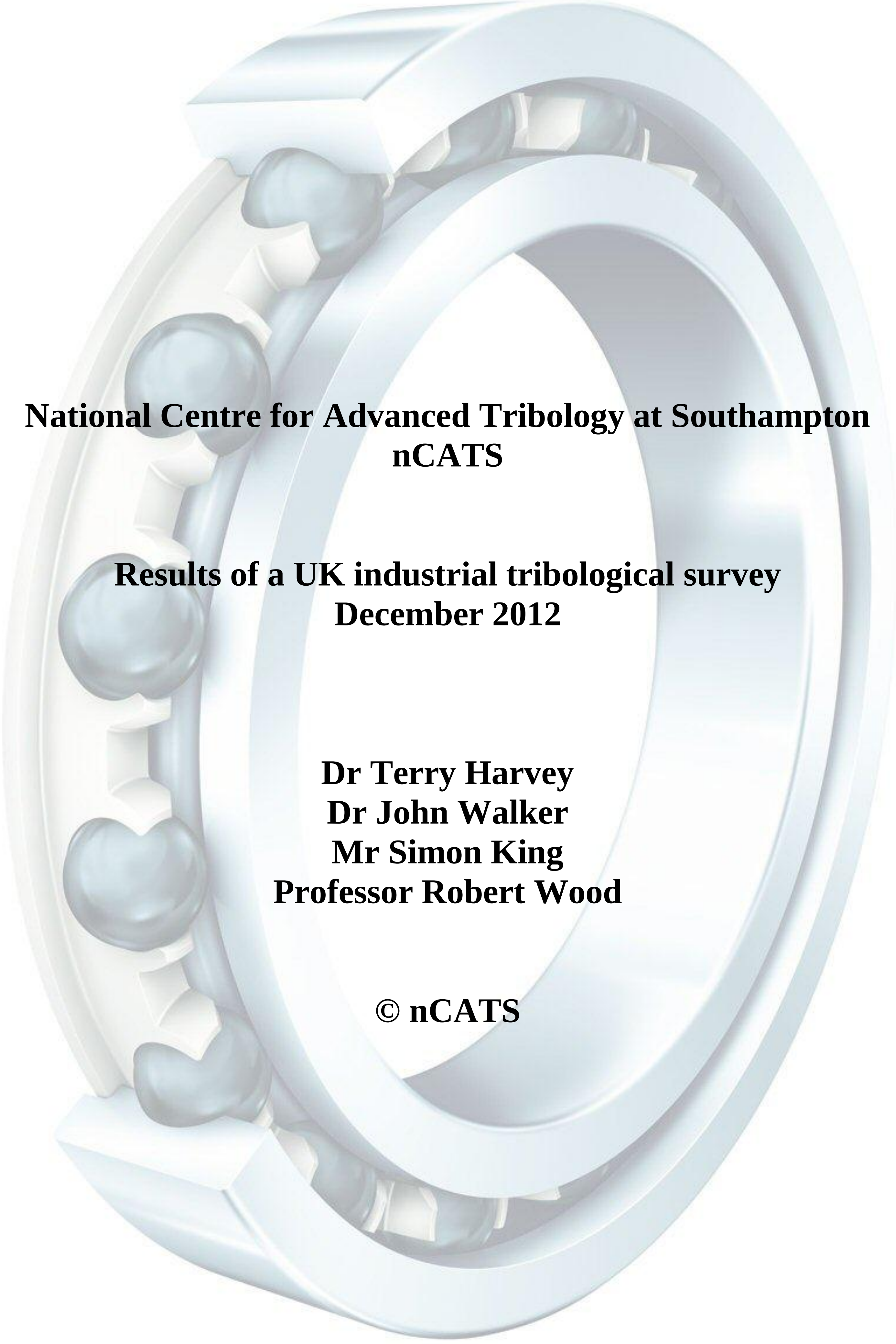

National Centre for Advanced Tribology at Southampton
nCATS

Results of a UK industrial tribological survey
December 2012

Dr Terry Harvey
Dr John Walker
Mr Simon King
Professor Robert Wood

Executive Summary

During the summer of 2012, the National Centre for Advanced Tribology at Southampton (nCATS) undertook a UK-wide industrial tribological survey in order to assess the explicit need for tribological testing within the UK. The survey was designed and implemented by a summer intern student, Mr Simon King, under the supervision of Drs John Walker and Terry Harvey and supported by the director of nCATS, Professor Robert Wood. The survey built upon on two previous tribological surveys conducted through the National Physical Laboratory (NPL) during the 1990's. The aim was to capture a snapshot of the current use of tribological testing within UK industry and its perceived reliability in terms of the test data generated. The survey also invited participants to speculate about how UK tribology could improve its approach to testing.

The survey was distributed through the nCATS industrial contact list, which comprises of over 400 contacts from a broad spectrum of commercial industries. The Institute of Physics (IOP) tribology group also assisted by distributing the survey to its membership list.

A total of 60 responses were received for the survey, out of which 39 had fully completed the questionnaire. Participants came from a broad spread of industrial backgrounds, with the energy sector having the highest representation. Only 40% of respondents were dedicated tribologists/surface engineers, again reflecting the multi-disciplinary nature of the field. It was found that the companies that had the highest annual turnover also appeared to expend the most on tribology. The majority of respondents indicated that as a percentage of turnover tribology accounted for less than 1%, however the lack of hard figures only for tribology make this a conservative estimate.

The greatest concern in relation to tribology of those who responded was the cost; however the influence of legislation and product reliability were also driving factors. Abrasive wear was still considered the number one tribological wear mechanism, with sliding contacts ranking as the most common type of wear interface. Metallic and hard coated surfaces were the most commonly encountered type of material suffering from tribological wear phenomena. Laboratory scale testing was a significant part of introducing a new tribological component, however component specific testing was considered the most reliable form of testing a new component over standardised test geometries.

Overall there appeared to be much potential for improving the reliability of tribological test data, with most respondents indicating that simply more testing was not the best perceived approach to improving tribological data but rather more reliable, representative tests with improved knowledge capture.

Most companies possessed an internal database to assist them with tribological information; however, many also expressed a strong desire for the use of a commercial or national database, although the format this might take was less clear. Opinions appeared split as to whether there would be a collective willingness to contribute to a centralised database, presumably on the grounds on the sensitivity of data.

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1 Introduction & Background

Tribology is the study of friction and wear and encompasses all aspects of interacting surfaces in relative motion. By its nature, this makes it one of the most multi-disciplined areas of science and engineering, with the consequences of tribology impacting across many modern global industries. In an effort to quantify the impact of tribology on society, there have been a number of studies over the last fifty years attempting to estimate the economic cost caused by friction, wear and corrosion. The Jost[1] report as well as a more recent investigation in China[2], all point to significant (several percent GDP) potential efficiency savings should the issues associated with wear and tribology be adequately addressed.

The National Centre for Advanced Tribology at Southampton (nCATS) was formed as a result of a UK Government Science and Innovation award (granted through the EPSRC) in 2008. One of the core activities of nCATS was the formation of special interest groups, or clubs, relating to pertinent areas of tribology considered as problematic across all types of industry. The “Robust Testing” club was designed to look at areas associated with tribological testing and was formed following two meetings; a dedicated “Robust Testing” club day held in November 2011 and coating Knowledge Transfer Network (KTN) event held in January 2012. The events highlighted the perceived need for more reliable data from tribological tests and the potential of a tribology database that could help inform surface engineering decisions.

In order to further explore this area, nCATS devised a UK-based industrial tribology survey designed to capture current tribology needs within UK industry in an attempt to formulate future strategy for reliable testing. Two similar industrial surveys were conducted in association with the National Physical Laboratory (NPL) during the 1990’s[3]. These explored the main types of wear problems encountered during operations, the applicability of current tribological test methods and an appreciation of the cost of tribology to the organisation. For a direct comparison, similar questions were also included in this survey in order to assess and change/progress in these key performance indictors over the last twenty years.

Over the summer of 2012, a 3rd year Mechanical Engineering student from the University of Southampton was employed to develop and publish this survey on tribological activities/problems. In consultation with various nCATS industrial partners a list of questions that were intended to be both simple and clearly word were formed. These were then incorporated into an on-line survey consisting of 23 questions and 4 comments boxes strategically placed through the survey. The questions allowed the survey participant to select from a number of options or add an alternative and 8 of the questions had multiple selections.

The survey was published on 20th July 2012 and emails were sent to over 400 nCATS industrial partners inviting participants to undertake the survey. The same link was also forwarded to the Institute of Physics Tribology Group mailing list. Over the course of the summer, 60 participants logged onto the survey and answered to varying levels, with 38 answering to the final question. Note that in some cases questions were skipped, which is presumed because the participant either did not have the information or regarded it as sensitive. In general, the analysis involved using responses to questions, eliminating the unanswered parts; however, for some questions the lack of a respond was taken as a deficiency related to that question, i.e. if you do not have a particular tribometer you cannot comment on the reliability of the data from it.

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[1] Jost, H. Peter. "Lubrication (Tribology)–A Report on the Present Position and Industry’s Needs." *Dep. of Education and Science, HM Stationarey Office, London* (1966).

