

## A Scientometric Analysis for the Research on Aerodynamics: Quantity and Quality Assessment during 2012-2021

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### Abstract

*This study measuring the research productivity of Aerodynamics research in world as per the number of publications appeared in the Web of Science database. During the period (2012-2021) a total of 6643 publications were published by the global researchers in the field of Aerodynamics. The average number of publications published was 1263.9 and the highest numbers of publications (1741) were published in the year 2021. In recent years, the number of publications in this field has gradually increased, and there is a large space for research and development. The publication data was analysed with respect to the type of publications where 95.81% are journal articles. The United States, China, England are the countries that have contributed the most in this field. The number of research results in this field supported by the Beihang University of China is in a leading position in the world; Authorship and collaboration trend towards multi-authored publications. The degree of collaboration among author is 0.90.*

**Keywords:** Aerodynamics, annual growth rate, trend analysis and degree of collaboration

### 1 Introduction

Aerodynamics is a branch of physics that deals with the motion of air and other gaseous fluids and with the forces acting on bodies passing through such a fluid. Aerodynamics seeks, in particular, to explain the principles governing the flight of aircraft, rockets, and missiles. It is also concerned with the design of automobiles, high-speed trains, and ships, as well as with the construction of such structures as bridges and tall buildings to determine their resistance to high winds.

The growth of information has been accelerating day by day and researchers of science and technology and academic communities are still trying to manage with the information crisis to keeping up the huge amount of literature. During the last few decades, many researchers have been used scientometrics to measure and analyse the scientific research outputs in various disciplines. Scientometric is the most reliable method to track the activities of science and technology and it helps to understand the identity of scientific discipline. It helps to understand

the trends and growth, author productivity, authorship patterns, relative growth rate, collaborative works between countries, authors and institutions and so on. Gradually the scientometric studies are attaining the status of inter-disciplinary in nature. This is clear from the scientometric evidence from 2012 to 2021, that the number of publications in the Web of Science database was increased from 1046 to 1204. Therefore, the present study has been evaluated to know the growth and development of publications in the field of aerodynamics.




## 2. Review of Literature

Rezadad, Sina and Maghami, Mohammad Reza presented a concise literature review of flapping wing MAV research by appraising 439 academic journal papers that are relevant to the topic and published between 2004 and April 2014. In this bibliometric research, these papers have been divided into different categories and research areas, with allocations to main and sub-categories based on primary focus for each paper. The implications discussed in this literature review should be of keen interest for researchers and practitioners considering flapping wing areas for future research activities. A comprehensive list of references is also presented. Ward et al, analysed a comprehensive bibliometric review of journal articles published on micro air vehicle research from 1998 until 2015. The articles are classified into three types of micro air vehicle: fixed-wing, rotary-wing, and flapping-wing (biomimetic). The analysis shows that the majority of the research articles are being written by organizations from the US, China, UK, France, and South Korea.

Ricardo Andrés García-León et al, presented a historical analysis of the behavior and evolution of published documents related to the subject of disc brakes across the years; for this purpose, the data was collected from the *Scopus* database and analyzed with the software R-Bibliometrix and VOSviewer. The results showed that 1,584 documents were published mainly in English by 2,971 authors from different parts of the world, with a growth rate of 8.78% from 1964 to 2020. Finally, the most representative journal on this topic is SAE Technical Articles, with 241 articles in quartile Q2. Xie Shaodong et al, explored a bibliometric approach quantitatively assessing current research trends atmosphere aerosol, using the related literature in the Science Citation Index database from 1991 to 2006. Articles were concentrated on the analysis by scientific output, research performances by individuals, institutes and countries and trend by the frequency of keywords used. Over the years, there had been a notably growth trend in research outputs, along with collaboration of institutes and countries.

