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A Bibliometric Analysis of Impact Energy Absorption System to Enhance Vehicle Crashworthiness

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ABSTRACT

In automotive engineering, crashworthiness is defined as an automobile's functionality to shield its occupants from critical harm or death just in case of accidents of a given proportion. The comprehensive study observed composite materials exhibit a high specific energy absorption rate in a controlled manner while crushing. Crashworthiness research has also captured attention, especially to evaluate the energy absorbing capacity of different components made from composite material while undergoing deformation. Composite materials may be custom designed to show that specific energy absorption abilities are better than the metal structures. The present study will benefit the community of engineers resulting in a sturdy automotive system. It is observed that a total of 1458 articles are published in different forms by past researchers. Following the trend of publications in the concerned area, the last six years are the point of significant contribution, and in the year 2016, a maximum of 263 articles are published worldwide. The detailed survey revealed that a maximum of journal articles are published compared to the other relevant sources. The United States is the leading country in the concerned research area publications, followed by China and Germany. Different energy absorbing system has shown promising attributes for reducing the fatality of accidents during a collision. Still, it has a long way to achieve a system that can absorb the total energy generated during a crash.

Keywords- Crashworthiness, Frontal crash, Carbon fibre, Energy Absorber

1.INTRODUCTION

Nowadays, crashworthiness is a vital development issue by considering the increasing road population of vehicles. Although well-designed energy-absorbing vehicle structures significantly reduced the fatality rate by collapsing in a controlled manner, which improves the and occupant safety. [1]

The crashworthiness of a road vehicle is defined by the vehicle structure's ability to absorb impact energy in a controlled manner while maintaining an adequate interior survivable space and providing protection to its occupants [2, 11]. Crashworthiness structure is achieved by preventing compartment intrusion and limiting the force or deceleration transmitted to the occupant. Vehicle designs with enhanced passenger safety need to address crash prevention in the first stage, crash severity reduction in the second stage, and occupant injury mitigation in the third stage. Paulius Griskevicius, Antanas Ziliukas 2003[12] studied energy absorption capacity/capability depending on three factors- design, material distribution, and lamination process. Using the above processes, the reinforced epoxy composite absorber is used as a bumper energy absorber used in pedestrian crash analysis. The composites ensure that maximum energy created during collisions is absorbed, and the minimum amount of energy is passed inside the cabin or to the pedestrians. Every composite material has a different energy absorption capacity/ capability and weight. The composite materials considered in this paper are CFRP, Gr/E, K/E, GI/E, polymer, epoxy, Nanocomposites, fiber-reinforced plastic composites. To find out the materials best suited for vehicle application, researchers carry out few tests. Gary L. Farley 1983 [13] studied Aluminum and different hybrid composite materials test specimens are created in tubes. Dimensions of the tube were length- 10.16cm, and inside diameter was 3.81cm. The dimensions selected on ease of fabrication and chamfering and notch are done on one end of each tube to avoid failure. Preliminary test- Preliminary test was conducted, and it is concluded that the modification leads to a reduction in peak loads. Static and Dynamic Crushing Test is performed on hydraulic loading machine. Impact tests are performed to determine post-impact results like dynamic crushing load, failure, energy absorption post crushing integrity with static results. It is observed that energy absorption was more in Gr/E than K/E or GI/E by performing the above tests. Ply Orientations show that Gr/E absorbs more energy. The energy absorption of hybrid composites was slightly better. S. Boria 2015[14] observed that in formula SAE racing car CFRP composite material is used as impact attenuator. The finite element model is implemented using two different shell elements and solid elements along with LS DYNA's nonlinear dynamic code. While performing the crushing experiments on circular tubes, it is observed that the attenuator's stable, progressive behavior. N.A. Warrior et al. 2003[15] have observed the significant effects of resin processing properties on composite tubes' crush performance. It is found that Glass/Epoxy absorbed more than glass/vinyl, which absorbed energy more than glass/polyester. Whereas glass/vinyl and glass/polyester gave high SEA/cost performance. Vinyl ester showed a 33% increase in absorption of energy over polyester. S.Ramakrishna and H.Hamanda 1998 [16] studied

