A bibliometric analysis of the research on shot peening

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Abstract: A bibliometric analysis of shot peening was carried out to provide insights into academic activities and trends of the research on surface treatment processes from 1997 to 2017 based on the publications collected from the database Science Citation Index. The analysis identified those countries, institutions, foundations, and journals which performed well in the research field of shot peening, and illustrated the collaborative relationships between countries and between institutions, respectively. The results suggest that the two subject categories, i.e. material science multidisciplinary and engineering mechanical, had the largest publication outputs, and that finite element modelling, ultrasonic shot peening, and parameters optimisation were the current hot spots. They also indicate that the current and future research should be focused on four aspects: (1) finite element analysis with new methods such as discrete element method for modelling; (2) ultrasonic shot peening as a counterpart in modifying properties of metallic surface; (3) parametric optimisation with advanced algorithms; (4) plasma nitriding as a complimentary process applying after shot peening treatment.

Keywords: Bibliometric analysis; shot peening; social network analysis; word cluster.

1. Introduction

Shot peening is a surface treatment imparting compressive residual stresses to metallic components to enhance their fatigue in terms of delaying crack initiation and retarding propagation of fatigue (Nam *et al.* 2016), fretting, and wear (Murugaratnam *et al.* 2015) in manufacturing industry. Due to its complexity of having many influential parameters, and producing both detrimental and beneficial effects, many investigations have been conducted to study this surface treatment in investigating the material of its target components (Sanjurjo *et al.* 2014), adjusting its influential parameters (Hong *et al.* 2008; Purohit *et al.* 2017), and controlling its detrimental effects (Baskaran *et al.* 2011; Yildiran *et al.* 2015), such as material hardening and deteriorated surface roughness while at the same time enhancing the beneficial effects arising from the induced compressive residual stresses.

As research in shot peening attracts increasing attention and enormous investigations have been published, it is indispensable to provide a global view on the field through an analysis of the relevant existing literature. A few researchers have

made their efforts in this regard. Bagherifard and Guagliano (2009), for example, reviewed shot peening processes to obtain nano-crystalline surfaces in metal alloys. Zimmermann and Klemenz (2010) researched the simulation of shot peening process, including the types of numerical models, the material properties, the evaluation of the outputs of shot peening. Shukla *et al.* (2014) compared the conventional mechanical shot peening to the newly emerging laser shot peening, and concluded that the former was cheaper but the later was more advanced. The latest work was conducted by Shijun Chen *et al.* (2019) comprehensively reviewed the numerical simulation and optimisation of shot peening process and indicated the technical status quo of shot peening. However, all these publications focused only on the technical aspects of shot peening, but they did not evaluate the development patterns underlying the relevant research activities, such as the publishing distribution among countries/areas, the international and inter-institutional collaboration, and the funding facilitating its development. One common downfall of these investigations is that they all require broad and deep knowledge accumulated by the researchers.

Bibliometric analysis, fortunately, is capable of providing a systematic view on a scientific field through mapping the growth of publications, activities (Patra and Muchie 2017) and knowledge frontiers (Chaomei Chen 2006). This method was first proposed by Pritchard (1969) and has been proven to be an effective tool to assess both the performance of publications and research trend in a specific field (L. Li *et al.* 2015). Though the effectiveness of bibliometric analysis was proven theoretically (Chaomei Chen 2006; Pritchard 1969) and verified in applications in many fields, such as engineering research (Patra and Muchie 2017), natural science (Sooryamoorthy 2013), environmental science (Zheng *et al.* 2017), this method has not yet been applied in the research field of shot peening, i.e., a Web of Science search reveals that there is no bibliometric analysis on this topic.

However, considering the importance of shot peening to enhance mechanical properties of materials, the complexity of this surface treatment process, and the vastness of the relevant publications, there is a pressing need to provide an overall insight into the research in shot peening field by bibliometric analysis. Such an analysis would fill the gap that there has been no such analysis in this field, and at the same time would provide a reference for the researchers to deepen their understanding of the distribution of the publications, the collaboration, the underlying funding, and the research trend of shot peening.

In this article, the publication records downloaded from the Web of Science Core Collection of Thomason Reuters (WOS) were analysed using bibliometric analysis. Two other tools were also applied: a statistical method as an auxiliary method (Newman 2004) to extract information of publications; and social network analysis (SNA) as effective toolbox (Farine and Whitehead 2015) aiding in analysing the collaborative relationships between countries and institutions. The publication outputs were both quantitatively and qualitatively evaluated in their general characteristics, country-wise growth and collaborations, leading institutions, dominant journals; and more importantly, the research hotspots and trends developed in order to provide insight into the field of shot peening research.

2. Research questions

The discussions above and the design of the project raise the following research questions:

- What is the growth pattern of shot peening research globally?
- What is the country-wise growth and collaboration pattern of literature?
- What are the most important research institutions in the field of shot peening research, and how do they collaborate in this field?
- What kind of publication is the mainstream, and what journals are the publication sources in terms of quality?
- What influence does financial support have on shot peening research?
- What future work can researchers do in the field of shot peening?
- What lessons are learnt from the established publication and collaboration patterns of shot peening research?

