CPNI
Centre for the Protection of National Infrastructure

Forcible Attack Resistant Materials (FARM)

Data Spreadsheet Guidance for Security Products Manufacturers

Foreword

This guidance document has been prepared and published by the Home Office Centre for Applied Science and Technology (CAST) on behalf of the Centre for the Protection of National Infrastructure (CPNI).

Audience

This guide is intended for security product manufacturers. The guide is split into three sections. The first section introduces and provides background to the Forcible Attack Resistant Materials (FARM) project. The second section details the research concepts and ideas and the final section provides information on the use of the 'Novel materials data spreadsheet'.

Introduction

What is FARM?

The Forcible Attack Resistant Materials (FARM) project is a collaborative area of work carried out by the Home Office Centre for Applied Science and Technology (CAST), directed and funded by the Centre for the Protection of National Infrastructure (CPNI).

The overarching objective of the FARM project is to seek and identify materials capable of improving the forcible attack resistance of security products against modern tools. One significant strand of this work is to increase the resistance of building fabric, particularly doors and walls, to battery-powered cutting attacks.

The research has identified, tested and demonstrated a number of materials and mechanisms that have the potential to prevent or hinder powered cutting, adding a delay to associated attack times.

A database has been produced detailing all the research carried out to date within the project. The data has been provided to facilitate further development, design and manufacture of security products with greater resilience to these tools. It is hoped that a reduction in cost and weight can also be achieved when compared to the conventional materials used within these products.

What guidance does this document provide?

This document provides guidance on several aspects of the selection and development of novel infill materials to be installed in the voids of security products (such as walls and doors):

- The types of mechanisms and methods that can be employed.
- Considerations when deciding what materials to incorporate.
- Choosing the most appropriate materials to incorporate to mitigate the risk of forcible attack.

This document also provides guidance on the use of the materials database.

What is not covered by this document?

Whilst the guide provides an overview of possible materials to mitigate and their performance against forcible attack, it does not include implementation details or replace the expertise of structural engineers, builders or installers.

Outside the scope of the guidance in this document are:

- The overall design of a security product.
    - The exact combination of materials and construction is the full responsibility of the manufacturer.
- The fixing methods required for the materials and material systems within a product.
    - The manufacturer is responsible for selecting an appropriate method.
    - Tests conducted by CAST used simplistic methods only.
- Guidance on fire safety and resistance of the product.
- Materials to provide ballistic protection (ability to withstand gunfire; for example, for use as a shelter for personnel).
- Materials to provide blast protection (ability to withstand an explosion; for example, from a terrorist bomb).

How should this guidance be used?

The information within this document is to provide advice on the types of materials and mechanisms that have the potential to resist forcible attack, namely from battery-powered tools. The data identifies the types of materials and combinations of materials that have exhibited favourable properties or behaviours for delayed cutting. The research and data presented are indicative of these properties and behaviours, demonstrating the groups of materials that could be used. The research and data is presented to manufacturers to allow further development and installation, building on the foundations tested by CAST. The manufacturer is responsible for this further development, designing a suitable material system for their individual product(s).

The list of materials detailed in the database should by no means be taken as a definitive list. A range of materials have been tested, providing a basis for further development. However, similar materials or materials with similar properties may also provide the same level of protection. Additionally, the information relating to the materials' cost is indicative only and is based on purchasing volumes required for testing.

Determining the type of risk you are mitigating against

The FARM research has investigated methods to mitigate potential vulnerabilities of conventional materials to battery-powered cutting. In recent years the development and advancement of this technology has posed a potential threat, reducing delay times provided by current security products (walls and doors). The use of novel materials, utilising alternative properties and/or novel material behaviours when cut compared to conventional materials, has been identified as a possible solution.

There are a number of cutting mechanisms used by the wide variety of easily accessible battery-powered tools. For the purpose of the research, the main forms (rotary and reciprocating) and the tools that pose the greatest threat (angle grinder, drill and reciprocating saw) have been investigated.

