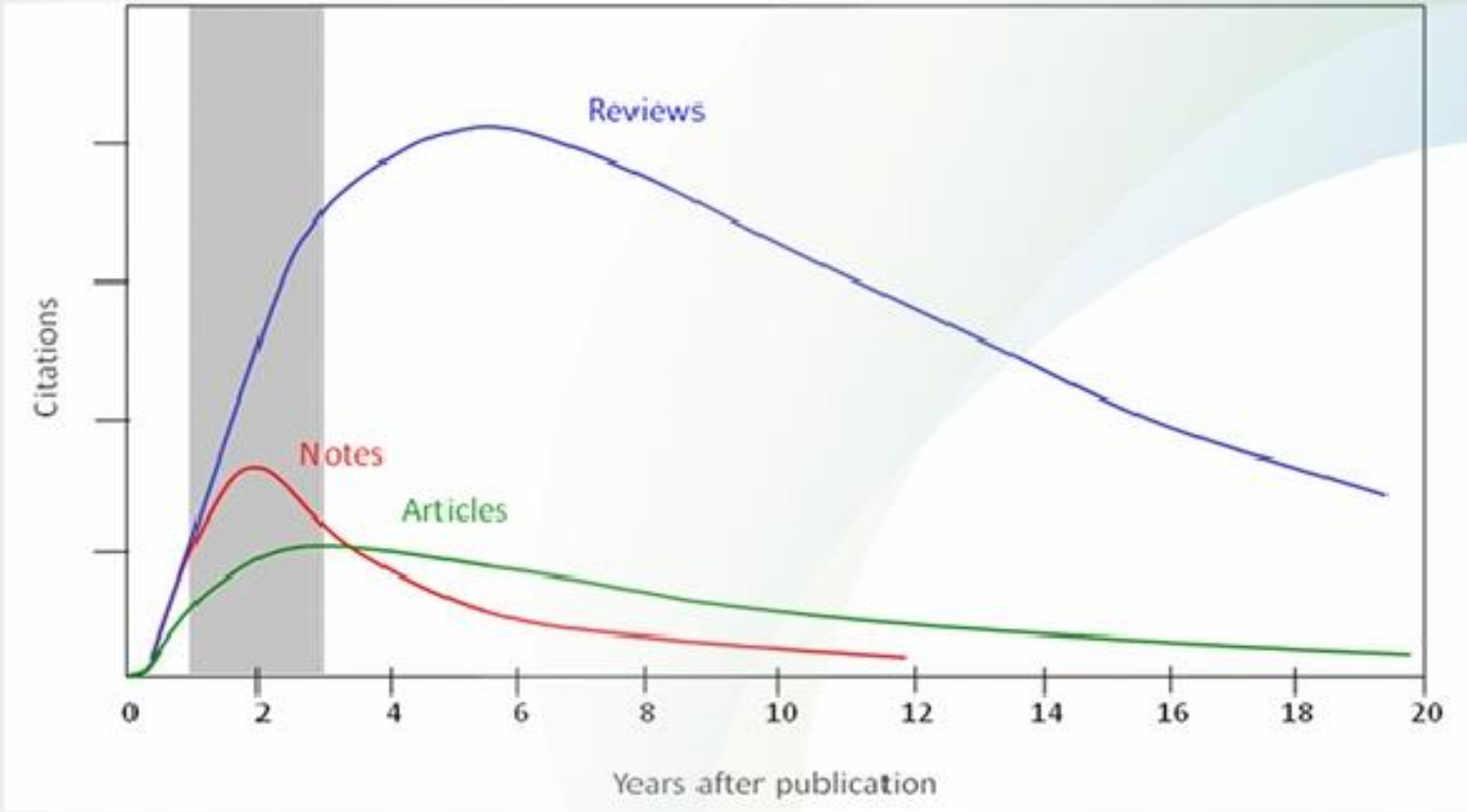
Citations per article type



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Impact Factor

The Impact Factor tells you how many times the papers in one journal are cited on AVERAGE.

It does NOT give an indication about a single (your) paper.

Some papers are heavily cited, others are never cited (even in journals with high Impact Factor).

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Choosing the right journal

Investigate all candidate journals on Elsevier.com to find out:

- Aims and scope
- Accepted types of articles
- Readership
- Current hot topics
  - go through the abstracts of recent publications

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Choosing the right journal cont..