3. Methods and Materials

All data used in this study were collected online from the WOS on 11th May, 2018. For the bibliometric analysis and social network analysis, the search query "shot peen*" (including three keywords "shot peening", "shot peened", and "shot peen") was used to retrieve and collect 2381 existing publications during 1997-2017. The collected information of these publications include title, author, abstract, keyword, publication year, contact address, funding source, publication source, and Web of Science category of the article. The collected information was manually pre-processed for data cleaning, integration, reduction, and transformation so as to ensure the data quality for subsequent analyses (Han *et al.* 2012). For example, articles from Ireland, Wales, Scotland, and England were reclassified as from one country, i.e., UK; articles from one identical funding agency but with different agency appellations were also reclassified as from one agency.

At first, this study used MS Excel 2013 and WOS together to process the relevant information to briefly assess the performance of publications. This processing refers to the number of total publications with regard to each year, country, institution, and category. Successively, SNA was used to process data collected above and visualise the corresponding results in order to understand the collaborations among institutions and countries. Social network is herein defined as a set of academics or research organisations in which they are connected with each other through collaborations. Concisely, the collected data pre-processed above were analysed through SNA by calculating their co-occurrence using CiteSpace 5.3.R1 and their collaboration strengths were calculated through the Cosine Algorithm (Jie Li and Chen 2016).

In addition, word cluster analysis was conducted to reflect the hot spots and research trends in the field of shot peening. The author keywords provided by the authors (Zhang *et al.* 2016), KeyWords Plus generated by WOS (Zhang *et al.* 2016), and substantives in titles were extracted from the publications collected above as the "word repository". Subsequently, those words/phrases with close relationship in terms of their acceptations were grouped together as a cluster. Finally, the main groups were

identified and displayed with nodes in different sizes and links in different thicknesses. These groups are clusters containing temporal information and representing probable hotspots (Zhang *et al.* 2016). This analysis was carried out using CiteSpace 5.3.R1 and the results were subsequently visualised.

4. Results and Discussions

4.1. Overview of the Publications

In order to obtain an overview of the research on shot peening, the characteristics of all the publications extracted above from WOS are listed annually below in Table 1. The annual amount of publications increased unstably from 38 in 1997 to 195 in 2017, but the general trend of growth was obvious (as displayed in Figure 1 (a)), turning out to reach a fivefold growth throughout the twenty years. Of all these publications, 2266 were published in English while the main others in Chinese (44), Japanese (43), German (23) and French (5) also were with English titles, abstracts and keywords. The number of co-authors per publication had a slight increase from 2.9 in 1997 to 3.4 in 2017; and the total pages count per publication remained generally unchanged. It is noticed that the number of times cited per publication had an overview decreasing trend from the highest 24.4 in 1998 to the 1.0 in 2017, especially those of the year from 2014 to 2017 were obviously low. One explanation could be that the citable time periods for these publications are relatively short. The highest three NC/TPs (number of times cited per publication) appeared in 2002 (24.6), 1998 (24.4), and 1999 (22.2), with the most frequently cited research articles (Kobayashi *et al.* 1998; Montross *et al.* 2002; Tao *et al.* 1999), respectively.

Table 1. Characteristics of publications during 1997-2017

[Table 1 near here]

4.2. Performance of Publications

4.2.1. Distribution and Collaboration in Countries

As demonstrated in Figure 1 (b), a total of 476 publications were from China which accounts for 19.9 % of the total number, indicating that China was among the highest ranked in the field of shot peening. This could be associated with the exponentially growing budget from the National Natural Science Foundation of China (NSFC) since 1986 (Yang 2016). This foundation, with high priority, financially supports mechanics, astronomy, and material science which is the field shot peening resides in. Secondly ranked was the USA with an amount of 375 publications accounting for 15.7 %; and thereafter was Japan with 318 publications accounting for 13.3 %. However, before

2009, USA had had the largest number of publications in most years, followed by Japan, Germany and China in different years, respectively. This situation changed by the dramatic steady increase from China which has taken first position from USA since 2010. It should be noted that the increase trend of China has been strong and constant since 1997, while those from USA and Japan have trended to slight decreases. The increase in China and Decrease in USA and Japan have leaded to a big gap between China and the other two countries both in the total amount of publications throughout the statistical period and annual number of publications from during 2010-2017.

[Insert figure 1 here]

Figure 1. The distribution of publications on shot peening in different countries during 1997-2107

As demonstrated in Figure 2, the collaborations were so prevalent that most countries had links with some others. The countries dominant in the amount of publications, i.e. China, USA, Japan, Germany, UK, France and Italy, constituted the centre of the global collaborations, as shown in the top right corner in Figure 2. Among these seven countries, USA had the most extensive collaborations with others countries with the number of collaborative publications accounting for 27.16 % of its total amount; followed by China with 25.26 % collaborative publications, ranked second. Although the total amount of publications from UK was less than the other six countries while its collaborative strength was relatively strong with 23.16 % of collaborative publications, this indicates that UK has done well in international collaborations. It should be noted that though China had no prominent links with the other six countries, the collaborative relationships of the other six countries with China were the strongest among their own collaborative relationships. This asymmetry indicates that China was the absolute international collaboration centre in the field of shot peening.