polymer composite materials and found good energy-absorbing properties during vehicle crashes. By properly selecting the microstructure of composite material and geometry of the component, it is possible to absorb the energy generated during a collision in a controlled manner. Specific energy is directly related to microfracture processes of the crash zone. Energy absorption characteristics are varied by controlling the properties of fibers and resins. Lingyu Sun 2009 [17] investigated that nanocomposites act as good energy absorbers. Its stiffness is more than conventional fiber-reinforced polymer composites during vibration damping and low-speed impact. Due to the formation of supramolecular bonding between nanofiller and matrix, it is observed that there is high shear strength compared to the conventional composites. Nanocomposites exhibit high tensile strength compared to others. P.H.Thoton 1985 [18] stated that they are best suited as an energy absorber due to all FRP composites' low-weight properties compared to conventional steel. In composite materials, because of the fracture of fibers, a large amount of energy is absorbed compared to metals, where conventional plastic deformation is a source of energy absorption. S. PADMA et al. 2006 [19] investigated that when 4 wt% of PMMA (polymethyl methacrylate) and 6 wt% of PC is mixed along with epoxy resin, the properties like the tensile strength, flexural strength, and impact strength of the composites are enhanced. A.K.Rana et al. 1997 [20] stated that when the compatibilizer is added to increase the linkage between the hydrophobic hydroxyl groups of jute and the carboxyl groups of the compatibilizer which results in a reduction of water absorption values and concluded that jute fiber cannot be used as filler fiber, but it can be used as a reinforcing fiber. Yang Cao, Bochu Wang 2009 [21] investigated that in the field of medical science the biodegradable materials are preferred over conventional materials due to its special properties of degradability. The silk fiber is a material with high fiber strength and controllable biodegradability, hemostatic properties used in drug delivery vehicles. Zheyi Zhang et al. 2018[22] studied that composite tubes, metal tubes, foam-filled tubes are used as energy absorbers during a crash because of their high energy absorbing capability. The author has performed the Quasi-static axial compression tests for determining failure parameters in glass fiber reinforced polymer. Dakshin Lakshmi Venkatesh 2018 [23] The Belleville washers are often used to solve vibration, thermal expansion, relaxation, and bolt creep problems by their conical configuration enables them to support high loads with relatively small deflections and solid heights compared to helical springs. J. Michael Starbuck et al. [24] compared square cross-section tubes with circular cross-section tubes. He found that the circular cross-section absorbs more energy than the square cross-section when tested along with identical testing variables (layup and strain rate).

Crashworthy composite materials are selected based on low-cost market availability and ease of manufacturing. After satisfying the said properties, it is further judged based on controllable parameters (like fiber arrangement, specimen geometry, etc.) and its energy absorption capabilities to design the most crashworthy structure.

The current bibliometric analysis is a summarized study to present the past researcher's contributions from 1969 to 2021. The present study gives a detailed analysis of worldwide research in different segments like subject area, source, country, funding sponsor, etc. The presented analysis will provide the path for the researchers working in a similar area with the necessary insights for review and future work.

2. PRIMARY DATA COLLECTION

Scopus is the most popular source of scientific database. For the current study, the Scopus database is used for analysis. The master and primary keywords used are summarized in table 1.

Table 1: Keywords used in Scopus Database

Master keyword	"Crash Energy Absorbers"
Primary keyword	"Crashworthiness" AND "Frontal Crash" AND "Belleville Spring" AND "Crash Testing Methods" AND "Carbon Fiber As A Energy Absorber" AND "Composite Material" AND "Occupant Safety"