It should be noted that for the purpose of this research if the drill could be defeated or prevented from fully penetrating a material layer, the use of the reciprocating saw (which requires a pilot hole to begin cutting) was considered to also be prevented.

The infill material(s) selected will be heavily dependent on the perceived threat as well as the likely attack scenario. The FARM research has strongly demonstrated that the different cutting mechanisms will cause differing behaviours of the materials, i.e. one material may defeat the drill but is easily cut by the angle grinder. Consideration of common forcible attack methods – levering and impacting – will also need to be taken into account to incorporate suitable properties to counter these.

It is important to decide which of the following requires mitigation:

- Drilling attack – rotary mechanism.
- Cutting attack – reciprocating saw (back and forth motion) and angle grinder – abrasive cut surface.
- Impact and levering – energy transfer and fracture of layers of materials.
- Multi-tool attack – this is the mostly likely where a number of tools and attack methods are employed to gain access.

When considering the attack scenario, the experience of the attacker will also need to be taken into account, in line with the CPNI MFES standard[1]. This will also determine the fixing methods of the infill material(s) within the panel or void.

Tool disruption

The majority of powered tools will incorporate a rotary or reciprocating motion, leaving the tool fitments prone to entanglement, jamming, clogging or blunting. These can be achieved with a number of material properties or mechanisms exploited by a material's structure, construction or configuration.

In cases where a multi-tool attack is the perceived threat, it is likely that a material system incorporating a number of materials and/or mechanisms will be required.

[1] For further information regarding the test standard please contact CPNI.

Loose materials

Loose materials that have the ability to move freely (fully or partially) within a void or panel have the potential to interact with the tool fitment, in a way that is detrimental to the cutting progress.

On contact with a rotating fitment, loose material such as fibres (natural, aramid, metallic) can be drawn in with the rotation, wrapping tightly around the fitment eventually jamming the mechanism and preventing further movement and cutting. The speed of the rotation of the tool will further add to the jamming mechanism, so the more the material comes into contact the more entanglement will occur. Additionally, as the material is drawn in a volume will collect, preventing the release and removal of the fitment from the panel or material layer.

On contact with the reciprocating or abrasive fitments, loose material can also get drawn in and prevent further rotation or movement. This may not be to the extent seen with rotating fitments described above, but it has been seen to be enough to momentarily stop cutting, which will add some delay as well as frustration to the attacker.

If the material itself oscillates at the same frequency as the blade, it will prevent the blade from gaining purchase.

The properties of the material will determine the effectiveness, with a degree of surface roughness required (to enable interaction with the fitment surface as well as surrounding material) and overall strength (so as to not snap and allow rotation/motion to continue, etc.).

Anti-cut or abrasive materials

A number of tools using abrasion are highly effective at cutting a large range of materials. One such tool is the angle grinder which uses an abrasive disc to wear away the surface at a high rate to cut through the material. There are a huge variety of discs for this type of tool but most will incorporate particulates that have high hardness properties (commonly ceramic).

By using high-hardness materials that have a higher hardness than the abrasive disc (such as high hardness steals, e.g. Manganese steel), the cutting rate can be hindered. However, as the tool technology progresses, a greater thickness of these steels is required for the same level of delay.

The use of alternate high-hardness materials could be the solution to the requirement for thicker metallic elements. The surface incorporating the higher hardness will cause the greater level of wear. A number of materials and material types are known for their high hardness properties; for example, ceramics which come in a number of forms – powders and particulates to continuous sheets. As with any material selection, all properties should be carefully considered; materials that have high levels of hardness tend to be inherently brittle and will require additional design to counteract.

The use of alternate materials could also reduce the associated weight and cost of the product as well as those of the manufacturing processes.