[Insert figure 2 here]

Figure 2. The pattern of international collaborations during 1997-2017 according to SNA

4.2.2. Distribution and Collaboration in Institutions

Through the analysis of publications from all the 200 diverse institutions, the ten most

productive institutions in the past 20 years are listed below in Table 2 in the order of publication quantity from high to low. Among these institutions, Shanghai Jiao Tong University was the leading institution with 73 articles which accounted for 3.052 % of the total amount of publications. This was followed by the United States Department of Defence which had 71 publications accounting for 2.968 %. Ranked third was Polytechnic University of Milan with 68 publications accounting for 2.843 %; and its NC/TP value (16.9) also took the third place. This excellent performance in both quantity and quality demonstrates its strength and academic interest in the field of shot peening. The higher NC/TP values were contributed by University of Technology of Troyes (25.8) and Chinese Academy of Sciences (35.6), which are both in the top 10 productive institutions ranked seventh and tenth, respectively.

Table 2. Top 10 productive institutions in research on shot peening during 1997-2017

[Table 2 near here]

The inter-institutional collaboration was much more extensive and closer than that between countries as indicated by Table 2. It shows that 83.218 % of the total publications of these ten institutions were completed by inter-institutional collaborations, and that most of their collaboration rates (CP/TP) were high. For example, three of them were even 100 %, i.e. those of the institutions numbered 5, 8, and 10. In addition, these top institutions were almost from the top countries mentioned above in section 4.2.1: three from China, three from USA, two from France, one from Germany and Italy, respectively.

The inter-institutional collaborations are demonstrated below in Figure 3. It is obvious that University of Cambridge had the most importance in the network of inter-institutional collaboration though it does not appear on the list of top 10 productive institutions above. This was followed by Shanghai Jiao Tong University which took the second place in the collaborative network. The other key institutions were the Chinese Academy of Sciences, Tohoku University, United States Air Force, and so on. Some of the institutions with high CP/TP values are not key institutions in the collaborative network might because they just collaborate with some few specific institutions so that their collaborations are not extensive. For example, the collaborations of Helmholtz Association were mainly with Karlsruhe Institute of Technology accounting for 68 % of its total collaborations. Hence, it was the Chinese Academy of Sciences that

performed well when comprehensively considering both the quantity of the publications and the pervasiveness of collaboration.

[insert figure 3 here]

Figure 3. The pattern of inter-institutional collaborations during 1997-2017 according to SNA

4.2.3. Funding Resources

Before analysis of the funding agencies, the following data were pre-processed: records from the "NSFC"(3 records), "National Science Foundation of China" (10 records), "Natural Science Foundation of China" (4 records), "National Nature Science Foundation of China" (5 records), and "National Natural Science Foundation of China NSFC" (7 records) were all merged into one agency as the NSFC; from "EPSRC" into "Engineering and Physical Sciences Research Council" (EPSRC); from "NSF" into "National Science Foundation"; from "China Scholarship Council CSC" into "China Scholarship Council", and from "ERDF" into "European Regional Development Fund".

The funding resources were very diverse as can be observed in Table 3 which lists the ten most productive funding agencies accounting for 10.034 % of the total publications. The most productive agency in terms of the number of total publications was NSFC accounting for 4.724 % with 113 publications, followed by EPSRC and Shanghai Carthing Machinery Co. Ltd. (SCMCL) sharing with much smaller proportions respectively at 1.003 % and 0.753 %. It can be observed that nearly half of the agencies (No. 1, 3, 4, and 8) were from China, while two (No. 2 and 10) from the UK (No. 2 and 10) and one respectively from US (No. 5), Germany (No. 6), and the European Union (No. 7). This result is consistent with the distribution of countries depicted above in section 4.2.1.

Table 3. Top 10 productive funding agencies in research of shot peening during 1997-2017

[Table 3 near here]

4.2.4. Distribution in Journals

Among 757 total journals, the top 20 productive journals accounting for 42.9 % are listed below in Table 4. The three most productive journals were Materials Science

Forum, Materials Science and Engineering-A, and International Journal of Fatigue, respectively accounting for 5.7 % with 137 publications, 4.2 % with 101 publications, and 3.7 % with 88 publications.

The highest three impact factors (IFs) were from Materials and Design (4.525), Applied Surface Science (4.439), and the Journal of Materials Processing Technology (3.647). The IF just reflects the quality of a journal but is not specific enough to reflect the influence in the field of shot peening. Hence, average citations per item (ACPI) was applied to access the performance and influence of the journals in this field. ACPI is defined as the Quotient of total citations divided by the number of records on "shot peening". The results suggests that the International Journal of Fatigue had the greatest value of ACPI (38.67), followed by Materials Science and Engineering-A (32.58), and Journal of Materials Processing Technology (24.81).

It should be noted that although Materials Science Forum was ranked first in total publication, its IF and ACPI were both very low, indicating its relatively small influence on the field of shot peening. The journals numbered 3, 2, 8, 4, 9, on the contrary, had high IFs and ACPIs, indicating better journal qualities and higher influences in the field.