## 3 Objectives for the Study

The main objective of this study focuses on the following aspects:

-  To study the year wise growth of publications
-  To study the most prolific authors
-  To study the highly productive countries

- ✚ To study the highly productive institutes
- ✚ To study the most preferred source titles and
- ✚ To study the high productive subject areas

#### 4 Materials and Methods

The relevant article for this study was collected using Web of Science database which published by Thomson Reuters, United States. While searching data 'Aerodynamics' was used as search strings. With effect of search strategy, a total of 6643 publications were found for ten years between 2012-2021. Each record contained complete bibliographic information in English Language i.e. publication year, author, author affiliation, country, language, source titles, and so on. The retrieved records were loaded into the Bibexcel for the analysis purpose.

#### 5 Data analysis and interpretations

##### 5.1 Distribution of publications by year

A total of 6643 publications were published during 2012-2021. The year wise analysis reveals that the year 2021 has the highest number of publications i.e. 997 (15.01%) and the year 2012 has the lowest number of publications with 419 (6.31%). The annual average output of publication is 664.3 articles. Table 1 shows the number of aerodynamics publications published globally each year. This number of publications shows a fairly consistent growth with just a few slight declines

##### 5.1.1 Measurement of Annual Growth Rate (AGR)

Annual growth rate (AGR) is the change in the value of a measurement over the period of a year. It is calculated by taking the arithmetic mean of the growth rate over the time periods in question. Table 1 provides the AGR of the documents for the study period (2012 to 2021). This can be calculated with the following formula

$$AGR = \frac{\text{End Value} - \text{First Value}}{\text{First Value}} \times 100$$

Table 1 Annual growth rate of research output

Year	No. of Publications	Cumulative Total	Annual Growth Rate
2012	419	419	-
2013	468	887	111.69
2014	530	1417	59.75

2015	552	1969	38.96
2016	592	2561	30.07
2017	684	3245	26.71
2018	682	3927	21.02
2019	819	4746	20.86
2020	900	5646	18.96
2021	997	6643	17.66

There was variation in Annual Growth during the study period and suddenly decreased from 111.69 in 2013 to 59.75 in 2014. There was slightly decreased from 38.96 in 2014 to and 17.66 in the year 2021. This decreasing trend in the AGR indicates that there is constant upward trend growth in the research output.

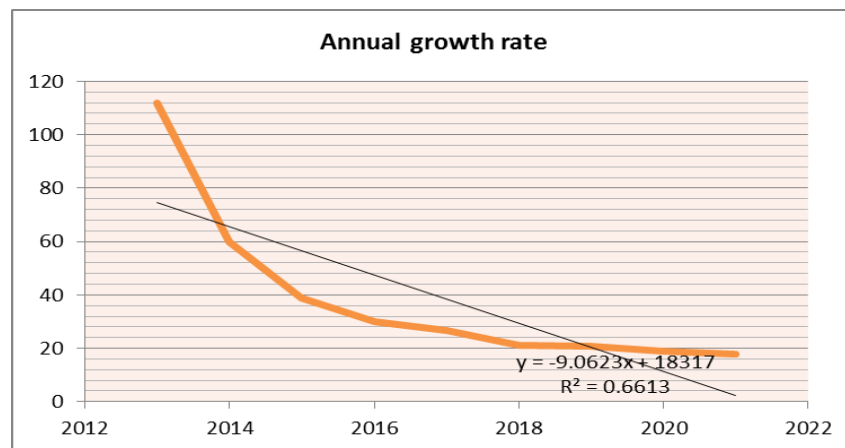


Figure 1 Annual growth rate of research output

### 5.1.2 Trend Analysis –Method of Least Squares

This is the best method for obtaining the trend values. It provides a convenient basis for obtaining the line of best fit in a series.

The straight line trend has an equation of the type:  $Y = a + bX$ ,

Where,

Y represents the estimated values of the trend, X represents the deviations in time period; 'a' and 'b' are constants.

The values of two constants 'a' and 'b' are estimated by solving the following two normal equations.

$$\Sigma Y = Na + b\Sigma X$$

$$\Sigma XY = a \Sigma X + b\Sigma X^2$$

Where N represents number of years for which data is given.