[2] *Tribological applications and research of the development strategy of tribology in China*, Chinese Academy of Engineering (CAE), 2006

[3] Gee, M. G., S. Owen-Jones, and National Physical Lab., Teddington (United Kingdom). Centre for Materials Measurement and Technology;. *Wear testing methods and their relevance to industrial wear problems*. National Physical Laboratory, 1998.

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The analysis in this report is based on the structure and types of questions in the survey; and has been split into five categories:

- **General**: The General category investigated background questions on the participant and the role in their company, the annual turnover and cost of tribology to their employer as well as the type of industrial sector they had operations in.
- **Important Factors**: The Important Factors category looked in detail at the importance of different factors impacting upon tribology and ranged from commercial pressures to technical performance.
- **Wear**: The Wear category focused on the different types of wear mechanisms commonly encountered as well as material type.
- **Testing**: The Testing category looked at the broad range of tribological testing available and assessed the perceived reliability of each test technique. Approaches to improving tribological testing was also addressed.
- **Databases**: The database category was a specific area of questions on company databases to the need for a national database on tribology.
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The appendix lists the questions in the survey and the options available for each question.

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2 General

The participants of the survey showed a wide spread of sectors, as shown by Figure 1, with energy providing the most participants. As can be seen by the insert in Figure 1 of the majority of the companies can be categorised into one sector, however quite a few span multiple sectors, with one company involved in every selectable sector. Other sectors not listed but indicated include mining, food processing, coatings, metrology research and oil & gas.

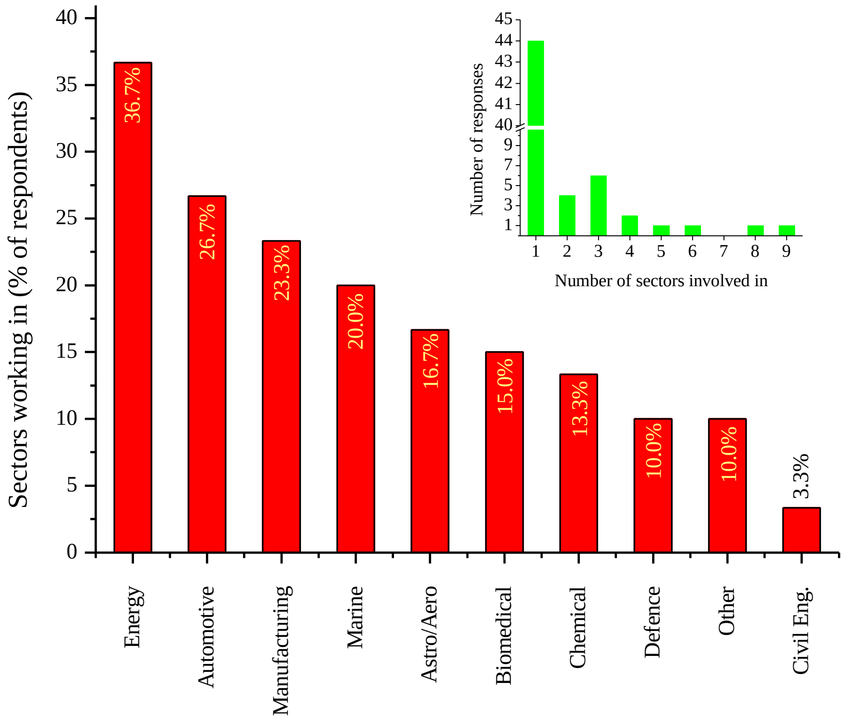

Figure 1 Sectors that the respondent indicated by their company works in, the insert graph shows that the majority work in companies dedicated to one sector, but some work in multi-sector (up to 9) companies.

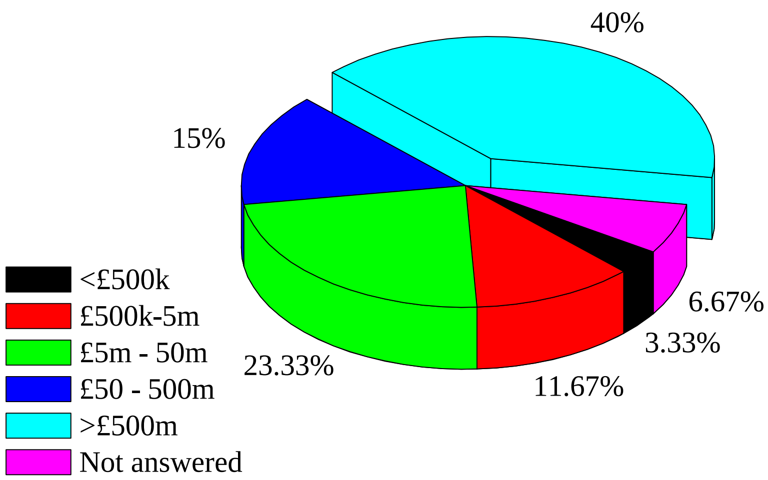

Figure 2 Company Turnover

The second question in the survey again related to the company, but this time the participant was asked to indicate the annual turnover and this is shown by a pie-chart in Figure 2. The highest level of turnover (> 500 million pounds) gave the largest proportion at 40%. Figure 3 show the estimated expenditure on tribology to the companies, again the largest selectable value, greater than one million pounds, was the largest proportion. Interestingly the next two (equally) largest portions are for the two lowest levels. By cross-correlating the annual turnover and expenditure on tribology, it can be seen that the companies with the largest turnovers have the highest expenditure on tribology, as shown in Figure 4. It can be inferred that the cost of tribology scales with operational size and suggests that efficiency saving from tribology are significant. However, the two lowest levels of expenditure are spread across the turnover range, with nothing in the lowest cost-lowest turnover. It is noted that two companies had a turnover lower than £500k but have tribological costs £50k - £100k, both are multi-sector companies.

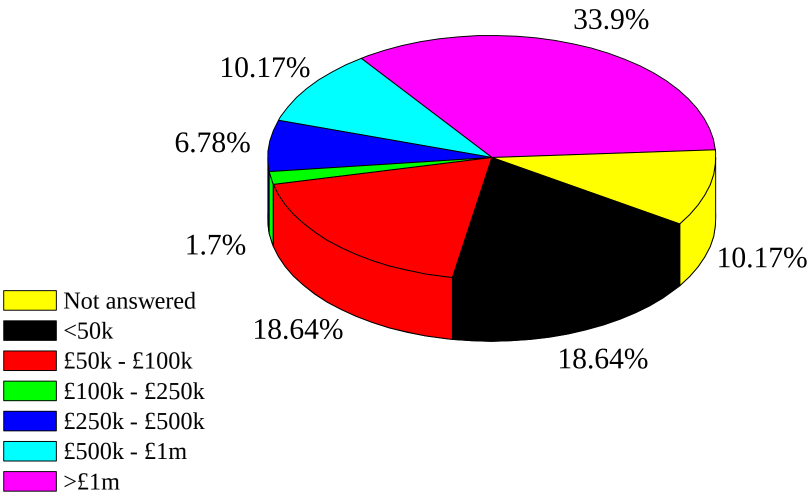

Figure 3 Estimated company expenditure on tribology

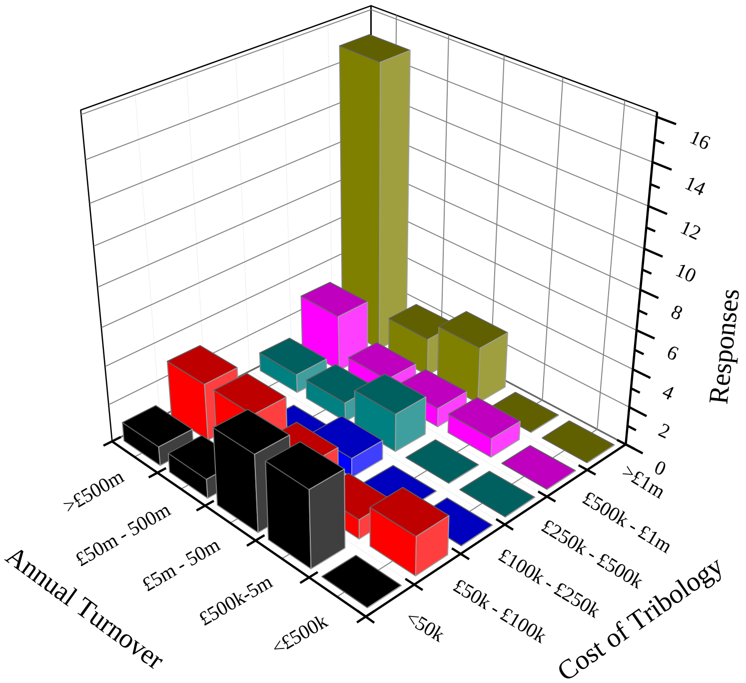

Figure 4 Turnover versus cost of tribology

To further elucidate where the tribological expenditure is higher the results are plotted for each sector in Figure 5, but this shows no clear correlation, except that the defence sector leans towards lower tribological costs. Energy has the highest number of responses for the highest level of expenditure and this may be related to push towards renewable energy sources, which has led to rapid development in this sector.