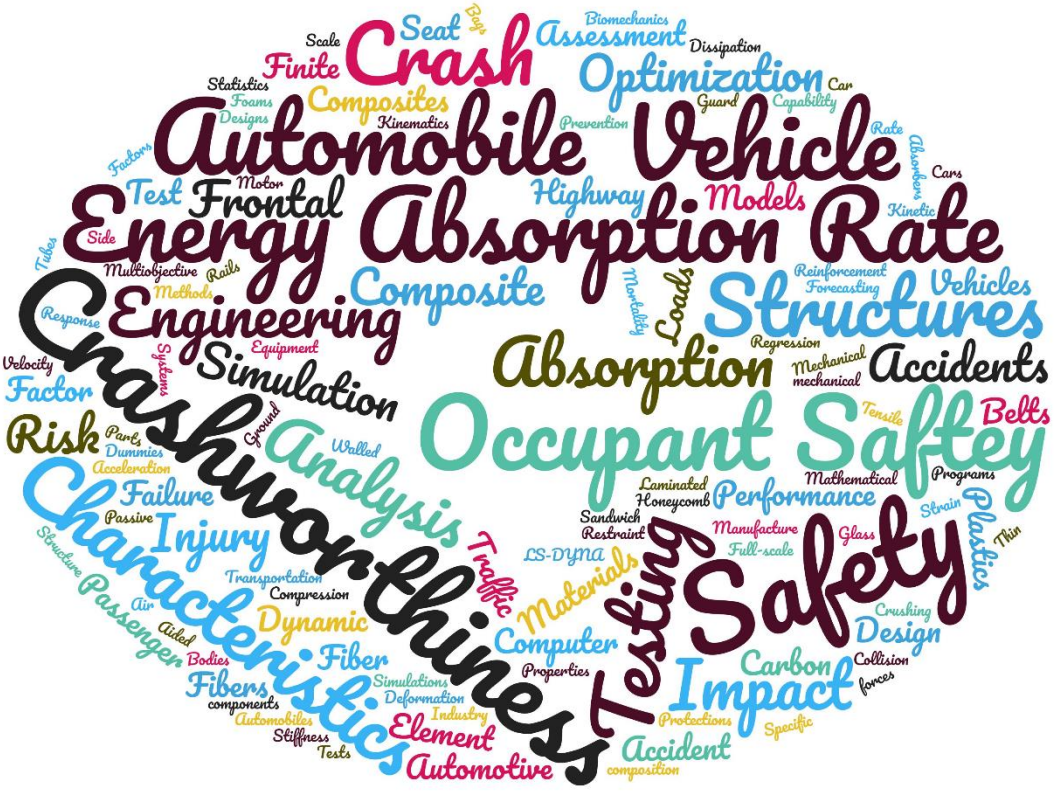

Figure 1: Word Cloud of Keywords

"Crash Energy Absorbers" is used as a primary source of keyword for database search. In this search, we found that 1664 publisher published their data in the Scopus database, while the search concerning the specific keywords for the analysis gives 2025 publications in the Scopus database (Data accessed till April. 14th, 2021). Figure.1 indicates the word cloud of secondary keywords. One can easily emphasize the impacting keywords for the research area under consideration using the cluster analysis.

3 ANALYSIS AND INTERPRETATION OF DATA

The details of database from literature available in the Scopus database, which contains access type, publication year, document type, subject area, source title, etc. the predictions are made as follows.

3.1 Analysis by Affiliation, Author, and Language of Publication

According to the Scopus resource data, after comparing the top 10 affiliations worldwide it is observed that Human University is having 96 affiliations which is maximum amount of affiliations worldwide.

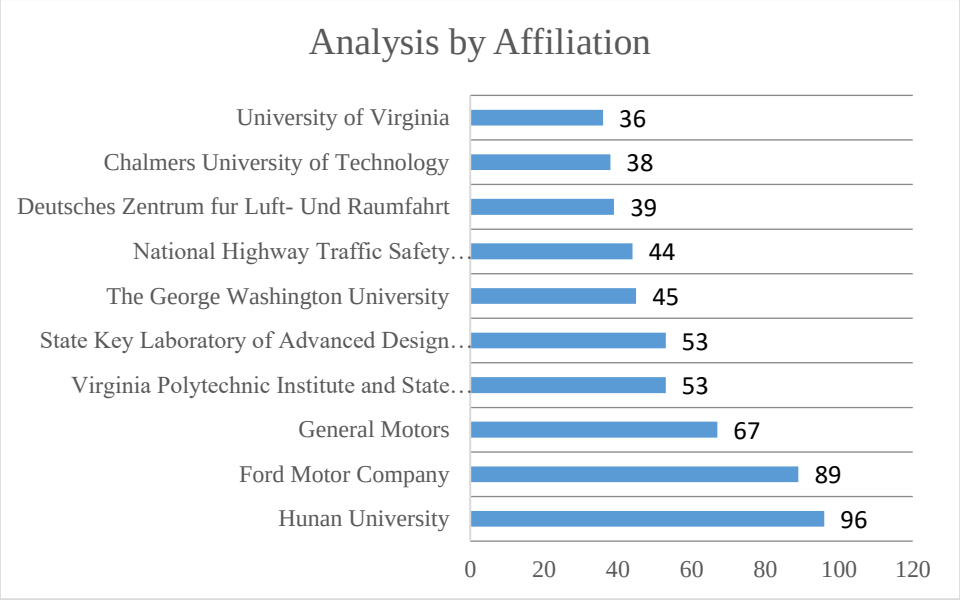

Figure 2: Analysis by Affiliation (Data access till April. 14th, 2021*)*

A total of 560 publications are noted for the top 10 affiliations in the current study of bibliometric analysis. Referring to the data available for authors; analysis shows that a total of 274 papers are published by the top 15 authors all over the globe. Considering the analysis of publication language; a maximum of 2763 publications contributing to 95% of a total count is written in the English language by the researchers to date worldwide. Other languages like Chinese is used in 4% publications and remaining like German, Japanese, Korean, and Spanish are used in single digit.

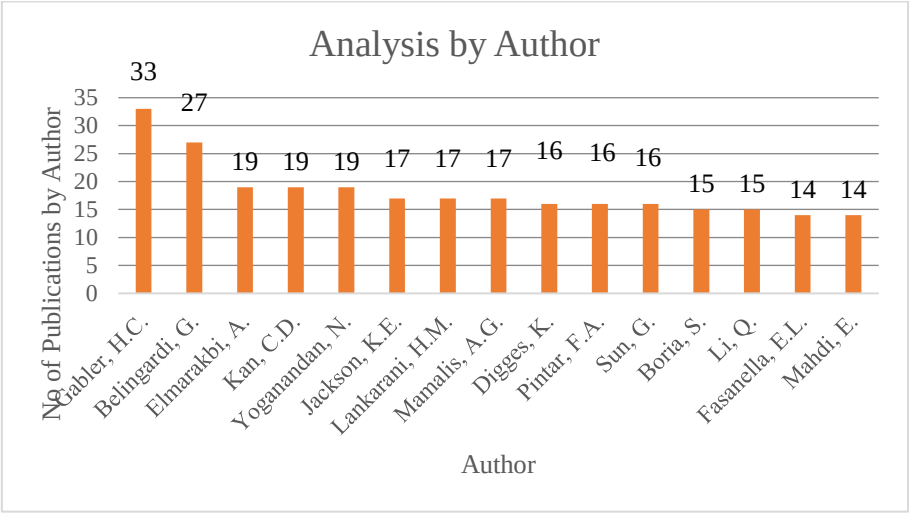

Figure 3: Analysis by Author (Data access till April. 14th, 2021*).*

Figure.2 and Figure.3 indicates the summary of analysis for top 10 affiliations and authors respectively in the current study. Table.2 shows a summary of data concerning the publication language.

