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HSE CONTRACT RESEARCH REPORT No. 118/1996

CHAIN MAIL AND OTHER CUT RESISTANT GLOVES AS PROTECTION AGAINST POWERED BLADES IN CLOTHING FACTORIES

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During normal working practices, operators of mechanically driven cutting equipment are exposed to the risk of personal injury from unguarded sections of the cutting blade. There is no PPE designed specifically for protecting hands against injury from mechanically driven blades. There has been no reliable method for establishing whether any protective gloves are suitable for use with the range of cutting equipment employed in clothing factories. A powered circular blade cut test has been developed which simulates, in a controlled manner, a severe accident with a typical cloth cutting device. The test has been used to compare the cut resistance performance of a range of protective gloves. Chainmail gloves provide a significantly higher level of protection against mechanically driven blades than other products investigated. The range of non-chainmail gloves investigated all provide a similar negligible level of protection against the powered circular blade cut test.

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1. Abstract

During normal working practices, operators of mechanically driven cutting equipment are exposed to the risk of personal injury from unguarded sections of the cutting blade. There is no PPE designed specifically for protecting hands against injury from mechanically driven blades. There has been no reliable method for establishing whether any protective gloves are suitable for use with the range of cutting equipment employed in clothing factories. A powered circular blade cut test has been developed which simulates, in a controlled manner, a severe accident with a typical cloth cutting device. The test has been used to compare the cut resistance performance of a range of protective gloves. Chainmail gloves provide a significantly higher level of protection against mechanically driven blades than other products investigated. The range of non-chainmail gloves investigated all provide a similar negligible level of protection against the powered circular blade cut test.

2. Background

During normal working practices, operators of mechanically driven cutting equipment are exposed to the risk of personal injury from unguarded sections of the cutting blade. It is not possible to permanently guard all of the cutting surface of the blade so strict working practices and extra precautions are necessary to minimise the risk of injury. One such precaution is the use of personal protective equipment (PPE) by the operative. There is, however, no PPE designed specifically for protecting hands against injury from mechanically driven blades. A number of clothing manufacturers stipulate that their cutting room operatives should wear chainmail gloves when operating cutting equipment. Most chainmail gloves are supplied with a disclaimer that if used with mechanically driven knives they may not offer adequate protection from injury. There has been no reliable method for establishing whether any protective gloves are suitable for use with the range of cutting equipment employed in clothing factories.

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3. Objectives

The objectives of this research were:

- To identify a series of tests for predicting the suitability of cut resistant gloves for use by cloth cutting operatives
- To assess the suitability of available PPE for use by cloth cutting operatives

4. Sourcing of gloves/protectors

A range of protective gloves was obtained for assessment and comparison. The range included:

- Partial and full chainmail gloves
- Knitted aramid gloves
- Steel reinforced knitted aramid gloves
- Leather and aramid reinforced leather gloves
- Rubber coated knitted cotton gloves.

Full descriptions of the gloves are given in Appendix I.

5.
Review of accident statistics

Accident statistics related to personal injuries from cloth cutting equipment were obtained from a number of sources:

- HSE MARCODE 2 Database, July 1992
- HSE incident investigation database, 1 April 1993 to 31 March 1995
- I.O.O.H., Vantaa, Finland - statistics for the Finnish Clothing Industry for the year 1991.
- Textil-Berugfsgenossenschaft, Germany - statistics for the German clothing industry for the year 1993.

The UK statistics show that the majority of accidents investigated involve bandknife cutters. In the majority of incidents the injured person was not wearing hand protection. In some cases the injured person was wearing a three fingered glove or a single glove and cut an unprotected finger. The majority of accidents occurred during cutting but a number occurred during other operations.

The German statistics reveal that accidents are fairly evenly distributed between bandknives, straight knives and round knives and there are a smaller but significant number of accidents involving servo cutters. Most accidents occur during cutting but many also occur during other operations including:

- Cleaning the blade
- Sharpening the blade
- Changing the blade
- Adjusting guards
- Moving the cutter

The accident statistics clearly illustrate the need for wearing full hand protection on both hands when working with or in the vicinity of mechanically driven cloth cutting equipment. The comprehensive statistics are given in appendix II.

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6. Literature search

Current methods of determining cut resistance of materials were reviewed and compared in a previous report to the Health and Safety Executive 'Standard tests potentially suitable for determining cut resistance of chain-mail and other protective gloves', see Appendix IV.

The report identified three main types of cut resistance tests one of which is not applicable to chain-mail materials. The other two types of test, i.e. impact cut and single cut straight blade tests, require some modifications to enable chain-mail materials and glove-sized specimens to be tested.

7. Survey of experienced cutting operatives

Experienced cutting operatives were interviewed at two clothing factories.

FACTORY 1

Cutting is carried out using two band knives, a variety of straight knife and circular blade hand held cutters, a servo cutter and, on lays of less than 30 plies, mechanical shears.

Chain mail gloves are provided for use with the band knives and circular cutters. Two of the operatives surveyed wear full gloves on both hands when using band knives. One of the operatives wears a three fingered glove on his left (front) hand when using band knives. The servo cutter operative wears a three fingered glove on his left hand but only if he is to be cutting for a long period.

None of the operatives like wearing gloves as they reduce sensitivity, make fabric manipulation difficult and cause hands to sweat.

One of the operatives who wears full hand protection often contacts the blade with the glove while cutting. When contact occurs it is immediately apparent and the operative reacts before the glove is damaged. The operative believes that the gloves give him more confidence and may result in him being more careless. The operative has never been cut.

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The second operative who wears full hand protection has contacted the back of the blade while cutting but has never contacted the cutting edge with or without gloves.

One very experienced operative who wears partial protection has never contacted the blade while wearing hand protection. The operative has received three cuts in the earlier part of his 42 years as a cutter, two to finger tips while cutting and one to the lower arm while reaching for fabric. The operative believes that full hand protection gives a false sense of security and leads to carelessness. He also thinks that the reduction in sensitivity and dexterity increases the likelihood of blade contact. The operative tried on Kevlar and Dyneema gloves supplied by SATRA. He preferred both over chainmail and Dyneema over Kevlar for comfort and sensitivity.

All operatives surveyed stated that they would not continue to cut with a knife that had a nicked or otherwise damaged blade.

FACTORY 2

Cutting is carried out using four band knives, straight knives are used for blocking out.

Operatives are required to wear chainmail gloves on both hands during all cutting operations. Two operatives wear three fingered gloves on both hands and the other two wear five fingered gloves on both hands. All four operatives wear thin cotton gloves under the chainmail to improve comfort.

One operative with 12 years experience had been using three fingered chainmail gloves for four years. He said that there is a loss of sensitivity but it does not take long to adapt to this. Problems may be encountered when counting layers of fabric but this is not often necessary and the gloves can be removed for this operation. The operative preferred three fingered gloves as they allow the lay to be gripped more firmly. He had sustained a cut to his left index finger when not using hand protection and believes that this would not have occurred if he had been wearing chainmail gloves. The operative had touched the band knife blade whilst wearing chainmail gloves but this was immediately apparent and the hand was moved away before any damage was caused to the glove.

