Seal Failure in Aerospace Applications - Creating a Global Open Source Database

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Abstract

Seals are important components in aerospace applications because they restrict leakage of fluids and prevent debris from entering systems. However, the failure of these components is detrimental and it is essential to understand how, why, where and how often they fail in service. There are been numerous reports where seal failure has led to aircraft incidents and jeopardized the safety of passengers and crew alike. However, there is a difficulty in finding these reports due to the varying reporting systems and databases in every country. We propose a plan to create a designated open source dataset for reports that involve seal failure that is accessible to everyone and allows for user interaction. Additionally, interested individuals can add to the dataset easily, allowing it to grow and add statistical power to its value.

1 Introduction

Seals are essential components used in numerous applications across engineering. A seal is a component that impedes the flow of fluid through a given system. The word 'impede' holds emphasis as there is no such thing as a zero-leakage seal. All seals leak, even if it is as low as 1 mm^3/year and referred to as 'emission' [1].

Although seals serve many purposes in aerospace applications, their main purposes are to restrict leakage out of a system and to prevent contaminants from entering a system, i.e. keeping fluids in and keeping debris out. When selecting a seal for a specific application, many criteria require consideration. These include but are not exclusive to installation and assembly, temperature and pressure, contact and non-contact, wear, and rotational and surface speeds. However, the perfect seal does not exist and the specific requirements crucial for optimum performance in that certain application must be considered when selecting a seal. It is also important to note that the definition of optimum performance will vary from case to case; for instance some applications can compromise on leakage for more rotor stability, while others require leakage to be minimized at any cost [2].

Seals face several challenges within the aerospace industry, and they often fail in service. While seals failing may seem inconsequential, this poses a threat to the overall safety of the aircraft. As outlined in a previous paper [3], the Maintenance, Repair, and Overhaul (MRO) of seals is a critical aspect of ensuring that they continue to operate successfully for their duration in service. This paper also mentions a few case studies where seal failure in an aircraft resulted in engine shut down or a potential unsafe situation for passengers and crew alike. Hence, it is evident that failure of these components is problematic, regardless of how minute or insignificant they may appear.

To understand the circumstances and ways in which seals fail in the aerospace industry, it is essential to understand not only why, but also how they fail. Knowledge of the type and location of failed seals could clarify and possibly predict which seals are more prone to failure and why, and by extension, what issues need addressing to rectify those faults. Thus, analysing enough cases of seal failure in industry, will not only help paint a clear image, but will also increase statistical power.

It is essential for the parties involved to make reports when incidents or accidents occur, followed up by an investigation. There is a designated platform for the publishing of such reports, varying from country to country. For the United Kingdom, the Air Accident Investigation Branch, an independent body under the Department of Transport, is responsible for such investigations. All reports are publicly available here for any incident.

However, there are innumerable reports scattered across many systems worldwide that involve an aircraft incident due to seal failure. Therefore, the aim of this work is threefold and is to:

1) **Create an open source database to aggregate all reported incidents of 'seal failure' from government reports worldwide:** The idea is to create an Open Source Database for Seal Failure and to make this the designated database where seal researchers or those interested can:

    a. Add to the database by filling out a Microsoft forms attached within the article, designed with questions to collect the necessary information from the official report:

https://forms.office.com/Pages/ResponsePage.aspx?id=7qe9Z4D970GskTWEGCkKHpED7jZuXaNLuo_aatPxR39UN1lPSTRSQ1RHVDExSkJMUVRQMjNEUUlIOS4u

a. Interact with the database without any licence required. They can sort and filter via Date, Region, Aircraft ID, Aircraft Type (e.g. Boeing 777), Oil/Air Seal, Cause of Failure, Effect on Aircraft of this failure and Injuries to any person. https://blogs.nottingham.ac.uk/digitalresearch/2021/02/01/seal-failure-database

b. Access the official report for a case they are interested in by using the Aircraft ID, which can be plugged into any search engine to bring up the specific incident report.

2) **Allow for Data Interaction and Access Statistics:** The database has been set up so that Key Parameters are presented with statistics for all the graphs and tables. Interacting, filtering, and sorting through the data allows the reader to learn about the repercussions or details of seal failure.

