Testing Motorcycle Riders' Clothing

and the Personal Protective Equipment Directive

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Abstract

Four new tests have been developed for determining the strength and abrasion resistance of motorcycle riders' clothing. These have been validated in 'dummy-tests' in a simulated accident, and by performing the tests on crash-damaged clothing. These tests, and others, have been combined in a test schedule for new clothing. The use of these tests and associated limit values and specifications are described. A small number of manufacturers have collaborated to produce designs and garments to provide the highest level of protection predicted to be possible in high speed accidents. These garments have been used to establish practical procedures for the tests and to show that the performance limit values can be achieved without radical changes to established designs and construction methods of motorcyclists' clothing.

INTRODUCTION

The Personal Protective Equipment (PPE) Directive EEC/89/686[1] has stimulated activity to harmonise existing PPE Standards within Europe and to create new standards for PPE where none existed before. CEN/TC 162 co-ordinates most work on PPE Standards. Working Group 9 (WG 9) was set up in 1991 to prepare a European Standard for Motorcycle Riders' Clothing. The results in this paper come from work in Cambridge University associated with the preparation of the Standard. The work is part of a longer term project from which early results were presented to IRCOBI in 1984.[2] With the exception of a specification for motorcycle riders' clothing in Sweden[3] there are, at present, no published standards. WG 9 unlike most CEN Working Groups, is therefore not able to call upon experience of testing and application of standards for such clothing in different countries. When new Standards are created it is necessary to prove that test methods measure the relevant protective properties of the clothing, and that the performance requirements are related to the levels of the hazards, and to the protection that can be provided by clothing that remains practical. The PPE Directive and CEN Standards for PPE place an emphasis on ergonomic aspects of clothing. These are difficult to define and difficult to test. Problems can arise if ergonomic requirements and tests impose restraints on clothing such that good designs are eliminated simply because they are difficult to test.

Four mechanical tests for motorcycle riders' clothing have been developed in Cambridge. These are an impact abrasion test, a cut test, a burst test, and an impact abrasion test for seams using a high energy impact. These have been used on clothing that had been involved in motorcycle accidents. The details of the test methods and the performance of crash-damaged clothing were presented to an ASTM meeting.[4,5] The locations and severity of damage to the clothing were analysed and related to test results obtained from the clothing. The framework of a specification for 'normal' and 'high' performance clothing was proposed.[6]

The PPE Directive provides for two main routes to "CE marking", a process which all PPE must have undergone before 1 July 1995. In the absence of a harmonised standard the route is by demonstrating compliance with the requirements of Annex II to the Directive in Type Approval testing. The practicality of the methods developed in Cambridge has therefore been assessed by using them for Type Approval testing of a small number of garments. The draft document setting out the requirements and procedures[7] has been circulated within the British Standards Institute PSM 34/3 and outside. A further document,[8] which demonstrates how each clause of Annex II to the Directive is satisfied, has also been circulated for comment.

METHODS AND RESULTS

Seven UK manufacturers* have collaborated to produce clothing that aims to meet the 'High' or 'Normal' performance proposals[6]. Ergonomic tests of clothing, of clothing restraint, and clothing adjustability have been developed, and these together with the Cambridge mechanical tests,[4,5] and the impact test for protective padding developed within WG9,[9] have been used to test the manufacturers' products.

1. Impact abrasion test

The impact abrasion test has been performed as described in the ASTM paper[4] and in a draft text submitted to WG 9 as a proposal for inclusion in the European Standard[10]. The current method is not significantly different from the initial proposal to WG 9[11]. No difficulties were experienced in testing single or multiple layers of leather or fabric, or special areas such as stretch panels. Table 1 summarises the results obtained. The manufacturers offer suits consisting of various materials. Some materials are restricted to particular areas of the clothing that can be related to the Zones with different levels of risk[6] (section 4). All garments are lined, and the aramid fibre fabric garments also have outer covering fabrics, but details of these are not included. Where a manufacturer offers alternatives such as cowhide or kangaroo skin the mean value of all the variants is given. The table shows the Zones in which a material is fit for use.

