# Patent Landscape on Non-destructive Testing in Gas Turbine Applications

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**Abstract**

Patent analytics is a useful tool to derive insights from publicly available patent data and leverage it to organize the intellectual property (IP) strategy for an organization. The current study describes the use of Derwent Data Analyzer, a patent analytics tool commercialized by Clarivate Analytics. The tool is used to extract patent data on non-destructive testing (NDT) modalities applied to gas turbine applications including aviation, power generation among others for various industrial applications. Within the scope of search, it was observed that aviation players have relatively higher filings compared to the power industry players. Ultrasonic inspection has seen high filing focus with X-ray inspection and thermal imaging not far behind. However, the patent space for microwave and Terahertz inspection has also been expanding. A deep dive patent study is also conducted on X-ray Inspection related filings. Boeing and General Electric have filings across most of the technology segments while Safran has a relatively higher filing count on image processing techniques. Canon and Nikon also have good filing presence focusing on the X-ray scanning system. It is observed that aspects such as inspection data sharing across multiple systems, licensing among others have seen relatively lower focus and could present themselves as potential filing opportunities.There could also be potential opportunities in applying machine learning algorithms to analyze large inspection datasets. The study is a representative example of leveraging patent data towards shaping the innovation strategy of an organization.

**Keywords:** *NDT; Patent analytics; Patent landscape; Derwent Innovation; Patent Database; Derwent Data Analyzer*

## 1. INTRODUCTION

Non-destructive testing (NDT) is a vital cog in the process flow of several industries ranging from aerospace, and power to automotive and manufacturing. NDT is a process to detect defects in materials and components without causing damage or destroying the specimen. NDT is employed in several applications to ensure and improve product quality and safety. With the advances in science and engineering proceeding at a rapid rate, there is a fervent need to keep pace with the various developments in the industry.

Patent analytics is a powerful tool and is a process of generating insights based on collating and analyzing publicly available patent data. The patent data is bounded by specific metrics such as technological keywords, patent timeline, patent filing jurisdiction and other related patent parameters. Patent analytics provides directional insights on innovation trends, key competitor focus areas, general market focus, potential filing, and market opportunities. It is a tool that can be leveraged by any company to not only analyze competitor data but also evaluate their own IP position. It can provide directions to the business with respect to investment in research and development activities, chart competitive strategy and explore technology licensing opportunities, which could be a potential avenue for revenue generation for the company. IP investment is a significant monetary commitment for the company and patent analytics is a valuable tool that can be leveraged to provide a sound basis to make these decisions. There is available literature on patent analytics in various applications, relative to the overall application of the methodology and specific instances. Oleg [1] presents a novel usage of patent analytics on a corporate level by adopting a combination of knowledge modelling techniques, technical analysis followed by 'insight-driven analytics' approach to facilitate its implementation in the company's technology management process. OuYang et al. [2] present a

patent analytics approach which combines the patent family with patent citation analysis in a new product design process. Grimaldi et al. [3] presents a framework to analyze and assess strategic patent information to help manage and leverage the value of patent portfolios. These publications serve to present the breadth of patent analytics in deriving useful insights.

NDT is a rapidly evolving field with increasing demand for improved techniques demonstrating high accuracy, repeatability, and efficiency. Patent analytics can serve as a powerful tool to cater to this growing industry and identify the latest trends and innovations in the field. There are several patent databases available commercially and they are usually supplemented with search and analytics tools such as Derwent Innovation, Innography, Patbase and Relecura. Derwent Innovation [4] is a patent research application that provides patent data information as well as tools to perform various analytics activities including tracking innovation trends, perform competitive landscapes and providing resources to make informed Freedom to Operate (FTO) opinions, patent licensing in addition to other features. The licensed user is allowed access to Derwent World Patents Index (DWPI), which is essentially an expert curated patent database with curated title, abstract and subject matter classification, coding, and indexing. The application also provides a family grouping methodology referred to as DWPI(Derwent World Patent Index) family. Derwent Innovation has several integrated features such as "Smart Search" which also utilize machine learning algorithms in patent searches while their "Themescapes" feature provides visualization of smart segregation of patent data. Using advanced data science algorithms, Derwent Data Analyzer [5] is a data-mining tool that converts patent data into actionable insights through intuitive workflow processes, some of which involved machine learning algorithms, and powerful visualization functions.

