Angle Grinder Sparks - Measuring Fire Hazards to Clothing

P.J. Fardell and Carol Rock
Fire and Risk Sciences (FRS), Building Research Establishment

ABSTRACT

Over a period of years, there have been regular reports to the Health & Safety Executive (HSE) by people using angle grinders of clothing fires. The Building Research Establishment (BRE) has carried out laboratory work for HSE to study the ignition of clothing by grinder sparks, and the subsequent flame spread. Many types of fabric could not be ignited as flat horizontal or vertical surfaces by grinder sparks. Sparks either bounced off or melted the fibres and a hole developed without ignition. Crumpled or curved surfaces could however be ignited. A test was developed to compare the times to ignition of different fabric samples. The flame-spread test used a textile sample held at 25° to the horizontal to obtain reasonable differentiation between samples. The results have relevance to the selection of clothing worn when operating an angle grinder, and to safe operating practices.

INTRODUCTION

Statistics gathered by the UK's Health and Safety Executive (HSE) as part of their 'FIREX' database [1] have shown a continuing incidence of burn injuries caused by the impact of hand-operated angle grinder sparks impinging on clothing. There have been at least ten such incidents over the last ten years including three serious injuries.

The Fire and Risk Sciences (FRS) division of the Building Research Establishment was invited to design, develop and establish standard test apparatus and procedures for measuring the time to ignition and rates of flame spread when clothing fabrics are subjected to constant stream of angle grinder sparks.

The intention is to use the method to determine the ignition and flame-spread characteristics of fabrics that may be encountered in the workplace, both as normal and workwear clothing. There was no requirement to set criteria for hazard classification although this would form a logical next step.

TEST METHOD DEVELOPMENT

The spark generator

The angle grinder used was a 'Ferm' model FAG115N, 710 Watt, for 115 mm (4½") grinding discs. It was fitted to the recommended stand and bolted on a workbench. A range of disc-cutting materials and workpieces were initially investigated for production of a continuous and repeatable stream of sparks. The final choice was a 'Screwfix Pro Grind' disc applied to a workpiece consisting of a mild steel square box section (standard stock) with outside dimensions 50mm square and wall thickness 7mm. A nominal 300mm length was found suitable for extended operation.

Figure 1 shows the final arrangement used.

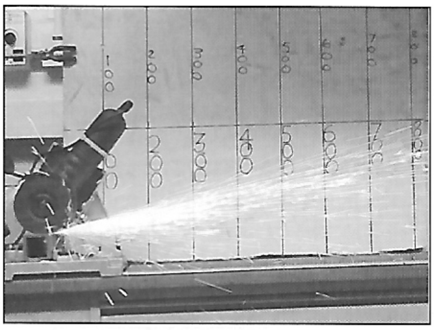

Figure 1: Apparatus developed to produce a uniform and repeatable stream of sparks from a proprietary hand angle grinder.

As shown in Figure 1, the test apparatus produced a uniform stream of sparks with a relatively compact central core up to approximately 300mm from the point of application of the grinder wheel to the workpiece. After this point the sparks diverged markedly and became less concentrated. Within relatively wide limits, the hand pressure applied to the grinder stand handle did not affect this pattern of sparks significantly, and several operators were able to readily duplicate the spark pattern shown in Figure 1.

Sample holder for determining time to ignition

Initial trials, to measure time to ignition, used a fabric sample stretched across the stream of sparks at the 300mm point. A wide range of synthetic, natural and mixtures of fabrics were subjected to the sparks but it was found impossible to ignite any fabrics in this way. Synthetic fabrics tended to melt at the point of impact, producing a hole in the sample which prevented further contact with the sparks: they simply passed through the hole. Most of the natural fabrics allowed the sparks to bounce off the surface (and in some cases produce a hole), with no opportunity for them to settle and cause ignition.

Later trials used a horizontal sheet of fabric but again the sparks bounced off the natural fabrics or produced a melted hole in the synthetic fabrics. The effect of an inert insulating substrate behind the test fabric was also studied but did not produce ignition with any fabric in any orientation. Figure 2 shows a typical effect obtained with a cotton, stretched-denim material.

