

Use of Tense and Aspect in Academic Writing in Engineering: Simple Past and Present Perfect*

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This study aims to analyze the use of tense and aspect in academic writing in engineering with a major focus on the use of simple past and present perfect. In general, one of the most difficult items for Japanese EFL learners is the appropriate use of tense and aspect. The previous literature pointed out that ESL learners are often confused about using them. Therefore, the American Psychological Association recommends that the past tense is used when discussing another researcher's work and reporting results, whereas the present perfect is used to describe an action beginning in the past and continuing to the present. Toward this end, the current study analyzed the use of simple past and present perfect using a small corpus compiled from 21 major journal articles in mechanical engineering. The study found that the frequently appearing simple past verbs were "showed," "occurred," "resulted," and "indicated." Additionally, "been" was the most frequently used verb in sentences that employ the present perfect. In addition, more than 90% of the sentences were followed by sentences that use the past participle of general verbs. Therefore, many forms of the present perfect clearly appeared in passive sentences.

Keywords: academic writing, tense, aspect, small corpus, engineering

1 Introduction

The previous literature frequently pointed out that the majority of Japanese learners of English face difficulty in the appropriate use of tense and aspect. One of the reasons underlying this notion is that the Japanese typically do not recognize tense and aspect and thus cannot make a clear distinction between them. Eto (2017) mentioned that the present perfect is one of the most difficult grammatical items for novice Japanese learners of English. Such

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learners may confuse the past tense with the present perfect when translating sentences with the present perfect into Japanese. Hofmann (2014) cited that many scientific ESL authors are confused about when to use past and present tense and are unsure if the past tense and present tense can be used simultaneously in the same sentence or paragraph. However, Higuchi and Hara (2018) suggested that, in English for Science and Technology settings, researchers should be aware of tense such that they can include their value judgments when writing their research articles. Hence, understanding the selection of appropriate tense or aspect in English writing is important for Japanese learners.

The study analyzes the use of the past tense and present perfect in academic writing mainly in academic articles for engineering. Students at KOSEN (National Institute of Technology), which was the author's former workplace, are expected to write and speak in English properly to play an important role as highly skilled engineers at the international level. English teachers are tasked to develop the students' ability to present research in English effectively. However, teachers lack knowledge about the characteristics of academic writing, such as grammar and vocabulary, from the engineering perspective because the specialty of most English teachers lies in other fields. Thus, they are frequently unable to provide appropriate advice. The results of the current study can provide valuable information for English teachers of students majoring in engineering.

2 Literature Review

2.1 Grammatical features of tense and aspect in English

According to Leech, Cruickshank, and Ivanic (2001), tense denotes the two forms of a verb, namely, present tense and past tense. It expresses the difference not only between the present and past but also between real and unreal meaning. Conversely, aspect "describes the way we view an action or state, in terms of the passing of time" (p. 54). Quirk, Greenbaum, Leech, and Svartvik (1985) classified the present perfect into three meanings, namely, state leading up to the present, indefinite event in a period leading up to the present, and a habit or recurrent event in a period leading up to the present. Furthermore, Biber, Conrad, and Leech (2002) explained that the present perfect and simple past tense typically refer to an event or state in the past, which can be used to refer to a state that exists over a period of time. The primary difference in meaning between the two is that the present perfect evokes a situation that continues to exist up to the present time, whereas the past tense describes an event that occurred at a particular time in the past. In addition, Quirk et al. (1985) indicated that "the overlap of meaning between

tense and aspect is most problematic in English in the choice that has to be made between simple past and present perfect” (p. 189). Therefore, the overlap between the past tense and present perfect is seemingly one of the biggest reasons for the difficulty that English learners face in distinguishing between the two tenses.

2.2 Tense and aspect in academic writing in English

Hofmann (2014) explained the rules for the appropriate use of tense and aspect in scientific writing. The past tense is used to describe the observation and specific conclusion, whereas the present perfect is used to describe findings and events that started in the past and are ongoing or have present consequences. Wallwork (2012) stated that the present perfect is used if the method is the subject of the verb, whereas the simple past tense is used if the author is the subject of the verb. Hence, the difference in the subject of the verbs affects the choice of tense and aspect. Moreover, the American Psychological Association (APA, 2019) suggested that the past tense is used to discuss another researcher’s work or to report the author’s results. In contrast, the present perfect is used to describe an action beginning in the past and continuing to the present. Table 1 shows the recommended tense and aspect in APA style papers.