The current study leverages Derwent Innovation to conduct a patent search on the technology topic of interest using keywords combined as a search string. The dataset obtained is subjected to patent analytics using Derwent Data Analyzer, a licensed tool from Clarivate Analytics. The analysis is done to study innovation and competitive trends in NDT modalities applied to gas turbine applications with limitations on the filing jurisdictions as well as the patent application filing date post 2012. The study presents a deep dive utilizing the X-ray inspection modality and attempts to provide a perspective on the role of patent analytics in driving strategic innovation.

## 2. PATENT ANALYTICS – PROCESS FLOW

The current section lists the basic process flow used in the current study and a schematic is provided in Figure 1.

**Step 1:** In the current study, the initial search scope covers patent data which relate to NDT without any limitation on the end application. However, due to the large data-size, the study is restricted to patents and applications filed on or after January 1st, 2013 (i.e., filed in the past 10 years). A further restriction is made to the jurisdictional coverage and the search is limited to filings in US, Europe (EP), WIPO PCT Filings (WO), Germany (DE), England (GB), France (FR), Canada (CA) and Japan (JP). China and other Asian jurisdictions are considered "out-of-scope" in the current study on account of difficulties in handling machine based English language translations of patents.

**Step 2:** A search strategy is formulated and is depicted in Figure 2. The search string is supplemented with limitations listed in Step 1.

**Step 3:** The search string is provided as input to Derwent Innovation and the resulting patent and application data is downloaded inthe prescribed format (.dda). The downloaded file comprises one member per INPADOC (International Patent Documentation Center) patent family. An INPADOC patent family [6] can be defined as comprising all patent documents sharing directly or indirectly (i.e., via a third document) at least one priority. One representative member of the INPADOC patent family is only considered for the current analysis. The search string essentially comprises a list of NDT related keywords in the title, abstract, claims or description section of the patent in addition to other limitations such as the application date of 1st January 2013 onwards and the limitation on jurisdictions as described in the previous steps.