Table 4. Top 20 most productive publication source

[Table 4 near here]

4.3. Hot Issues and Research Trends

4.3.1. Trend of Categories

All the other publications were grouped into 56 subject categories except one record which was not considered due to its lack of relevant information. The top 10 subject categories in terms of their total publications are listed below at the top left as depicted in Figure 4, and their change trends of annual records are demonstrated by the corresponding polylines. Among these 10 subject categories, "material science multidisciplinary" was the most popular category with 1207 total publications accounting for 50.5 % of the total number of records, ranked first; followed by "engineering mechanical" which included 659 total publications accounting for 27.6 %, ranked second. The third was "metallurgy metallurgical engineering" which had 575 total publications accounting for 24.0 %. Each of the other seven categories included a significant number of records which cannot be ignored.

Generally the publication record of each subject category increased, especially that of "material science multidisciplinary" having soared from 18 in 1997 to 71 in

2017. This significant increase leaded to an impressive bigger gap with other subject categories. In addition, “engineering mechanical” and “metallurgy metallurgical engineering” also increased steadily and had notable advantages relative to the other categories not listed herein in terms of annual publications. It is obvious that “material science multidisciplinary” is the research centre of the field of shot peening and the present hot spot at the level of subject category.

[insert figure 4 here]

Figure 4. Publications of the top WOS categories during 1997-2017

4.3.2. Trend of Keywords

In order to explore the intellectual evolution of shot peening research, the cluster analysis result is depicted in Figure 5 as a Timezone View. This figure arranges the word clusters chronologically according to its first co-occurrence year and exhibits the relevant publications adjacent to the corresponding clusters. The research focuses transferred from “parameters optimisation” in 1990s, “severe plastic deformation” and properties of some particular alloys (“aluminium alloys” and “Mg-10Gd-3Y-0.5Zr”) affected by shot peening in 2000s, to the latest “DEM-FEM coupling”, “finite element modelling”, “ultrasonic shot peening” and “plasma nitriding” in 2010s. This transfer indicates that the present hot spots at keyword level are ultrasonic shot peening, finite element modelling, and plasma nitriding.

[insert figure 5 here]

Figure 5. Trend of keywords in the publications from 1997 to 2017

To further explore the performance of these current hotspots, their numbers of annual publications are statistically demonstrated in Figure 6 as polyline plot. The cluster “severe plastic deformation” had a steady increasing number of publications since severe plastic deformation in essence is one of the effects of shot peening process (and also ultrasonic shot peening). Its increase trend indicates the increasing research interests in the field of shot peening by researchers. This is consistent with the annual publications of shot peening as depicted in section 4.1.

The dominant clusters were “finite element modelling”, “ultrasonic shot peening”, and “parameters optimisation” which had the top three largest number of publications in the period from 1997 to 2017 and furthermore increased in recent years. Among these three clusters, finite element modelling was such a hot concern for researchers that even its branch, DEM-FEM, encountered a slight increase since 2009 and had grown into an independent cluster itself. DEM is usually combined with finite element modelling to simulate the shot streams and it exists a competitive potential as FEM in modelling shot peening process (Tu *et al.* 2017). It should be noted that the cluster “ultrasonic shot peening” as a new technique appeared in the field of shot peening, indicating the traditional shot peening technique has one new complimentary counterpart. As for parameter optimisation, its increase benefits from the new advanced

optimisation algorithms, such as genetic algorithm (Baskaran *et al.* 2011) and response surface method (Unal 2016), differed from Design of Experiments method (Baragetti 1997; Romero *et al.* 2001) which was generally applied in the years around 2000.

In addition, the cluster "plasma nitriding" had an obvious increase in its number of annual publications since 2015. It is a surface treatment applied after shot peening as a post-processing to aid in producing hard and wear resistant surface layers (Jayalakshmi *et al.* 2016) on the target material.

[insert figure 6 here]

Figure 6. Annual publications of each keyword during 1997-2017

5. Discussions

This study evaluated totally 2382 publications on the research of shot peening from the year 1997 to 2017 using bibliometric analysis through which seven aspects were analysed including research characteristics, countries, institutions, funding resources, publishing journals, subject categories, and keywords. The corresponding results revelled the status quo and research trend in the field of shot peening over the world.

Generally the total number of publications increased annually although the number of times cited per publication deceased to some extent. This increase was contributed by many countries, such as China, USA, Japan, and Germany etc., among which China was definitely the predominant contributor for it not only took the first place in the number of publications accounting for 19.9 % of the total publications but also performed as the collaboration centre in this field. The collaboration between institutions was more extensive and much stronger than that between countries. Nearly all the institutions had strong collaborative links with others though no absolute leader among them was identified. In the light of both the influence in the collaborations and quantity of publications, Chinese Academy of Sciences performed well while Shanghai Jiao Tong University took the first place in quantity of publications and University of Cambridge was the leader in terms of importance in collaboration. The publications were sponsored by diverse funding resources, such as NSFC, EPSRC, and SCMCL, and the funding agencies were mostly from the top countries like China and USA. As for the journals, Materials Science and Engineering-A, and International Journal of Fatigue had high influence although Materials Science Forum had the largest amount of publication outputs.