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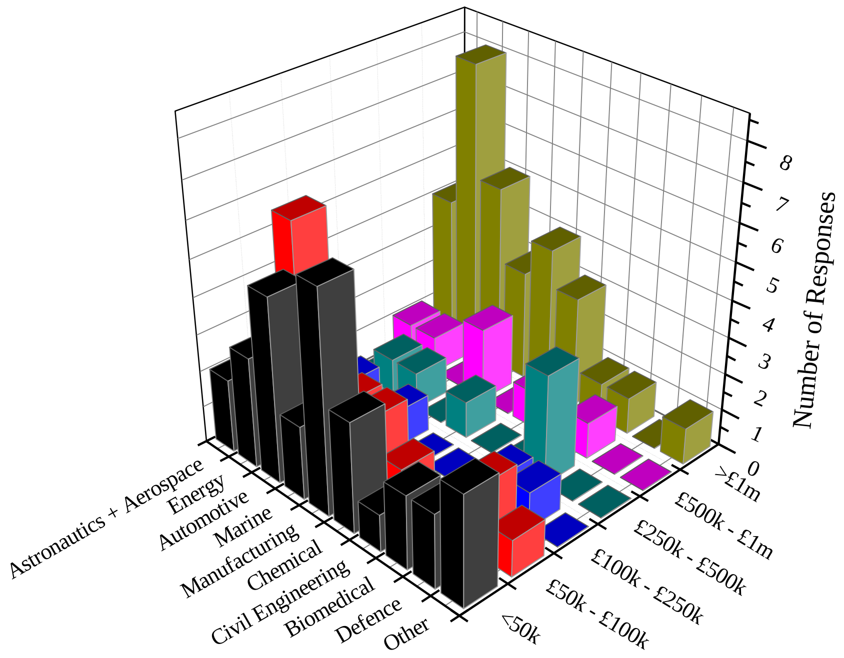

Figure 5 Sector versus cost of tribology

It was noted by quite a few of the participants that the true cost of tribology was hard/impossible to estimate across all company operations as no hard figures exist for this data; also what factors should be included in the cost of tribology also made estimation difficult, which might explain the strange distribution of cost estimates with few indicating values in the middle ranges and the majority either high or low levels. It is also noted some participants indicated the majority of the cost is associated tribological testing. A conservative estimate of the percentage turnover attributed to tribology (the highest turnover bracket and lowest cost of tribology) suggests the majority of the respondents reported less than 1% turnover Previous estimates of the cost to UK tribology had been placed at approximately 0.25% turnover[4], however Figure 4 shows how this number clearly varies So what it is the 'true cost of tribology'? One approach would be examine what the difference would be if wear rates were very low for everything (in some situations this is not desirable) but the consequences would be components will last for much longer, service intervals will be increased significantly and development will be much less intensive. For most industries this would represent a massive saving in annual budget, but for some industrials that rely on tribological development it would mean working in a different field as the need would dry up.

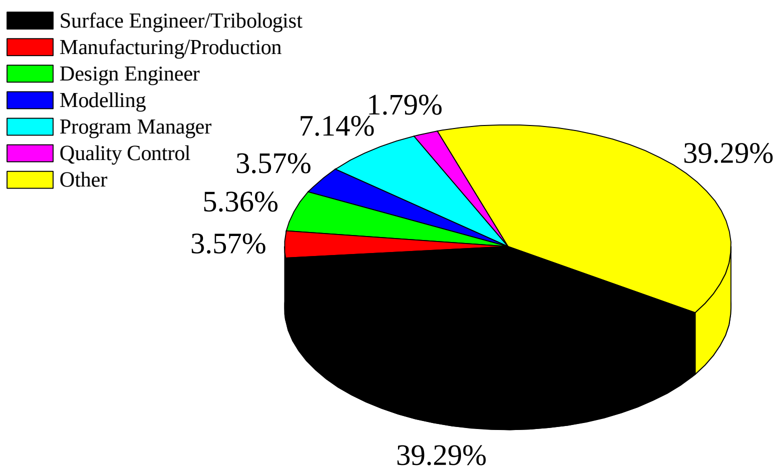

Figure 6 Pie chart indicating the role of the respondent.

[4] ibid

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The last question in this category was related to the participant themselves and the role they play in the company; this is shown by the pie-chart in Figure 6. As expected ‘surface engineers/tribologist’ were high, but ‘other’ was equally high, suggesting that the selection was not broad enough to encompass the roles of non-specialists for whom tribology is a role they undertake within companies. The question did allow the participant to add/expand on this and a range of engineers (materials, preservation, metallurgical, chief, test), managers (discipline, R&D, MD, research), as well as a few specialised positions were noted.

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3 *Factors*

The first question in the factors sector asked the participant to rank the drivers that influence tribology. As expected the most influential driver on tribology is cost, as shown in Figure 7, followed by legalisation and then reliability.

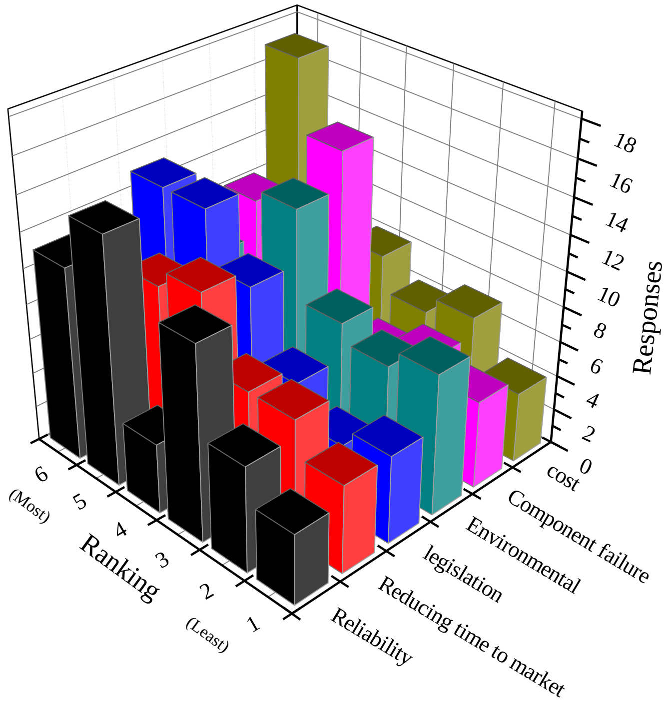

Figure 7 The drivers for tribological change

After this, the ranking becomes less clear until the values are averaged and the results, shown in Figure 8, indicate a complete ranking as thus:

Cost > Legalisation > Reliability > Component Failure > Reducing time to market > Environmental

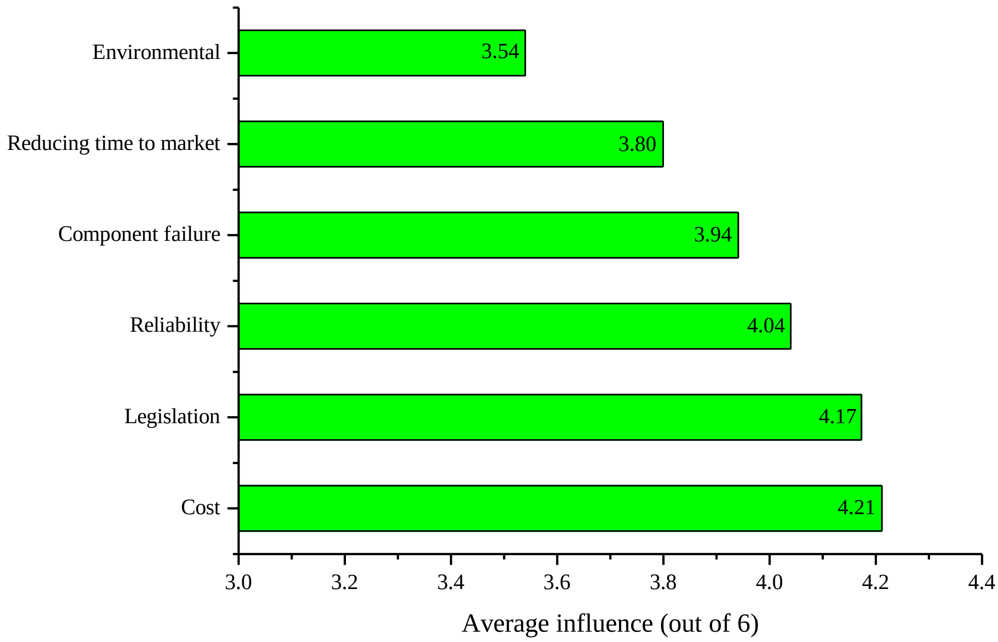

Figure 8 Average influence values of the drivers for tribology.

From Figure 9 it is noted that tribology is important to all three: design process, component wear and new materials, with component wear indicated as the most important.