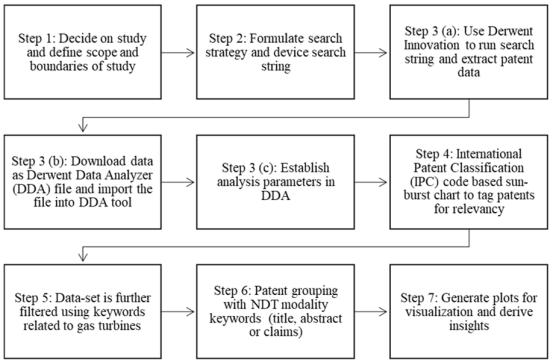


**Figure 1.**Patent Search and Analysis Process Flow in Derwent Innovation and Derwent Data Analyzer

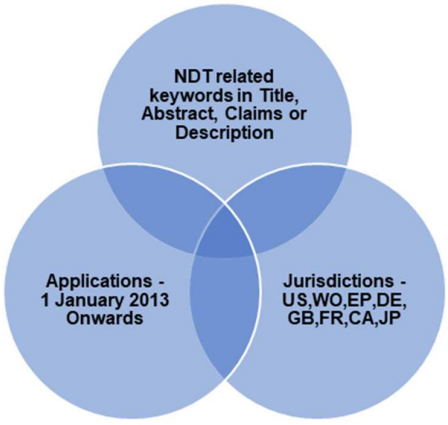


**Figure 2.**Representative Search string used in Derwent Innovation is the intersection region of the three circles

**Step 4:** International Patent Classification (IPC) codes available for each patent are used to produce an IPC code-based sun-burst chart. IPC codes are a hierarchical system of language-independent symbols for the classification of patents and utility models according to the different technical fields to which they belong [7]. Symbols are arranged in a hierarchical, tree-like structure [7,8]. Figure 3 depicts the sun-burst chart of the IPC classification codes of patent data obtained in the previous step. The width of each sector is a representation of the count of INPADOC patent families under that classification. It can be observed that patents with G class (broadly relates to physics) are relatively higher in number compared to the other codes. Within the G class, the classification G01 appears to have a relatively larger dataset for the current search scope. G01 relates to measuring and testing. There are further definitions on patent code sub-classifications available in [7]. It should be noted that typically every patent or published patent application is tagged with one IPC code and in most cases with multiple codes. Based on the data obtained, the patents tagged with 'A' classification which relates to "Human necessities" [8] have not been included in the current search scope.

**Step 5:** In the next step, the search results were further restricted to gas turbines (used in aero-engines, power industry, Oil and gas turbo machinery and related examples). This restriction was accomplished by employing keywords related to gas turbines anywhere in the text of the patent.


**Figure 3.**IPC sun-burst chart of search results

**Step 6:** The dataset obtained from Step 5 is further analyzed by segmenting patents on the appearance of keywords related to common NDT modalities including ultrasonic, X-ray inspection, acoustic inspection, thermography, visual inspection among others.

**Step 7:** Based on the above analysis, visualization is adopted to derive insights on the innovation timeline, key players, and their relative position broadly across the NDT modalities. It is noted here that the accuracy of the current analysis is based on the defined search scope (limited due to the large dataset for the present study) and the accuracy of the tool in segmenting patents in the dataset into select groupings. A further example of X-ray inspection is also described.

## 3. DISCUSSION

The outcome of the patent analytics process flow is provided in the current section. Figure 4 lists the modalities and the associated count of INPADOC patent families. The plot depicts percentage of total filing count.

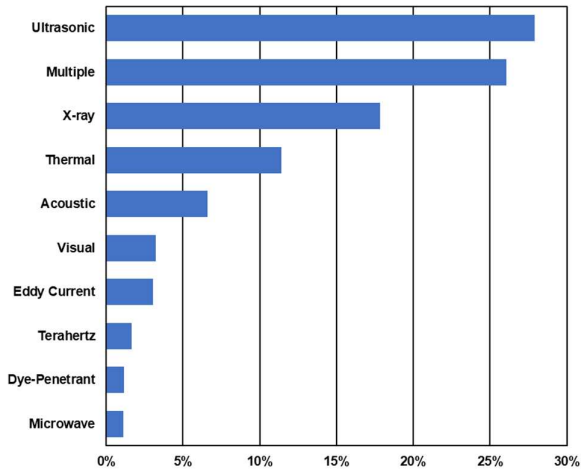


**Figure 4.**NDT modality and associated INPADOC patent family count

Within the scope of search, the results have been listed in terms of percentage coverage of the total dataset obtained. Ultrasonic inspection as well as radiographic inspection, independently have the highest filing presence. In the figure, multiple modalities relate to patents where multiple NDT modalities have been listed. A typical example would relate to an application where the surface irregularities could be assessed by eddy current inspection and defects present deeper in the sample could be evaluated using ultrasonic inspection. There is lower filing focus on modalities such as microwave inspection and dye-penetrant inspection.

Figure 5 depicts the count of INPADOC patent families as percentage coverage of the total dataset for the listed NDT modalities applied to gas turbines against the application year. The application year for a filing relates to the date when the application is filed with the patent office. The filing trends for NDT modalities can be visualized for patent data that is publicly available. Typically, it takes eighteen months for a patent application to become public from the time of filing the application. There isgood possibility for an increase in the filing counts, particularly in 2021 and 2022. Within the scope of search, the filing trends across all modalities are reasonably consistent. There is no distinct spikein the filing count. It can also be seen that relative to the individual modalities, the segment “Multiple” which relates to either a combination of modalities or the concept applicability to more than one NDT modality, is typically higher. This trend, based on the current search scope, is suggestive of higher filing focus on inspection image processing, data analytics and data transfer which could be leveraged across multiple modalities. Though there are a few filings which relate to the combination of multiple modalities, there could be potential filing opportunities in employing data fusion to drive desired results by combining the data from multiple modalities.

