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## Analysis of Laminated Beams: A Bibliometric Review

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# **Analysis of Laminated Beams: A Bibliometric Review**

Keywords: Laminated; composite; analysis

## **Introduction**

In many engineering structures composite materials are found to be of extensive use due to their many superior properties. Some worth mentioning properties are high strength to weight ratio, high stiffness to weight ratio, thermal and electrical conductivity and many more. Not only this but according to the need of particular structure, properties of composite structures can be engineered. This is the reason; laminated composites are gaining more and more importance in spite of their limitations such as high cost and difficult analysis.

During the survey it was found that only few review articles are available on laminated composites.

The behaviour of thin-walled laminated beams with due consideration to buckling and post buckling effect has been studied by (Mittelstedt 2020). He has also distinguished between local and global buckling of beams and gave overview of different analytical methods that take into account the original properties of composite materials such as shear deformation, coupling effect, anisotropy. An analysis of a z section with asymmetric cross-section using closed form solution has been presented by (Lu et al. 2019). Authors investigated the effect of structural configurations and laminate properties on various sectional properties like warping stiffness, centroid, torsional stiffness, shear centre. The discussion based on the review of layer-wise theories for the analysis of composite structures has been presented by (Liew et al. 2019). From the study of literature they found that layer wise theories in which each layer is considered

individually; gave the results in line with the 3D elasticity theories. (Zhang et al. 2019), presented available literature for analysis of smart structures. Smart structures are the plates and shells made up of piezoelectric materials. Authors have surveyed the articles giving emphasis on geometrically nonlinear theories, electrostatic materials, coupled modelling. The dynamic analysis of rotating shaft made up of functionally graded material has been presented by (Ben et al. 2017). This analysis is done considering the displacement through thickness field. Authors concluded that dynamic behaviour of the shaft gets significantly affected by orientations of fibre, stacking sequence and shear normal coupling. A critical review of literature on flexure, buckling analysis and free vibration of isotropic, laminated composite and sandwich beams has been presented by (Sayyad and Ghugal 2017). This review is based on equivalent single layer theories, layer-wise theories, zig-zag theories and exact elasticity solution. The literature available on timber engineering and various hybrid-approaches for structural design of timber has been presented by (Vallee et al. 2017). For structural connection of timber elements where natural adhesives were used for many years, authors have thrown light on use of synthetic adhesives. They have also discussed variety of hybrid approaches. The literature review of composite beams subjected to vibration is presented by (Hajianmaleki et al. 2013). Authors scrutinized the theories adopted as well as methods applied for the analysis. They also considered various areas such as methods of experiment, complicating effects in structure and materials. Thermal analysis of simply supported hollow cylinder made up of functionally graded piezo-thermo-elastic material has been studied and presented by (Wu et al. 2011). The hollow sandwich cylinders were made up of functionally graded materials and were subjected to thermal loading. Authors studied effects of parameters like varying diameter, radius to thickness ratio, surface conditions; on the behaviour of cylinders. A higher order zigzag theory has

been developed by (Chakrabarti et al. 2011) for static analysis of sandwich beam with soft core. The in plane displacement under consideration is varying cubically. The analysis is done using  $C_0$  quadratic finite element beam model. The vibration analysis of unsymmetrical sandwich plates having a viscoelastic core is presented by (Amichi et al. 2010). The plate under consideration is having arbitrary orientation. At each node there are nine degrees of freedom. To check accuracy of the presented model authors have compared it with classical finite element model. The electro-mechanical response of piezoelectric laminated composite beams having different boundary conditions has been presented by (Hsu 2005). The method adopted is differential quadrature method. Authors confirmed validity of this method for the considered beam. The active vibration control of E-glass/epoxy laminated composite beam by using an experimental set up consisting of smart sensors and actuators has been studied and demonstrated by (Song et al. 2002). Fundamental properties of the beam modal frequencies and shapes were disclosed using both theoretical and finite element method. Authors compared results of these methods and found those in line with the results of experimental testing. The review of various laminated beam theories along with their merits and demerits has been critically discussed and presented by (Ghugal and Shimpi 2001). Considering literature review as the base authors have thrown a light on various critical beam theory issues. (Carrera et al. 2013) expanded unknown displacement variables using different functions such as trigonometric, Taylor's series, zigzag, exponential and hyperbolic. It was found that performance of higher order theories is improved and satisfactory results are obtained. Finite element method was used along with Carrera Unified function for analysis of functionally graded structures by (Mashat et al. 2014). Need of through-the-thickness displacement field was identified by (Gherlone et al. 2013) Authors compared two existing zigzag functions for analysing sandwich and composite beams.