A second operative with 30 years experience has been using three fingered chainmail gloves for 4 years. He never contacts the blade with the glove and has never been cut.

The third operative has been employed as a cutter for less than twelve months and has always worn hand protection. Initially he wore three fingered gloves but he had cut one of the unprotected fingers of his left hand and had switched to five fingered gloves. Because the operative has wide hands he wears a large glove to prevent abrasion to the backs of his hands. This however results in the glove fingers being approximately 25 mm too long. Some of the loose chainmail is accommodated by the inner glove but the length of the gloves causes some dexterity problems. The operative often contacts the band knife blade with the chainmail glove but this is immediately apparent through vibration and the hand can be moved away without damaging the glove.

The fourth operative has 9 years experience and has always worn hand protection while cutting. The operative wears five fingered gloves and sometimes touches the side of the band knife blade. On one occasion part of an oversized chainmail glove he was wearing became trapped between the side of the band knife blade and its slot. The operative stopped the machine and was able to remove the glove without damaging it.

All operatives surveyed stated that they would not continue to cut with a knife that had a nicked or otherwise damaged blade.

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All operatives complained that they frequently snagged their chainmail gloves in the metal clamps used to hold lays together.

All operatives surveyed believe that chainmail gloves are a good idea and the loss in dexterity and feel is a small price to pay for the safety benefits they confer.

8. Prototype cut test

A prototype cut test has been developed which simulates the effects of a mechanically driven blade contacting a finger with a speed and force of the same order as those found in a typical cutting operation.

The basic principle of the test is to lower an artificial finger, clad in the protective material under test, onto the rotating blade of a round cloth cutting knife. The time required to cut through the protective material to the finger is measured.

The basic design of the test apparatus was established early in the project and refinements to the mechanics of the apparatus and the test procedure were made as information became available.

The rate that the finger is lowered onto the blade and the force between the finger and the blade were established by observing typical cutting room practice.

Cutting forces and speeds of straight blade hand held knives

The forces required to move two straight blade knives were measured by pulling them with a spring balance through a lay of 80 plies of shirting weight fabric and freely across the cutting surface.

Eastman 'Bluestreak' straight knife with 15.24 cm blade and blade stroke of 2.68 cm

Force required to cut through fabric lay 7.36 N
Force required to move cutter freely across table 4.91 N.

Maimin 'Powermaster' straight knife with 20.32 cm blade and blade stroke of 2.67 cm

Force required to cut through fabric lay 12.75 N.
Force required to move cutter freely across table 9.81 N.

Eastman Cardinal round knife with a blade diameter of 12.5 cm

Force required to move cutter freely across table 1.96 N.
The mean force required to cut through a lay of 80 plies of shirting weight fabric was 10.06 N.

The mean force required to move the cutters freely across the cutting surface was 5.56N.

The speed of cutting was determined by measuring the time required to cut a straight line through:

1. 80 plies of shirting weight fabric over a distance of 0.92 m using a straight knife.
2. 100 plies of cotton gabardine over a distance of 1.0 m using a straight knife.
3. 80 plies of suiting weight fabric over a distance of 1.0 m using a straight knife.

Fabric	Distance (m)	Time (s)	Speed (ms^{-1})
Shirting	0.92	26.43	0.035
Gabardine	1.0	49.20	0.020
Suiting	1.0	43.47	0.023

The mean value for the measured cutting speeds is 0.026 ms^1.

This small trial illustrates that cutting forces and speeds are dependent on a combination of variables including:

- Type of fabric
- Depth of lay
- Type of cutting equipment
- Operative dexterity
- Size and complexity of pattern pieces.

To gain a comprehensive knowledge of the range of cutting forces and speeds used in the UK clothing industry would require an extensive study outside the scope of this project.

The trial described above was sufficient to provide a guideline for standardising the parameters of the prototype cut test.

The force applied to the test specimen throughout the cut test was chosen to be approximately mid way between the average force required to move cutters freely over the cutting surface and through 80 plies of fabric.

The velocity at which the test specimen impacts the test blade was chosen to be the mean of the speeds measured in the trial.

Design of prototype cut resistance test apparatus

A round knife hand held cloth cutter was mounted on a rigid base with the plane of its blade at 90° to the horizontal and the exposed part of the blade uppermost. Vertical steel runners were placed either side of the blade. The test specimen holder slides up and down the runners on low friction PTFE bushes. The runners were positioned so that the test specimen contacts the blade at its highest point, figures 1 and 2.

The specimen holder is in the form of an artificial finger which can be positioned at a variety of angles relative to the test blade, figure 3. The mass of the assembly is such as to exert a force of 7.6 N onto the blade during the test.

The height from which the specimen holder begins its descent can be altered. Initially the holder was held at its start position by an electromagnet and the specimen could be dropped onto the moving blade by interrupting the power to the magnet. The speed at which the test specimen impacts the blade could be altered by varying the height from which it was dropped.