Thermal changes

During the cutting and drilling process, heat is released (friction as the two surfaces interact). Materials that undergo thermal changes could be advantageous at jamming or clogging the fitment. Materials that melt with temperature increases (e.g. plastics) could coat the fitment, accumulate and eventually preventing cutting. The increase of temperature at the material surface could also be used to activate chemically reactive materials. A material that itself could increase the temperature at the cutting surface could aid in destabilising the fitment.

CAST material testing

The research conducted by CAST and academia has identified, tested and demonstrated a number of materials and mechanisms that have the potential to prevent or hinder powered cutting, adding a delay to associated attack times. The full performance and mechanisms are listed in the FARM data sheet, but of particular interest are:

- Loose fibres:
  - Both high performance and low performance fibres were seen to effectively jam the drill bit, with some disruption of the functioning of the angle grinder.
  - The amount of fibres present, length and how the fibres were fixed (to reduce likelihood of loss of coverage) were seen to be key factors in the success of this group of materials.
  - Coiled fibres were also seen to rapidly jam the drill bit (however, no cut resistance was seen).
- Woven fabrics:
  - As with the loose fibres, a range of woven fabrics were seen to effectively jam the drill bit, especially when loosely fixed.
- Ceramics:
  - Highly effective at preventing cutting and cause significant wear to drill bits, angle grinder discs[2] and reciprocating saw blades.
  - The effectiveness of this group of materials will be highly dependent on one or more of the following: the grade, fixing method and form; however, low grade ceramics have been seen to perform well.

[2] Please note the angle grinder discs tested were general purpose, which are most commonly used. High performance discs, such as Diamond etc., have not been tested and performance is likely to be different due to the increased abrasive nature of these discs.

  - A material system of low grade ceramic spheres ('baking beans') within a resin matrix was seen to provide significant resistance to all tools trialled; however, the inherent brittleness of ceramics will also need to be carefully considered and may require reinforcement or dampening system to counter impact.

- Moving elements – having elements within a system that move or rotate with the cutting fitment has been seen to reduce effectiveness of the tool. This could be sheets of material free to move (fixed one end) or spinning rods.

Material selection considerations

In addition to the properties and behavioural mechanisms of the materials previously discussed, there are a number of further aspects that need to be considered when selecting appropriate infill materials.

- Fire safety.
- Fixing methods – careful consideration needed as the fixing method will be integral to some mechanisms effectiveness.
- Sustainability and environmental impact.
- Maintenance of breakdown and through life of product.

FARM material data spreadsheet

The FARM 'Novel Materials data spreadsheet' details the materials identified and tested to date within the project that have the potential to delay battery-powered cutting tools such as the drill (and therefore reciprocating saw due to restricted access) and angle grinder. The database indicates the type of material or material system's potential performance against these tools. The aim of this database is to advise and aid the development and production of security products incorporating novel materials to prevent powered cutting.

The data detailed should be taken as **indicative**; it is to be used as a guide and is by no means a definitive list. The materials tested will also aid in identifying similar materials that could be used to produce the same mechanism and performance. It should be noted that it is likely that a combination of materials or a material system is required to delay multiple tools.

The data is presented in several sub-groups, with each subsequent sub-group detailing the performance data in greater detail. A colour-coded system has been used for easy identification of performance levels.

The following should be noted:

- Due to the nature of the tests (small-scale research) implications associated with scaling up have not been addressed and are therefore not included within the data.
- Limited or basic fixing methods have been researched and as such it is recommended that those detailed are used as a starting point.
    - Appropriate fixings should be chosen to suit the specific application and requirements of the mechanism being employed.
- Due to the similarity between performances of the mains and battery powered (36 V) versions of each tool, the performance indicated is applicable for both.
- At time of testing, 36 V tools were considered the likeliest threat.
    - It has since become apparent that tool manufacturers are concentrating on the development of the 18 V tool and battery technology.
    - Initial testing carried out indicates that the performance and mechanisms seen with the 36 V are still applicable.