Table 1. Recommended Verb Tenses in APA Style Papers (APA, 2019)

Paper section	Recommended tense
Literature review (or whenever discussing the work of other researchers)	Past and present perfect
Method	Past and present perfect
Description of procedure	Past
Reporting of result	Present
Discussion of implications of results	Present
Presentation of conclusions, limitations, future directions and others	Present

Table 1 indicates that the past tense and present perfect are used in literature reviews, methods, and description of procedure. However, the choice of tense and aspect in these sections seems to be one of the difficult points for EFL authors.

Chen (2009) investigated the tense alternation of reporting verbs used in native speakers’ articles in literature reviews. The author mentioned that the past tense and active voice tend to be associated with reporting detail, and passive-perfect verbs frequently initiate new subtopics. The research addressed the distributions of tenses of reporting verbs in literature reviews in engineering and concluded that more than 55% were written in simple present tense, approximately 19% in the simple past, and approximately 18% in perfect sentences. Swales and Freak (2012) argued that tense usage varied

and largely dependent on different sub-genres of journal articles. Table 2 shows the tendencies of tense usage in the different sub-genres of academic articles according to specific functions.

Table 2. Frequencies of Verb Tense (Swales & Freak, 2012)

Type/section	Introduction	Methods	Results	Discussion
Present tense	High	Low	Low	High
Past tense	Middle	High	High	Middle
Present perfect	Middle	Low	Low	Middle
Passive	Low	High	Variable	Variable

Table 2 denotes that based on the difference between the past tense and present perfect, their frequency is the same in the “Introduction” and “Discussion” sections, whereas the frequency of the past tense is higher than the present perfect in the “Methods” and “Results” sections.

In addition, Wang and Tu (2014) investigated the main variations of tense usage between be-verbs and reporting verbs in journal article abstracts in the field of applied linguistics based on their corpus. The authors analyzed journal article abstracts within the framework of move theory. In the study of genre analysis, a move is a rhetorical element and functions as a communicative role between each transition of the rhetorical structure. They found that the tendency of verb tense usage is dependent on different moves or journals, whereas the variations of tense were strongly connected and interrelated with moves. Moreover, Arsyad and Adila (2018) analyzed tense and aspect in literature citations in English research articles written by Indonesian authors. The authors found that the present tense was dominant, whereas the frequency of the past tense was nearly the same as that of the present perfect.

These studies suggested that the present tense is the most frequently appearing tense in certain sections of research articles, and a similar tendency exists in terms of the appearance of the simple past tense and present perfect aspect. However, the difference in function between the past tense and present perfect in academic writing remains unclear.

2.3 Research questions

The present study addresses the following research questions (RQs) to clarify the uses of tense and aspect in academic writing. RQ 1 intends to investigate the verbs frequently used in simple past sentences; RQ 2 explores verbs frequently used in present perfect sentences; and RQ 3 ascertains the use of verbs in various grammatical forms.

RQ1: Which verbs appear the most in the simple past tense form in research articles in engineering?

RQ2: Which verbs appear the most in the present perfect form in research articles in engineering?

RQ3: What differences are observed in the manner of using the same verb in different forms, i.e., past and present perfect?

As has been observed, the overlap of meaning between simple past and present perfect is one of the biggest reasons for the difficulty of using them correctly. To answer the above RQs will give us valuable information about the usages of simple past and present perfect. Thus, the present study aims to quantitatively analyze the use of simple past and present perfect sentence constructions and to qualitatively examine the actual use of such sentences in academic writing by observing several characteristic expressions.

3 Method

A small corpus was compiled from several major journals to analyze the use of simple past and present perfect in research articles in engineering, specifically mechanical engineering. Previous studies on the use of a small corpus indicate the advantages of analyzing the specific use of grammatical items. For example, O’Keeffe (2007) pointed out that the specificity of representation narrows and concentrates the coverage and brings the signature uses of language in the given contexts of use into clear focus. Koester (2010) also suggested that the main advantage lies in the close link that exists between language patterns and contexts of use because a small specialized corpus can provide valuable insights into specific areas of language use.

Okuyama (2016) set three conditions for selecting articles from major journals to ensure the quality of the small corpus as follows:

Condition 1: The journal is highly ranked in the field of mechanical engineering according to Google Scholar Metrics.