The analyses of research trend found that the two subject categories, i.e. material science multidisciplinary and engineering mechanical, had the largest publication outputs and that finite element modelling, ultrasonic shot peening, and parameters optimisation were the current hot spots in the field of shot peening. The word cluster revealed that the current and future research should be focused on the following four aspects: (1) finite element analysis with new methods such as DEM for modelling; (2) ultrasonic shot peening as a counterpart and different direction in modifying properties of metallic surface; (3) parameter optimisation with the advanced algorithms; (4) plasma nitriding as a complimentary process to be applied after shot peening treatment.

6. Concluding remarks

This work provides an overview on the research conducted on shot peening in recent decades based on the data accessed from WOS. The results suggest that there is an obvious disparity in the publication distribution in diverse countries and institutions. For example, the most prolific countries are all from North America and Eastern Asia while countries from the other continents have not yet made their mark. The study also showed that the most productive institutions appeared consistently from these top countries in terms of the total amount of publications. On one hand, such a disparity may be attributed to the differences in financial support from the corresponding countries/institutions. This can be substantiated by the solid and secular financial supports from these governments and institutions, as discussed above. On the other hand, the different collaborative strengths may also make the distribution different, since the most prolific institutions have much stronger collaborative relationships with the others. Hence, financial inputs contributed by the governments and collaborations are expected to occur between institutions to enhance the profile of the research on shot peening.

The word cluster analysis reveals that finite element modelling has already become one of the main research methods to deepen the understanding of the shot peening process. However, to better utilise the beneficial effect of this surface treatment technique, much effort is also made to optimise its process parameters. In the near future, new modelling methods, such as DEM, are expected to gain more attention from researchers; and some other auxiliary surface treatment techniques like plasma nitriding are also being academically considered nowadays. As a branch of shot peening and an advanced version of conventional mechanical shot peening, laser shot peening is now developing very rapidly and would demonstrate its importance in industry and in research field, shortly. Finally, researchers should focus their attention to these potential future developments of the shot peening process.

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Table 1. Characteristics of publications during 1997—2017

PY	TP	AU	AU/TP	PG	PG/TP	NC	NC/TP
1997	38	112	2.9	397	10.4	329	8.7
1998	54	136	2.5	444	8.2	1316	24.4
1999	60	166	2.8	502	8.4	1331	22.2
2000	76	218	2.9	640	8.4	1200	15.8
2001	64	178	2.8	495	7.7	1113	17.4
2002	79	229	2.9	571	7.2	1947	24.6
2003	80	218	2.7	629	7.9	1493	18.7
2004	84	203	2.4	561	6.7	1002	11.9
2005	89	257	2.9	634	7.1	971	10.9
2006	126	360	2.9	864	6.9	1301	10.3
2007	106	305	2.9	697	6.6	1132	10.7
2008	94	275	2.9	894	9.5	854	9.1
2009	143	434	3.0	1068	7.5	2138	15.0
2010	172	475	2.8	1221	7.1	1430	8.3
2011	169	502	3.0	1241	7.3	1246	7.4
2012	140	461	3.3	985	7.0	917	6.6
2013	120	382	3.2	945	7.9	750	6.3
2014	195	602	3.1	1486	7.6	182	0.9
2015	133	478	3.6	1134	8.5	577	4.3
2016	175	584	3.3	1616	9.2	417	2.4
2017	195	669	3.4	1875	9.6	204	1.0

PY: year; publication year; TP: total publications; AU: number of authors; AU/TP: number of authors per publication; PG: number of pages; PG/TP: number of pages per publication; NC: number of times cited; NC/TP: number of times cited per publication.

Table 2. Top 10 productive institutions in research on shot peening during 1997—2017

No.	Institutions	TP (%)	NC	NC/TP	CP	CP/TP
1	Shanghai Jiao Tong University	73 (3.052)	713	9.8	51	70%
2	United States Department of Defence	71 (2.968)	876	12.3	71	100%
3	Polytechnic University of Milan	68 (2.843)	1152	16.9	40	59%
4	French National Centre for Scientific Research	65 (2.717)	843	13.0	59	91%
5	United States Air Force	58 (2.425)	768	13.2	58	100%
6	Helmholtz Association	53 (2.216)	748	14.1	53	100%
7	University Of Technology of Troyes	53 (2.216)	1418	25.8	41	75%
8	US Air Force Research Laboratory	49 (2.048)	647	13.2	49	100%
9	Northwestern Polytechnical University	44 (1.839)	239	5.4	17	39%
10	Chinese Academy of Sciences	42 (1.756)	1495	35.6	42	100%

TP: Total publications; SP: Single institutional publications; CP: Inter-institutionally collaborative publications; NC: number of times cited; NC/TP: number of times cited per publication.