(Mohammad-Abadi et al.2015) used modified couple stress theory for analysing laminated composite beams. It was the first time introducing couple stress-curvature relationship for Reddy beam model. (Pagani A. and Carrera, E. 2017) done the geometric analysis of beams with solid cross section and thin walls using Carrera Unified Formulation. A new analytical solution for functionally graded (FG) beams has been given by (Ghumare and Sayyad 2020). They studied flexural properties of beam subjected to hygro-thermo-mechanical loading. A thermal analysis of simply supported two-layer antisymmetric and three-layer symmetric composite laminated and sandwich beams has been done by (Kulkarni and Ghugal 2020) using a parabolic shear deformation theory.

The present manuscript deals with a bibliometric study using a database of Scopus to understand the progress in research in laminated composite beam analysis.

## **Methodology**

In the current work authors have considered period from 2000 to 2020 for analysis. Reason behind this was for a period of 1967-2021 number of documents found to be 4096 out of which more than 75% documents are published in last 20 years. So it is observed that the rise has been increased substantially in last two decades only. Keywords adopted for search are “Analysis”, “Laminated” and “Beams”. All document types like articles, books, conference papers, review articles are considered for analysis without any exclusion.

‘Analyse the Search Results’ the function in Scopus which is used to scrutinize the literature, in terms of publications per year, publications by subject area, publications by different authors, research institutions and countries. When it is searched using keywords for “Analysis of Laminated Beams”, the search showed 3040

documents, out of which research articles occupy almost 70.78% of the database. This is shown in fig.1

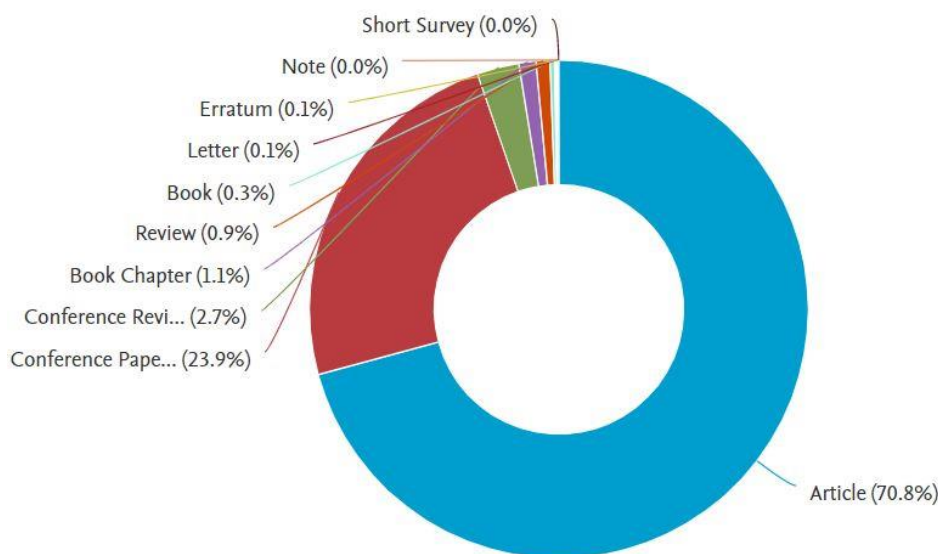


Figure 1 Distribution based on types of documents Source: <http://www.scopus.com>

(retrieved on 6th January 2021)

### ***Year wise scrutiny***

Figure 2 shows year wise survey of publications starting from year 2001. Graph clearly shows that interest of researchers in this particular field is increasing continuously. Total number of publications in first decade from 2000 to 2010 total publications was 1045 whereas in last decade this number has reached to 1995. In 2001 publications were 93, in 2020 it is 252. Similarly it is also observed that no of patents are also increased from 2195 in 2001 to 5392 in 2020. This indicates that there is growth of 90% in publications and 108% in patents. Total number of Patents in these two decades is 89556.