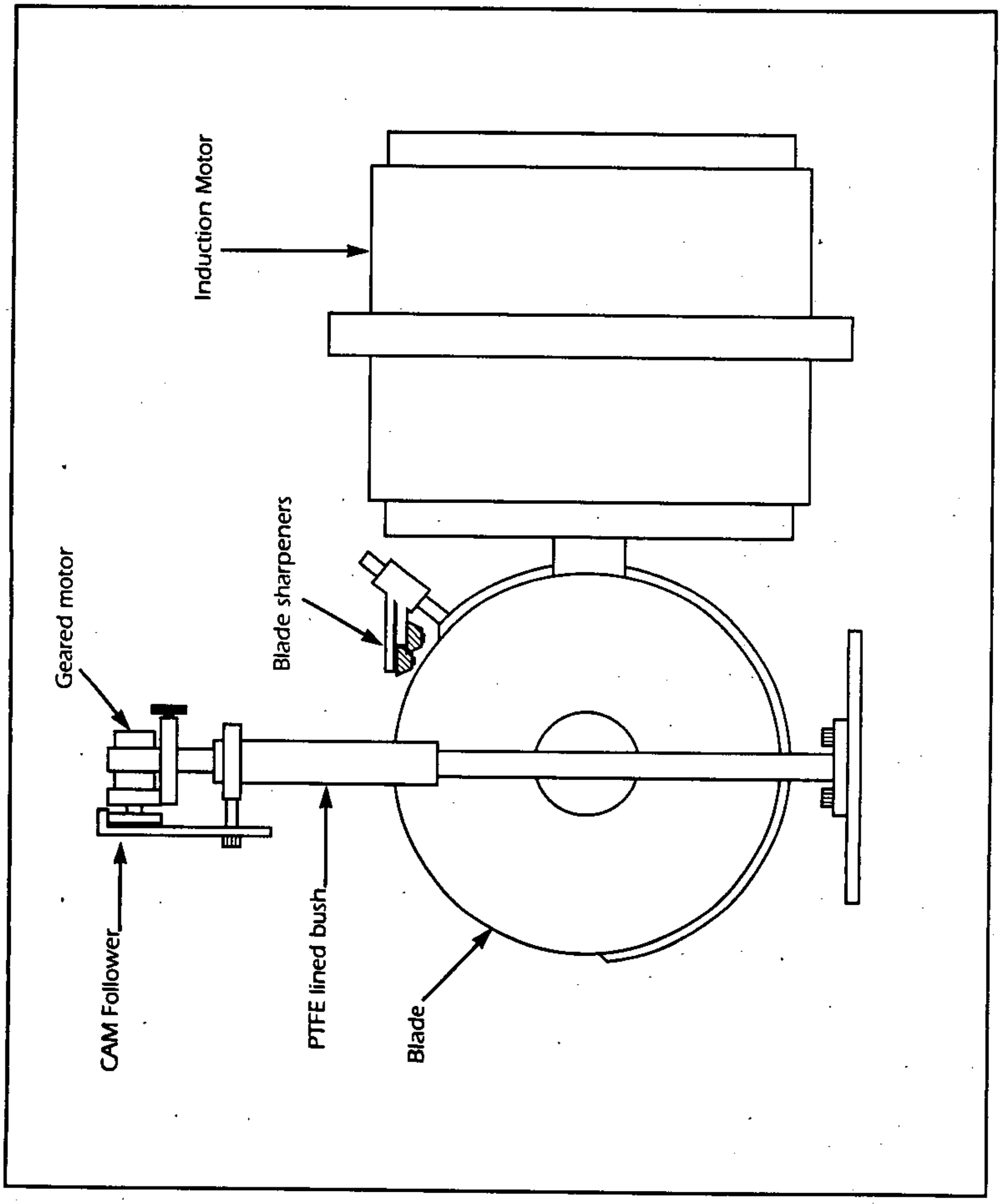

Figure 1. Prototype cut tester (side view)

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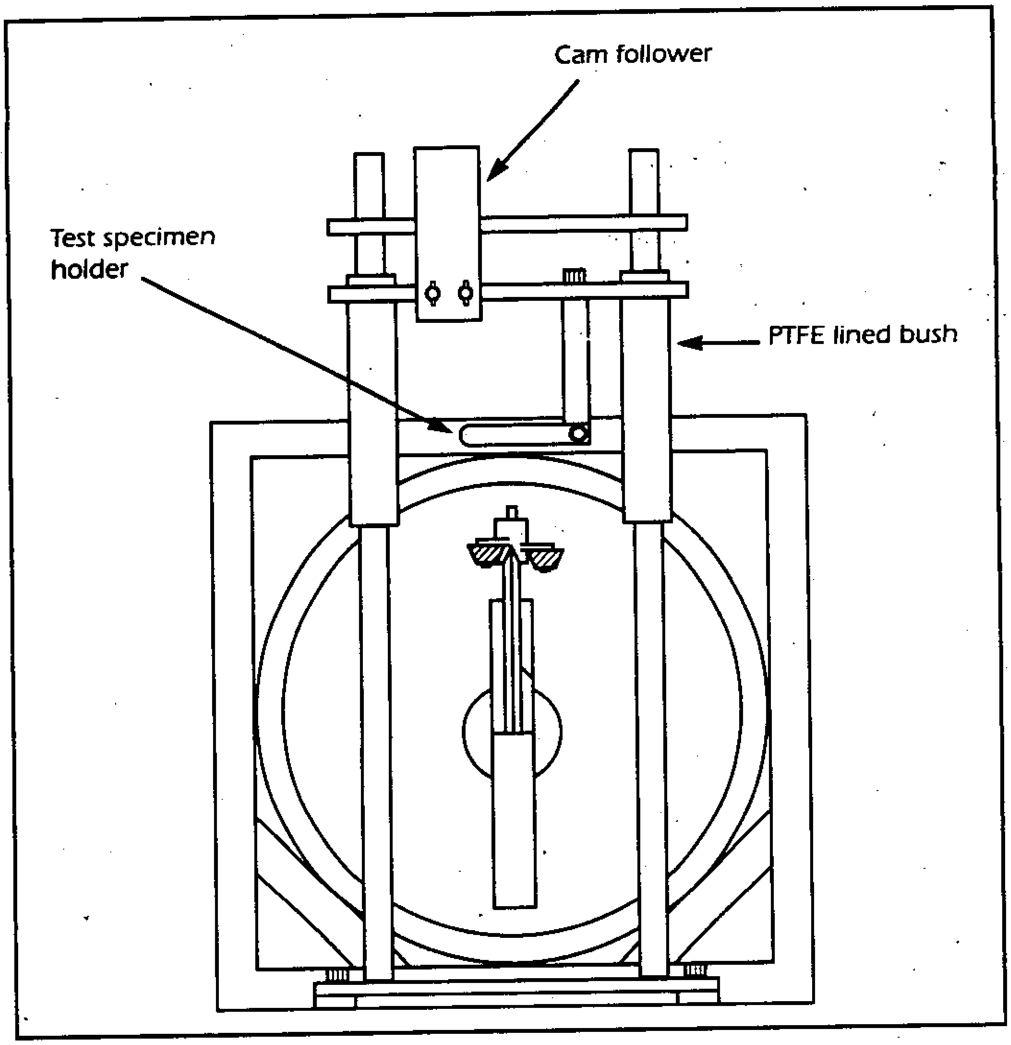

Figure 2. Prototype Cut Tester (end view)

Studies of actual cutting operations showed that average cutting speeds of 0.026 ms^{-1} are achieved. A free falling body will reach this speed after dropping from a height of 0.034mm. Adding 20% to take into account friction between the PTFE bearings and the runners gives a drop height of 0.041mm. As this height is difficult to reproduce accurately for every test a different approach was taken.

The electromagnet was removed and replaced with a geared motor and cam system that lowers the specimen holder at the desired rate.

The test specimen is lowered onto the blade by a cam attached to the shaft of a geared dc electric motor with a measured rotational speed of 56.5rpm, figure 4. The profile of the cam is shaped to lower the specimen at a nominal constant velocity of 0.026ms^{-1}, Figure 5. The maximum vertical displacement of the specimen is approximately 10mm. The cam is positioned so that the specimen is at its highest position at the beginning of the test. The entire cam and specimen assembly is adjusted so that the distance between the blade and the part of the specimen it will contact is exactly 5mm at the beginning of the test to ensure that the specimen has reached the desired velocity when it contacts the blade. The distance between the specimen and the blade is set using a calibrated 5mm square steel spacing rod.