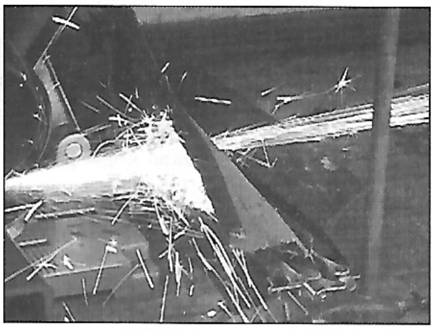

Figure 2: Sparks impinging on a flat fabric surface (cotton stretch-denim) showing a hole developing.

It was observed that if sparks were allowed to impinge on a fabric specimen that had been randomly crumpled to produce several folds and cavities, the sparks tended to bounce within the cavities resulting in a higher residence time and leading to ignition with many fabric types.

Figure 3 shows a sample of open-weave, cotton fabric igniting in this way.

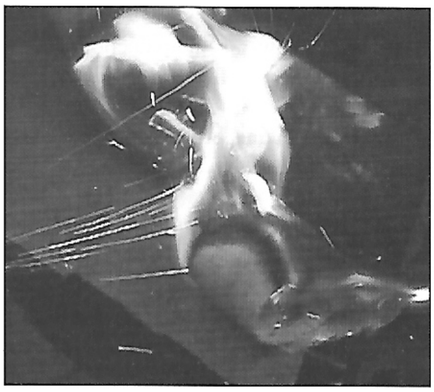

Figure 3: Ignition of a crumpled fabric sample (open-weave cotton) following exposure (about 25 seconds) to a stream of sparks from a hand angle grinder.

Following further trials, a prototype sample holder was developed, which produced a vertical 'U'-shaped cavity in the fabric approximately 15mm wide and 65mm deep.

Figure 4 shows the prototype sample holder with fabric in position.

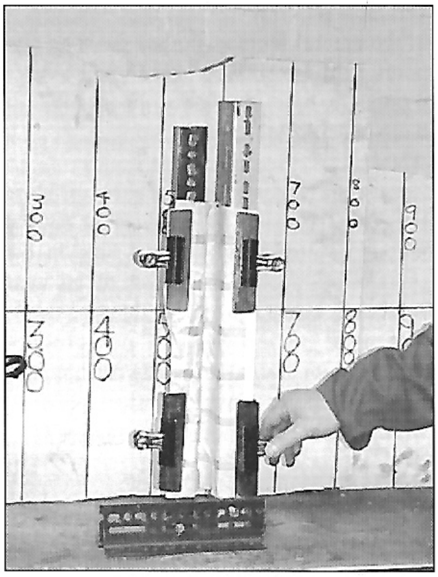

Figure 4: Prototype fabric sample holder for ignition trials with hand angle grinder sparks showing the 'U'-shaped cavity required to increase the sparks' residence time

Measurement of time to ignition

Following the development of a method for producing a repeatable and uniform stream of sparks that could ignite fabric samples in a prototype vertical sample holder, it was observed that the time needed for ignition of a particular fabric sample was still subject to some variation. The procedure adopted therefore was to carry out five nominally similar timed applications of sparks to a fresh fabric sample surface. Only when all five samples ignited was this time taken as the 'time to ignition'. Time increments (in seconds) used were 5, 10, 15, 20, 30, 40 and 'longer'. For this work a new sample holder, constructed from an open-wire mesh was used which showed some reduction in time to ignition of fabrics from that obtained with the 'handy angle' prototype - ascribed to the greater 'heat sinking' properties of the handy angle holder.

Rate of flame spread - the 'FMVSS' apparatus

It had been originally intended to measure both time to ignition and rate of flame spread using the same apparatus. Although a reliable method of measuring times to ignition had been developed and progressive vertical propagation of flames occurred after ignition, it proved very difficult to observe the rate of movement of the flame front in the vertical sample holder. Subtle folds and pieces of fabric twisting and falling in a random manner were obviously affecting the flame spread characteristics. The actual flame front on the fabric surface was also often obscured by the flame itself and in some cases by the associated dense fumes/smoke. This resulted in difficulties in accurately timing the process.

It was considered necessary to develop a separate apparatus for measuring flame spread where the conditions could be better controlled and progress of the flame front accurately observed and measured. An ignition source of higher intensity than provided by the grinder sparks was required (as ignition was to be assumed) with the only requirement being to measure self-propagating flame spread.