2. The burst test for measuring leather, fabric, zip fastener and seam strengths

The burst test described earlier[5,12] has been used to measure the bursting strengths of all types of seams and zip-fasteners. Samples have been taken to their bursting point except where the pressure required was more than 50% above the performance limit for the Zone in which the seam is used. The apparatus and method are essentially those given in ISO 2960-1974. Table 2 summarises the results obtained. Leather garment manufacturers use many different seams for particular purposes. The results are therefore grouped by the Zones in which the seams are used. Zip-fasteners are included as a special type of seam. In calculating the mean values for the strengths of the seams, the values used were the bursting pressure, or the performance limit x 1.5 if the seam did not burst below this pressure. The numbers of different designs of seams or material combinations used by the manufacturer are shown in parentheses.

3. Impact cut test

This has been carried out as previously described[5,13], with the addition of the use of a reference canvas material as in the abrasion test. Results are expressed as a relative cut resistance based on two layers of the French canvas specified in EN388. This material has a knife penetration of 14.0 mm from a 400 mm drop. Each sample is tested six times: if it is a fabric the orientations of the blade are along the warp, along the weft and at 45° to the warp and weft. Leather is tested in three directions at the same angles as fabrics. The results are summarised in Table 3.

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Table 1 Relative abrasion resistance of fabrics and leathers and the proposed performance limits.

		Relative abrasion resistance, s		
		Zone 4	Zone 3	Zones 1 & 2
'Normal' performance limits		>1.5	>2.5	>7.0
'High' performance limits		>2.5	>4.0	>12.0
Manufacturer A	Elastic fabric	3.6		
	Single leather	6.5	6.5	
	Leather stretch panels	20.4	20.4	20.4
	Double leather	18.3	18.3	18.3
	Triple leather	55.3	55.3	55.3
B	Elastic fabric	3.6		
	Perforated leather	3.9		
	Punched leather	4.7		
	Single leather	6.9	6.9	
	Leather stretch panels	20.7	20.7	20.7
	Double leather	14.9	14.9	14.9
C	Coated net	4.5		
	2 layers aramid fabric	5.7	5.7	
	3 layers aramid fabric	18.1	18.1	18.1
D	Elastic fabric	3.6		
	Single leather	5.4	5.4	
	Single suede leather	17.9	17.9	17.9
	Leather stretch panels	21.1	21.1	21.1
	Double leather	19.7	19.7	19.7
E	Single leather	4.4	4.4	
	Leather stretch panels	23.9	23.9	23.9
	Double leather	13.5	13.5	13.5
	Triple leather	22.8	22.8	22.8

Table 2 Mean bursting strengths of seams and zip-fasteners and the proposed performance limits

Performance limits:	Bursting strength, kPa			
	Lining	**Zone 4**	**Zone 3**	**Zones 1 & 2**
Normal	>250	>450	>600	>800
High	>250	>500	>800	>1250
Manufacturer A	287 (1)	752 (3)	1056 (8)	1683 (4)
B	362 (2)	683 (4)	1001 (20)	1619 (6)
C	438 (3)	727 (1)	1173 (2)	1535 (2)
D	311 (1)	743 (1)	1034 (5)	1571 (2)
E	287(1)	648 (1)	921 (4)	1843 (3)

Table 3 Knife penetration in the impact cut test. A 200 mm drop is used on Zone 3 and Zone 4 material, and a 400 mm drop on Zone 1 & 2 materials or construction.

		Knife penetration, mm		
		Zone 4 200 mm drop	**Zone 3** 200 mm drop	**Zones 1 & 2** 400 mm drop
'Normal' performance limits		<30	<25	<15
'High' performance limits		<25	<20	<10
Manufacturer	**Material**			
A	Elastic fabric	11.4		
	Punched leather	15.2	15.2	
	Leather stretch panels	pass	pass	5.3
	Single leather	8.8	8.8	
	Double leather	pass*	pass	4.9
	Triple leather	pass	pass	1.7
B	Elastic fabric	11.4		
	Perforated leather i	16.8		
	ii	22.3		
	Punched leather	12.1	12.1	
	Leather stretch panels	pass	pass	6.1
	Single leather i	12.9	12.9	
	ii	17.1	17.1	
	Double leather i	pass	pass	7.6
	" ii	pass	pass	6.9
	" iii	pass	pass	5.7
C	Coated net	7.2	7.2	
	2 layers aramid fabric	13.8	13.8	
	3 layers aramid fabric	pass	pass	8.8
D	Elastic fabric	11.4		
	Single leather i	18.6	18.6	
	" ii	17.5	17.5	
	" iii	18.0	18.0	
	" iv (suede)	1.9	1.9	
	Leather stretch panels ii	pass	pass	2.2
	Single leather iv	pass	pass	5.2
	Double leather	pass	pass	7.9
E	Leather stretch panels	pass	pass	4.1
	Single leather	9.5	9.5	
	Double leather	pass	pass	6.5
	Triple leather	pass	pass	3.0