- Ask for help from your supervisor or colleagues
  - The supervisor (who is often a co-author) has co-responsibility for your work.
- DO NOT gamble by submitting your manuscript to more than one journal at a time.
  - International ethics standards prohibit multiple/simultaneous submissions, and editors *WILL* find out! (see also our webcast on publishing ethics www.elsevier.com/editorsupdate).

TIP: Articles in your references will likely lead you to the right journal.

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Read the '*Guide for Authors*'!

- You can find the Guide for Authors on the journal homepage on Elsevier.com
- Stick to the Guide for Authors in your manuscript, *even in the first draft* (text layout, nomenclature, figures & tables, references etc.). In the end it will save you time, and also the editor's.
- Editors (and reviewers) do not like wasting time on poorly prepared manuscripts.

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Summary – What steps do I need to take before I write my paper?

- Determine if you are ready to publish
- Decide on the type of manuscript
- Choose the target journal
- Check the Guide for Authors

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Why is language important?

- Without proper language, the editor and reviewers will not understand what you mean
- Poor language will lead to rejection of your paper
- English language should be used throughout the entire manuscript, including figures, charts, graphs, and photos.

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Do publishers correct language?

- No. It is the author's responsibility to make sure his paper is in its best possible form when submitted for publication

- However:
  - Publishers often provide resources for authors who are less familiar with the conventions of international journals. Please check your publishers' author website for more information.
  - Some publishers may perform technical screening prior to peer review.
  - Visit http://webshop.elsevier.com for translation and language editing services.

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Manuscript Language – Overview

Write with clarity, objectivity, accuracy, and brevity.

- Key to successful manuscript writing is to be alert to common errors:
  - Sentence construction
  - Incorrect tenses
  - Inaccurate grammar
  - Mixing languages

Check the Guide for Authors of the target journal for any language specifications

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Manuscript Language – Sentences

- Write direct and short sentences
- One idea or piece of information per sentence is sufficient
- Avoid multiple statements in one sentence

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Manuscript Language – Tenses

- Present tense for known facts and hypotheses:
  "The average life of a honey bee is 6 weeks"
- Past tense for experiments you have conducted:
  "All the honey bees were maintained in an environment with a consistent temperature of 23 degrees centigrade…"
- Past tense when you describe the results of an experiment:
  "The average life span of bees in our contained environment was 8 weeks…"

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Manuscript Language – Grammar

- Use active voice to shorten sentences
  - Passive voice: "It has been found that there had been…"
  - Active voice: "We found that…"
  - Passive voice: "carbon dioxide was consumed by the plant…"
  - Active voice: "…the plant consumed carbon dioxide.."
- Avoid abbreviations: "it's", "weren't", "hasn't"
  - Never use them in scientific writing
  - Only use abbreviations for units of measure or established scientific abbreviations, e.g. DNA

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Manuscript Language – Grammar

- Minimize use of adverbs: “However”, “In addition”, “Moreover”
- Eliminate redundant phrases
- Double-check unfamiliar words or phrases

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Summary – How can I ensure I am using proper manuscript language?

- Proper manuscript language is important so that editors and reviewers can easily understand your messages
- Refer to the journal's Guide for Authors for specifications
- Check that your paper has short sentences, correct tenses, correct grammar, and is all in English
- Have a native English speaker check your manuscript or use a language editing service

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General structure of a research article

- Title
- Abstract
- Keywords

Make them easy for indexing and searching! (informative, attractive, effective)

- Main text (IMRAD)
  - Introduction
  - Methods
  - Results
  - And
  - Discussions

Journal space is not unlimited.

Make your article as concise as possible.

- Conclusions
- Acknowledgements
- References
- Supplementary Data

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Authorship

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General principles for who is listed first

- First Author
  - Conducts and/or supervises the data generation and analysis and the proper presentation and interpretation of the results
  - Puts paper together and submits the paper to journal
- Corresponding author
  - The first author or a senior author from the institution

Avoid

- Ghost Authorship
  – leaving out authors who should be included
- Gift Authorship
  – including authors who did not contribute significantly
- Spelling names: Be consistent!