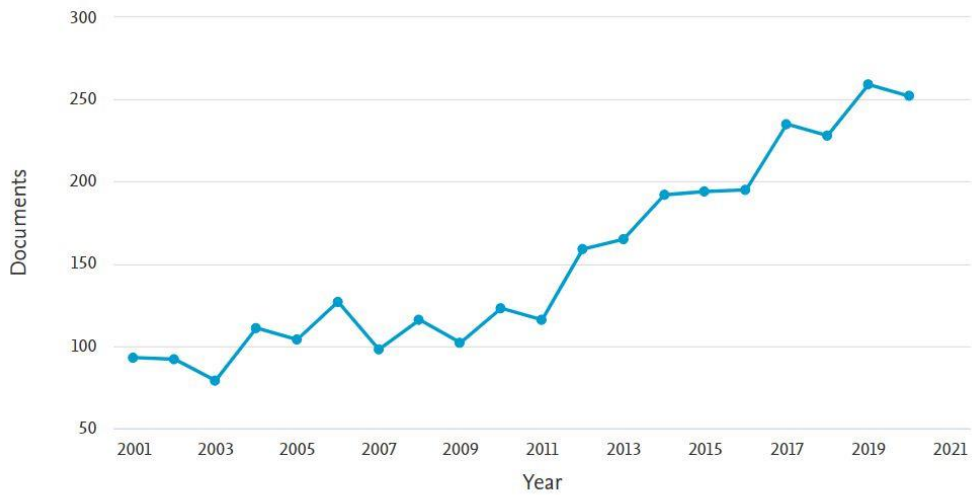


Figure 2. Year wise publications Source: <http://www.scopus.com> (retrieved on 6th January 2021)

### *Scrutiny based on territory*

Figure 3 shows publications from top 10 countries. It gives the idea of the intensity of worldwide research on this particular topic. China has acquired topmost position with 619 publications whereas United States and India are on second and third position with 484 and 261 publications respectively.

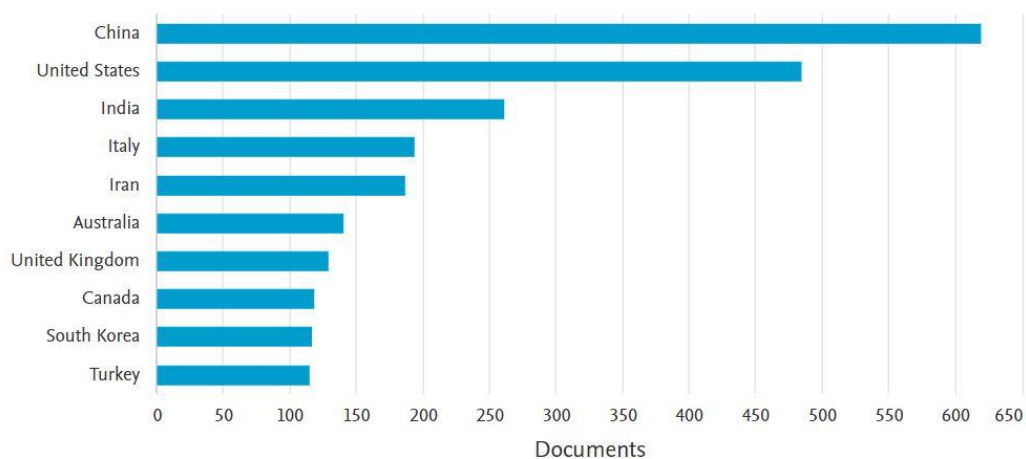


Figure 3. Territorial analysis Source: <http://www.scopus.com> (retrieved on 6th January 2021)

### *Scrutiny according to Subject area*

Figure 4 shows division on the basis of subject area. It can be observed that major literature is from engineering consisting of 2596 documents. Research in Material Science is on second rank with 1606 documents followed by Physics and Mathematics with 516 and 361 documents respectively.