*Materials passing for Zones 1 and 2 will also pass for use in Zones 3 and 4.

4. Garment examination - Zoning

The proposed scheme for marking up the risk Zones on clothing[6] was tested. Marking all the Zone lines on a suit took an impractical length of time. Tightly fitting racing suits could not be correctly assessed using the templates which were too wide. The simplified scheme below, which allows for different garment styles, was therefore developed.

<u>Zone 1 (impact areas) and Zone 2 (high abrasion risk areas) - dimensions</u>

Three different styles of garment were used: a made-to-measure racing suit, a ready-to-wear suit, and a two piece oversuit containing impact protectors and designed to be worn over everyday clothing. Template dimensions were calculated from measurements made on the outside of the garments according to the scheme below. The Zone 1 dimension is multiplied by the figure in parentheses to obtain the equivalent Zone 2 dimension.

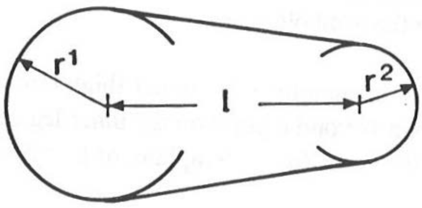

Figure 1 The basic template shape. The narrow end is distal.

<u>Zones 1 and 2 Template dimension determinations</u>

Elbow	r^1	=	Elbow circumference x 0.15 (Zone 2 x 1.8)
	r^2	=	Sleeve circumference at 0.25 distance from the cuff to the elbow x 0.15 (Zone 2 x 1.8)
	l	=	Cuff to elbow distance x 0.55 (Zone 2 x 1.0)
Shoulder	r^1	=	Circumference over shoulder through armpit x 0.14. (Zone 2 x 1.2)
	r^2	=	r^1 x 0.5 (Zone 2 x 1.2)
	l	=	r^1. (Zone 2 x 1)
Hip	r^1	=	Top of waistband to ankle cuff along side seam distance x 0.08 (a circular disc) (Zone 2 x 1.3)
Knee (High boots - ending above the middle of the shin)	r^1	=	Knee circumference x 0.16 (Zone 2 x 1.5)
	r^2	=	Leg circumference at 0.25 distance from knee to ankle cuff x 0.12 (Zone 2 x 1.5)
	l	=	Knee point to ankle cuff distance x 0.4 (Zone 2 x 1.0)
Knee (Low boots - ending below the middle of the shin)	r^1	=	Knee circumference x 0.16 (Zone 2 as for high boots)
	r^2	=	Leg circumference at 0.75 distance from knee to ankle cuff x 0.12 (Zone 2 as for high boots)
	l	=	Knee point to ankle cuff distance x 0.6 (Zone 2 as for high boots)

Zone 2 is only partly specified using these templates. It also includes the area from the waist to the level of the crutch posteriorly, and it extends forwards to join the hip Zone 2 area, from where it continues down the trouser side-seam to the knee. It extends not less than 75 mm forward of this seam and 50 mm to the rear. These dimensions can be checked visually and with a tape measure, templates and lines are not required.

Zone 4 (areas at low risk of abrasion damage)

The definition of Zone 4 given before[6] has been simplified to the following:

Torso - Not more than 35% of the torso circumference on the anterior surface, and not closer than 30 mm to the shoulder Zone 2 template;

Neck - A depth of not more than 100 mm from the top edge of the collar;

Arm - Not more than 15% of the arm sleeve circumference on the medial side and not closer than 50 mm to the wrist cuff, or 75 mm to the armhole seam;

Abdomen - Not more than 35% of the abdomen and upper thigh circumference and not closer than 20 mm to the hip Zone 2 template. Not beyond a point on the inner leg seam halfway from the crutch to the knee. Not less than 30 mm from the knee Zone 2 template, or less than 130 mm from the trouser side-seam.