An existing standard apparatus, used to measure the horizontal flame spread of fabrics used for vehicle interiors - the Federal Motor Vehicle Safety Standard (FMVSS) 302 (1972) [2] - was subsequently adapted for this purpose. This standard test is also the basis for other standards concerned with fabric flammability in vehicle interiors viz BS AU 169A [3], ISO 3795:1989 [4] and forms one of the three tests called up under EU Directive 95/28/EC [5].

The apparatus, shown in Figures 5 and 6, consists of a stainless steel combustion chamber, of dimensions 360 mm high by 385 mm wide by 204 mm deep. The front panel is a removable fire-rated glass observation window.

To allow free passage of air, the bottom of the chamber has a two by five array of vent holes with a corresponding 15 mm high vent slot along the top edge of the compartment sides.

The sample holder consists of two U-shaped metal plates, each measuring 361mm long by 100 mm wide by 10 mm high. The sides of the U-frames are 25 mm wide and the bases are 31 mm wide, which leaves an exposed area of fabric sample 330 mm long by 50 mm wide. A wire support is utilised to hold the fabric in flat planar orientation with no significant folds. A 0.25 mm diameter heat-resistant wire spans the lower U-frame at 25 mm intervals. Grooves, 2 mm wide, are cut into the base of the lower U-frame to guide the wire and locking screws at both ends of the frame and hold it firmly in position.

The sample holder is held in a support frame such that the lower face of the specimen is 178 mm above the floor of the chamber. The front edge of the sample holder is positioned 22 mm from the end of the chamber, equidistant between the back and front. Molten material is caught in a drip tray positioned beneath the sample holder.

To aid flame spread rate observations, measuring points are marked at 25.4 mm intervals across the top of the sample holder. The first and last measuring points are located 38 mm and 292 mm respectively from the open end of the holder.

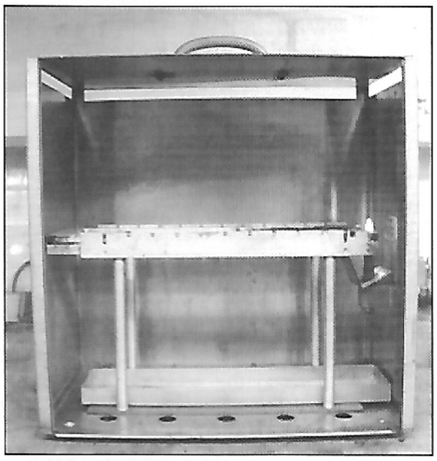

Figure 5: The 'FMVSS' test apparatus adapted for use to measure the rate of flame spread on fabrics that may be ignited by sparks from a hand angle grinder (horizontal specimen)

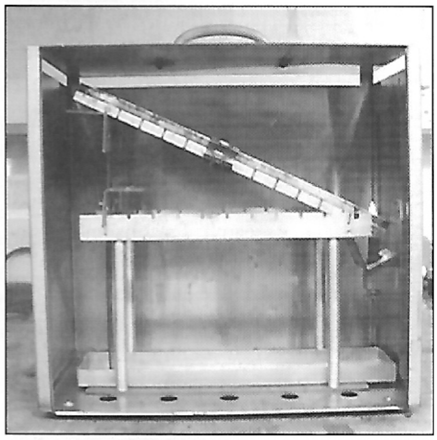

Figure 6: The 'FMVSS' test apparatus adapted for use to measure the rate of flame spread on fabrics that may be ignited by sparks from a hand angle grinder (25° inclined specimen)

Ignition source in the FMVSS flame spread test

The flame ignition source is a Bunsen burner, used in the 'diffusion flame' mode (i.e. no premixed air) fuelled by natural gas and having a burner inside diameter of

9.5mm (0.4"). The burner is located such that the centre of the nozzle is 19 mm (0.75") below the open edge of the specimen.

The gas flame is adjusted to a height of 38 mm and the flame is allowed to stabilise for at least 60 seconds before starting the test. The open edge of the test specimen is then exposed to the flame for a period of 15 seconds.

Pass/Fail criteria for the FMVSS test

There are two criteria for 'pass/fail' stated for the original application:

(i) The flame should extinguish before reaching the end of the specimen, or failing that,

(ii) The horizontal burning rate should be less than 100 mm/min.

The test in its original intended application provides a means of screening out materials that are likely to facilitate lateral flame spread, which might allow a fire to spread between materials in the interior construction of some types of motor vehicle. These criteria may also therefore be applicable to this work to determine acceptable levels of flame spread on fabrics ignited by grinder sparks.