Table.2 Summary of data concerning the publication language.(Data access till April. 14th, 2021*)*

Sr. No.	Publication Language	No. of Publications in Scopus
1	English	2763
2	Chinese	117
3	German	12
4	Japanese	8
5	Korean	8
6	Spanish	1

3.2 Analysis by Access and Document Type

In this type of analysis, one can find the analysis of the current study by access and document type. Referring to the available data in the Scopus database; there are 367 publications as an open-access and the rest are 437. Figure.4 as shown below shows the representation of the analysis by access.

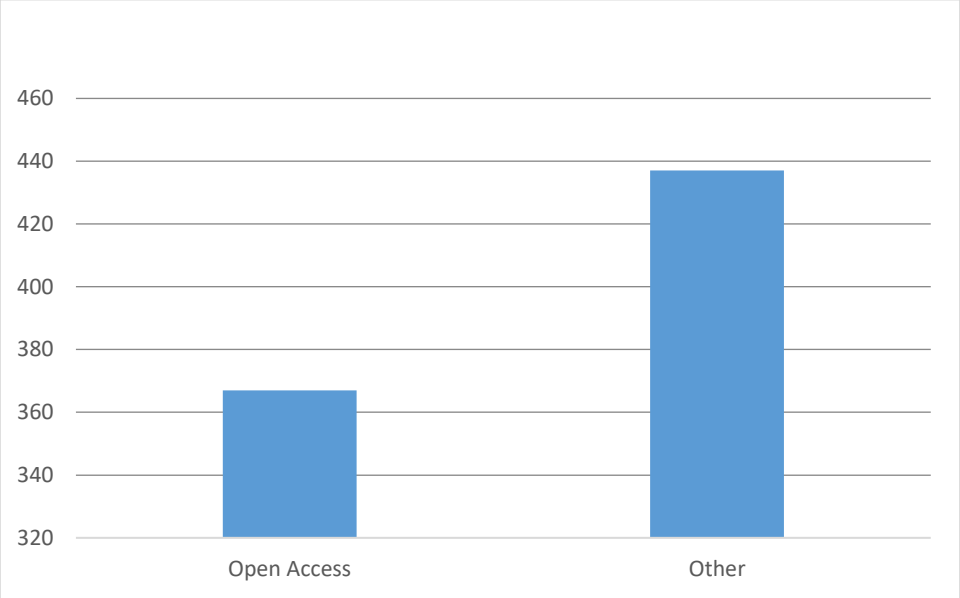

Figure 4: Analysis by Access (Data access till April. 14th, 2021).

Based on document type; most of the publications are observed as an article category. Table.3 shows a summary of data based on the Scopus database.

Table 3: Summary of Data based on Document Type (Data access till April. 14th, 2021*).*

Sr. No.	Document Type	No. of Publications in Scopus
1	Research Article	1458
2	Conference Paper	1341
3	Review Paper	52
4	Book Chapter	28

5	Book	8

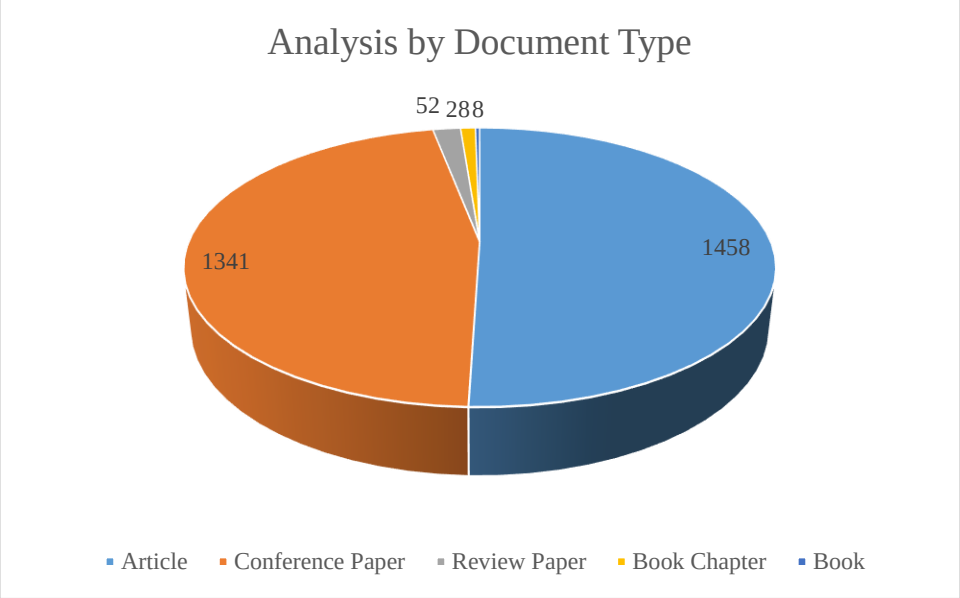

Figure 5: Analysis by Document Type (Data access till April. 14th, 2021).