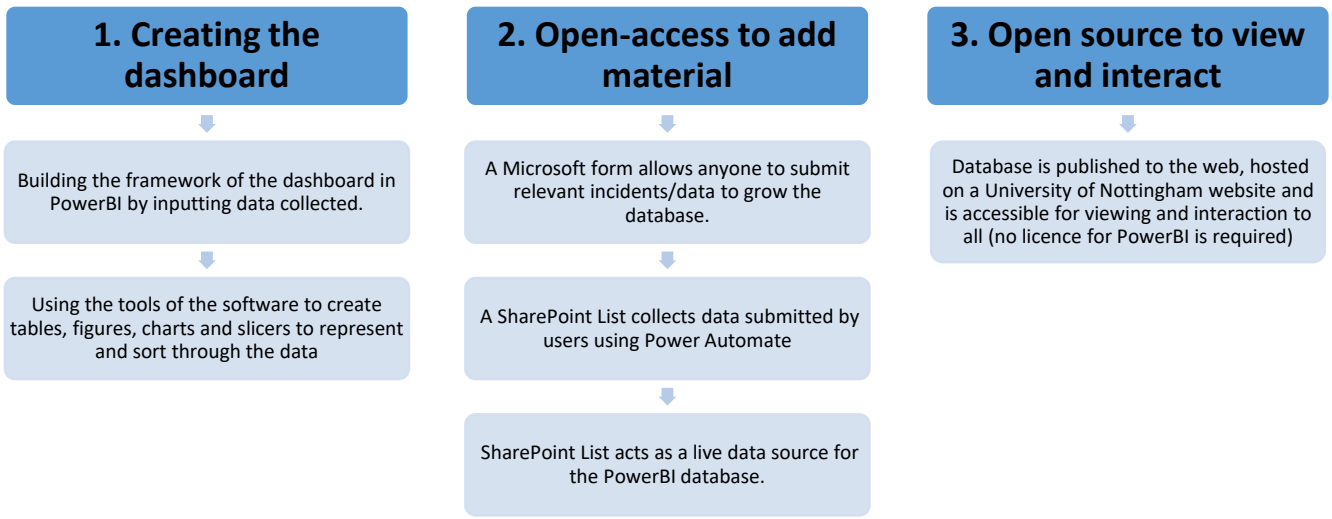
   For instance, a reader who wishes to find aircraft reports in which oil seal failure was involved in the United Kingdom from 2005-2007 can sort through the panel on the left-hand side and the results on pages 1 and 2 of the dashboard will update accordingly.

3) **Highlight the 'why'**: The purpose of this is to highlight the importance of seal research and present its functionality in an aircraft through practical means. Reading real statistics of seal failure in industry and being able to access the report of particular incidents you are looking for is helpful in making a case to emphasize the need for work in this field. It is tedious to search for reports of cases where seal failure has occurred, and this initiative is designed to be open-source and easy to access and to build upon.

   To present an example, oil seals like mechanical or carbon seals placed in aero-engines to ensure that there is no unintended leakage out or debris coming in. Failure of these seals allows oil to escape into the high-pressure compressor and a common result is the cabin filling up with smoke (due to contamination of the bleed air). By filtering through the database, note that while such cases of seal failure do not usually result in serious injury or death, their failure is statistically more common than other seals that fail in the UK cases. Understanding and studying seal failure is useful for my work and helps present the 'why' in my PhD thesis, explaining why the work I do is meaningful and how it affects the industry directly.

2 Methods

The database and dashboard are created in the following manner:



3 Discussion

The Seal Failure Dashboard aims to analyse the data collected from the incident reports. A series of slicers allow for filtering the graphs and bar charts by “Seal Type”, “Date”, “Aircraft Type” and “Region” on the left-hand side. The charts on the dashboard update according to the searched results.

Page 1 of the dashboard has two pie charts: “Cause of Incident” and “Effect of Component Failure”. The first one is a pie chart containing all the different causes of the failure of component. These include options such as “Damaged Oil Seal”, “Unknown due to poor MRO”, “Missing Seal”, “and Investigation Ongoing” amongst others. Users can also interact with the legend of this pie chart and select a certain “Cause of Incident” to see the corresponding “Effect of Component Failure” for the selected cause/causes.

The second pie chart, “Effect of Component Failure” contains all the effects of these seals failing. Options include “Smoke-contaminated Bleed Air”, “Engine Damage”, “Gear Extension Limited” and “Damaged Fuselage” amongst many others. As mentioned previously, users can interact with the legend of this pie chart and select a certain “Effect of Component Failure” to see the corresponding “Cause of Incident” for the selected effect/effects. Note that for both these options, users can enter a new cause or effect into the Microsoft form if none of the current choices is appropriate. This entered option will then appear in the legends as the dashboard updates.

Page 2 of the dashboard has three bar charts, “Frequency of each Aircraft by Type”, “Injury Frequency by Seal Type” and “Cases of Seal Failure by Year”. The first one sorts the cases by the aircraft type, such as “Boeing 777”, “AirbusA330” or “Bombardier DHC 8”. The number of cases associated with each aircraft is represented in this bar chart. The second one sorts the Type of Cause of Seal Failure by the number of injuries with which they are associated. For instance, from all the cases of “Damaged Oil Seals” only 2 cases have resulted in any injury (small or big) to persons. Even if one individual is injured, it counts as an injury. The last bar chart sorts all the cases in the database by year. For instance, it is possible to see how many incidents occurred in any given year or range of years (universally, or by region, seal type and aircraft type).

Page 3 contains a chart that displays the list of Aircraft ID’s for the given selection, allowing the user to note these down and google the specific cases they are looking for. If the Aircraft ID is input into a search engine, the case will be easily accessible. After the user has sorted and filtered through the slicers and found the type of reports they seek, they can leave with the desired information and report details for a thorough read.

The reliability of any statistic relies on the data size, and the current analysis lacks this statistical power. Opening this database to everyone who wishes to contribute will help grow this data set and in turn, provide more reliable statistics as time goes on. We would like this database to be the designated dataset for all seal related aircraft incidents to provide seal researchers, manufacturers, designers and any interested parties to acquire the reports and information they are seeking with ease and time efficiency.

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