Table 2 Computation of straight line trend by the least squares method

Year	Actual value (Y)	Deviation	Multiply (X)	XY	X <sup>2</sup>	Trend value
2012	419	-4.5	-9	-3771	81	256
2013	468	-3.5	-7	-2376	49	347
2014	530	-2.5	-5	-2650	25	438
2015	552	-1.5	-3	-1656	9	528
2016	592	1	1	592	1	710
2017	684	1.5	3	2052	9	800
2018	682	2.5	5	3410	25	891
2019	819	3.5	7	5733	49	982
2020	900	4.5	9	8100	81	1072
2021	997	5.5	11	10967	121	1163
2022			13			1254
2023			15			1344
2024			17			1435
2025			19			1526
2026			21			1616
2027			23			1707
2028			25			1798
2029			27			1888
2030			29			1979
2031			31			2070
Total	<b>6643</b>			20401	450	

The equation of the straight line trend is  $Y = a + bX$

Since  $\Sigma X = 0$ , therefore

$$a = \frac{\Sigma Y}{N} = \frac{6643}{10} = 664.3$$

$$b = \frac{\Sigma XY}{\Sigma X^2} = \frac{20401}{450} = 45.34$$

Thus, substituting the value of 'a' and 'b' in the straight line of the trend, we get

$$Y = a + bX$$

Estimate of 2031 will be calculated on the basis of  $X = 31$

$$Y_{2031} = 664.3 + (45.34) \times 31 = 2070$$

With the use of the trend analysis, the trend values are calculated up to 2031. The trend line and actual line are presented in the figure 2. And, it is seen from the table 2, that the actual trend was standard in the year 2012 since then there is an upward trend up to the year of 2021 except in the year 2018. The trend value has been increased from 256 in 2012 to 2070 in 2031. It is interesting to note that there is an upward trend in the growth of the literature. From this it can be interpreted that the upward trend in the actual line reflects in the trend line also.

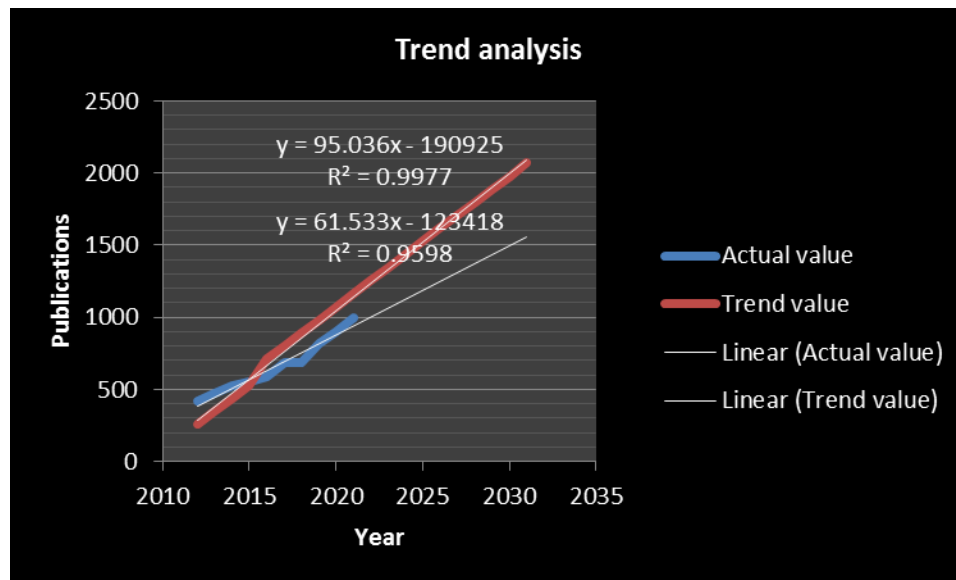


Figure 2 Trend analysis of research output

### 5.1 Form of publications

Table 3 - Form of Publications

S. No.	Title	Articles	Percentage
1	Articles	6365	95.81
2	Review articles	219	3.30
3	Editorial materials	41	0.62
4	Corrections	8	0.12
5	Book reviews	3	0.04
6	Letters	2	0.03
7	News Items	2	0.03
8	Biographical-Items	1	0.02
9	Reprints	1	0.02
10	Poetry	1	0.02
<b>Total</b>		<b>6643</b>	<b>100.00</b>