Full-scale manikin tests

Following the completion of the test method development and obtaining ignition times and flame spread rates for ten fabrics and variants (i.e. including fabrics contaminated with common flammable 'workshop' materials and laundered and unlaundered flame retarded (FR) materials) two tests were carried out on a manikin 'dressed' in a non-FR and a 'Proban' FR-treated cotton material. To simulate the approximate thermal properties of a human, the arms, legs and torso of the manikin were constructed from mineral wool.

RESULTS

Summary

Table 1 summarises the results for time to ignition on the various fabrics used in the study.

Table 1: Summary of results of ignition times and flame spread rates, for fabrics ignited by sparks from a hand angle grinder

Material number	Fabric description	Time to ignition (Seconds)	Mean rate of flame spread (horizontal) (mm/min)	Mean rate of flame spread (25° incline) (mm/min)
1	35% polyester, 65% cotton	10	176	889
2	100% cotton (close weave)	20	131	891
3	100% cotton "FR" (interliner)	10	0	450
4	100% polyester	Not measurable (melted and formed hole).	0	85
9	100% wool (suiting)	45	0	0
10	100% cotton "FR" (corduroy)	Did not ignite.	0	143
11	Denim (cotton) stretch fabric	20 (lengthwise) 30 (widthwise)	84	407
12	Polyester fabric quilt over wadding	10	80	391
13	100% polyester	Not measurable (melted and formed hole)	0	248
14	100% polyester over 100% wool (two layers)	30	0	0
16	100% cotton with "Proban" FR treatment - unlaundered sample.	30 (only small flamelets observed for 2 seconds).	0	0
17	100% cotton with "Proban" FR treatment - laundered sample.	10 (only small flamelets observed for 2 seconds).	0	0
18	100% cotton (material 2 equivalent) with grease contaminant.	15	140	728
19	100% cotton (material 2 equivalent) with paint contaminant.	Ignited in only one trial at 60s. Feeble fleeting flame.	91	496
20	100% polyester (material 13) with grease contaminant.	Ignited in only one trial at 40s.	254 (Extinguished after 16 secs)	9.4
21	100% polyester (material 13) with paint contaminant.	30	170	587

The test specimens were conditioned to EN Standards [6] for at least 24 hours but not more than seven days in an environment with a temperature of 23±2°C and a relative humidity of 50±5%. The specimens were maintained under these conditions until immediately prior to testing. As shown the fabrics tested included pure natural and synthetics, natural synthetic mixtures, combinations, FR types, a laundered FR type and those where a contaminant (grease or paint) was present on the surface.

Natural and synthetic fabrics

The ignition study showed no particular distinction between natural and synthetic fabrics in terms of time to achieve ignition. However the 'mechanism' in each case was different. Natural fabrics (e.g. cotton and wool) tended to form a surface char whereas synthetic fabrics tended to melt and form a hole. Both mechanisms could result in a 'no ignition' result for some fabrics. Unsurprisingly synthetic/natural mixed fabrics showed both mechanisms. Where ignition did occur, ignition times for different fabrics could vary between 10 and more than 60 seconds.

With flame spread, rates were generally significantly faster for the fabrics inclined at 25 degrees to the horizontal and in some cases produced flame spread not observed with a horizontal sample. As with ignition times, there appeared to be no particular distinction between natural and synthetic fabrics - both could exhibit 'zero' flame spread although again the mechanism of natural fabrics charring and synthetic materials melting was obviously affecting the result. Flame-spread rates varied between 80 and 254mm/min for the horizontal samples and 89 and 891 mm/min for the inclined samples. These can be compared with the 'FMVSS' pass-fail criterion of 100mm/min.

FR treated fabrics and effects of laundering

One FR-treated, cotton material (fabric 3), sold as an 'interliner' from a local store, ignited after 10 seconds. A sample of 'Proban' (an FR compound based on phosphorus) treated cotton was therefore obtained from a supplier to the workwear garments trade and checked for phosphorus content by elemental analysis. This showed a phosphorus content of 2.2% - within the accepted rang for an adequately FR-treated, cotton material [7]. This latter material ignited after 30 seconds but flaming was not sustained. No flame spread was observed in either of the two orientations used. The fabric was then subjected to a standard laundry cycle [8] and retested. The laundered material ignited after 10 seconds but again the flaming was not sustained for longer that a few seconds. No flame spread was observed.