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A digital timer is linked to the tester to record the time elapsed from the beginning of the descent of the specimen holder until it makes contact with the blade. The timer is triggered by a microswitch placed on the specimen holder and is stopped when there is electrical continuity between the specimen holder and the blade. The timer is latched through a relay that prevents it from restarting if there is an intermittent break in continuity between the specimen holder and the blade.

The power to the induction motor which drives the blade is also discontinued when there is electrical continuity between the specimen holder and the blade.

9. Testing

Where there was sufficient material for testing, specimens of each of the gloves described in appendix I were tested in accordance with:

The prototype cut test, appendix III
Blade cut test BS EN 388: 1994: Clause 6.2
Impact cut resistance test BS EN 388: 1994: Clause 6.5

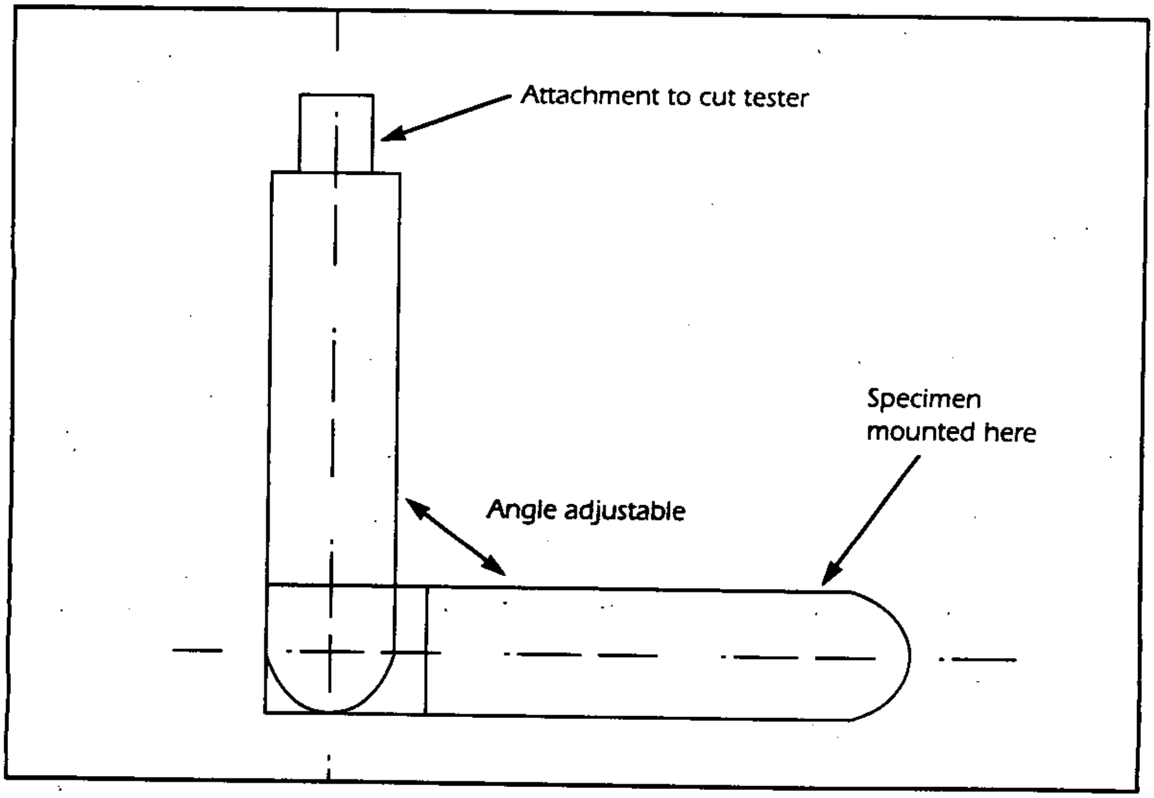

Figure 3. Test Specimen Holder

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N.B. chainmail and steel reinforced knitted gloves could not be tested in accordance with Blade cut test BS EN 388: 1994: Clause 6.2 as they are electrically conductive and prevent the blade cut tester operating.