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Title

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- A good title should contain the *fewest* possible words that *adequately* describe the content of a paper.
- Effective titles
  - Identify the main issue of the paper
  - Begin with the subject of the paper
  - Are accurate, unambiguous, specific, and complete
  - Are as short as possible
- Articles with short, catchy titles are often better cited
- Do not contain rarely-used abbreviations

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Keywords

Used by indexing and abstracting services

- They are the labels of your manuscript.
- Use only established abbreviations (e.g. DNA)
- Check the 'Guide for Authors'

Article Title	Keywords
"Silo music and silo quake: granular flow-induced vibration"	Silo music, Silo quake, stick-slip flow, resonance, creep, granular discharge
"An experimental study on evacuated tube solar collector using supercritical CO2"	Solar collector; Supercritical CO2; Solar energy; Solar thermal utilization

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Abstract

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… is freely available in electronic abstracting & indexing services [PubMed, Medline, Embase, SciVerse Scopus, ….]

- This is the **advertisement of your article**. Make it interesting, and easy to be understood without reading the whole article.
- You must be **accurate** and **specific**!
- A clear abstract will strongly influence whether or not your work is further considered.
- Keep it as **brief** as possible!!!

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Introduction

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Provide context to convince readers that you clearly know why your work is useful

- Be brief
- Clearly address the following:
  - What is the problem?
  - Are there any existing solutions?
  - Which solution is the best?
  - What is its main limitation?
  - What do you hope to achieve?
- Try to be consistent with the nature of the journal

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Methods

Describe how the problem was studied

- Include detailed information
- Do not describe previously published procedures
- Identify the equipment and describe materials used

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Ethics Committee approval

- Experiments on humans or animals must follow applicable ethics standards
  - e.g. most recent version of the Helsinki Declaration and/or relevant (local, national, international) animal experimentation guidelines
- Approval of the local ethics committee is required, and should be specified in the manuscript
- Editors can make their own decisions as to whether the experiments were done in an ethically acceptable manner
  - Sometimes local ethics approvals are below internationally accepted standards

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Results – what have you found?

- Tell a clear and easy-to-understand story. **RED THREAD**
  - Be structured (sub-headings)
- The following should be included:
  - The main findings
    - Thus not all findings (Add Supplementary Materials for data of secondary importance)
    - Findings from experiments described in the Methods section
  - Highlight findings that differ from findings in previous publications, and unexpected findings
  - Results of the statistical analysis

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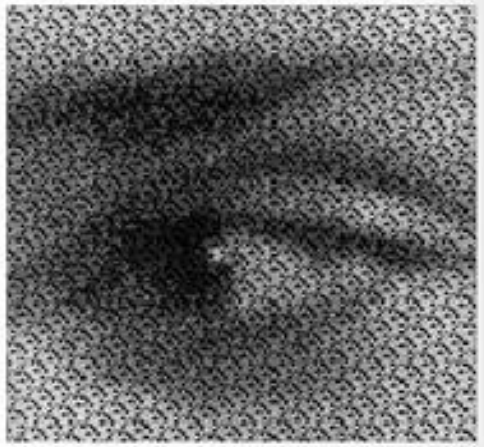
Results – Figures and tables

- Illustrations are critical, because
  - Figures and tables are the most efficient way to present results and;
  - Results are the driving force of the publication

- Captions and legends must be detailed enough to make figures and tables self-explanatory

- No duplication of results described in text or other illustrations



"One Picture is Worth a Thousand Words"
Sue Hanauer (1968)

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Discussion

What the results mean

- Most important section
- Make the Discussion correspond to the Results
- You need to compare published results with yours

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Conclusion

How the work advances the field from the present state of knowledge

- Should be clear
- Justify your work in the research field
- Suggest future experiments

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Acknowledgments

Ensures those who helped in the research are recognised

Include individuals who have assisted with your study, including:

- Advisors
- Financial supporters
- Proofreaders
- Typists
- Suppliers who may have given materials

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References

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Cite the main scientific publications on which your work is based

- Do not use too many references
- Always ensure you have fully absorbed material you are referencing and do not just rely on checking excerpts or isolated sentences
- Avoid excessive self-citations
- Avoid excessive citations of publications from the same region
- Conform strictly to the style given in the Guide for Authors

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Summary – How do I build up my article properly?

- Title
- Abstract
- Keywords
- Main text (IMRAD)
  - Introduction
  - Methods
  - Results
  - And
  - Discussions
- Conclusion
- Acknowledgement
- References
- Supporting Materials

- Structure your article properly
- Make sure each section of the paper fulfills its purpose clearly and concisely

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با آرزوی موفقیت در مسیری که انتخاب کرده اید!؟

(با هدف گذاری...؟ و با برنامه ریزی برای رسیدن به هدف...؟)

Email: m.azadi.1983@gmail.com