Fabrics contaminated with grease or paint

A natural (cotton) fabric (equivalent of fabric 2) and a synthetic (polyester) fabric (fabric 13) were both contaminated with a petroleum-based grease and a commonly available oil-based (dried) gloss paint. With grease contaminant the cotton material showed a reduced time to ignition from 20 seconds (uncontaminated) to 15 seconds (contaminated) but with paint the ignition time was extended to over 60 seconds and the flame was fleeting and feeble. The polyester material, which did not ignite when uncontaminated, ignited fleetingly with grease contamination at 40 seconds in one trial and after 30 seconds with paint contaminant.

Flame-spread rates were similar with the cotton fabric with and without grease. With the polyester fabric grease contaminant produced a relatively rapid flame spread in the horizontal orientation for 16 seconds before extinguishing (it showed zero flame spread without contaminant) but a reduced flame spread in the inclined orientation.

These variable results must be considered to be due in part to the difficulties experienced in applying a uniform and consistent level of contamination on the fabrics.

Manikin tests

Figures 7 and 8 illustrate the results of the tests on a manikin dressed in an FR-treated and a non-FR-treated 'boiler suit' respectively.

The 'Proban' FR-treated boiler suit showed no sign of igniting after five minutes of sustained impact from sparks. The main effect was to punch a hole in the fabric, which smouldered and glowed at the edges for a few seconds after halting the flow of sparks.

The non-FR-treated boiler suit ignited readily after approximately 20 seconds of sustained impact from sparks.

Figure 7: Application of hand angle grinder sparks to a 'Proban' FR-treated 'boiler suit' on a clothed manikin. No self-propagating flames were observed after 5 minutes of sustained spark impingement

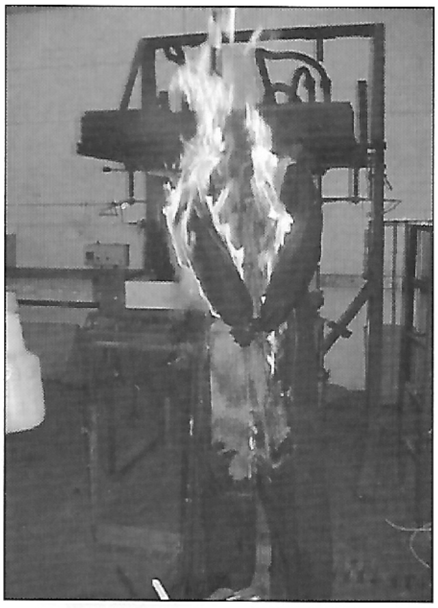

Figure 8: Application of hand angle grinder sparks to a non-FR-treated 'boiler suit' on a clothed manikin after approximately 45 seconds. Self-propagating flames were observed after approximately 20 seconds of sustained spark impingement

REFERENCES

1. "FIREX" - HSE Technology Division's Database

2. Federal Motor Vehicle Safety Standard (FMVSS) 302: flammability of interior materials. US Federal Register Vol. 36 No. 232

3. BS AU 169a: 1992. 'Method for determination of burning behavior of interior materials for road vehicles, tractors and machinery for agriculture and forestry' BSI 1992

4. International Standard ISO 3795:1989 'Method for determination of burning

behavior of interior materials for road vehicles, tractors and machinery for agriculture and forestry' International Organisation for Standardisation, Geneva, 1989

5. EEC Directive 95/28/EC of the European Parliament and of the Council of 24 October 1995 relating to the burning behaviour of materials used in the interior construction of certain categories of motor vehicle. 'Burning behaviour of internal materials' Issue: 1 January 1996

6. EN 13238 'Reaction to fire tests for building products - Conditioning procedures and general rules for selection of substrates'

7. Phosphorus levels in 'Proban' treated textiles. Northenden Textiles Ltd., Rengate House, 221 Palatine Road, Didsbury, Manchester M20 2EE. Mr. Tony Purcell (private communication)

8. 'Textiles. Commercial laundering procedure for textile fabrics prior to flammability testing'. (Reduced procedure) BS EN ISO 10528 :1995

Please direct queries to:
Alan Tyldesley
Principal Specialist Inspector
Health and Safety Executive
Magdalen House
Bootle, Merseyside L20 3QZ
tel 0151 951 4769
mail to: Alan.Tyldesley@hse.gsi.gov.uk