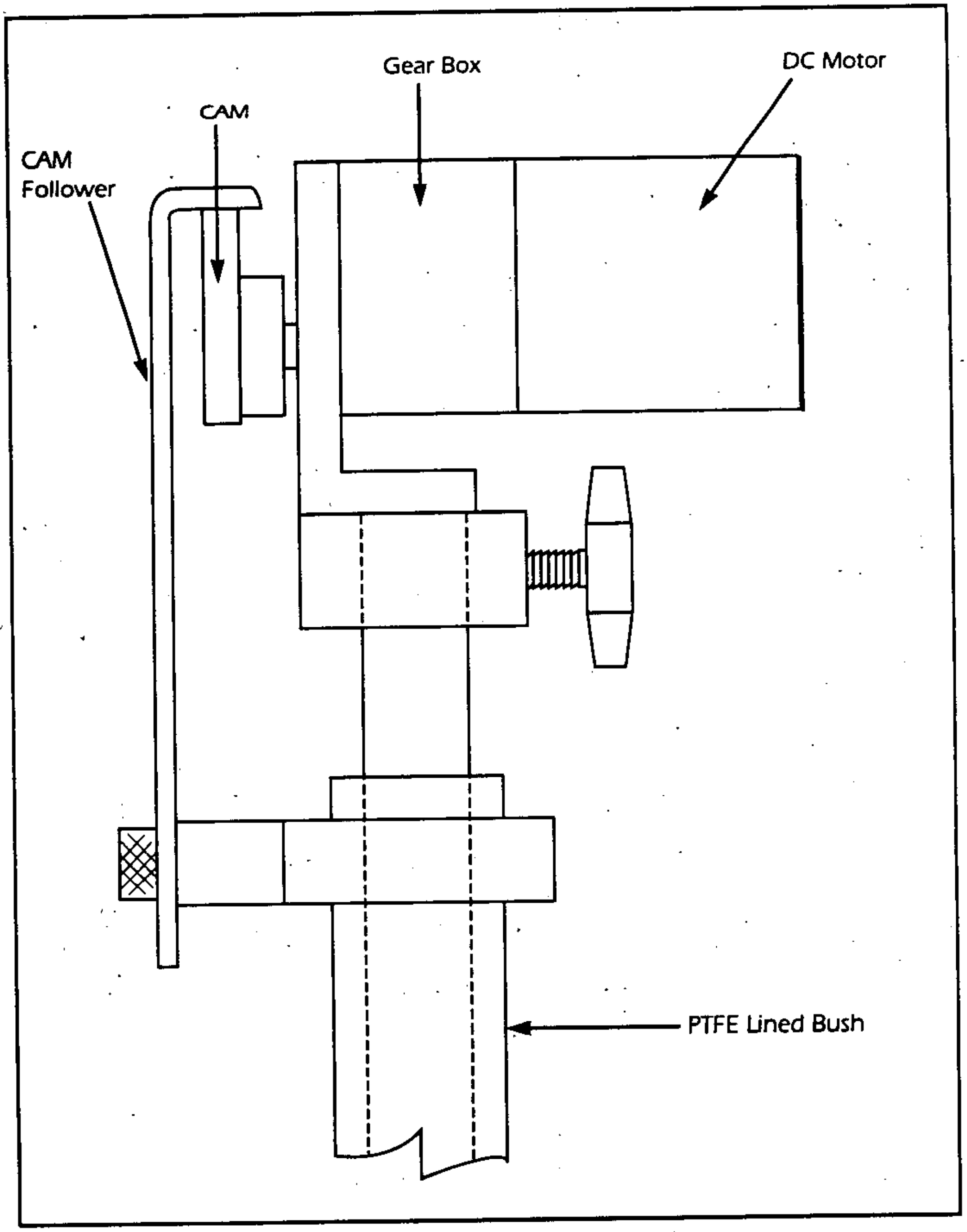

Figure 4. Motor/Cam Assembly

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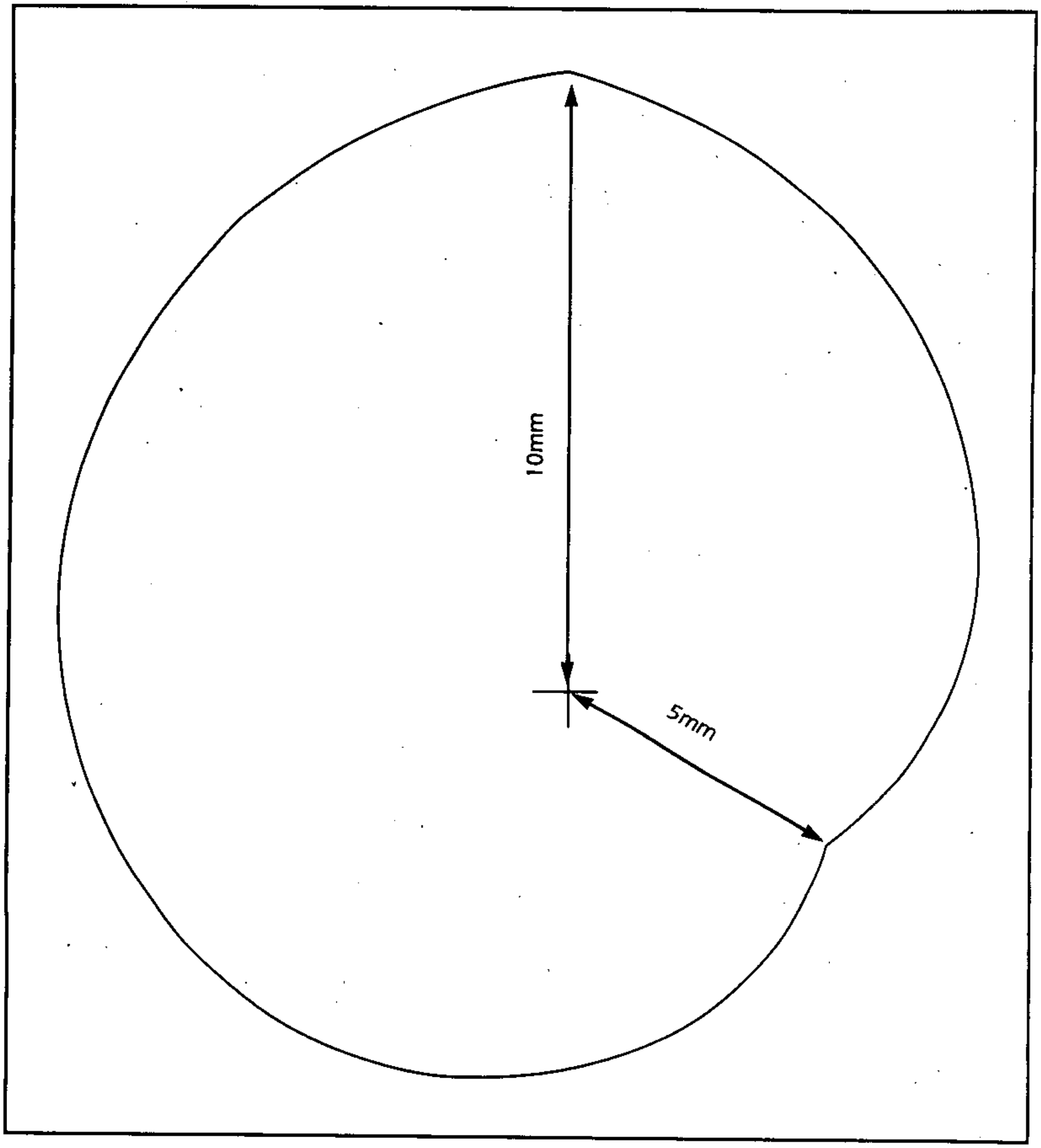

Figure 5. CAM Profile

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10.
Results

Resistance of gloves to cutting by mechanically driven knives (prototype test)

Glove ref	Glove type	Mean cut through time (s)	Minimum cut through time (s)
001	Kevlar	0.09	zero
002	Kevlar	0.01	zero
003	Kevlar	0.13	0.03
005	chainmail	3.88	2.11
006	aramid/steel	0.04	zero
007	aramid/steel	0.01	zero
008	chainmail	3.92	1.19
009	chainmail	2.75	1.53
013	leather/Kevlar	0.03	zero
014	leather	0.01	zero
015	rubber/cotton	0.02	zero
016	Spectra/steel	0.21	0.07

Resistance of gloves to cutting by mechanically driven knives (prototype test) - damaged blade

Glove ref	Glove type	Mean cut through time (s)	Minimum cut through time (s)
005	chainmail	0.92	0.28
003	Kevlar	0.08	0.06

Resistance of gloves to cutting by mechanically driven knives (prototype test) - angled blade

Ref: 011 chainmail glove - finger horizontal and at 45° to the axis of the blade;

Mean cut through time = 4.05 s, Minimum cut through time = 1.19 s

Ref: 011 chainmail glove - finger parallel to the axis of the blade and at 45° from the vertical plane of the blade;

Mean cut through time = 4.96 s, Minimum cut through time = 0.85 s

Blade cut test BS EN 388: 1994: Clause 6.2

Glove ref:	Glove type	Blade cut index	Protection level
001	Kevlar	1.74	1
002	Kevlar	3.80	2
003	Kevlar	15.05	4
013	leather/Kevlar	3.40	2
014	leather	1.36	1
015	rubber/cotton	1.92	1

Impact cut resistance test BS EN 388: 1994: Clause 6.5

Glove ref	Glove type	Mean penetration (mm)	Maximum penetration (mm)
001	Kevlar	19.69	27.48
002	Kevlar	15.90	21.29
003	Kevlar	9.31	14.48
005	chainmail	7.53	16.09
006	aramid/steel	17.33	23.35
007	aramid/steel	20.68	24.08
008	chainmail	9.55	14.26
011	chainmail	6.97	14.42
012	chainmail	7.50	15.04
016	Spectra/steel	27.64	33.91
016	Spectra/steel	20.46	24.71

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11. Conclusions

A powered circular blade cut test has been developed which simulates, in a controlled manner, a severe accident with a typical cloth cutting device. The test has been used to compare the cut resistance performance of a range of protective gloves.