Figure 6 depicts the INPADOC patent family count of select patent assignee/ applicant against the application year. The assignees with relatively higher filing count have been selected for the plot.

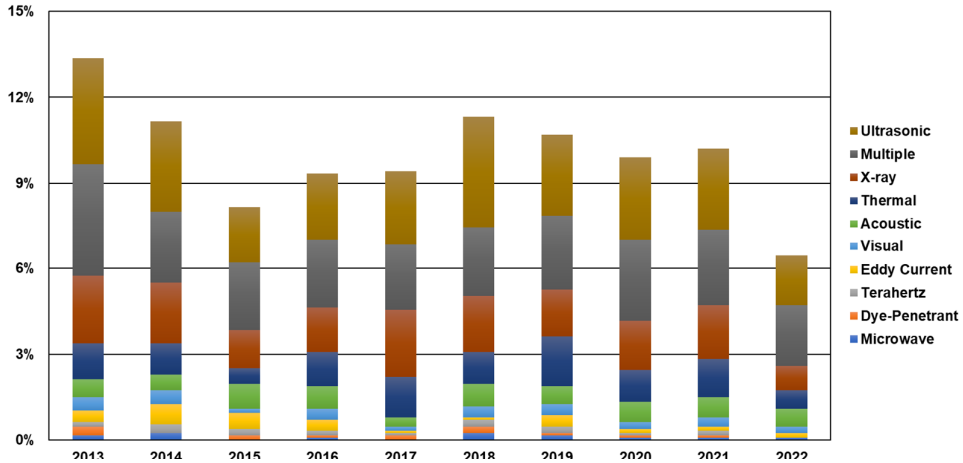


**Figure 5.** Plot of NDT modality patent family count Vs Application Year

patent family count of select NDT modalities plotted against select assignee/applicant.