Condition 2: The university or institution of the author is located in the United States.

Condition 3: One of the authors is assumed to be a native speaker of English based on name.

Okuyama (2016) explained why Google Scholar Metrics was selected as a criterion. Google Scholar Metrics is a form of index, which provides an easy means for authors to quickly gauge the visibility and influence of recent articles in scholarly publications and summarizes recent citations to many publications. Therefore, higher-ranked journals have larger impacts in their research fields. The second condition was set as benchmarks for avoiding differences in native English languages, such as American, British, and others.

The author also checked each article author's personal history on his or her research institute's web pages based on the third condition. Following the abovementioned conditions, eight additional articles were added to Okuyama's (2016) corpus to enhance the precision of the small corpus of the present study.

Table 3. Details of the Small Corpus Compiled by the Author

Name of Journal	N of A	W Tokens	W Types	TTR
<i>Composite Structure (CS)</i>	5	23,624	2,399	10.15
<i>International Journal of Engineering Science (IJ)</i>	6	40,301	3,780	9.38
<i>Journal of the Mechanics and Physics of Solids (JM)</i>	5	42,219	3,238	7.67
<i>Wear (WE)</i>	5	20,070	2,605	12.98
Total	21	126,214	6,788	5.38

Note: N of A = number of articles; W Tokens = word tokens; W Types = word types; TTR=Type Token Ratio.

Table 3 shows the details of the small corpus compiled by the present study. The total number of word tokens and word types reached 126,214 and 6,788, respectively, which were calculated by Antconc version 3.5.8w (Anthony, 2019). The total number of word tokens is not equal to the sum of the aforementioned four tokens because some words are overlap in four journals.

4 Result and Discussion

4.1 RQ1: Frequently observed verbs in simple past sentences

This section examines the details of the corpus concerning the appearance of the simple past tense in academic articles. Table 4 indicates highly-ranked verbs, which appeared frequently in simple past sentences. Relative frequency denotes the frequency of appearance of each word per 10,000 words. Given that the other verbs appeared less frequently in simple past sentences in the corpus, analysis was narrowed down to the four high-ranking verbs.

Table 4. Frequency of the Simple Past of Most Frequently Observed Verbs

	Raw FR of PA	Relative FR of PA
Showed	44	3.49
Occurred	20	1.59
Resulted	12	0.95
Indicated	11	0.87

Note: Raw FR of PA = raw frequency of past tense; Relative FR of PA = relative frequency of past tense.

Statements (1) to (4) are examples of sentences using the simple past tense.

- (1) The results also *showed* that the SNCM is more accurate than the STM and approximately equal in accuracy to the VPSC. (*JM*: Result and Discussion)
- (2) Maximum tool temperatures *occurred* on the cutting-edge radius of the tool model. (*WE*: Result)
- (3) The small discontinuities seen between 100% DLL and 140% DLL apparently *resulted* from the intermittent characteristics of damage extension previously discussed. (*CS*: Result and Discussion)
- (4) The upper grip was manually rotated until the system *indicated* zero torque. (*IJ*: Method)

The examples of “show,” “occur,” and “result,” were noted in the “Result and Discussion” section of each article, whereas the last example “indicate” appeared in the “Method” section. Therefore, these examples may suggest that past tense sentences tend to appear frequently in those sections, which correspond to the suggestion of APA (2019).

4.2 RQ2: Frequently observed verbs in present perfect sentences

This section examines the frequently appearing verbs in present perfect. Table 5 shows the high-ranking verbs that frequently appeared in present perfect sentences. “Been,” which is the past participle of “be” ranked first. This finding corresponds to the indication of Biber et al. (2002), that is, the present perfect “have or has + been” is common in all registers. In statement (5), the sentence using “been” appeared in the “Introduction” section, which is partially consistent with the tendency pointed out by Swales et al. (2012), that is, the present perfect is a relatively frequent occurrence in academic papers. Conversely, other verbs, such as “shown” and “found” appeared less frequently in present perfect sentences; however, in case they are used in present perfect, many occurrences were noted in the “Introduction” section. Statements (6) to (8) provide examples of present perfect sentences.