Observing the analysis based on document type; maximum publications are observed as 1458 research articles, whereas; the conference papers are 1341, review papers are 52, and book chapter contribution is 36 as shown in figure 5. This shows the quality contribution of past researchers in various aspects.

3.3 Analysis by Year

The comprehensive summary of the year-wise publication is presented under this section. The publications in the last 51 years; 1969 to 2021 are analyzed for the current study.

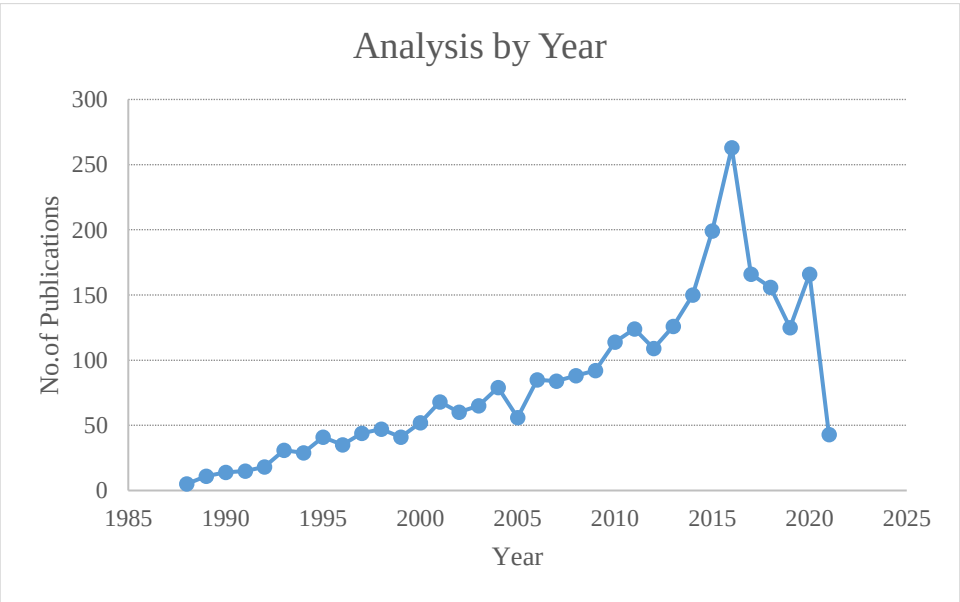

Figure 6: Analysis by Year (Data access till April. 14th, 2021*).*

A maximum of 263 publications is observed in the year 2016 which is the highest of the last 51 years. Figure.6 shows the analysis of the literature by year based on Scopus data. Crashworthiness was the untouched area before 1985 but from 2000 to 2015 when speed is need of hour from that time we can find the increasing trend in publication on Crashworthiness. In the last 7 years; from 2014 to 2021 the contribution is significant and is maximum in the year 2016.Observing the trend based on the year's analysis; one can notice the increasing citations in the last 10 years and significant improvement after 2016 year as attributed in years analysis as well.

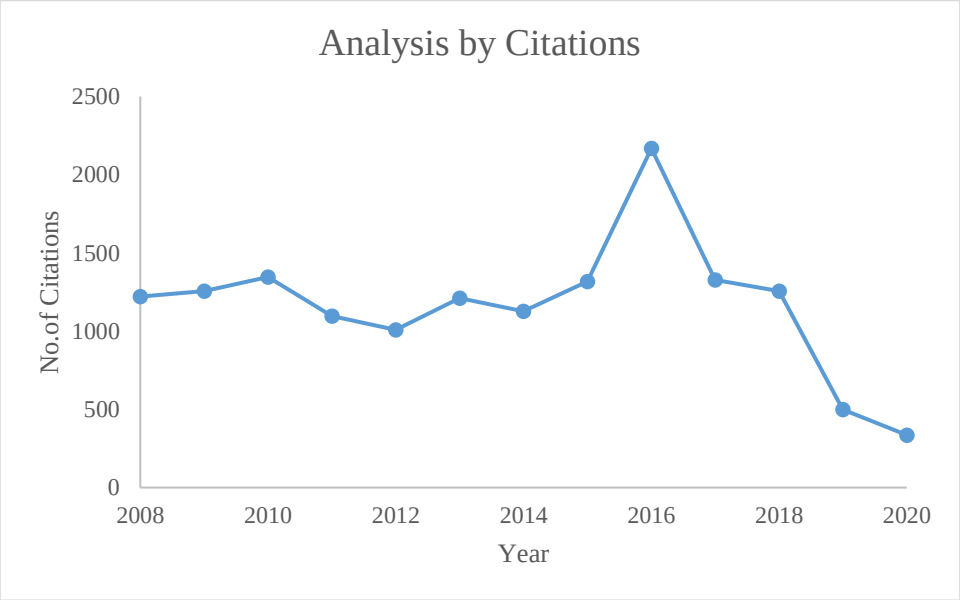

Figure 7: The Trend of Citations Year wise (Data access till April. 14th, 2021).