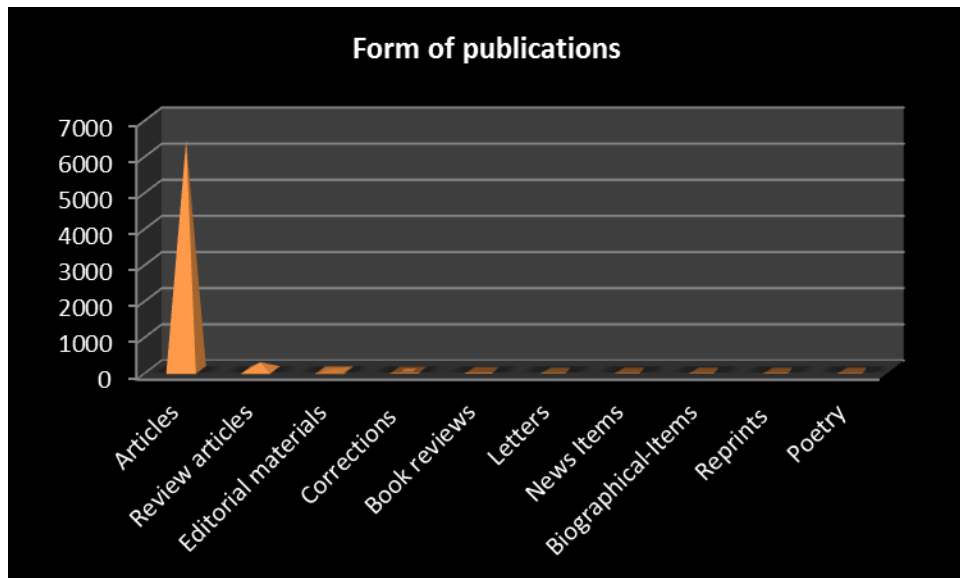


Figure 3 Form of publications

Aerodynamics research has been published in different forms of publications in the world as presented in table 3. Out of the 6643 published papers, 6365 (95.81%) were Journal articles followed by Review articles with 219 (3.30%), and the remaining forms are less than 1% of the publications. It could be noted from the study that, majority of researchers has contributed more in the form of journal articles.

5.3 Most prolific authors

Table 4 Most prolific authors

S. No.	Author	No. of publications	Percentage
1	Takizawa K	50	0.75 %
2	Tezduyar T E	48	0.72 %
3	Blocken B	43	0.65 %
4	Liu H	36	0.54 %
5	Thompson M C	32	0.48 %
6	Bazilevs Y	29	0.44 %
7	Wu T	29	0.44 %
8	Kopp G A	28	0.42 %
9	Zhang J	28	0.42 %
10	Liu Y	27	0.41 %

The table 4 represents the rank list of top 10 prolific authors and who have contributed more than 27 publications are examined to avoid a long list. Takizawa, K is the most productive author with 50 (0.75%) publications followed by Tezduyar, T E with 48 (0.72%) publications, Blocken, B with 43 (0.65%) publications, Liu, H with 36 (0.54%) publications, Thompson, M C with 32 (0.48%) publications, Bazilevs, Y with 29 (0.44%) publications, and Wu, T with 29 (0.44%) publications. Apart from this, authors published below 27 articles in a total research output. It is observed that these 10 prolific authors contributed a total 5.27% (350) article to the research output. And a total of 13,898 authors are contributed entire research output of the period under study.