To request a copy of the database please contact CPNI through the 'Contact us' section of the CPNI website at www.cpni.gov.uk/contact-us/.

How to use the spreadsheet

The spreadsheet has been designed to provide a range of information on all of the materials and material systems tested by CAST during the FARM project. This also includes details on the academic-based projects. An overall performance rating is provided and allows further investigation of each material or material system with the rating of specific factors, such as type of mechanism, level of wear of fitment, etc.

The spreadsheet also includes details of the related academic projects as part of the FARM project.

A simple colour-coded system clearly identifies the indicative level of performance for each material or material system.

- Green – successful at delaying or defeating the tool.
- Amber – partially successful, may require further development.
- Red – little to no effect.

The spreadsheet also provides other useful information such as:

- examples of the materials used during the CAST testing;
- details of academic and industrial partners and points of contacts;
- suggested possible funding opportunities.

Easy-to-use links allow navigation from section to section, providing access to more detailed performance and associated additional information. A back button at the bottom of each page will navigate back to the overall performance page.

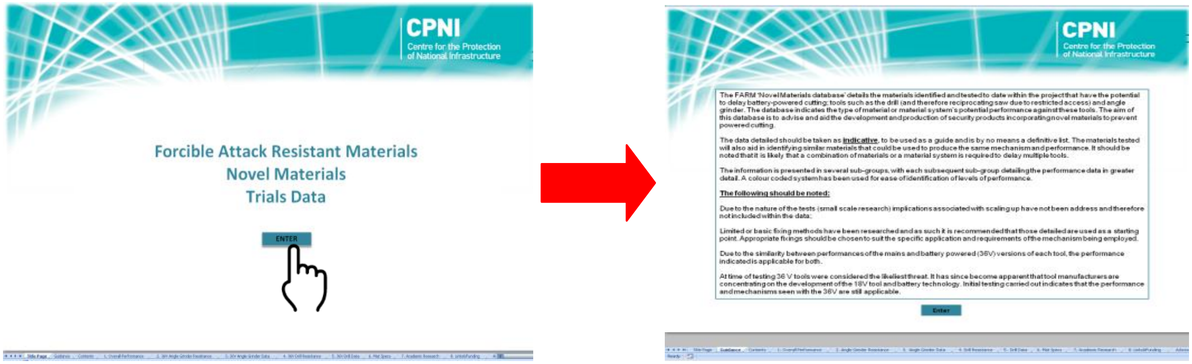
All pages displaying performance information will list the material type, material configuration, and overall performance rating as referenced.

Navigation – step-by-step guide

1. Introduction

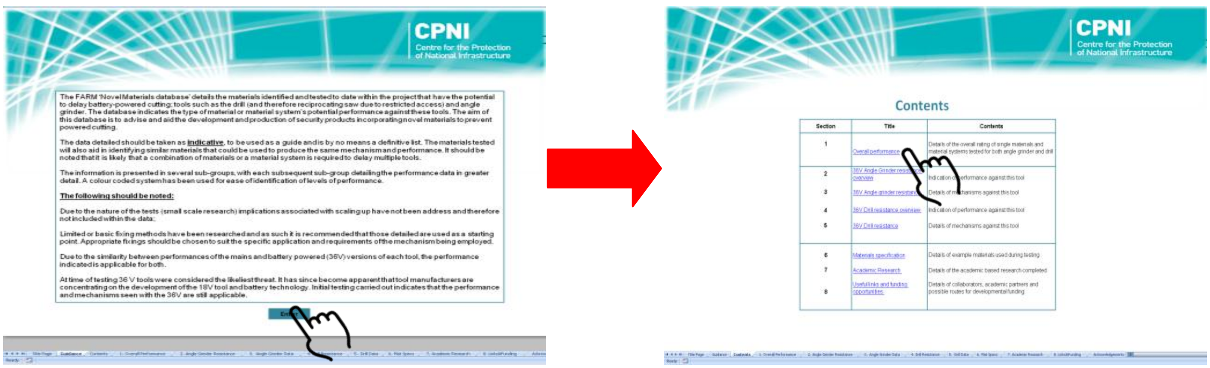
On opening the spreadsheet the title page should be the first page visible; if this is not the case the page can be accessed via the tabs at the bottom of the page.