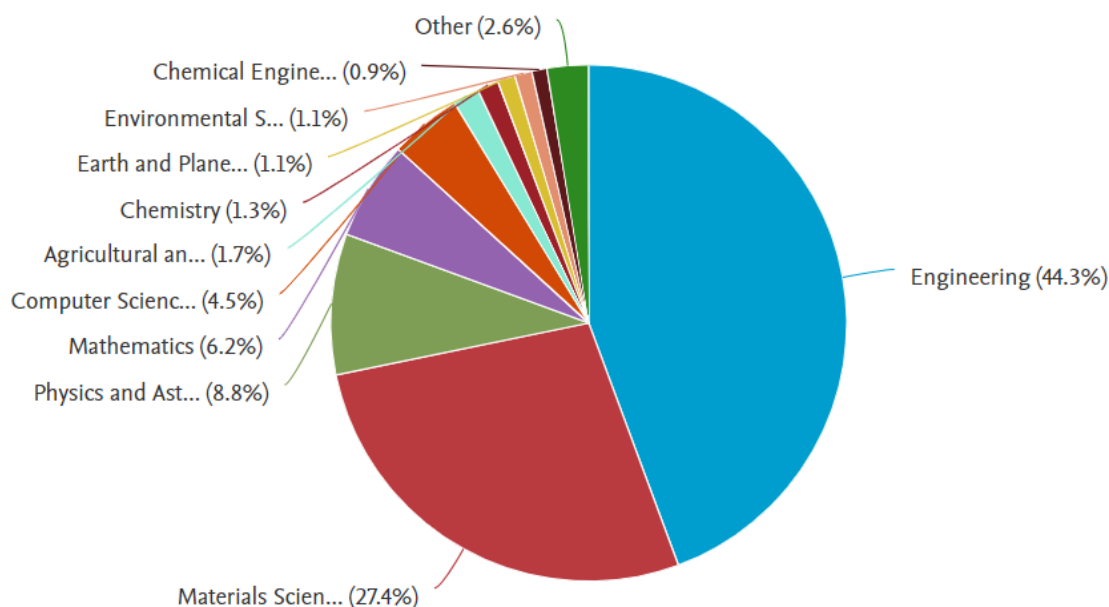


Figure 4 Year wise publications Source: <http://www.scopus.com> (retrieved on 6th January 2021)

### *Scrutiny according to Authorship*

Ranking of authors according to contributions in the concerned area is indicated in figure 5. Top 10 authors are enlisted with Carrera in leading role with 54 publications. Citation numbers of these authors along with their publications and h-index are as given in table 1.



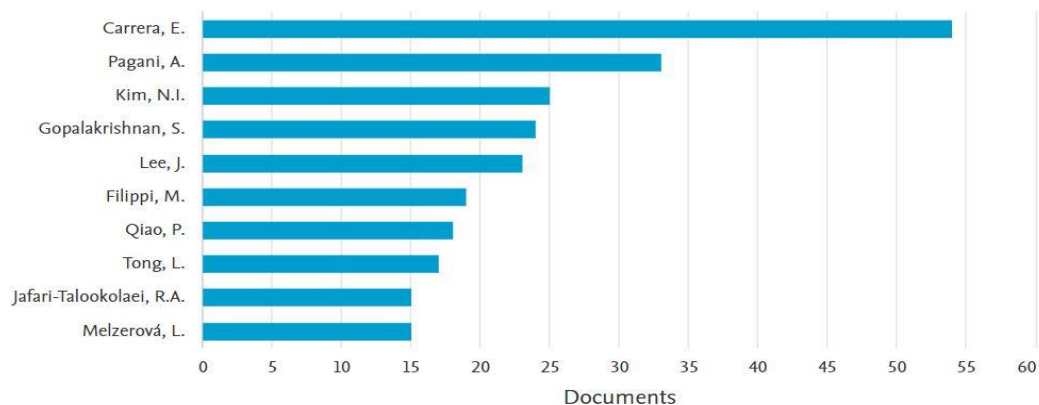


Figure 5. Year wise publications Source: <http://www.scopus.com> (retrieved on 6th January 2021)

Table 1 Top ten authors along with their publication details

Name of the Author	Publications in Scopus	Total Publications	Total Citations	H index
Carrera Erasmo	54	575	18580	67
Pagani Alfonso	33	126	1472	22
Kim Nam-il	25	98	1009	17
Gopalakrishnan Srinivasan	24	269	5830	42
Lee Jaehong	23	232	4850	36
Filippi M.	19	66	918	18
Qiao Pizhong	18	282	6800	45
Tong Liyong	17	217	3853	36
Jafari-Talookolaei Ramazan Ali	15	50	342	10
Melzerová Lenka	15	22	59	5
Kapania Rakesh K.	14	511	5305	31
Sheikh Abdul Hamid	14	142	2271	29
Shen Hui shen	14	306	14443	65
Bedon Chiara	13	152	1567	23
Harursampath Dineshkumar	13	104	508	12

Source: <http://www.scopus.com> (retrieved on 6th January 2021)

## Conclusion

Bibliometric survey based on different criteria such as number of publications, patents, leading nations and authors in the field of laminated composite beams is presented in this paper. Study underlines the growing need of research in this field. From the numbers obtained in the analysis it can be concluded that with every passing year the thrust of research in this area is consistently increasing. Due to the versatility of material, authors are coming up with different theories globally. Thus it is a field with tremendous future scope for research.

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