Table 3. Top 10 productive funding agencies in research of shot peening during 1997—2017

No.	Funding Agencies	Records (%)
1	National Natural Science Foundation of China	113 (4.724)
2	Engineering and Physical Sciences Research Council	24 (1.003)
3	Shanghai Carthing Machinery Co. Ltd	18 (0.753)
4	China Scholarship Council	17 (0.711)
5	National Science Foundation	15 (0.627)
6	German Research Foundation DFG	12 (0.502)
7	European Regional Development Fund	11 (0.460)
8	973 Program	10 (0.418)
9	Natural Sciences and Engineering Research Council of Canada	10 (0.418)
10	Rolls Royce PLC	10 (0.418)

Table 4. Top 20 most productive publication sources

No.	Source titles	Records (%)	IF (2017)	ACPI
1	Materials Science Forum	137 (5.7)	0.366*	2.82
2	Materials Science and Engineering-A Structural Materials Properties Microstructure and Processing	101 (4.2)	3.414	32.58
3	International Journal of Fatigue	88 (3.7)	3.132	38.67
4	Surface and Coatings Technology	77 (3.2)	2.906	23.68
5	Key Engineering Materials	66 (2.8)	0.224*	1.34
6	Advanced Materials Research	62 (2.6)	-	0.75
7	AIP Conference Proceedings	56 (2.3)	-	0.71
8	Journal of Materials Processing Technology	54 (2.3)	3.647	24.81
9	Materials and Design	46 (1.9)	4.525	19.15
10	Fatigue and Fracture of Engineering and Materials Structures	45 (1.9)	2.533	17.78
11	Procedia Engineering	42 (1.7)	-	5.45
12	Journal of Materials Engineering and Performance	36 (1.5)	1.340	9.33
13	Applied Surface Science	33 (1.4)	4.439	16.55
14	Rare Metal Materials and Engineering	29 (1.2)	0.290	2.86
15	Materials Transactions	28 (1.2)	0.841	16.57
16	Wear	28 (1.2)	2.960	17.71
17	Surface Engineering	26 (1.1)	1.978	6.54
18	Journal of the Japan Institute of Metals	24 (1.0)	0.598	3.75
19	Materials Science and Technology	24 (1.0)	1.803	12.21
20	Applied Mechanics and Materials	23 (1.0)	-	1.83

Note: APCI = Average citations per item; - = Unknown; 0.366* means the value is from the year 2006 and 0.224* from 2005 respectively.

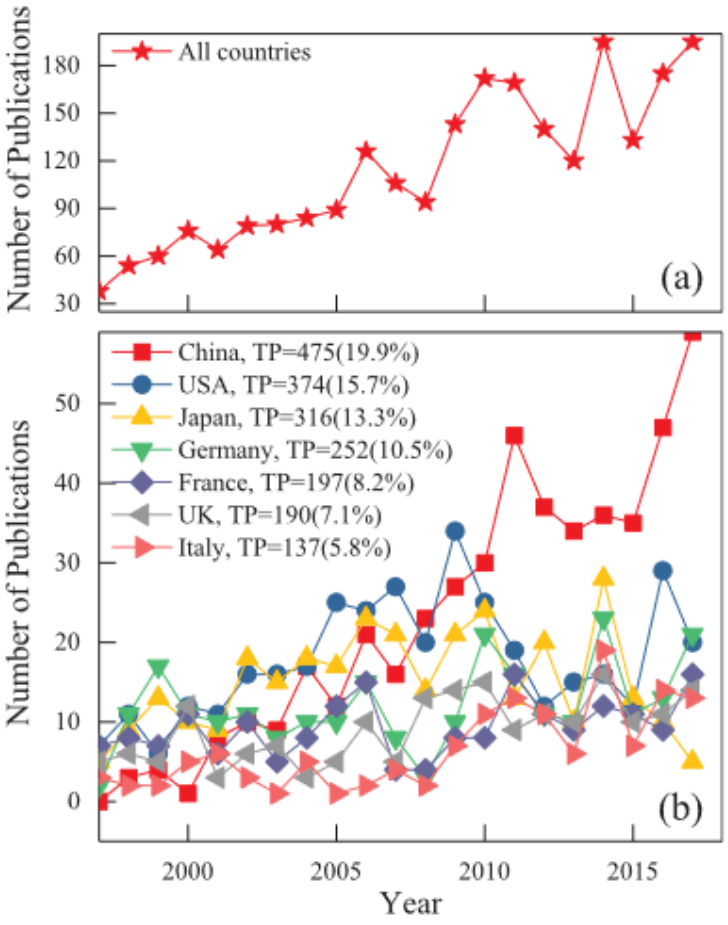

Figure 1. The distribution of publications on shot peening in different countries during 1997-2107