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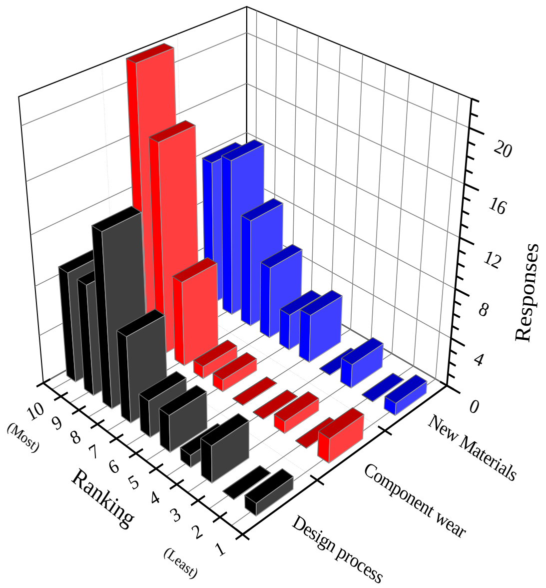

Figure 9 Importance of tribology to design process, component wear and new materials.

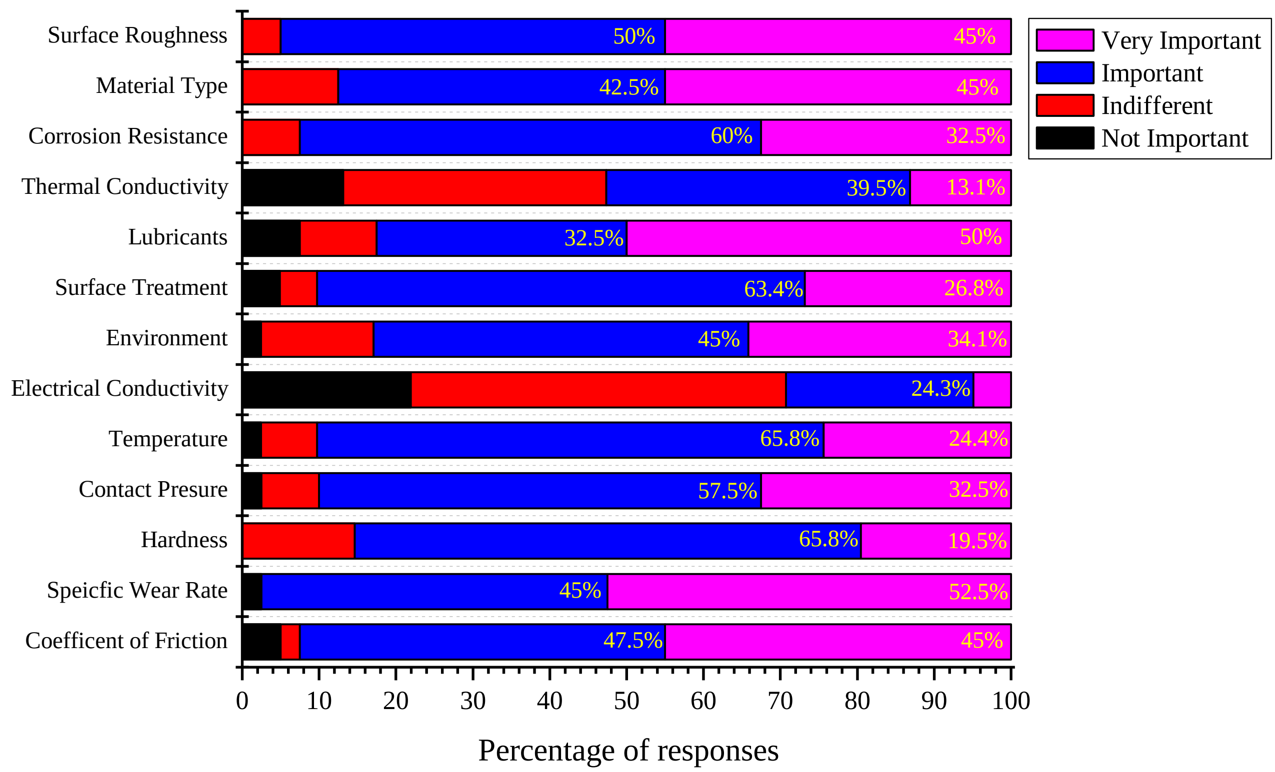

Figure 10 Importance of factors in designing tribological components

Figure 10 shows the factors that are important in designing tribological components. Analysing the "Very Important" responses, specific wear rate was considered to be of the highest concern, which suggests that component lifetimes are considered more critical compared to other factors such energy losses from friction, etc. Of slightly less importance was the type of lubrication a contact would experience, whilst surface roughness, coefficient of friction and material type were all considered to be equally very important after lubrication. Beyond this, materials properties (hardness and corrosion resistance) along with the contact conditions (temperature, contact pressure and environment) were of less importance. The lowest ranking categories in the "Very Important" responses were thermal and electrical conductivity. It should be noted that this is an overall rank of importance from all responses and that the application will often determine the conditions that are considered critical.

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4 Wear

The assessment of wear attempted to rank how problematic different types of wear mechanisms are, with the responses are shown in Figure 11. Examining just the highest importance rank (8), it can be seen that adhesive has the highest response, followed by abrasive, with fretting and corrosive wear the lowest two. The figure was cropped to decrease the influence of cryogenic wear, which with an importance ranking of 1 received 65% of the response given and was clearly the least important type of wear.

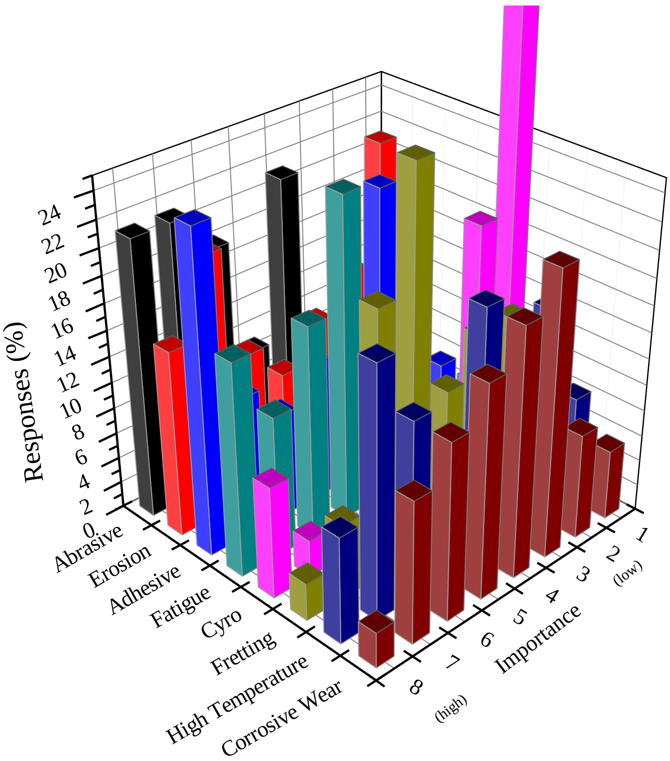

Figure 11 Importance of wear mechanism to companies

If the results are simplified by averaging the ranking scores as a percentage (such that a ranking of 8 was equivalent to 100%), as shown in Figure 12, the results show a slightly different trend; with abrasive wear now the most problematic, followed by fatigue, while 'cryogenic wear' is indeed of the lowest importance. This was in-line with previous surveys, were abrasive and erosive mechanisms (categorised under the same heading) were the most common type of wear, followed by adhesive and fretting. The most significant difference to previous surveys was the ranking of fatigue related failure which was second highest in the present study, but which had previously only been considered as contributing to 5% of tribological failures. It is difficult to attribute the direct cause of this as a multitude of factors specific to different components and industries would have to be considered.

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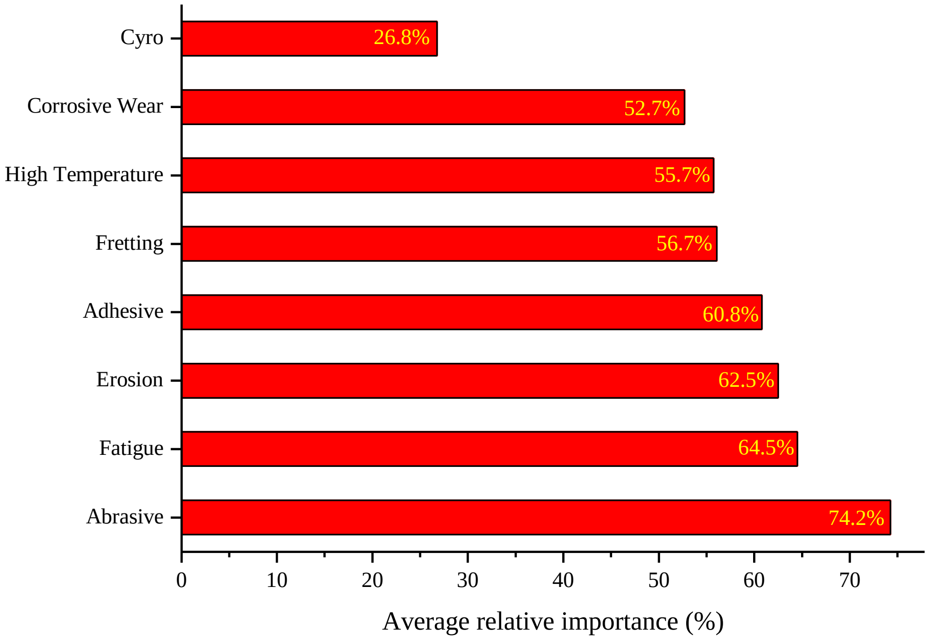