Lower leg - The bottom 35% of the trouser leg between the knee and the ankle cuff and an area continuing up the posterior of the leg to behind the knee. The width on the upper shin should not exceed 25% of the circumference. The width and height of the area behind the knee should not exceed 35% of the circumference of the knee.

Zone 3 (areas at moderate risk of abrasion damage)

Zone 3 is the residue between Zones 2 and 4.

New suit examination

The new suits were all assessed using the appropriate templates cut to the sizes determined by the application of the scheme above. Impact protectors extended beyond the Zone 1 template edges, and double leather or triple Kevlar fabric, as appropriate, extended beyond the Zone 2 template edges. Zone 4 features and construction were checked visually and with a tape measure; none extended into Zone 3.

5. **Garment examination** - attachment of impact protectors

This was carried out using an electronic force gauge or with a spring balance. Most of the impact protectors were attached by hook and pile fasteners or sewn in. None of these moved significantly at a force of 50 N. (The limit proposed is 20 N.) The exceptions were those sewn into pockets in suit linings. These cannot be tested in an opened out suit like those attached by hook and pile fasteners. In racing suits, hip pads in lining pockets cannot move during use, but the only way to verify this has been to attach clips and string to them and then to try to pull them out of place when the suit is worn by an appropriate size of subject. The pads could not be moved significantly in the new garments.

Table 4 Zone 1 and Zone 2 template dimensions, mm, for three styles of garment

Template	Zone	Racing Suit			Ready to wear Suit			Wide Over-suit		
		r^1	r^2	l	r^1	r^2	l	r^1	r^2	l
Elbow & forearm	1	54	42	150	59	44	160	68	51	154
	2	97	63	150	106	79	160	122	92	154
Shoulder	1	76	38	76	77	39	77	85	43	85
	2	91	46	76	92	47	77	102	52	85
Hip	1	75	-	-	77	-	-	77	-	-
	2	98	-	-	100	-	-	100	-	-
Knee for use with high boots	1	75	49	150	77	50	156	75	50	160
	2	112	74	150	115	75	156	112	75	160
Knee and leg for use with low boots	1	75	34	225	77	40	234	75	39	240
	2	112	74	150	115	75	156	112	75	160

6. Impact test

This test has been carried out on an apparatus built to conform to the draft requirements of the impact test prepared by WG9[9]. The results for different manufacturers' pads constructed of Norsorex* polynorbornene material are given in Table 5. Five impacts were made on the main pad area. Then two areas that might have least protection were tested as "worst cases". These areas were usually the slits in the pad material put in to aid flexibility.

7. Garment restraint

Circular cross-section cones shaped approximately like arms and legs were proposed at an early meeting of WG9 as a means of testing the ability of clothing to stay in place in an accident. The dimensions of representative small, medium and large arms and legs were sought from anthropometric tables[14], however, cones made to these dimensions have not proved satisfactory because the wrists and ankles are too small. A further series of cones has been made based on knowledge from manufacturers of made-to-measure garments. The test has been simplified: the garment is adjusted around the cone with the cuff at the 'zero' line while the garment lies on a table. A horizontal pull of 50 N is applied to the arm cone and its movement measured, this should not exceed 60 mm. A pull of 35 N is applied to the leg cone, and movement should not exceed 100 mm. Testing restraint of clothing around the waist has been done according to the previous description[7], except that the weights used on ankle cuffs have been reduced to 10 kg each. All the garments tested satisfactorily met the criteria.

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*Norsorex 1910 is manufactured by Volcrepe Limited, V.C. Works, Glossop, Derbyshire, SK13 8QB, UK.

Table 5 The mean peak transmitted forces recorded below impact padding and clothing materials in 50 J and 75 J impacts.