Chainmail gloves provide a significantly higher level of protection against mechanically driven blades than other products investigated.

The range of non-chainmail gloves investigated all provide a similar negligible level of protection against the powered circular blade cut test.

The BS EN 388 Blade cut test discriminates well between gloves of low cut resistance and is unsuitable for testing chainmail. The test is similarly unsuitable for testing gloves manufactured from other conductive material such as steel reinforced aramid fibre.

The BS EN 388 Impact cut resistance test generally discriminates between high performance and low performance gloves. Whist the lowest blade penetrations were generally found with the chainmail gloves, a similar level of protection was shown by one of the Kevlar gloves. The stabbing action of the test is thought to be unrealistic in the context of cloth cutting and the relatively good performance of the Kevlar glove is not seen in the prototype cut test which is known to be more representative of the equipment used in the clothing industry.

12. Recommendations

The current standard tests for assessing the cut resistance of protective gloves are inadequate for determining their resistance to mechanically driven cloth cutting equipment. A test which simulates the action of cloth cutting equipment has been developed and is described in this report.

Tests carried out in this study show that gloves constructed from steel chainmail materials offer the best protection against mechanically driven cloth cutting devices. The best chainmail gloves offer a level of protection which in our opinion should enable wearers to respond to blade contact and significantly reduce the risk of cutting injury. Other types of protective gloves should not be recommended for use with cloth cutting equipment unless they can be shown to perform to an acceptable standard when tested in accordance with the prototype test described in this report.

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The cut resistance of chainmail gloves varies considerably within and between individual test specimens. We recommend a standard of performance of a minimum cut through time of 1.5 s when tested in accordance with the test method described in this report based on the cut resistance of commercially available protective gloves. A minimum of ten tests should be carried out on a specimen glove and should include all fingers. Gloves which meet the standard should be clearly marked with a warning that they will not offer protection against prolonged contact with a mechanically driven blade.

There have been a number of instances where cutting operatives wearing full hand protection on one hand only have injured their unprotected hand. We therefore recommend that full hand protection of both hands should be employed when carrying out any operation involving mechanically driven cloth cutting equipment.

An alternative approach to ensuring operative safety is that used in the meat processing industry. Operatives of meat grinding machines wear electrically conductive steel reinforced knitted gloves which are wired into the grinding machine. If the operative contacts the grinding machine blade with the conductive gloves the machine is stopped instantaneously with an inductive braking system.

GLOVES

Ref	Description
001	small size, fine gauge knitted Kevlar
002	medium size, coarse gauge, 'Neptune' coated, knitted Kevlar glove
003	large size, coarse gauge, knitted Kevlar glove
004	two fingered chainmail glove (previously tested by supplier
005	five fingered chainmail glove
006	pair Pro-tex knitted gloves size 9-10
007	pair steel reinforced knitted Anti-bac gloves
008	five fingered chainmail glove
009	three fingered chainmail glove, size 1
010	three fingered chainmail glove, size 1
011	five fingered chainmail glove, medium size
012	chainmail material
013	slash resistant Kevlar reinforced leather glove
014	leather 'driver's' glove
015	nitrile rubber coated knitted cotton glove
016	steel reinforced knitted Spectra

N.B. Although chainmail gloves can be obtained from many sources they originate from a small number of manufacturers.

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PROTOTYPE TESTER

The test apparatus used in the prototype test for Resistance of gloves to cutting by mechanically driven knives has the following features.

A mechanically driven circular blade with:

- An outside diameter between 118 mm and 127 mm
- A hardness of 60 HRC to 64 HRC
- An angular velocity of 1400 rpm ± 50 rpm from the commencement of the test to the point when the test specimen is cut through.

A specimen holder with dimensions shown in figure 6.

A means of lowering the blade or test specimen at a constant velocity of $0.026 ms^{1} \pm 0.001 ms^{-1}$.

A means of maintaining a contact force between the blade and test specimen of N 7.6 ± 0.15 N

Means of detecting the point at which the test specimen is cut through

Means of disconnecting the drive from the blade immediately the specimen is cut through.

Means of measuring the time required to cut through the specimen to an accuracy of ± 0.01 s, e.g. an electrical cut through detector.