Table 5. Frequency of the Present Perfect of Frequently Observed Verbs

	Raw FR of PP	Relative FR of PP
Been	142	11.25
Shown	8	0.63
Found	4	0.32
Used	3	0.23
Considered	2	0.16
Presented	2	0.16

Note: Raw FR of PP = raw frequency of present perfect tense; Relative FR of PP = relative frequency of present perfect tense.

- (5) In particular, the wear of the cones in geothermal well drilling results in the loss of hard inserts, and that *has been* the subject of prior work in this laboratory [2]. (*WE*: Introduction)
- (6) ..., we *have shown* that certain strength models, e.g., those based on a generalized Taylor relation, produce a physical behavior. (*JM*: Introduction)
- (7) Such structures *have found* use for a long time in the form of multi-layer dielectric stacks used commonly in reflective coatings, for example. (*JM*: Introduction)
- (8) Indeed, we *have used* such a model (Edmiston, 2012) to benchmark the alternative model proposed in this work. (*IJ*: Introduction)

However, the small corpus presents an important finding. The majority of the use of “been” was followed by the past participle of general verbs. In other words, most of the present perfect sentences that appeared in the small corpus were passive sentences. A total of 70 “have + been + past participle (p.p.)” sentences were observed out of 74, whereas 65 “has + been + p.p.” sentences were noted out of 68. In other words, approximately 95% of present perfect sentences using “been” were passive sentences. This finding seemingly imparts important information regarding the use of the present perfect in academic writing. Thus, closely examining the tendency of the appearance of the verb after “been” is necessary. Table 6 illustrates the frequently appearing verbs in present perfect passive sentences. In addition, the frequency of each verb in present perfect sentences is also presented.

Table 6. Frequency of Verbs after “been” of Most Frequently Observed Verbs

	Raw FR of verb after <i>been</i>	Relative FR of verb after <i>been</i>	Raw FR of PP	Relative FR of PP
Shown	13	1.02	8	0.63
Used	8	0.63	3	0.23
Developed	6	0.48	1	0.08
Reported	6	0.48	1	0.08
Found	5	0.40	4	0.32
Proposed	5	0.40	1	0.08

Note: Raw FR of verb after *been* = raw frequency of verb after “been”; Relative FR of verb after *been* = relative frequency of verb after *been*; Raw FR of PP = raw frequency of present perfect; Relative FR of PP = relative frequency of present perfect.

Table 6 indicates that “shown” is the most frequently appearing verb in present perfect passive sentences. In addition, the study observes that all verbs in Table 5 were more frequent in passive than active voice sentences. Statements (9) to (12) are examples for each verb that appeared in present perfect passive sentences.

- (9) For submerged plates near the free surface, the in-water resonant frequencies *have been shown* to decrease with increasing submergence depth due to increasing added mass effects to a point.... (CS: Introduction)
- (10) However, these models historically *have not been used* for diamond turning due to the inherent difficulties measuring wear and predicting tool temperatures. (WE: Introduction)
- (11) A number of constructive algorithms *have been developed* for the recovery of the coefficients of the Sturm Liouville problem with finite spectral data. (IJ: Literature Review)
- (12) Higher-order elastic constants are difficult to measure standard tests ... and *have been reported* for few low-symmetry materials. (JM: Introduction)

The examples of “shown,” “used,” and “reported” appeared in the “Introduction” section of each article, whereas “developed” was found in the “Literature Review” section. Biber et al. (2002) pointed out that the present perfect evokes a situation that continues to exist up to the present time, such that the situations indicated by the sentences continue to exist in their research area. Seemingly, the authors of each article intended to explain the research background or present the situation using such sentences.

4.3 RQ3: Difference in the use of verb across tenses and aspects

This section examines the difference in the use of the same verb in a different tense or aspect using several typical verbs. Three types of appearance of the same verb was noted in different tenses or aspects. The first is verbs that appear in all sentence types: past, present perfect, and present perfect passive.

- (13) They *showed* that the free surface can have a significant effect on the dynamic response of the plate. (CS: Introduction)
- (14) Some recent work (Berryman, 2005 and Berryman, 2011) *has shown* how to simplify methods used to quantify estimators to some extent. (IJ: Introduction)
- (15) These simplifications are valid since tool forces in diamond turning *have been shown* to be largely independent of cutting speed [34]. (WE: Literature Review)

As shown by statements (13) to (15), “show” appeared in the three abovementioned sentence types. In the first two examples, the subject of each sentence, “they” and “some recent work”, serves as an agent of “show,” and the sentences are in the active voice. In contrast, the subject of “show” in statement (15) is “tool forces,” which serves as a patient of “show.” The sentence is in the passive voice.