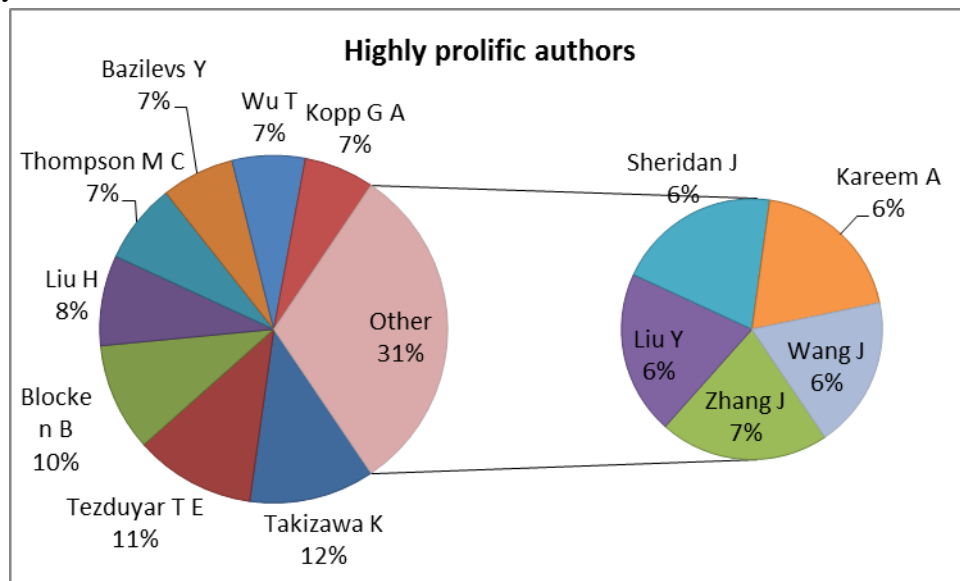


Figure 4 Highly prolific authors



## 5.4 Authorship patterns

### 5.4.1 Degree of Collaboration

The degree of collaboration is defined as the ratio of the number of collaborative research papers to the total number of research papers in the discipline during a certain period of time.

Table 5 Authorship patterns

Year	Single Author		Multi Authors		Total Publications	Total Authors	Degree of Collaboration (DC)	Collaboration Index (CI)
	No. of Output	%	No. of Output	%				
2012	53	7.71	366	6.14	419	861	0.87	2.05
2013	47	6.84	421	7.07	468	1013	0.90	2.16
2014	41	5.97	489	8.21	530	973	0.92	1.84
2015	67	9.75	485	8.14	552	1127	0.88	2.04
2016	64	9.32	528	8.87	592	1315	0.89	2.22
2017	59	8.59	625	10.49	684	1756	0.91	2.57
2018	81	11.79	601	10.09	682	1358	0.88	1.99
2019	61	8.88	758	12.73	819	1632	0.92	1.99
2020	93	13.54	807	13.55	900	1824	0.90	2.03
2021	121	17.61	876	14.71	997	2039	0.89	2.05
<b>Total</b>	<b>687</b>	<b>100.00</b>	<b>5956</b>	<b>100.00</b>	<b>6643</b>	<b>13898</b>	<b>0.90 (Average)</b>	<b>2.09 (Average)</b>

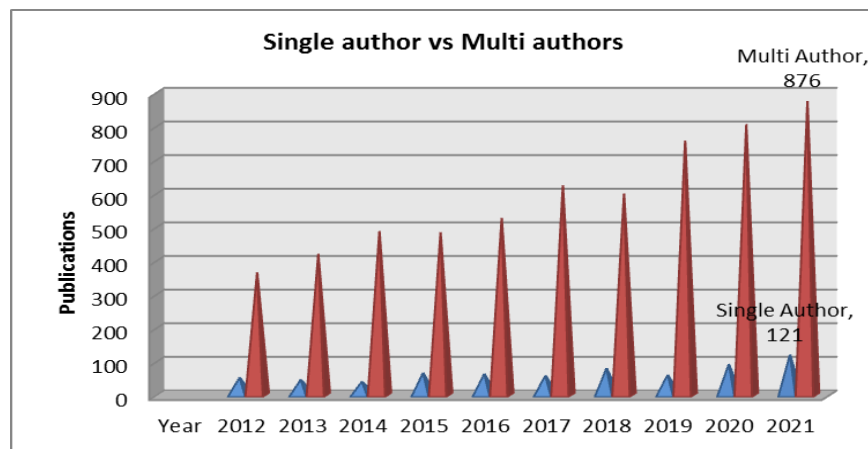


Figure 5 Single author Vs Multi-authored articles

The authorship pattern was analysed to determine the percentage of single and multiple authors. Table 5 presents the single and multiple authors productivity pattern on yearly basis. There were 5956 (89.66%) multi authored and only 687 (10.34%) single authored publications. The authorship patterns on the aerodynamics publications are much contributed by the multiple authors than the single author since 2012 to 2021.