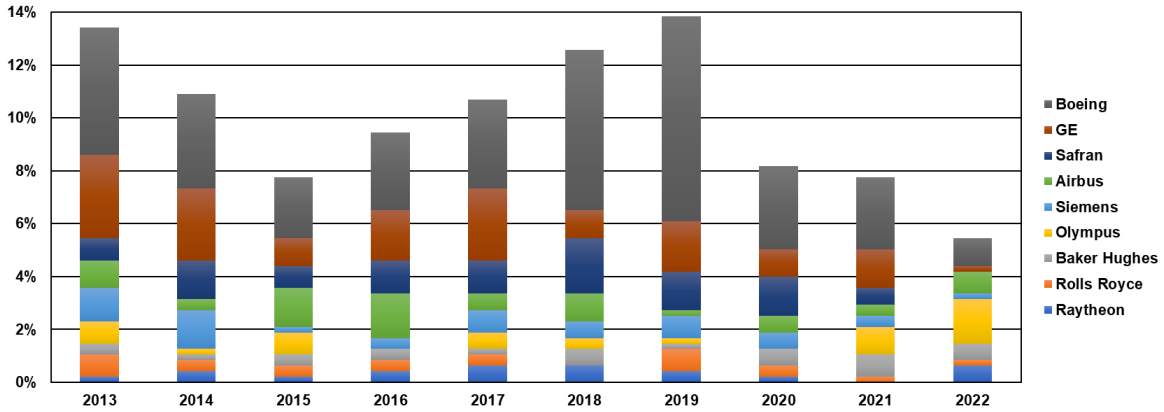


**Figure 6.** Assignee/Applicant patent family count Vs Application Year

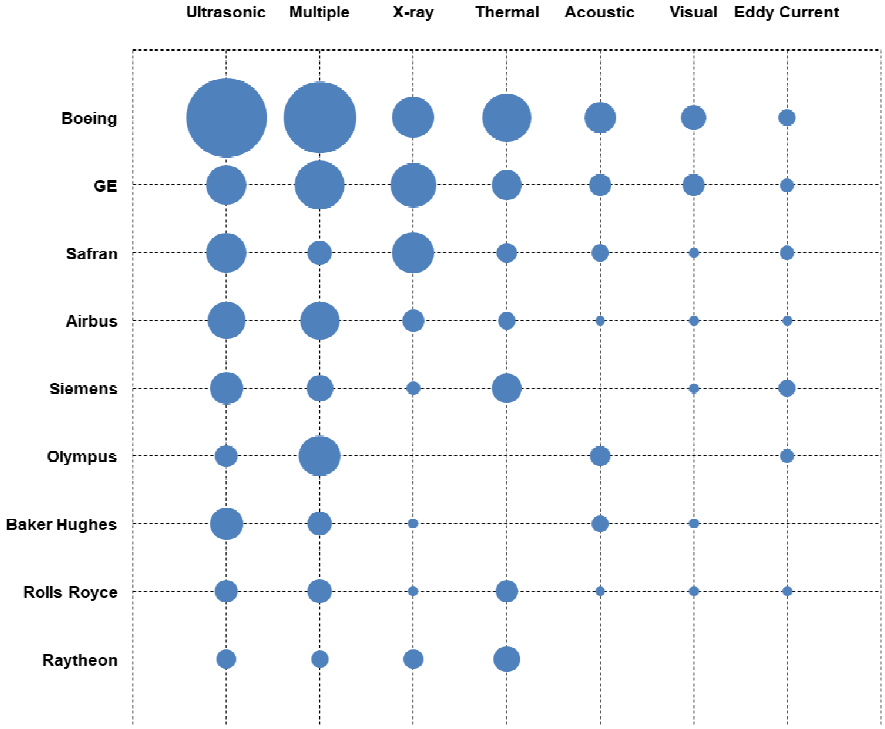


**Figure 7.** Assignee/Applicant patent family count Vs NDT modality

The assignee refers to the owner of the patent rights for the respective patent. It can be an individual or an organization. Within the scope of search, Boeing and General Electric (GE) have sustained their filing activity across NDT modalities. Olympus has increased its filing activity in the past two years. However, for the rest of the assignees listed in the plot, the filing trend has been maintained with no noticeable peaks in filing activity.Figure 7 depicts the The size of the bubble is representative of the INPADOC patent family count for the select assignee and NDT modality. Select players have been identified, particularly from the Aviation and Power industry including airframer such as Boeing and Airbus as well as aircraft engine OEM's. Boeing leads the count followed by GE and Safran. Boeing's filings in the current search scope have high focus on ultrasonic inspection, in most cases, for composite component inspection and data analytics and multiple

modality inspection. The general trend across the select assignees in the plot is suggestive of higher filing focus in ultrasonic inspection as well as multiple modality inspection followed by X-ray radiography/computed tomography. Other modalities such as Terahertz, Microwave and dye-penetrant inspection have not been included in the bubble chartas they have relatively lower filings compared to the other listed modalities. Airframers and engine manufacturers are primarily focused on ultrasonic inspection, X-ray radiography and thermal imaging techniques for their select applications. Olympus and Baker Hughes also have a relatively high filing focus on ultrasonic inspection and multiple modality inspection. A few filings from Baker Hughes also cover inspection data report generation and sharing. Though two representative examples of plots have been provided, it is possible to analyze the dataset further to generate insights on assignee timeline and broad innovation focus areas for a specific modality or a specific industry player.

To illustrate an example for a specific NDT modality, the dataset for X-ray inspection is chosen for further analysis. The dataset is filtered to include only those records which relate to X-ray based inspection, either as an independent modality or in combination with other NDT techniques. The data is then subject to a manual analysis to segment each record in the dataset into one of eight segments (listed below) based on the independent claim.