Figure 12 Importance of wear mechanism to companies (based on average response)

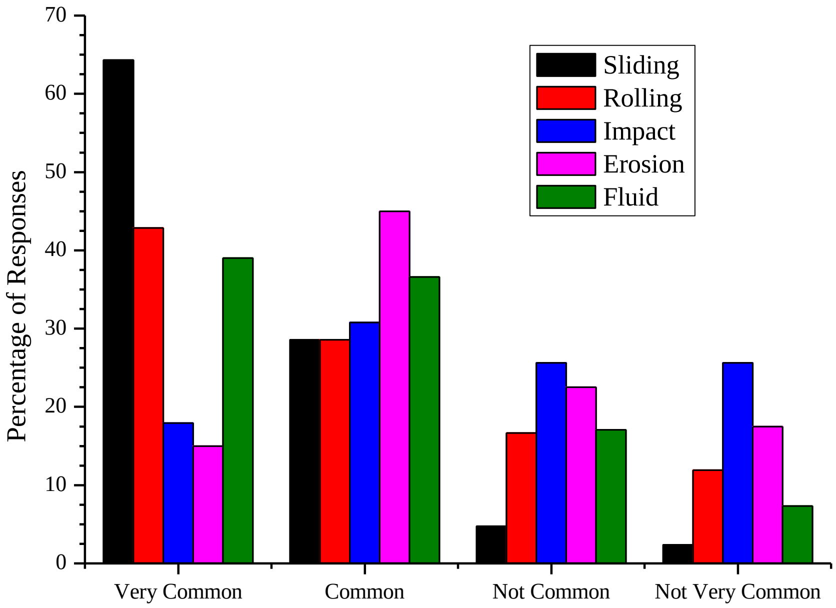

Figure 13 Commonly occurring wear types

To elaborate further on the wear mechanisms, respondents were asked about the most common type of contact that encountered during wear. Figure 13 shows the outputs to this question were it can clearly be seen that sliding contacts were the most common, followed by rolling and fluid. Erosion, although not scoring highly in the ‘very common’ rank, can be classified as ‘common’, whilst impact conditions could be considered the least likely type of contact occurring.

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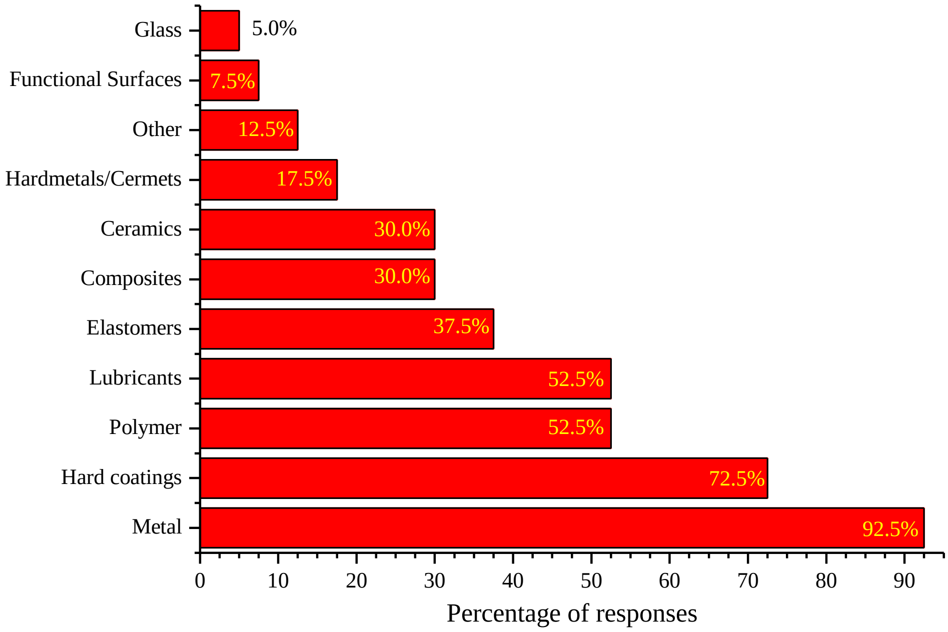

Figure 14 Percentage of respondents encountering materials that wear

The different classes of materials that were encountered during tribological processes are summarised in Figure 14 as a percentage of total responses received. Clearly metals were by far the most common material group encountered that have wear issues, followed by hard coatings. Interestingly, 53% of respondents were encountering wear of polymeric materials, whilst 53% were encountering lubricants, suggesting that half of contacts were dry sliding and half were lubricated. The use of composite materials, hard ceramics and cermets were encountered only a third of the time or less, whilst glass and functionalised surfaces were the least encounter of all surfaces.

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5 Testing

In the testing category a number of avenues are explored from how companies perform testing, how reliable laboratory tests are and how accurately do they related to the final solution to accelerated testing and how to improve what testing is done.

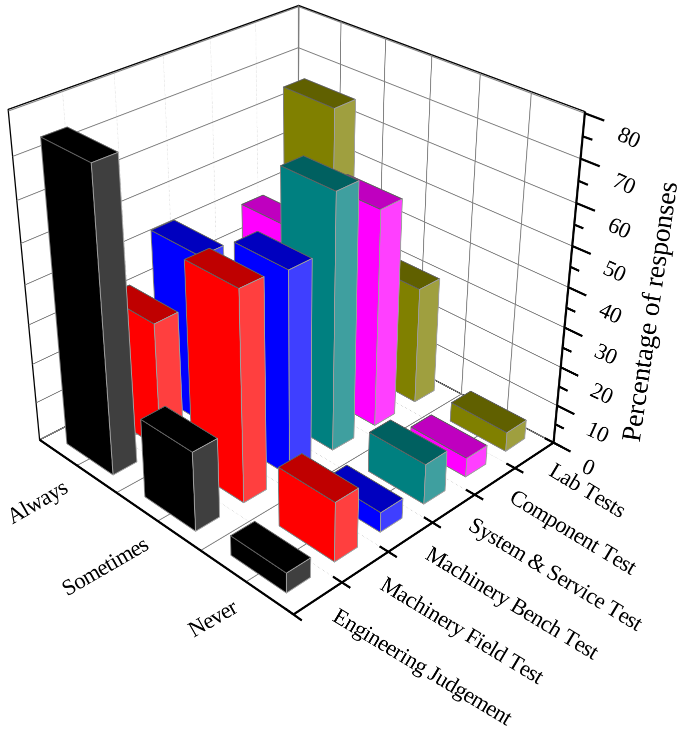

Figure 15 Prior to the introduction of a new tribological component would you perform any of the following with your own internal tests?

Generally in the development of new tribological components a range of testing is employed as shown by Figure 15 and that 'Engineering Judgement' and 'Laboratory Tests' are the most commonly applied, which is probably down to the relatively low cost associated with these. It is also noted that 5 participants indicated that all of these tests/judgement are always employed, while another 4 participants indicated five out of six are always employed, which presents approximately 25% of the total number answering this question. This indicates that the cost of development is a significant expenditure for these companies.

The participant was asked whether testing was subcontracted out to external companies and if so what kind of testing was performed; from Figure 16 it is shown that approximately a fifth do not undertake external testing. While those that do, laboratory testing is by far the most commonly done (at 56%), with the other four types around the 25-30% mark. This is really not surprising as laboratory testing is more generic and thus more readily available.

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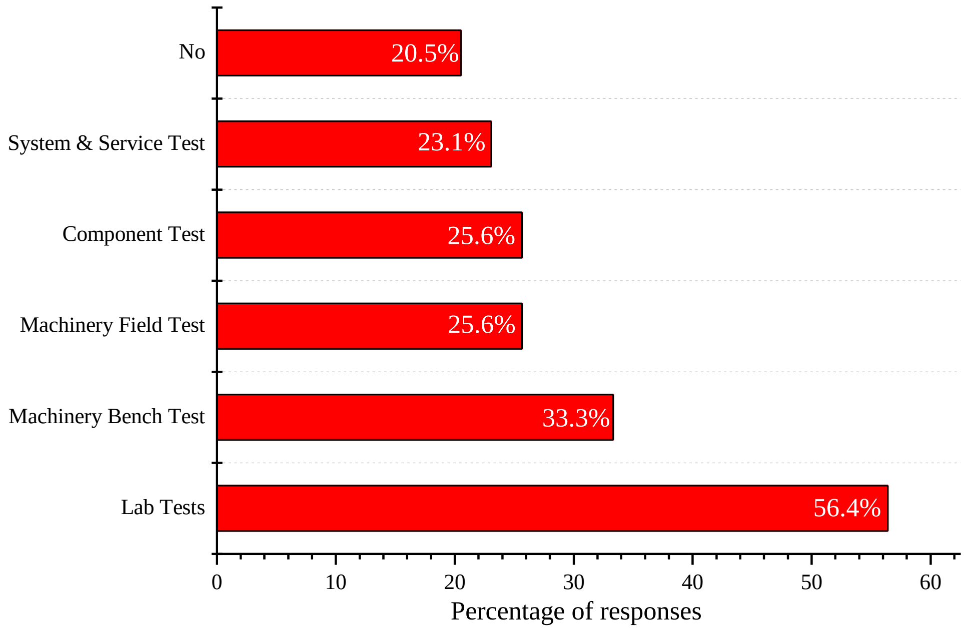