The degree of collaboration is determined by using this formula based on this study, the result of degree of collaboration  $C = 0.90$ . i.e, 90 percents of collaborative author's articles is published in this study. The degree of collaboration in producing research output on aerodynamics research has shown a fluctuating trend during the study period.

Collaboration Index means number of authors per joint papers. Analysis in the table 5 shows the variation in the Collaboration Index. It varies from 1.84 in 2014 and highest collaboration notices in 2017 i.e. 2.57. The average collaboration index is 2.09. It implies the research team falls between 3 and 4 authorship pattern in field of aerodynamics.

**5.5 Highly productive countries**

Table 6 Highly productive countries

S. No.	Country	Total Publications	S. No.	Country	Total Publications
1	USA	1658 (24.96%)	6	France	311 (4.68%)
2	China	1609 (24.22%)	7	Canada	297 (4.47%)
3	England	704 (10.60%)	8	Japan	265 (3.67%)
4	Germany	427 (6.43%)	9	South Korea	244 (4.18%)
5	Italy	336 (5.06%)	10	Australia	230 (3.46%)

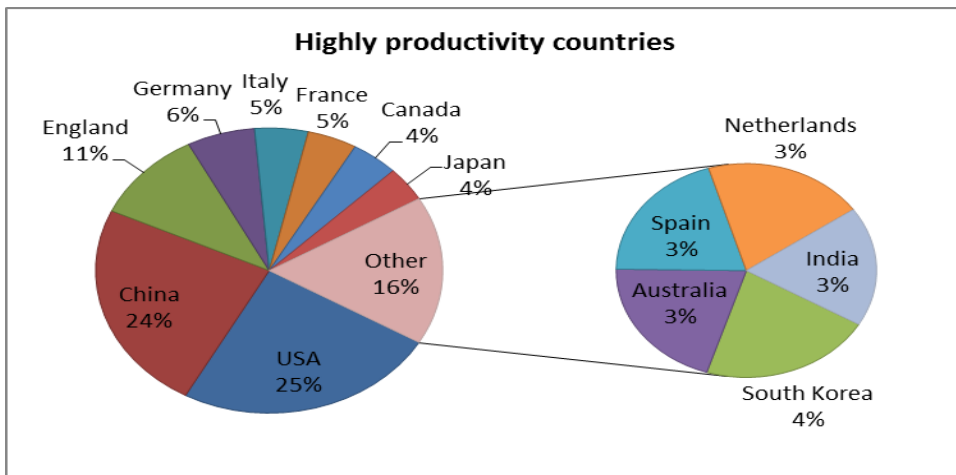


Figure 6 Highly productive countries

To examine the growth of publications with collaborative works among the 88 countries, top 10 countries has been counted which indicated in table 6. USA topped the list with highest

share 1658 (24.96%) of publications. China ranked second with 1609 (24.22%) share of publications followed by England 704 (10.60%) share of publications, Germany 427 (6.43%) share of publications, Italy with 336 (8.54%) share of publications, Italy with 956 (7.56%) share of publications, France with 311 (4.68%) share of publications and Canada with 297 (4.47) share of publications respectively.