The second type refers to verbs that did not appear in one or more sentence types.

- (16) They also *observed* that the crystal orientation influenced the Dc components corresponding to the D non-zero macroscopic components. (*JM*: Literature Review)
- (17) Such large reductions in the COF *have been observed* for sulfur implantations into steel [5] and [37] during dry sliding conditions. (*WE*: Result and Discussion)
- (18) No visible exterior crack progression *occurred* during LS-3 and LS-4. (*CS*: Result and Discussion)

The verb “observe” appeared in the simple past and present perfect passive sentences. However, no usage was noted in present perfect sentences. The reason may be because the observation of the research was typically carried out by the authors who intended to mention the observed phenomena objectively. Moreover, no usage was found for the verb “occur” for present perfect and present perfect passive sentences. In Longman Dictionary of Contemporary English (LDOCE), “occur” is used especially when talking about unplanned events. Therefore, “occur” is not frequently used in perfect sentences, and we were unable to find any usage in these types of sentences.

The third verb type pertains to verbs that did not appear in all three sentence types.

- (19) ..., a series of test variable scoping experiments *was conducted* before applying the new test to screen candidate materials. (*WE*: Introduction)
- (20) In Section 2.2, we first *conduct* a convergence study on a reduced polycrystal containing eight crystals to determine the required mesh resolution. (*JM*: Introduction)

The verb “conduct” was absent in simple past, present perfect, and present perfect passive sentences. In other words, nearly all usages of “conduct” were found in passive sentences, except for the three usages in statement (20), where the subject of each active sentence is “we,” as shown by the small corpus of the present study. Okuyama (2016) pointed out that certain academic journal guidelines have recommended the use of the active voice where possible. However, the current study infers that previous authors tended to use passive voice with regard to certain verbs, such as “conduct,” and avoid clarifying the actor of the study or survey to give an objective flavor to their research articles.

5 Conclusion

The present study revealed the use of the simple past and present perfect tenses in academic writing in engineering. Academic writing recommends the use of the past tense to describe observations and specific conclusions, whereas the present perfect tense can be used to describe findings and events that started in the past and are ongoing or have present consequences. Although a similar tendency in the appearance of the simple past tense and present perfect aspect is observed, the difference in function between them in terms of academic writing remains unclear.

With regard to RQ1, corpus analysis was carried out to determine the actual use of the simple past in academic writing. Result revealed that the frequently appearing verbs are “showed,” “occurred,” “resulted,” and “indicated” in simple past sentences. Moreover, the appearance of these verbs is consistent with the suggestion of the APA (2019), that is, the past simple can be used in the “Method” and “Result and Discussion” sections. For RQ2, the most frequently appearing verb was “been,” which correspond to the finding of Biber et al. (2002), that is, the present perfect is common in all registers. In addition, approximately 95% of usages of present perfect sentences that appeared in the small corpus were passive sentences. “Shown” was the most frequently appearing verb in present perfect passive sentences, whereas the number of appearance of each verb is more frequent in the passive than active voice. The reason may be that the authors of each article in the corpus aim to explain the research background or present a situation using passive sentences. With respect to RQ3, three types of appearance were observed (i.e., past, present perfect, and present perfect passive) of the same verb in different tenses or aspects, namely, appearance in all sentence types, no appearance in one or more sentence types, and no appearance in all sentence types.

The following limitations of the study should be considered for further research. First, the results should be compared with a reference corpus addressing the general or scientific use of English. The research used and analyzed the simple past and present perfect based on only four engineering journals. Thus, the question that still remains is whether the features of the uses of tense and aspect in English are distinctive in the field of engineering. Comparison with the reference corpus may add clarity to the features of the use of tense and aspect in academic writing. Second, the tendency of the appearance of verbs with regard to differences in genre requires a close examination. In this research, the selected examples of sentences only considered the grammatical functions of tense and aspect. Therefore, investigating the difference or similarities of the use of tense and aspect in each section of articles is necessary. Lastly, the characteristics of articles written by Japanese researchers in the same field should be analyzed. By comparing, the actual use of tense and aspect in academic writing may serve

as a very useful reference for Japanese ESP teachers in designing lessons on writing research articles in English.