3.4 Analysis by Subject Area

The analysis by subject area helps in identifying the key areas of concentration for the current study. A total of 2538 publications are noted under the Engineering subject area followed by 571 publications in the area of material science. Figure 9 shows the analysis by subject area based on the Scopus database.

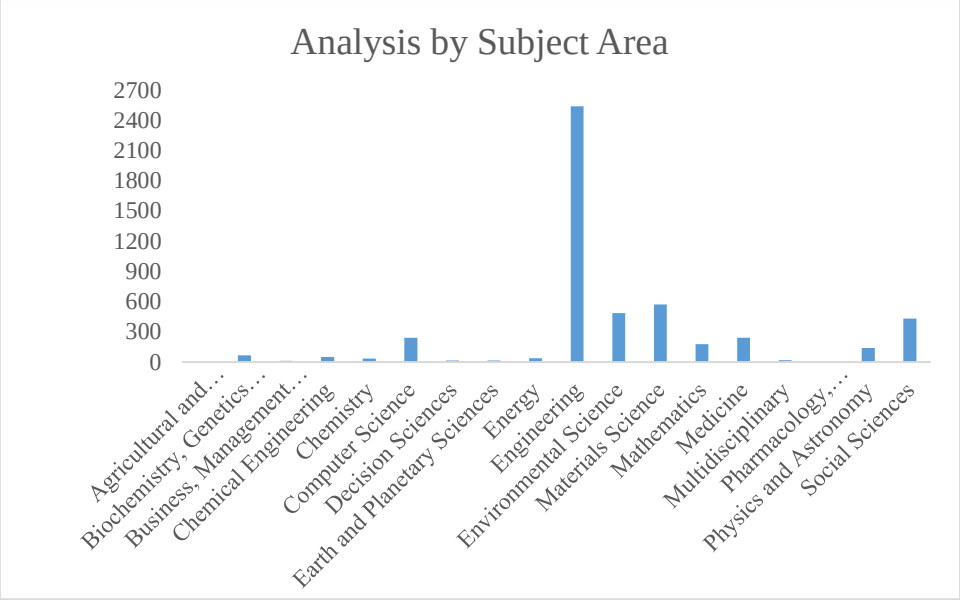

Figure 8: Analysis by Subject Area (Data access till April. 14th, 2021).

The maximum contribution in the area of engineering and material science is attributed to the core applications of minimum quantity lubrication in machining and material characterization aspects. Various material like carbon fiber, glass fiber, plastics are taken in to consideration as energy absorber according to its energy absorbing property. Other areas apart from engineering and material science are computer Science, Environmental science and social science.

3.5 Analysis by Source

This section describes the summary of data concerning the various sources based on the Scopus database. A maximum of 438 publications is noted from the SAE Technical papers followed by 171 in the International Journal of crashworthiness. Table.4 shows the summary of data concerning the analysis for the top 10 sources.

Table 4: Summary of Data based on Source (Data access till April. 14th, 2021).

Sr. No.	Source Title	No. of Publications in Scopus
1	SAE Technical Papers	438
2	International Journal Of Crashworthiness	171
3	Composite Structures	89
4	Accident Analysis And Prevention	78
5	American Society Of Mechanical Engineers Applied Mechanics Division AMD	76
6	Qiche Gongcheng Automotive Engineering	45
7	Thin Walled Structures	44
8	ASME International Mechanical Engineering Congress And Exposition Proceedings Imece	43

9	Traffic Injury Prevention	39
10	Proceedings Of The Institution Of Mechanical Engineers Part D Journal Of Automobile Engineering	32