Clicking the ENTER button will direct you to the introduction and general guidance on how to use the spreadsheet and information detailed within.



N.B. Navigation tabs at the bottom of the screen can also be used to navigate through the spreadsheet; **however**, it is strongly recommended, especially on the first time of use, that the links and process described in this guidance are used to navigate through the information in order.

From the guidance page, clicking the ENTER button will direct you to the contents page. Here each page of information can be accessed by clicking on the desired section title. On first use it is recommended to click Overall Performance, which will direct you to the overview of material performance.



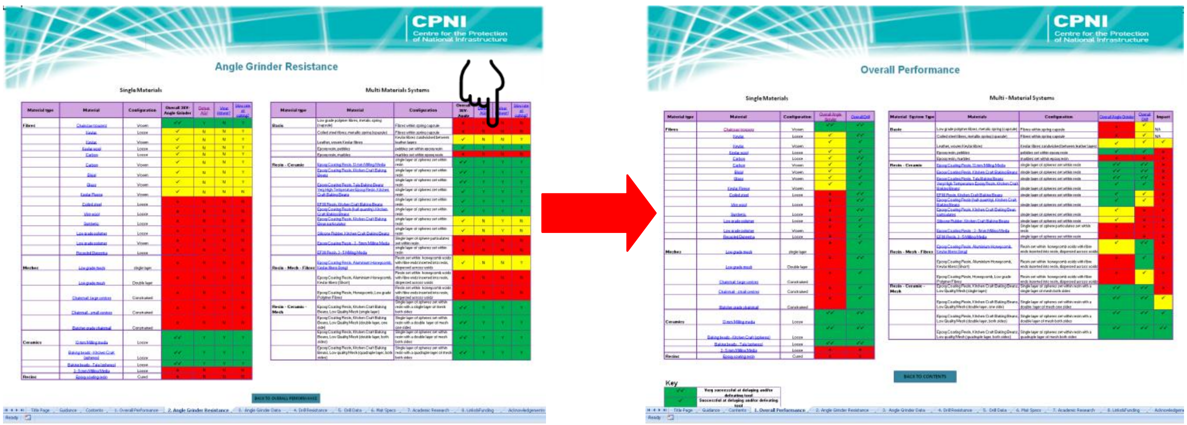
2. Performance overview

This section provides an overview of the overall **indicative** performance of all the materials and material systems tested. This rating has been calculated using a number of factors, such as level of wear, level of disruption and level of cutting rate affected.

A colour-coded rating system (Green, Amber, Red) has been used for easy identification of performance. Additionally a tick and cross category has also been used, indicating the level of success or failure. A key detailing the categories can be found at the bottom of the page.