Manufacturer	Impact energy, J	Transmitted force, kN							Mean
		Individual values for main pad area					"worst cases"		
A	50	23	23	23	22	23	23	24	22.9
	75	29	32	30	29	28	26	28	28.9
B	50	25	23	23	24	23	23	23	23.4
	75	31	32	32	33	32	31	31	31.7
C	50	27	26	26	26	26	31	28	27.1
	75	32	34	34	37	36	32	36	34.4
D	50	21	21	21	21	22	23	23	21.6
	75	29	29	30	31	32	31	32	30.6
E	50	31	26	30	31	28	28	26	28.6
	75	33	36	34	34	34	31	31	33.3

8. Ergonomic assessment

A list of 35 questions has been prepared to be answered by an experienced rider who uses the test garment to ride two styles of motorcycle under various conditions, and to carry out set tasks over a period of at least one hour. Each answer is scored: '0' for good performance of the garment; '1' for adequate performance; '2' for poor performance with high ergonomic cost; '100' for any hazardous and completely unacceptable feature. The maximum scores for each performance level and the results from the test garments are given in Table 6. Heavier suits give better protection but have a higher ergonomic cost, hence the more generous limits in the table.

Table 6 Ergonomic assessment scores

Performance Limits:	Garment type		
	Jacket	Trousers	Suit
Normal	< 7	< 8	<13
High	<10	<12	<20
Manufacturer A	-	-	7
B	-	-	9
C	-	-	3
D	-	-	2
E	-	-	5

DISCUSSION

The seven manufacturers collaborating in this project produce high quality garments that are known to give a good measure of protection in accidents[5,6]. Four of them have extensive experience of producing made-to-measure clothing for racers who demand the highest quality. The best features from different designs have been combined to produce the current garments. This has caused significant changes to some designs, so that, for example the inset seam of the sleeve is as strong as other seams in areas at high risk of road impact. The results show that the manufacturers have been able to adapt their designs to enhance mechanical performance without compromising the ergonomic performance.

1. Impact abrasion test

The new impact abrasion test[4,10,11] gives consistent results. The results from the simulated accident tests, and the analysis of crash-damaged clothing, show that the method is able to provide numerical data related to the protective qualities of fabrics and leathers. The manufacturers were able to meet the high performance requirements without difficulty. Those using leather did not have to change their materials nor the numbers of layers, except for using a double rather than a single layer of the elastic fabric. The aramid fibre suit is a new development and the net has been developed specifically to provide ventilation while protecting against abrasion. The whole suit has been tested in the simulated accident, and the results confirm the impact abrasion test results.

Impact abrasion resistance is the single most important characteristic of motorcycling clothing designed to prevent injury from road surface impacts. The new test provides appropriate data for the selection of materials that meet the performance requirements predicted from analysis of crash-damaged clothing and included in the proposals for a Standard.[6,7] The 'Darmstadt' test[15] used in Germany and Switzerland cannot provide such data as it is a pass/fail test designed to examine materials from Zone 3 areas only. It does not provide numerical data that would allow a material to be evaluated for all Zones and at different performance levels in a single measurement. The results from the 'Darmstadt'test do not correlate with UK crash data: sheep leather that was known to be of inadequate strength passed the 'Darmstadt'criteria.

2. Leather, fabric, zip fastener and seam strengths

Throughout the development phase of the work, samples have been taken to their bursting point[16]. It is now proposed that the test should be conducted so that the pressure applied to samples is raised until they burst, or is 50% above the limit value against which they are being assessed. Thus a seam with a performance requirement of >800 kPa would be taken to its bursting point or to 1,200 kPa. If it does not burst the value of 1,200 kPa is used in calculating the 'mean value'. This procedure avoids having to use very high bursting pressures to meet a "requirement" to burst samples.