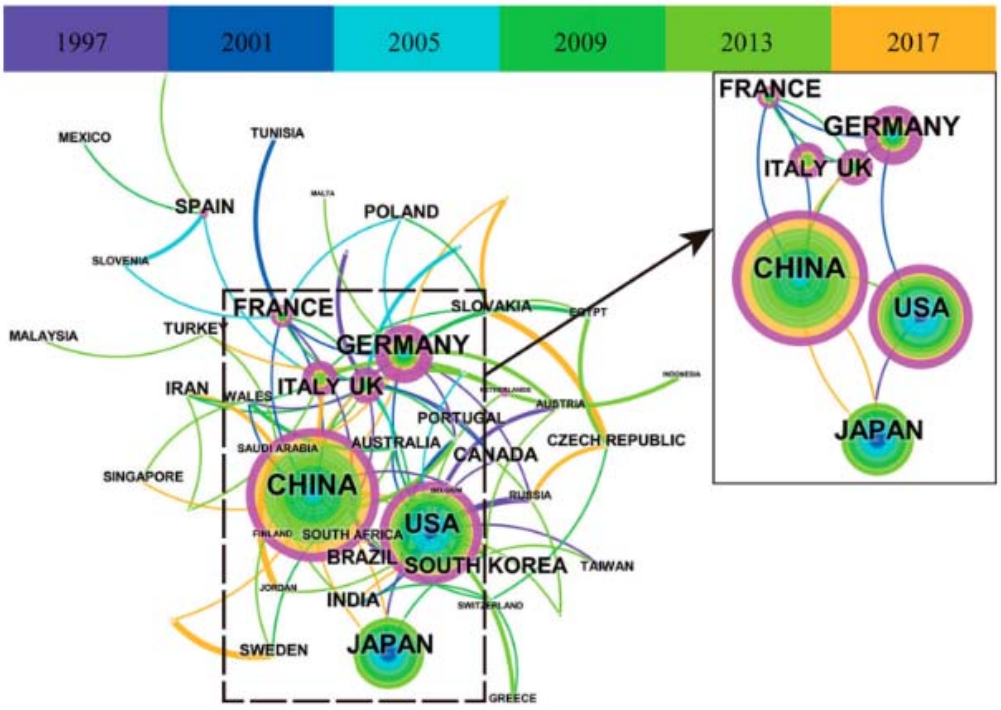

Figure 2. The pattern of international collaborations during 1997-2017 according to SNA

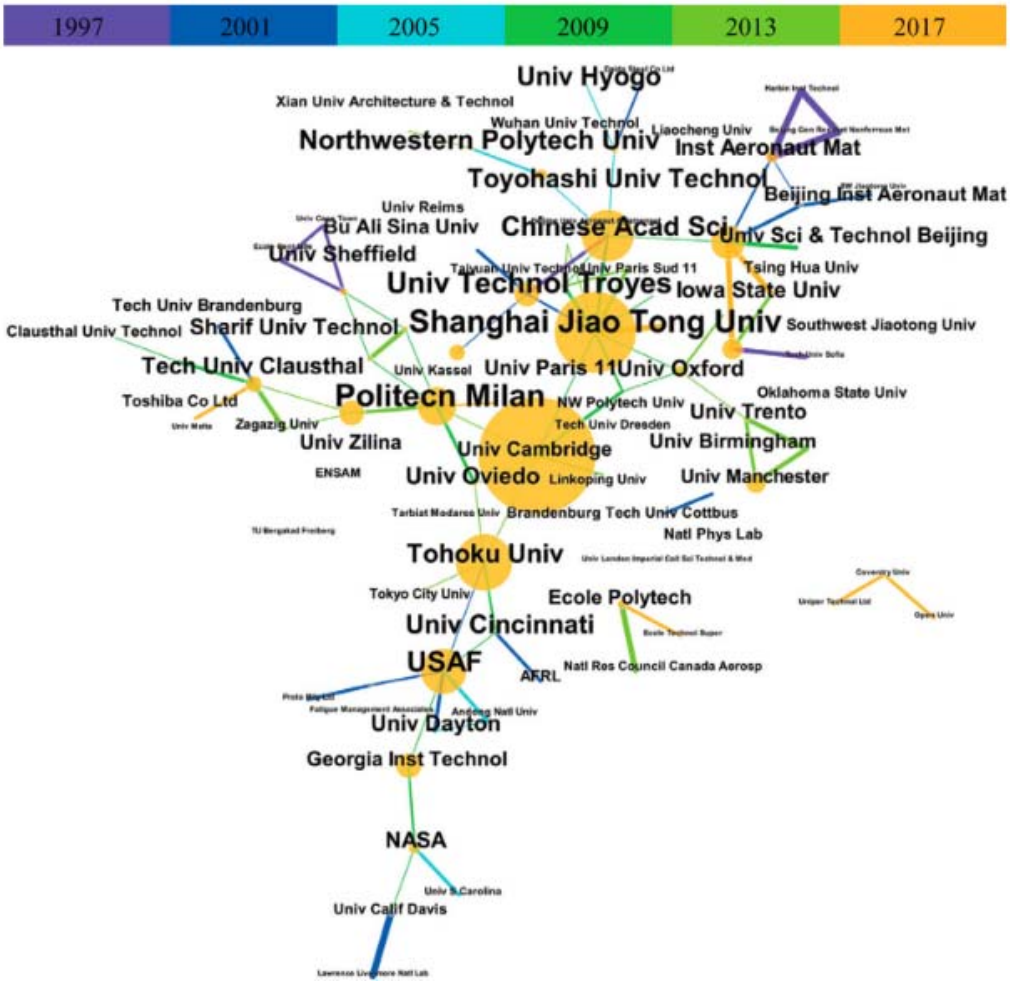

Figure 3. The pattern of inter-institutional collaborations during 1997-2017 according to SNA