Figure 16 External Testing – whether done and what type

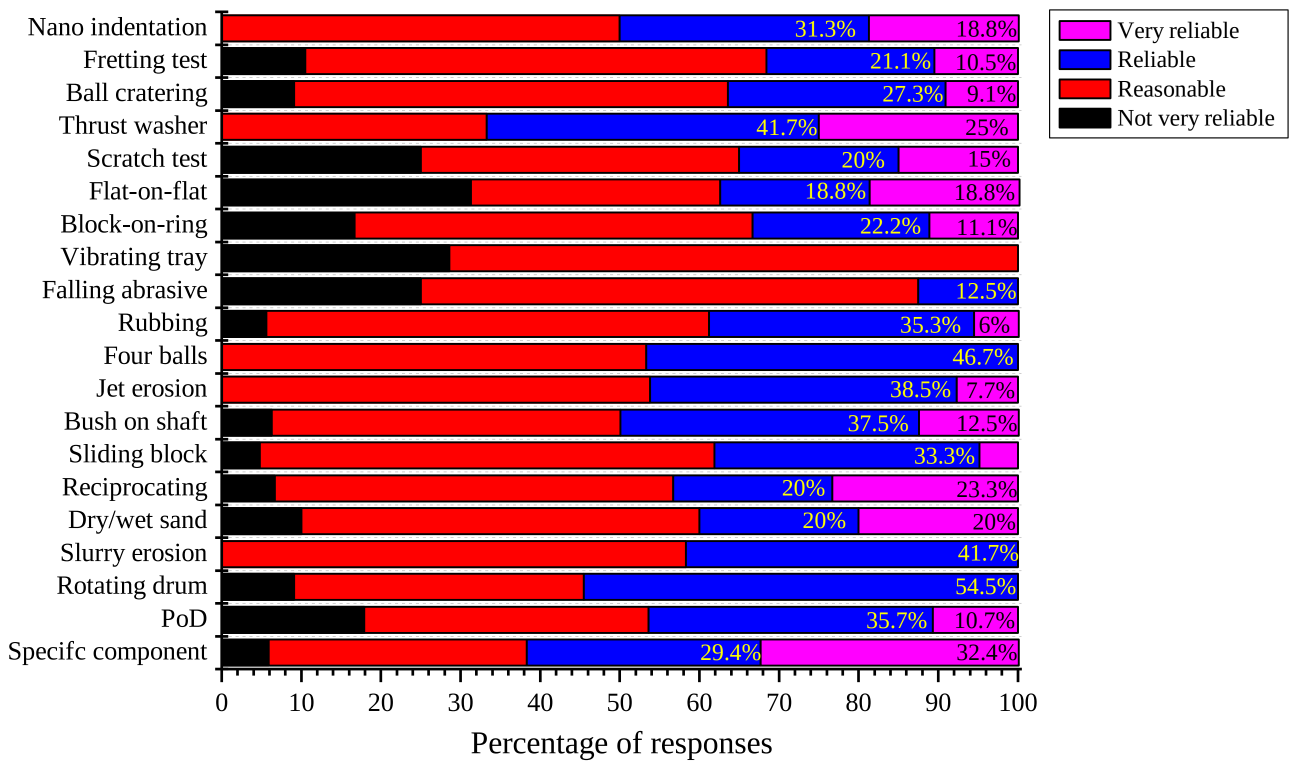

Figure 17 The quality of data from tribological testing

Figure 17 shows the perceived data quality of various tests, mainly laboratory based tests. The specific component tests gave the highest ranking in the 'very reliable' classification at 32.4%, followed by thrust washer and reciprocating at 25% and 23.3% respectively, with the rest at 20% or lower. If the 'very reliable' and 'reliable' classifications are combined, the thrust washer becomes the most *reliable* test, with specific component second. Five of the tests are not perceived as 'very reliable' and these are: rotating drum, slurry erosion, four ball, falling abrasive and vibrating tray, the latter only reaching 'reasonable'. If we now explore the 'not very reliable' only five tests are perceived not to fall into this classification: nano-indentation, thrust washer, jet erosion, four ball and slurry erosion; the latter two have only been classified reasonable or reliable. Of these classified with 'not very reliable', it can be seen that four the tests received

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above 20%, with flat-on-flat the highest at 31%, oddly this also received around 19% in the 'very reliable' classification, suggesting a wide range of experiences with this test rig.

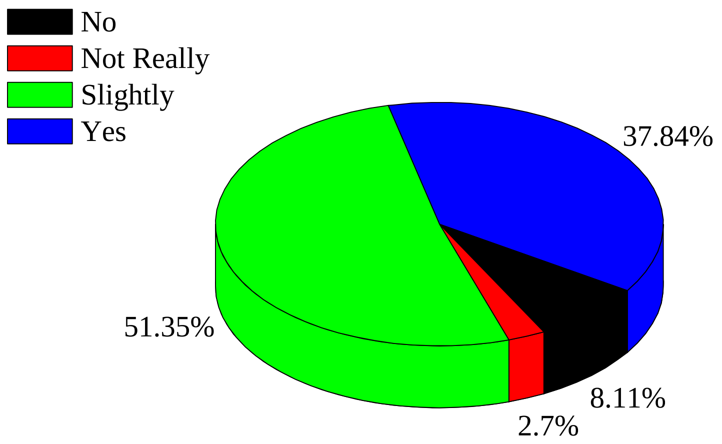

Figure 18 How good is tribological testing at informing users what they need to know.

Following on from how reliable is the data from testing is; to what that actually means; it could mean how repeatable the rig in providing consistent data or it could mean how good is the data produced at relating to the component/system of interest. The latter was explored in the survey and the results, shown by the pie-chart in Figure 18, which suggests that in general there is some information that is used for the final application/solution, with only 38% indicating that the data produced is useful. Around 52% indicate the information is slightly useful. Oddly over 10% indicate that testing was not useful, which probably means it was undertaken to pass an internal standard that is not related to the application of the component.

It was found that 79% of the companies performed accelerated testing and the pie-chart shown in Figure 19, indicates about 30% of the data generated is considered reliable or very reliable. Only 2.6% consider the data not very reliable.

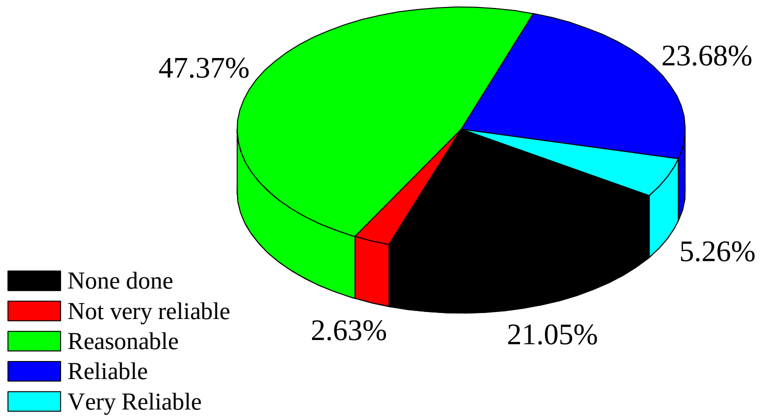

Figure 19 Reliability of accelerated testing data

Figure 20 shows that tribological testing should be more component representative, indicating a desire to push away from generic testing configurations, such as the pin-on-disc, to testing of real components where possible or closer geometries matching when not. There is also indication that better knowledge capture and more reliable tests are desired. Other comments indicate replicating field conditions with respect to temperature, pressure and composition of surrounding media would be a desirable improvement; which poses the challenge that most testing does not replicate field conditions and in some cases rigs have not been developed, except maybe bespoke industrial rigs not seen by the general public, to fully replicate some field

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environments. Also repeat and multi-stationed testing were indicated as useful improvements, which is a push for more reliability in the data that is outputted.