(a) **Machine:** Filing relates to describing machine aspects including X-ray inspection system layout or portable systems.
(b) **Machine-Source / Source:** Filing relates to the X-ray source assembly or their construction.
(c) **Machine-Detector / Detector:** Filing relates to the X-ray detector configuration.
(d) **Machine-Scanner / Scanner:** Filingrelates to the X-ray scanner system.
(e) **Application:** Filing relates to the end-application (specific component being inspected) such as composite fan blade, composite components, in-situ inspection in additive manufacturing and component repair.
(f) **Image processing:** Filing relates to image processing.
(g) **Analytics:** Filing relates to analytics on the inspection data obtained to derive the parameter of interest. It also includes instances where machine learning algorithms are used in defect detection.
(h) **Others:** Filing relates to data sharing, fleet management, signal processing and other related aspects.

The segmented data is further plotted against application year and assignee. Figure 8 depicts the variation of filing count based on the above listed technology segments with application year. It is evident that the innovation timeline is suggestive of increasing focus on data analytics as well as image processing algorithms for defect detection. There is also interest in applying machine learning algorithms for defect detection. Besides analytics, it can be observed that there is also an increasing focus on the X-ray detector configurations, the related delivery optics arrangement as well as other related features for improved durability.

Figure 9 depicts a bubble chart mapping INPADOC patent family count of select assignees to pre-defined technology segments. Boeing's filings are focused on X-ray inspection system layouts, innovations in the scanner and detector systems, primarily to handle composite inspection. Furthermore, Boeing and GE have filings across most of the technology segments while Safran has a relatively higher filing count on image processing techniques. In addition to Aviation and Power generation players, Canon and Nikon also have filing presence focusing on the X-ray scanning system. Within the scope of the current search, aspects such as inspection data sharing across multiple systems, license sharing among other features have seen relatively lower filing focus. Though there are filings from several players utilizing data analytics for NDT, there are potential opportunities to explore machine learning algorithms to improve the detection speed without compromising on detection accuracy. The example presented is also a relatively broad study and can be further explored to derive useful insights on specific aspects of X-ray inspection. It can thus be seen that the information obtained from patent analytics could be leveraged to understand competitor activity. This information is useful in formulating the innovation strategy for the organization.