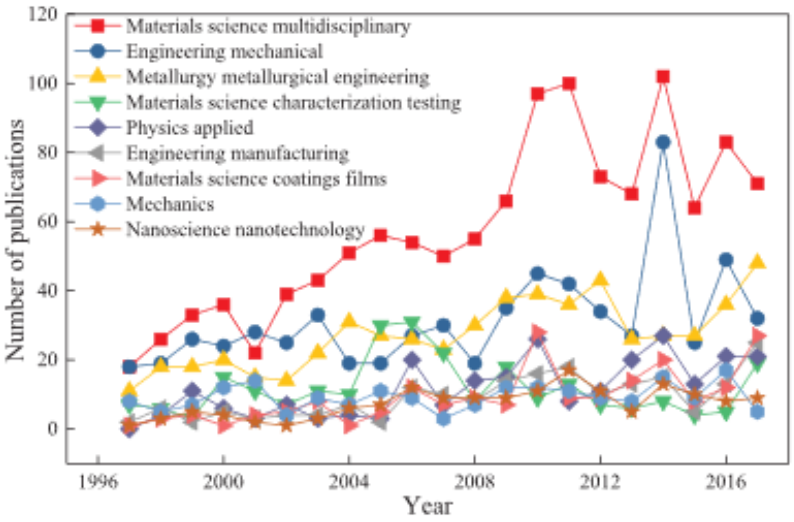

Figure 4. Publications of the top WOS categories during 1997-2017

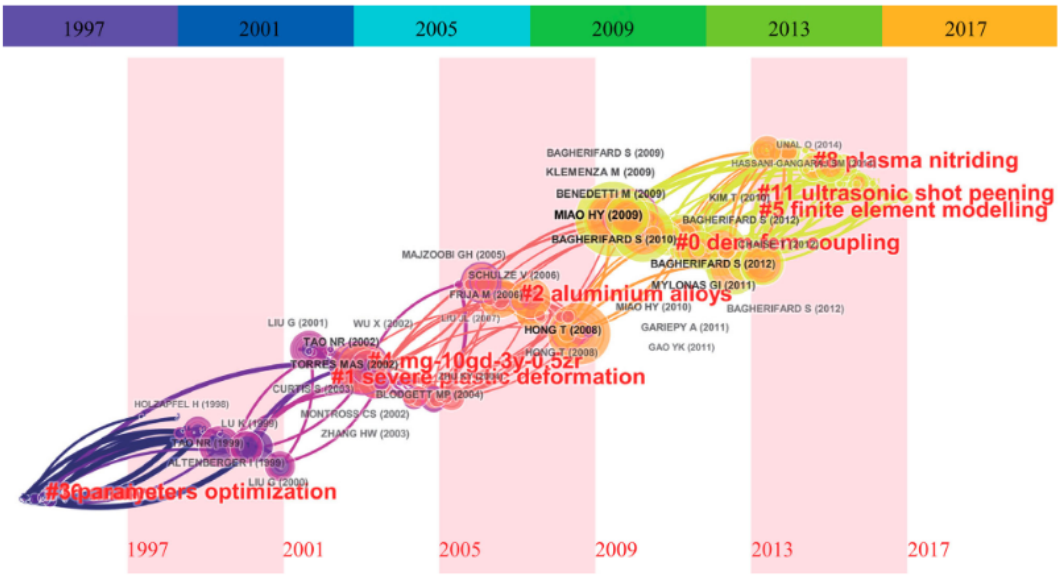

Figure 5. Trend of keywords in the publications from 1997 to 2017

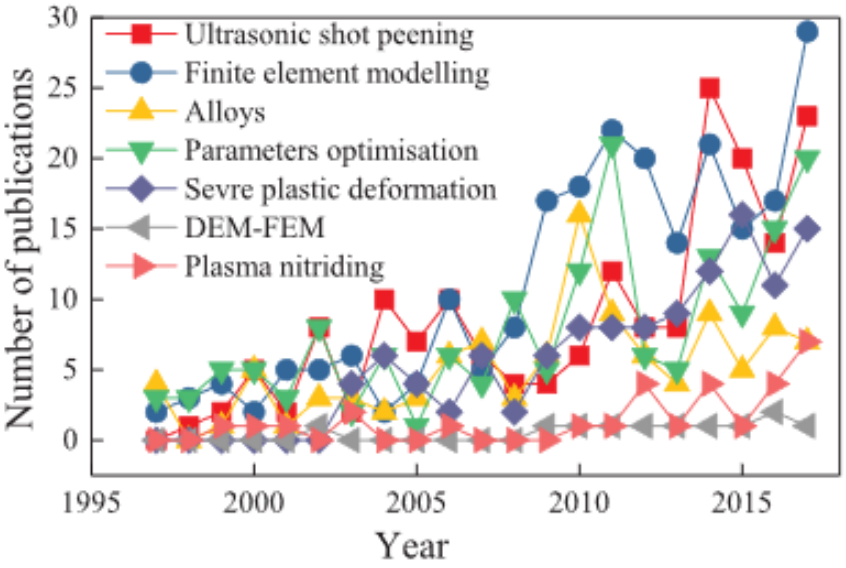

Figure 6. Annual publications of each keyword during 1997-2017