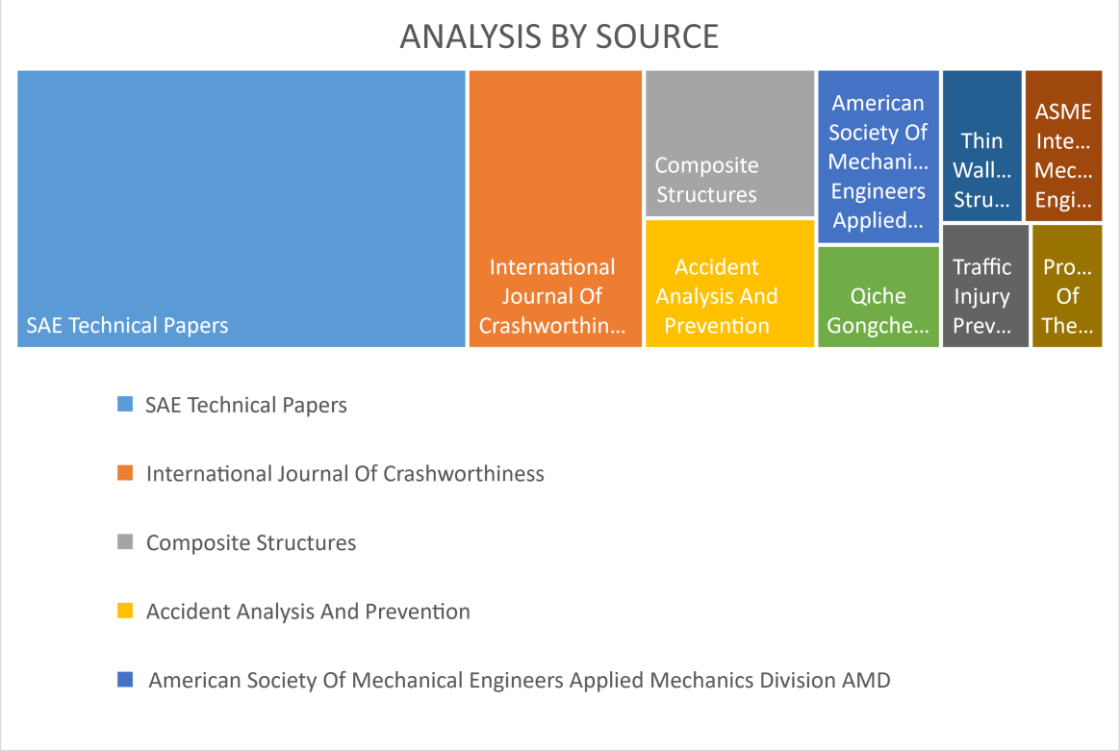

Figure 9: Analysis by Source (Data access till April. 14th, 2021).

3.6 Analysis by Country

Analysis of country is presented to understand the concentrations in the concerned research area. Based on the Scopus database; it has been observed that a maximum of 1022 publications is contributed from United States followed by 424 in China, and 171 in the Germany as the top three countries worldwide. The top 10 countries are taken into consideration to present the analysis. Figure.10 shows the analysis by country based on the Scopus database under consideration.

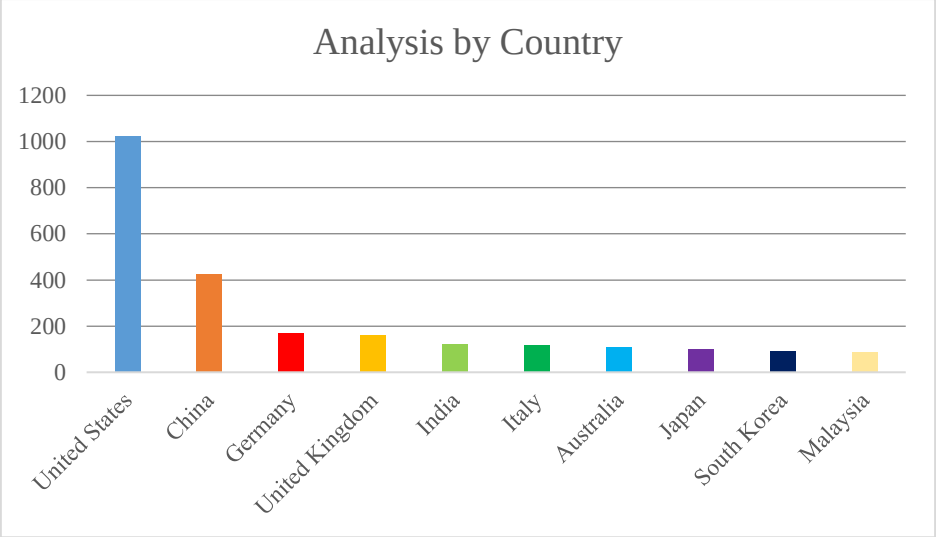

Figure 10: Analysis by Country (Data access till April. 14th, 2021).

In addition to the above; the topographical locations of the country having publications in the Scopus database is located and presented using Imap builder software.

Figure 11: Topographical Locations of the Country (Data access till April. 14th, 2021).

3.7 Analysis by Funding Sponsor

Funding for the research work promotes the researchers for motivation and acts as a catalyst in the entire process of the research. This section emphasizes the analysis by the funding sponsor. Figure.12 shows the representation of the analysis for the top 10 funding sponsors worldwide.