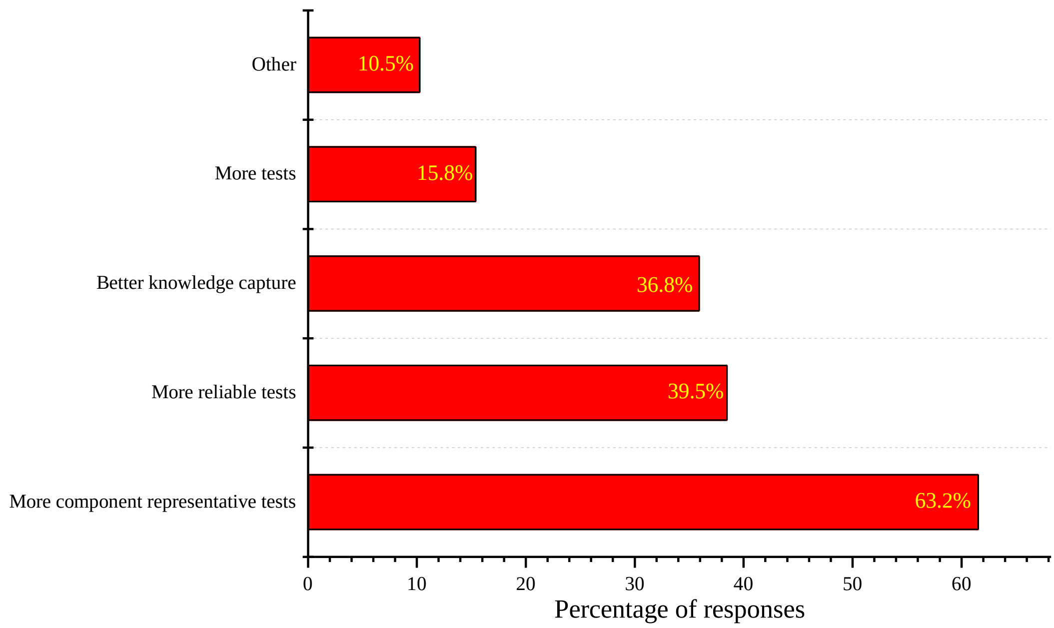

Figure 20 Ways to improve tribological testing

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6 Databases

This section has been split into two parts, the first examining what databases companies have, while the second part tackles the need for a national database and the form it might exist in.

6.1 Company databases

As can be seen from Figure 21, databases are integral part of most companies, with materials, tribological and component databases being the top three, it is also noted that companies with tribological databases that 68.4% also had of materials databases and 47.4% had a component database, while 36.8% had both. The analysis also indicates that 70.6% had more than two databases, 38.2% had more than three, while 17.6% had four or more. For the 'other' option, databases on lubricant properties, heat treatment, fleet and data capture from report library are also indicated.

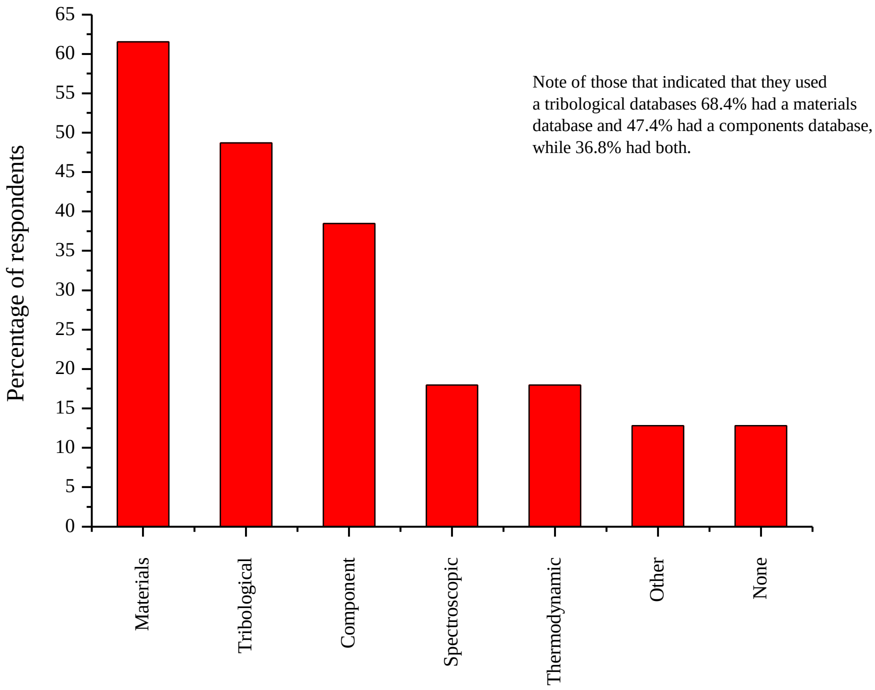

Figure 21 Types of databases in companies

Figure 22 shows that the vast majority of databases employed in companies are custom, this would indicate commercial available databases are general not available or adaptable for the purpose or that the cost is more expensive than designing and building one. This would suggest an integration of databases either together or into specific software requirements/systems within companies.

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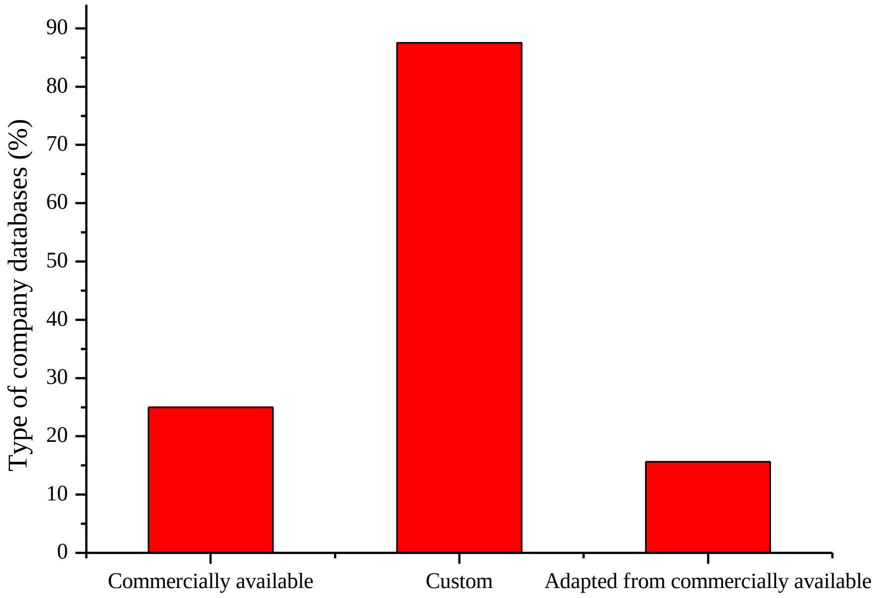

Figure 22 Databases: custom or commercial?

6.2 National Database

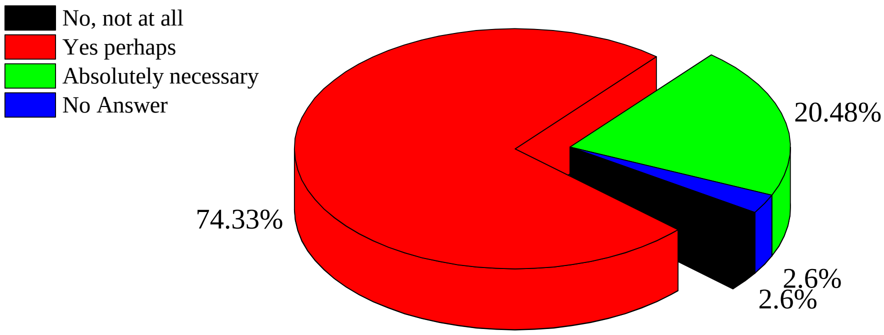

Figure 23 Is there a need for a National Tribological database?

This section explores the need for a national tribological database, how it would work and how it might evolve/form. As shown by Figure 23, there is a clear need for having a national database, with 20.5% saying it is absolutely necessary and 74% indicating yes/perhaps. In terms of subscription, three quarters indicate that this maybe (combined yes and maybe from pie-chart in Figure 24) a way forward, but Figure 25 shows that a downloadable access system, with option of annual subscription, is likely to be the format most favoured. This would have the advantage of appalling to large and smaller companies alike.

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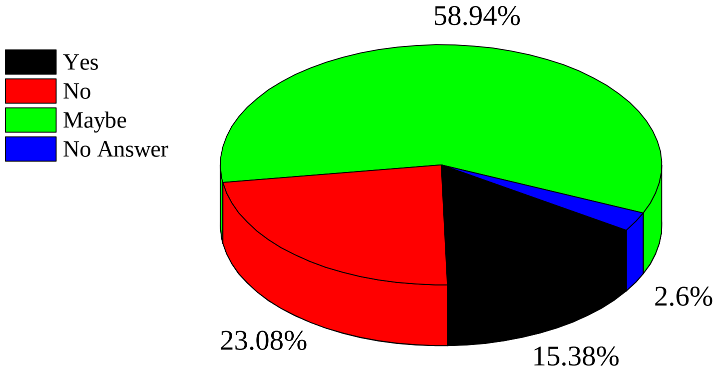

Figure 24 Willingness to subscribe to a National Tribological database

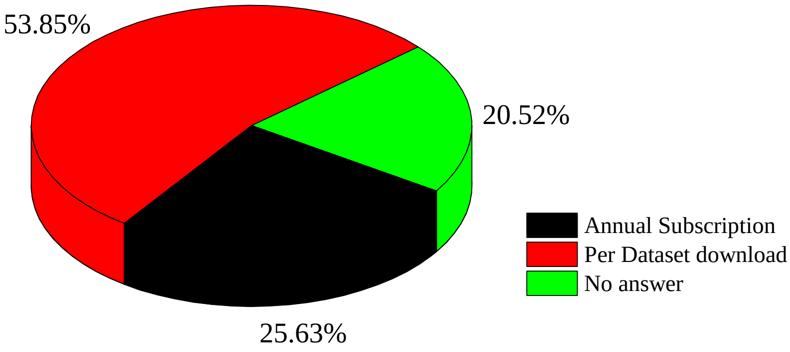

Figure 25 Type of access to National Tribological database

As for how a national database will be formed, this was probed by asking whether company data could be contributed, in a confidential and anonymous manner, and the pie-chart in Figure 26 shows the results indicating a slight bias towards building from this resource. How this would happen and if the academic community could also contribute is something to consider for the future and would probably require considerable time from parties interested to build a self-sustaining entity.