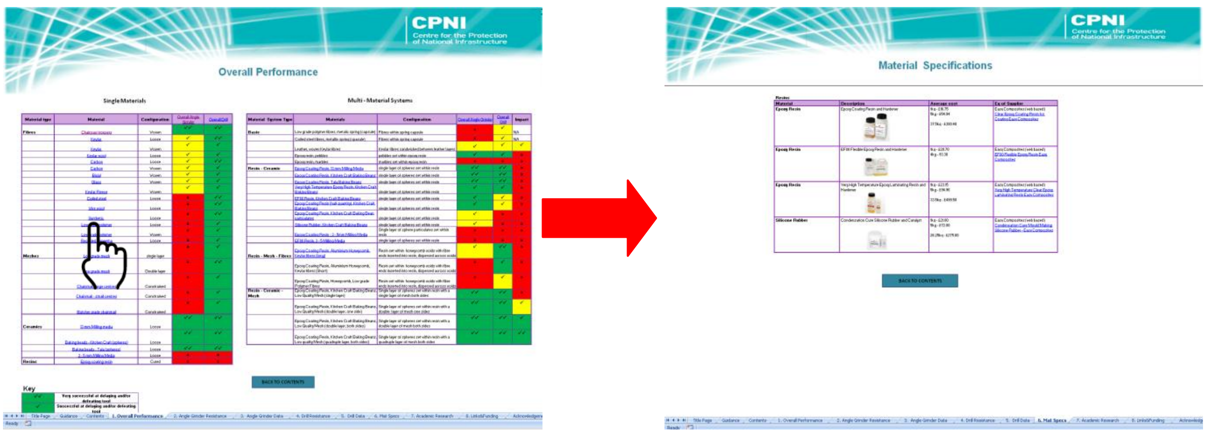
There are a number of links within the Overview to direct to more detailed information. Any information that is in blue and underlined is a link to this further information.

Clicking on the links at the top of the columns (e.g. overall angle grinder) will direct you to further information indicating the mechanisms or effects of delay and/or defeat.



Click on the BACK button to return to the Overall Performance page.

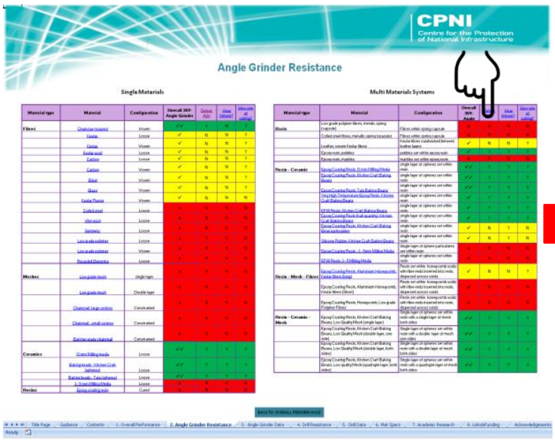
Clicking on each material, e.g. Low Grade Mesh, will direct you to the specifications of the materials tested by CAST. Please note these are only examples of available materials.

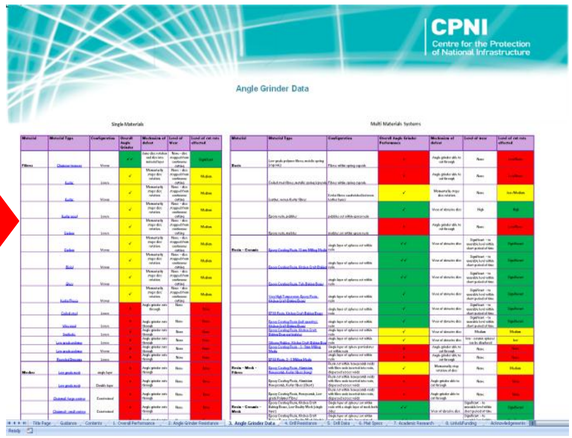


Click the BACK button to return to the Contents page.

3. Performance against specific tool type

Having clicked on the desired tool on the Overall Performance page, further information on the mechanisms or effects can be seen. This includes how the mechanism works, level of fitment wear and how the cut rate is affected. Clicking on the links at the top of the columns (e.g. Wear Fitment?) directs to you this information.