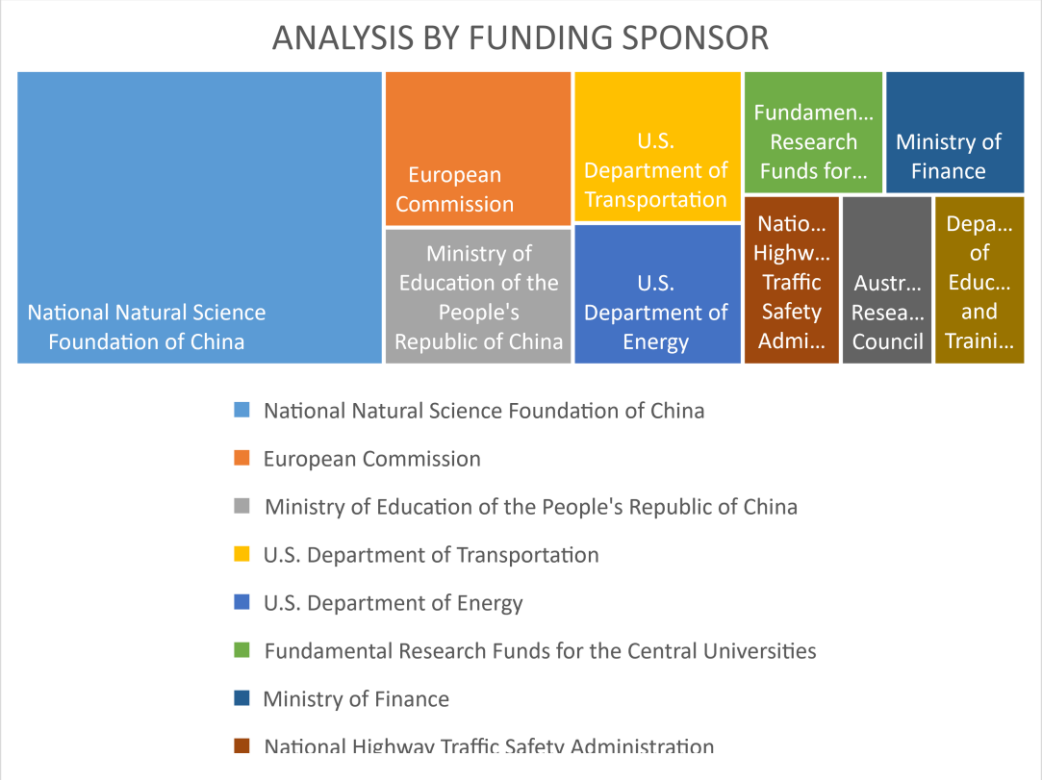

Figure 12: Analysis by Funding Sponsor (Data access till April. 14th, 2021).

Based on the analysis; one can note that the National Natural Science Foundation of China is the top most funding source in the world accounting for a maximum of 117 publications. Table. 5 shows the summary of data for the top 10 funding sponsors based on the Scopus database.

Table 5: Summary of Data based on Funding Sponsor (Data access till April. 14th, 2021).

Sr. No.	**Source Title**	**No. of Publications in Scopus**
1	National Natural Science Foundation of China	117
2	European Commission	32
3	Ministry of Education of the People's Republic of China	28
4	U.S. Department of Transportation	28
5	U.S. Department of Energy	26
6	Fundamental Research Funds for the Central Universities	19
7	Ministry of Finance	19
8	National Highway Traffic Safety Administration	18
9	Australian Research Council	17
10	Department of Education and Training	17

4. CONCLUSIONS

Crashworthiness is a broader concept and outreach to every possible aspect of Engineering and Society as a key attribute. The research contribution in the last six years is well articulated worldwide to signify the maximum energy absorbing capability of a structure to enhance a vehicle's crashworthiness by absorbing the energy generated during impact. The compatibility of the energy absorbing system is evaluated. The performance evaluation is done by past researchers concerning the various materials, crash mitigation technologies, and the energy-absorbing rate is the sign of sustainable tomorrow. A detailed, comprehensive study was carried out on the different materials used to manufacture other vehicle structures of the vehicle to reduce the vehicle's weight, which improves fuel efficiency. With increasing public demand for safety and legislation, the cars are fitted with energy absorbers to absorb impact during a collision. The review has touched on many aspects of the crashworthiness of composite materials. By selecting the proper material, it is possible to absorb impact energy in a controlled manner. The specific energy absorption rate of CFRP material is more than other conventional materials. It is observed from the literature review that carbon fiber is the most suitable material with maximum energy capability. The future scope for the presented bibliometric analysis would be the comprehensive study of Crashworthiness structure which will absorb the maximum energy generated during crash. This would enable researchers to study and refer to different energy absorbers made up of lightweight composite material for increasing occupant safety by reducing the fatality rate. They concluded that weight saving has become more critical since environmental issues are growing day by day. To increase the fuel economy with enhanced safety and performance of automobiles, composites are used compared to heavier materials. The current comprehensive study compares the automotive materials, which are commonly used, and give an overview of the optimized composite materials.

The comprehensive study is presented in the current bibliometric analysis emphasize the Scopus-based data of the last 52 years, 1969 to 2021. The significant contribution in the year 2016 is observed in the concerning research area, and it is well attributed to the exponential rise in the last six years. It justifies the attention of the researchers to address and promote sustainable practices for the time to come. The presented bibliometric analysis's future scope would be the comprehensive study of different composite materials and crash mitigation

technologies. It will enable researchers to study and refer to the complete sustainability cycle and productivity for a better tomorrow.

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