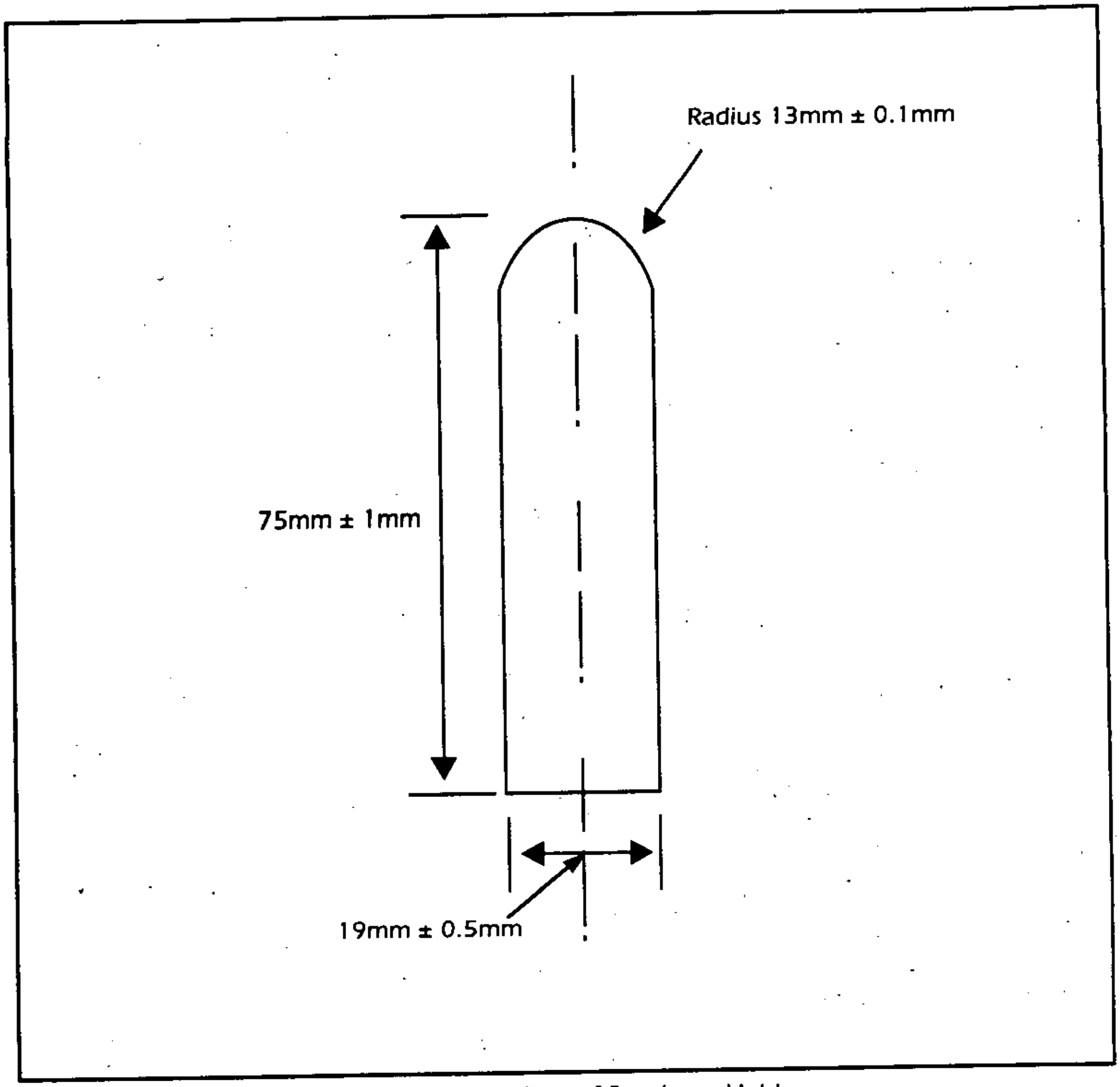

Figure 6. Dimensions of Specimen Holder

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TEST METHOD

Combined Test Method and Operating Instructions: Resistance of gloves to cutting by mechanically driven knives.

1. Procedure

1.1 *Loading test specimen*

1.1.2 Remove any burrs from the aluminium finger using the file. Cover the uninsulated area of the finger with a piece of aluminium tape measuring approximately 3 cm x 1 cm.

1.1.3 Secure a piece of vulcanised rubber measuring 6 cm x 4 cm over the aluminium tape.

1.1.4 Place the test specimen over the finger and secure it in place using cable ties. Ensure that the area of the specimen that is to be cut is evenly tensioned.

1.1.5 Clamp the finger into the test rig ensuring that it is perpendicular to the plane of the circular blade.

NOTE: When testing chainmail gloves ensure that there is no electrical continuity between the glove and the finger. Press the RESET button on the control panel and zero the timer then lower the finger onto the blade. If the timer relay cuts in and locks out the timer, there is electrical continuity between the glove and finger.

1.2 *Sharpening blade*

1.2.1 Lower the safety cage and thread the blade sharpening cord through the cage mesh.

1.2.2 Ensure that the cage is closed correctly and press the RESET button on the control box. Turn the EMERGENCY STOP button clockwise to start the cutter.

1.2.3 Pull the cord firmly so that both abrasive wheels contact the blade. Sharpen the blade continuously for 2 minutes.

1.2.4 Release the cord and press the EMERGENCY STOP button. ALLOW THE BLADE TO STOP BEFORE OPENING THE SAFETY CAGE.

1.2.5 Inspect the blade for sharpness. The blade is sufficiently sharp if no edge is visible when viewed end on. There should be no nicks visible in the blade edge.

1.2.6 If there is a visible edge or nicks in the blade the sharpening procedure should be repeated until these are removed.

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1.3 *Testing a specimen*

1.3.1 Using the POSITION button on the control panel, rotate the cam until the specimen carriage is at its highest point.

1.3.2 Place the spacer bar horizontally on the top edge of the blade and lower the entire specimen carriage/cam assembly until it makes contact with the spacer bar.

1.3.3 Secure the specimen carriage/cam assembly and remove the spacer bar.

1.3.4 Securely close the safety cage.

1.3.5 Press the RESET button on the control panel and set the timer to zero.

1.3.6 Turn the EMERGENCY STOP button clockwise to start the cutter.

1.3.7 Allow the cutter at least 10 s to reach normal running speed.

1.3.8 Press and hold down the START TEST button for at least 5 s.

1.3.9 When cut through occurs and the tester stops, record the time indicated by the timer to the nearest 0.01 s.

1.3.10 Subtract 0.25 s from the indicated time to allow for time taken for the specimen to lower onto the blade and the cut through time of the vulcanised rubber.

1.3.11 If the tester has not stopped after 15s press the ABORT TEST button on the control panel and record the time indicated by the timer to the nearest 0.01 s.

1.3.12 Press the EMERGENCY STOP button.

1.3.13 ENSURE THAT THE BLADE HAS STOPPED MOVING BEFORE OPENING THE CAGE.

1.3.14 Remove the finger from the specimen carriage and examine the damage to the glove.

2. Reporting

2.1 Report the time required for the glove to be cut through to the nearest one hundredth of a second.

2.2 Briefly describe the damage which occurred.

2.3 If the test was aborted before cut through occurred note this and describe any damage which may have occurred to the glove or rubber support.

Appendix IV

REPORT

Standard tests potentially suitable for determining cut resistance of chainmail and other protective gloves.

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Standard tests potentially suitable for determining cut resistance of chainmail and other protective gloves

Contents

1. SUMMARY

The Health and Safety Executive currently recommends that clothing cutting operators wear chainmail gloves to protect against injury from cutting equipment. However, chainmail gloves are supplied with a warning that they are not suitable for protection against the types of cutting equipment used in the clothing industry. Standard cut resistance tests have been reviewed to determine their potential for comparing the suitability of chainmail and cut resistance gloves for protection against mechanically driven knives. There are three main types of cut resistance tests one of which is not applicable to chainmail materials. The other two types of test, i.e. impact cut and single cut straight blade tests, require some modifications to enable chainmail materials and glove sized specimens to be tested. Limited studies have shown that results obtained by the test methods reviewed show a high degree of correlation. Further work is required to extend the range of materials tested to cover chainmail and to relate results to the actual effects of mechanically driven knives on protective gloves.

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2. INTRODUCTION

The Health and Safety Executive currently recommends that operators of mechanically driven cutting equipment in the clothing industry should wear chainmail gloves to reduce the risk of injury.

However, many chainmail gloves are supplied with a disclaimer that, if used with a mechanically driven knife they will not offer adequate protection.

The cutting of bulk fabric is carried out by two basic methods: 1. Computer Numerically Controlled cutting where the operative is remote from the cutting apparatus and is therefore not at risk.