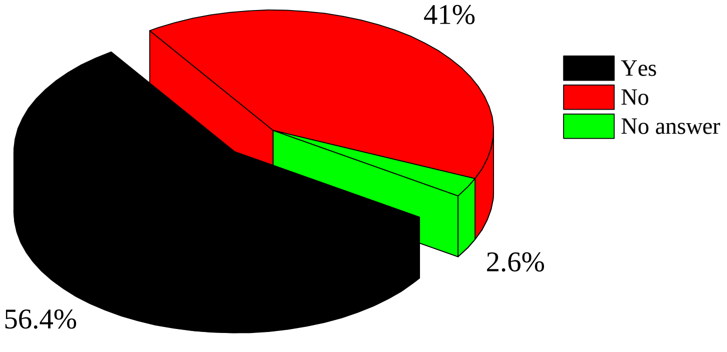

Figure 26 Willingness to contribute data to National Tribological database

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7 Summary

The analysis of the tribological survey was split into five categories and this summary will state some of the key findings from each category:

1. **General**
   a. The survey attracted participants from a wide spread of sectors, with the energy sector exhibiting the highest participation.
   b. The cost of tribology appeared to be highest for companies in the highest turnover bracket, across the sectors, with the energy sector experiencing higher costs compared and defence the lowest.
   c. What is the **true** 'cost of tribology'? For some tribological testing was the biggest outlay. For others it was hard to estimate tribological costs for development, testing right through to the consequences of wearing components.
2. **Important Factors**
   a. Cost is the most important factor for tribological change, followed by reliability and component failure.
   b. Component wear/specific wear rate for tribological components is the most important factor, suggesting component lifetime is of critical importance, especially when it is a system limiting component.
   c. All the factors, from coefficient of friction to environmental conditions to materials, are important to varying degrees, which reflect the vast array of applications and conditions for tribological components.
3. **Wear**
   a. Adhesive wear is ranked the highest when examining just the highest level of importance, but a deeper analysis reveal that overall abrasive wear is the most problematic, followed by fatigue. Indicating when adhesive wear happens it is very problematic, but is generally avoided, while abrasive wear is a problem but cannot always be avoided, such as in mining and oil & gas industries.
   b. Sliding and rolling appear to be the most common type of contacts, but erosion and fluid are also fairly common.
   c. Unsurprisingly metals are by far the most common material type to encounter wear; this is followed by hard coatings, which clearly shows a drive for harsher conditions.
4. **Testing**
   a. Engineering Judgement and Laboratory Tests are most commonly applied in the development of new tribological components, which is probably down to their relatively low cost. It is also noted approximately 25% indicated that all types of the tests stage were always employed, indicating significant expenditure cost of development for these companies.
   b. Approximately 80% indicated that they used an external company to perform testing during development, with laboratory testing being the most commonly done.
   c. In terms of reliability of data from laboratory testing, a mixed response was given, with over 50% of respondents indicating that test data was only slightly useful.
   d. It was found that 79% of the companies performed accelerated testing, but about 30% of the data generated is considered reliable or very reliable, but only 2.6% consider the data not very reliable.
   e. More component representative testing was indicated a clear direction for future testing, with comments also indicating a desire to replicate field conditions (temperature, pressure and composition of surrounding media) as improvements. It was indicated repeat testing for more reliability in the data with better knowledge capture would be desirable.
5. **Databases**
   a. A full range of databases were utilised by companies with materials and tribological databases being quite common. It was interesting that the vast majority of tribological databases were custom, indicating lack of commercially available databases or that 'tailor made' are preferred due to cost or integration with current databases/systems.

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b. There is a clear indication a national tribology database is needed, probably in the form of downloadable access system, with optional annual subscription. There is a slight preference (56%) for this to be formed from company databases.

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8 *Appendix*

The on-line survey consisted of five pages and the questions are listed below with the possible selections, also the type of response available is shown in red.

Page 1

Q1. What sector do you work in? Select multiple areas if applicable. (Multiple tick boxes selection plus ‘other’ text box)

Astronautics + aerospace
Energy
Automotive
Marine
Manufacturing
Chemical
Civil Engineering
Bio-medical
Defence
Other

Q2. What is the approximate turnover of your company? (Single tick box selection)

<£500k
£500k-5m
£5m - 50m
£50 - 500m
>£500m

Q3. How would you describe your role? (Single tick box selection plus ‘other’ text box)

Surface Engineer/Tribologist
Manufacturing/Production
Design Engineer
Modelling
Program Manager
Quality Control
Other

Q4. What is the estimate cost of tribology as part of your company? (Single tick box selection)

<50k
£50k - £100k
£100k - £250k
£250k - £500k
£500k - £1m
>£1m

Page 2

Q5. Please rank from most influencial (1) to least influencial (6) the drivers that affect how tribological changes? (Single selection between 1 and 6 for each part)

Reliability
Reducing time to market
legislation
Environmental
Component failure
cost

Q6. How important is tribology to the following, from not very relevant (1) to very important (10) (Single selection between 1 and 10 for each part)

Design process
component wear

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New Materials

Page 3

Q7. Which of these values are important when designing a tribological component? (Single tick box selection between 'Not Important'; 'Indifferent'; 'Important' and 'Very Important' for each part)

Coefficient of Friction
Specific Wear Rate
Hardness
Contact Pressure
Temperature
Electrical Conductivity
Environment
Surface Treatment Conditions
Lubricants
Thermal Conductivity
Corrosion Resistance
Material Type
Surface Roughness

Q8. What wear mechanisms do you consider as problematic in your sector? (Single drop list selection between 1 and 8 for each part)

Abrasive
Erosion
Adhesive
Fatigue
Cyro
Fretting
High Temperature
Corrosive Wear

Q9. What are the main material groups you deal with that cause wear? (Multiple tick box selections plus 'other' text box)

Metal
Hard coatings
Ceramics
Polymer
Lubricants
Hardmetals / Cermets
Elastomers
Composites (Metal, Polymer, Ceramic)
Glass
Other
Functional Surfaces (Carbon-nanotubes, graphene)

Q10. What contact types are most common in the occuring wear mechanisms? (Single drop list selection between 'Not very common'; 'Not common'; 'Common'; 'Very common' and 'N/A' for each part)

Sliding
Rolling
Impact
Erosion
Fluid

Q11. Prior to the introduction of a new tribology component would you perform any of the following with your own internal tests? (Single tick box selection between 'Always'; 'Sometimes' and 'Never' for each part)

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Engineering Judgement
Machinery Field Test
Machinery Bench Test
System & Service Test
Component Test
Lab Tests

Q12. Do you commission any external tests? If so at what stages? (Single tick box selection)

Machinery Field Test
Machinery Bench Test
System & Service Test
Component Test
Lab Tests
No

Q13. How do rate the quality of data you obtain from the following tests? (Single drop list selection between 'Not very reliable'; 'Reasonable'; 'Reliable'; 'Very reliable' and 'N/A' for each part, plus a comments box)

Specifc component
PoD
Rotating drum
Slurry erosion
Dry/wet sand
Reciprocating
Sliding block
Bush on a rotating shaft
Jet erosion
Four balls
Rubbing
Falling abrasive
Vibrating tray
Block-on-ring
Flat-on-flat
Scratch test
Thrust washer
Ball cratering
Fretting test
Nano indentation

Q14. When you perform the above tests, does the data tell you what you want to know? (Single tick box selection)

No
Not Really
Slightly
Yes

Q15. Do you perform accelerated tests? (Single tick box selection)

Yes
No

Q16. If yes, how reliable is the data you generate? (Single tick box selection)

N/A
Not very reliable
Reasonable
Reliable
Very Reliable

Q17. In your opinion do you agree with any of the following? Add options that we have not included (Multiple tick boxes selection plus 'other' text box)

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More tests
More reliable tests
More component representative tests
Better knowledge capture
Other

Page 4

Q18. Do you use you use your own databases? (Multiple tick boxes selection plus ‘other’ text box)
Spectroscopic
Component
Materials Databases
Tribological
Thermodynamic
Other

Q19. If you have any databases are these: (Single tick box selection)
Commercially available
Custom
Adapted from commercially available

Q20. Do you think there is a need for a National Tribology Database, providing basic material tribological data? (Single tick box selection)
No, not at all
Yes perhaps
Absolutely necessary

Q21. Would you be willing to subscribe to such a service? (Single tick box selection)
Yes
No
Maybe

Q22. If so, would you pay? (Single tick box selection)
Annual Subscription
Per Dataset download

Q23. Would you be willing to contribute data, if it was confidential? (Single tick box selection)
Yes
No

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