### 5.6 Highly productive institutes

Table 7 Highly productive institutes

S. No.	Institutions	Country	No. of Publications
1	Beihang University	China	149 (2.24%)
2	North Western Polytechnic University	USA	132 (1.99%)
3	Delft University of Technology	Netherlands	121 (1.82%)
4	Nanjing University of Aeronautics and Astronautics	China	117 (1.76%)
5	Politecnico di Milano	Italy	91 (1.37%)
6	Shanghai Jiao Tong University	China	90 (1.35%)
7	Chinese Academic of Sciences	China	89 (1.34%)
8	Tsinghua University	China	88 (1.32%)
9	Cranfield University	UK	87 (1.31%)
10	Technical University of Denmark	Denmark	83 (1.25%)

The study identified 3388 institutions for a total of 6643 research output and table 7 shows top ten productivity institutions has been taken to the account for analysis. Among these top 10 institutions 5 are from China, each one from USA, Netherlands, Italy, UK and Denmark. Beihang University, China topped the list with 149 (2.24%) publications followed by North Western Polytechnic University, USA with 132 (1.99%) publications, Delft University of Technology, Netherlands with 121 (1.82%) publications, Nanjing University of Aeronautics and Astronautics, China with 117 (1.76%) publications and Politecnico di Milano, Italy with 91 (1.37%) publications.

### 5.7 Most preferred source titles

Table 8 Source Title of Publications

S. No.	Source Title	No. of Publications	Percentage	Impact Factor
1	Journal of Wind Engineering and Industrial Aerodynamics	345	5.19	4.082
2	Aerospace Science and Technology	280	4.21	5.107

3	AIAA Journal	205	3.091	2.624
4	Journal of Aircraft	204	3.07	2.60
5	Journal of Fluid Mechanics	197	2.97	4.245
6	Journal of Fluids and Structures	174	2.62	2.917
7	Proceedings of The Institution of Mechanical Engineers Part G Journal of Aerospace Engineering	154	2.32	0.454
8	Wind Energy	125	1.88	2.73
9	Renewable Energy	119	1.79	8.634
10	Energies	118	1.78	3.004

Table 8 provides the leading journals each with number of publications and impact factor. The scientific literature on aerodynamics is spread over 806 different Web of science source journals. It reveals that Journal of Wind Engineering and Industrial Aerodynamics the list with the highest number of publications 345 (5.19%) and the impact factor is 4.082, followed by Aerospace Science and Technology with a share of 280 (4.21%) publications and the impact factor is 5.107. AIAA Journal occupies the third position with 205 (3.09%) publications and the impact factor is 2.624. The fourth highest source title is Journal of Aircraft with 204 (2.97%) publications and the impact factor is 2.60, Journal of Fluid Mechanics with 197 (1.21%) publications and the impact factor is 4.245 and Journal of Fluids and Structures with 174 (2.62%) publications and the impact factor is 2.917.

### 5.8 High productivity subject areas

Table 9 High productivity subject areas

S. No.	Subject	No. of Articles	Percentage
1	Engineering	5172	77.86
2	Physics	661	9.95
3	Energy Fuels	656	9.87
4	Computer Science	283	4.26
5	Science Technology	282	4.24
6	Materials Science	239	3.60
7	Automation Control Systems	200	3.01
8	Robotics	200	3.01
9	Mathematics	139	2.09
10	Life Sciences Biomedicine	113	1.70

The scientific literature on aerodynamics is spread over 66 different subjects. Table 9 shows high productivity subjects which are contributing more than 110 articles. It is found that Engineering has highest number of articles with 5172 (77.86%) followed by Physics contributing 661 (9.95%) articles. Energy Fuels occupies the third position with 656 (9.87%) articles. The fourth highest articles belonged to the subject Computer Science with 283 (4.26%), Science Technology with 282 (4.24%) and Materials Science with 239 (3.60%) articles respectively.

## 6 Conclusions

The present study is to analyze the number of contributions brought out by researchers of the aerodynamics research published on web of science database during the span of 2012 to 2021. The analysis showed that a total of 6643 publications were published in the field of aerodynamics. This study observed that the growth of contribution gradually increased, and the trend value also has been increased from 256 in 2012 to 2070 in 2031. Takizawa, K is the most productive author with 50 (0.75%) publications followed by Tezduyar, T E with 48 (0.72%) publications and a total of 13,898 authors are contributed entire research output of the study. The study identified that highly preferred source title to contribute their research by authors that is Journal of Wind Engineering and Industrial Aerodynamics with highest number of publications 345 (5.19%) and their impact factor is 4.082

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