2. Manual cutting using mechanically driven equipment. This latter category can be further sub-divided:

i) Static cutting machines where the material being cut is guided towards the blade. Typically machines have smooth edged continuous blades which may be several metres long. These machines are known as bandknives.

ii) Portable cutting machines which are guided through the material being cut with one hand while the other hand is used to hold the material steady. The blades used are smooth edged although some straight blades may have a wavy edge profile. Portable cutting machines may have a vertically reciprocating straight blade 6in. to 13in. long (straight knife, servo knife) or a vertical circular blade of diameter 2in. to 6in. Some circular knives may be fitted with blades that have four or eight curved edges.

While blade edges are smooth they are normally dressed using a carborundum material which puts a very fine rough edge on the blade. This rough edge results in a sawing action when the blade moves through the material at high speed.

A method for establishing and comparing the suitability of chainmail and other cut resistance gloves for protection against mechanically driven knives is required.

Existing standard test methods for determining cut resistance of various materials have been investigated.

3. STANDARD TESTS FOR CUT RESISTANCE

Currently standard tests for cut resistance of materials for use in personal protective equipment (PPE) fall into three main categories:

- Impact cut tests.
- Reciprocating circular blade under constant load.
- Single cut with straight blade under various loads.

3.1 Impact cut tests

In these tests a standard knife is dropped verticall onto the test specimen from a specified height. Th length of blade protruding through the back of the specimen, if the material is penetrated, can be measured.

Impact cut tests are included in the EN 412: 199? standard for protective aprons (part 4 penetration test) and prEN 388: 1992 standard for protective gloves (part 6.5 impact cut resistance). EN 412 requires results to be classified by measuring the length of blade protruding through the specimen but EN 388 gives no assessment method.

3.2 Reciprocating circular blade test

This test forms part 6.2 of the prEN 388: 1992 standard for protective gloves, blade cut resistanc A circular blade under a load of 5N is drawn repeatedly back and forth across a flat specimen until it is cut through. The number of cycles required to cut through the sample is recorded.

3.3 Single cut straight blade tests

In these tests a straight blade is drawn across a test specimen mounted on a semi-circular mandr under a number of fixed loads. The length of cut required to cut through the specimen at each load is recorded and the load required to cut through the specimen in a specified distance is determined by regression analysis.

Tests of this type have been independently developed by IRSST (Institut de recherche en sant et en sécurité du travail du Québec) in Canada an DuPont Advanced Fibre Systems in the U.S. These form the basis of the draft test method 'Protective clothing -Test method for the determination of the resistance to cutting of textiles, composites, leathe and membranes by sharp edges' proposed by ISO/TC94/SC13/V

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4. COMPARISON OF STANDARD TEST METHODS

4.1 Ideal test method

An ideal test method for determining the resistance of protective gloves to the cutting action of mechanically driven knives would be:

- Repeatable and reproducible.
- Realistic in severity and type of risk.
- Able to rank gloves in relation to true protection against mechanically driven blades and discriminate unequivocally between good and bad gloves.
- Accurate and sensitive.
- Applicable to all cut-resistant gloves.
- Low cost and easy to operate.
- Independent of a single supplier of critical parts.
- Verifiable.
- Safe to operate.

4.2 EN 412: 1993 Clause 4 - Penetration test - impact cut

Advantages

- Applicable to a wide range of materials including chainmail.
- Test blades are available from several sources.
- Simple to operate.

Disadvantages

- Requires test specimen 400mm x 400mm therefore unlikely to be suitable in most cases for testing actual gloves.
- The stabbing cutting action is not representative of actual risk.
- There is no step for verifying blade sharpness.

SATRA is equipped to carry out this test.

4.3 prEN 388:1992:Clause 6.5 - Impact cut resistance

Advantages

- Applicable to wide range of materials including chainmail.
- Test blades are available from several sources.
- Simple to operate.

Disadvantages

- Requires test specimen 120mm x 120mm therefore can only test hand area of relatively large gloves.
- The stabbing cutting action is not representative of actual risk.
- There is no step for verifying blade sharpness.
- Test method is ambiguous and open to interpretation.

SATRA is equipped to carry out this test.

4.4 prEN 388:1992:Clause 6.2 - Blade cut resistance

Advantages

- Includes a step for verifying blade sharpness.
- Small and very portable test apparatus.
- Requires test specimen 80mm x 100mm therefore can test hand area of relatively small gloves.
- Simple to operate.

Disadvantages

- Not suitable for chainmail gloves or steel reinforced gloves as the blade deteriorates rapidly and will not cut the material.
- Maximum cutting speed of 10 cm/s is not representative of actual risk.
- Cutting action is not representative of actual risk.

SATRA is equipped to carry out this test.

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4.5 IRSST and DuPont cut tests (1)

Advantages

- Includes step for verifying blade sharpness.
- Test specimens as small as 25mm x 25mm may be used.

Disadvantages

- Not suitable for testing chainmail gloves with currently specified blade.
- Maximum cutting speed of 5mm/s is not representative of actual risk.
- Results more complicated to interpret than other tests.
- Cutting action is not representative of actual risk.

SATRA is **NOT** equipped to carry out this test.

5. CORRELATION OF RESULTS FROM CUT RESISTANCE TESTS

As part of their work to develop an international test method for the determination of cut resistance the ISO/TC 94/SC 13/WG5 project group 6 have carried out a limited inter-laboratory trial of the various cut test methods. (2)

Tests were carried out on 16 assorted test fabrics using prEN 338 Blade cut resistance, EN 412 Impact cut, and the IRSST and DuPont tests. Chainmail materials were not included in the trial.

The trial showed a high level of correlation between the test methods.

6. CONCLUSIONS

Of the various cut-resistant tests available, none is totally suitable for testing chainmail gloves in their unmodified forms.

Impact cut tests are suitable for testing chainmail materials but require modification to allow whole gloves or areas of gloves to be tested.

The IRSST and DuPont tests are suitable for small test specimens but would require a different blade for assessing chainmail materials

The prEN 388 Blade Cut Resistance test is unsuitable for chainmail materials.

The cut resistance tests correlate very well and rank materials in their expected order of protective ability†.

None of the tests replicate the rapid sawing action produced by industrial cloth cutting equipment.

† The correlation data available does not include chainmail materials.

7. FURTHER WORK

Further experimental work is necessary to establish the ability of the various test methods to determine the level of protection offered by chainmail gloves against mechanically driven cloth cutting equipment.

To achieve this the effects of cloth cutting equipment on various types of protective gloves will be investigated. Results of this investigation will be related to data from tests on chainmail gloves using modified impact cut and IRSST/DuPont blade cut tests as appropriate.

Impact cut tests will be carried out by SATRA. Discussion with IRSST and/or DuPont to determine whether their test equipment can be suitably modified to cope with chainmail materials may be expedient.

8. REFERENCES

(1) Lara J et al "A New Test Method to Evaluate the Cut Resistance of Glove Materials" - **Performance of Protective Clothing: Fifth Volume ASTM STP 1237**, Philadelphia 1995.

(2) ISO/TC94/SC
18th January

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