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Appendix

List of Selected Articles for Mechanical Engineering Corpus of This Research

International Journal of Engineering Science (IJES)

1. Berryman, J. G. (2013). Combining analysis of random elastic polycrystals with poroelasticity for granular composites having orthotropic porous grains and fluid-filled pores. *International Journal of Engineering Science*, 72, 11–21.
2. Brenner, H. (2013). Steady-state heat conduction in a gas undergoing rigid-body rotation. Comparison of Navier–Stokes–Fourier and bivelocity paradigms. *International Journal of Engineering Science*, 70, 29–45.
3. Edmiston, J., Steigmann, D. J., Johnson, G. J., & Barton, N. (2013). A model for elastic–viscoplastic deformations of crystalline solids based on material symmetry: Theory and plane–strain simulations. *International Journal of Engineering Science*, 63, 10–22.
4. Freed, A. D., & Einstein, D. R. (2013). An implicit elastic theory for lung parenchyma. *International Journal of Engineering Science*, 62, 31–47.
5. Haynes, R. A., & Armanios, E. A. (2012). The challenge of achieving hygrothermal stability in composite laminates with optimal couplings. *International Journal of Engineering Science*, 59, 74–82.

6. Joshi, S., & Walton, J. R. (2013). Reconstruction of the residual stresses in a hyperelastic body using ultrasound techniques. *International Journal of Engineering Science*, 70, 46–72.

Journal of the Mechanics and Physics of Solids (JMPS)

1. Clayton, J. D. (2013). Nonlinear Eulerian thermo elasticity for anisotropic crystals. *Journal of the Mechanics and Physics of Solids*, 61(10), 1983–2014.
2. Dobson, M., Luskin, M., & Ortner, C. (2010). Accuracy of quasicontinuum approximations near instabilities. *Journal of the Mechanics and Physics of Solids*, 58(10), 1741–1757.
3. Krishnan, D., & Johnson, H. T. (2009). Optical properties of two-dimensional polymer photonic crystals after deformation-induced pattern transformations. *Journal of the Mechanics and Physics of Solids*, 57(9), 1500–1513.
4. Mayeur, J. R., & McDowell, D. L. (2013). An evaluation of higher-order single crystal strength models for constrained thin films subjected to simple shear. *Journal of the Mechanics and Physics of Solids*, 61(9), 1935–1954.
5. Tonks, M. R., Bingert, J. F., Bronkhorst, C. A., Harstad, E. N., & Tortorelli, D. A. (2009). Two stochastic mean-field polycrystal plasticity methods. *Journal of the Mechanics and Physics of Solids*, 57(8), 1230–1253.

Composite Structures (CS)

1. Bergan, A., Bakuckas Jr, J., Awerbuch, J., & Tan, T. M. (2014). Assessment of damage containment features of a full-scale PRSEUS fuselage panel. *Composite Structures*, 113, 174–185.
2. Motley, M. R., & Barber, R. B. (2014). Passive control of marine hydrokinetic turbine blades. *Composite Structures*, 110, 133–139.
3. Motley, M. R., Kramer, M. R., & Young, Y. L. (2013). Free surface and solid boundary effects on the free vibration of cantilevered composite plates. *Composite Structures*, 96, 365–375.
4. Reddy, J. N., & Berry, J. (2012). Nonlinear theories of axisymmetric bending of functionally graded circular plates with modified couple stress. *Composite Structures*, 94(12), 3664–3668.
5. Williams, T. O. (2014). A new, unified, theoretical framework for the formulation of general, nonlinear, single-scale shell theories. *Composite Structures*, 107, 544–558.

Wear (W)

1. Autry, L., & Marcus, H. (2015). On the inhibition of metal transfer through ion implantation. *Wear*, 322, 1–9.
2. Blau, P. J., & Dehoff, R. R. (2013). Development of a two-body wet abrasion test method with attention to the effects of reused abrasant. *Wear*, 302(1–2), 1035–1039.
3. Budinski, K. G. (2013). Effect of hardness differential on metal-to-metal fretting damage. *Wear*, 301(1–2), 501–507.
4. Lane, B. M., Dow, T. A., & Scattergood, R. (2013). Thermo-chemical wear model and worn tool shapes for single-crystal diamond tools cutting steel. *Wear*, 300(1), 216–224.
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