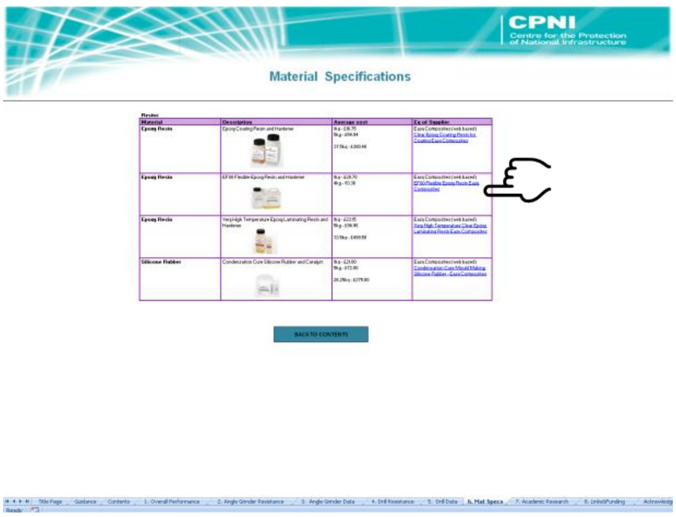


Click the BACK button to return to the Overall Performance page.

4. Material specification

This page provides examples of the materials used within the tests completed. Details of examples of possible suppliers and average costs (at time of publication) are also listed. Clicking on a supplier's name links to their associated website.

N.B. Due to the small scale nature of the tests, these suppliers may not be appropriate for larger bulk orders.



Click the BACK button at the bottom of the page to return to the Contents page.

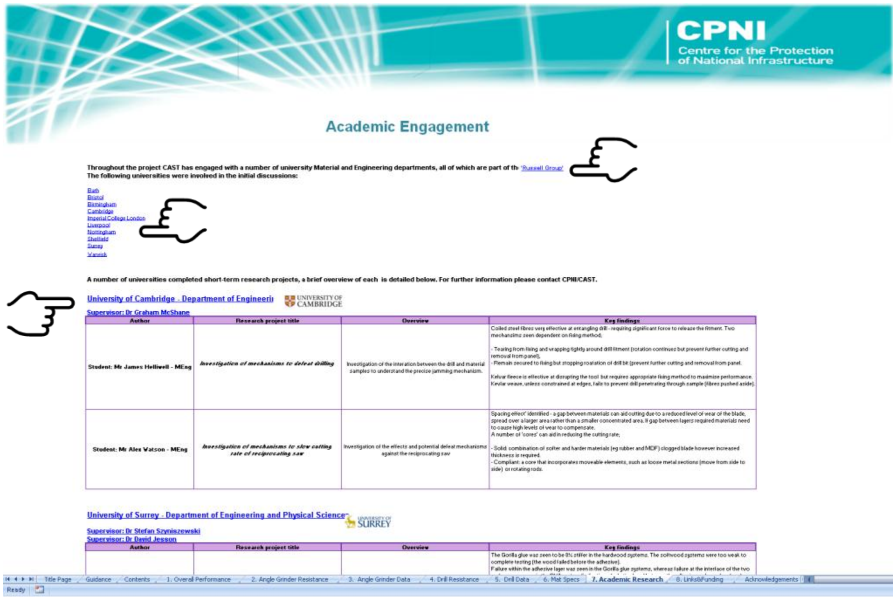
5. Academic research

This page provides useful academic-based contacts used to inform the project. The universities contacted are part of the 'Russell Group' – detailing universities known for their research excellence. Further information on the Russell Group and its members can be found by clicking the link (Russell Group).

This page also lists a number of universities who were involved in initial discussions regarding materials and mechanisms. Clicking on each university will direct you to their associated material/engineering departments where further information on the current research and points of contact can be found.

The page also provides an overview of the five short-term research projects completed as part of the FARM project. For further detailed information regarding these projects, please contact CPNI/CAST.

Further information on each of the universities, as well as contact details of the project supervisor, can be accessed by clicking the links provided.



Click the BACK button at the bottom of the page to return to the Contents page.

6. Useful links and funding information

This page provides useful links and information on possible funding opportunities to aid research and development. A number of examples of government initiatives, with links to the associated websites, can be accessed by clicking each of the initiative names.

Information on possible academic collaboration, as used by CAST throughout the project, has also been provided. Please note that further information on the terms of academic collaborative partnership will need to be accessed via the selected university's website.