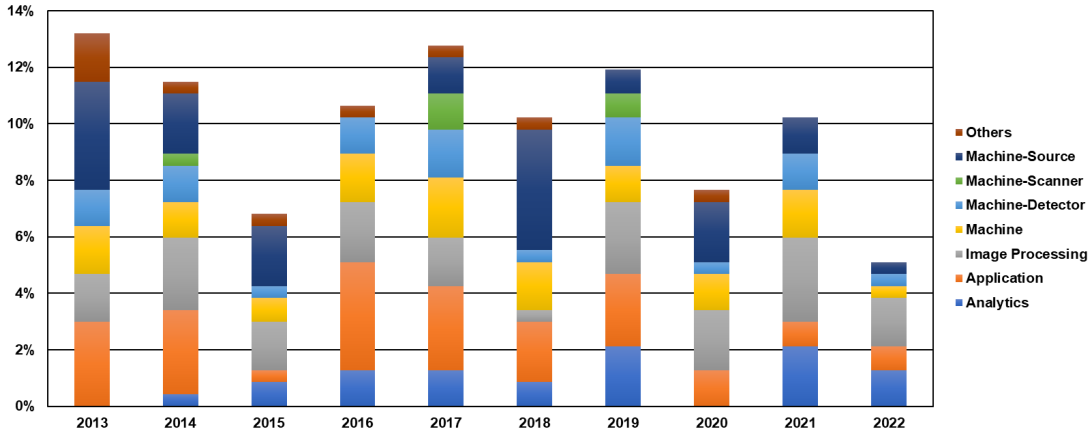


**Figure 8.**X-ray Inspection: Technology Segment plotted against application year

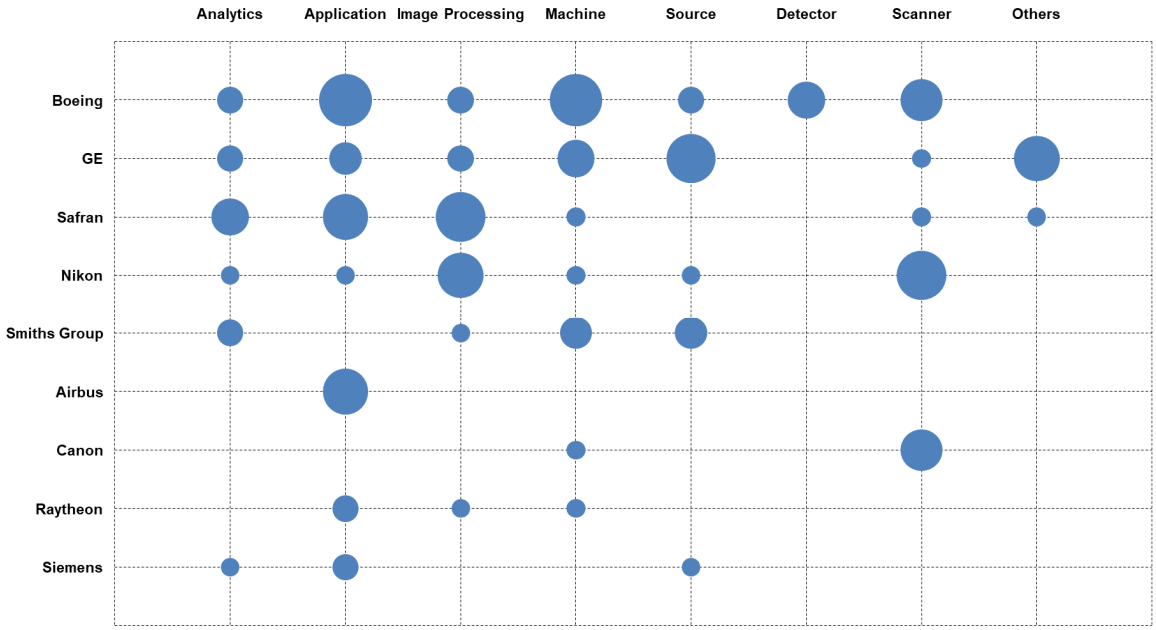


**Figure 9.** Bubble chart of Assignee/Applicant and technology segment

## 4. CONCLUSION

The study focused on understanding the patent landscape with application to gas turbines along with jurisdiction and application year restrictions. Within the scope of search, the key observations are listed below.

- Broadly, across all modalities, ultrasonic inspection as well as radiographic inspection, independently have the highest filing presence.
- There is relatively lower filing focus on modalities such as microwave inspection and dye-penetrant inspection.
- Within the scope of search, Boeing and GE have sustained their filing activity across NDT modalities. Olympus has increased its filing activity in the past two years.
- Potential filing opportunities exist in employing data fusion to drive desired

results by combining the data from multiple modalities.

- Boeing has high filing focus on ultrasonic inspection, in most cases, for composite component inspection and data analytics and multiple modality inspection.
- Airframers and engine manufacturers are primarily focused on ultrasonic inspection, X-ray radiography and thermal imaging techniques for their non-destructive inspection needs. Olympus and Baker Hughes also have a relatively high filing focus on ultrasonic inspection and multiple modality inspection. A few filings from Baker Hughes also cover inspection data report generation and sharing.
- A further study has been conducted on X-ray inspection related filings. Boeing and GE have filings across most of the technology segments while Safran has a relatively higher filing count on image processing techniques.
- In addition to aviation and power industry players, Canon and Nikon also have filing presence focusing on the X-ray scanning system.
- Within the scope of the current search, aspects such as inspection data sharing across multiple systems, license sharing among other features have seen relatively lower focus and could present themselves as potential filing avenues.

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