The crash-damaged garments had a wide range of seam strengths and a large number of seam designs. The manufacturers involved in the current work made use of this information to select the most appropriate seam designs and seam combinations, and to produce new designs for testing. In high performance garments they are now able to meet the relevant performance limits for seams over the whole garment. The following were significant factors:

a) **The choice of leather or fabric** - these should have tensile and tear strengths well above the target seam strength.

b) **The choice of thread, stitch length and loop tension** - these should provide similar compliance properties as the folded material in the seam. For woven aramid fabrics, aramid thread is appropriate. For leather, monofilament polyamide has been found to give the strongest seams. Low twist thread is better than high twist. Ticket 40 thread is just adequate in stiff thick leather, but Ticket 20 thread is necessary in elastic leather. Recommendations cannot be more precise as the seam design and material used affect the choice of thread.

c) **The choice of seam designs** - these should be appropriate to the region of the garment concerned. Higher strengths are obtained when two or more rows of stitches are stressed at the same time. Thus inseams are the weakest type. Top stitching cannot be considered to increase strength in areas at high risk of abrasion damage. If double leather is used to provide added abrasion resistance the layers should normally be sewn together with independent seams. If the seams do not overlie each other or are in different orientations protection is increased.

d) **Attention to construction quality** - in seams with multiple rows of stitches or when hook and pile fasteners are attached to the inside of the garment, for the adjustable attachment of impact padding, is very important to avoid overstitching previous rows of stitches. Adequate spacing of stitch rows appropriate to the material being sewn, the stitch length, and the needle size and type can be determined by testing and experience.

3. Impact cut test

The cut resistance results from testing crash-damaged clothing[6,17] did appear to indicate resistance to certain types of damage but there is little experience with this type of test in predicting injury prevention, so the performance limits are currently set generously. Experience will show if they should be altered. Many fabrics have a low impact cut resistance. The aramid fibre fabrics used in one suit tested gave a just adequate performance. Knitted aramid fabrics have a higher cut resistance but much lower tensile strength, and thus seam strength. More development work is needed on these materials if they are to realise their potential in motorcycling clothing.

Leather gives results that depend on its softness. It is noticeable that soft and very stretchy leathers have a low cut resistance, while harder and stiffer areas of the same hide have a good cut resistance. Soft leather tends to fail in accidents as the result of folding and abrading, the effect of cutting by road-stones, and also of impact with parts of the motorcycle and collision partner vehicles. The impact cut test is the best test among those used, for assessing this tendency. This test is very quick to perform and should be used extensively to accumulate data so that its potential to predict material performance in accidents can be evaluated. It is expected to be particularly important in testing motorcycling gloves.

4. **Garment examination** - Zoning

The Zoning scheme for suits allows relevant performance levels to be set for areas with different levels of risk. However, it must be possible to tell in which Zone a part of the garment lies in order to show compliance with requirements based on Zones. The different styles and fits of garments available made the application of the proposed scheme[6] unworkable. A modified scheme using templates cut for each garment on the basis of its dimensions, appears to work well, and it is rapid to carry out. The formulae used in the template size calculations may need adjusting when more garments have been assessed.

5. **Garment examination** - attachment of impact protectors

The test posed no problems for protectors held by hook and pile material or sewn into the garment shell. Hip pads in lining pockets were apparently satisfactory, but they were difficult to test. Had elbow and forearm protectors been supplied in lining pockets in loose ready-to-wear garments it is anticipated that movement would have been detected by the clip and string method. It is suggested a test force of 40 N should be applied, in this modification of the test.

6. Impact test

The test apparatus used has recently been altered in parallel with decisions on WG9, so that data could be provided for use in drawing up the draft CEN Standard[9] for impact testing of motorcycle riders' clothing. The apparatus worked perfectly satisfactorily. The small templates that are specified in the draft Standard[9] are to be used in marking the area on clothing in which impact testing is to be carried out. The centre of the anvil may lie anywhere in the marked area. It was assumed in discussions on WG9 that manufacturers would make padding at least 20 mm larger all round than the test area. With the Zoning system described in this paper (see section 4), the impact padding is required to be just larger than the Zone 1 templates whose dimensions reflect the style and size of the garment being tested.. Test impacts are made with the anvil centre at least 20 mm from the Zone 1 line. Real pads are tested in the form supplied. This system is both more flexible and more certain in its application than the one under discussion by WG9, which relies on a prediction of manufacturer, behaviour, and on minimal areas of protection based on the smallest garments.

All the padding tested was made of 'Norsorex 1910' since the manufacturers have found it offers the best compromise between performance, comfort and cost. Some of the pads were a single layer 8 mm thick, and others were two layers each 4 mm thick. The performance of the material is similar in both types, but two layers offer the possibility of greater freedom of movement and the ability to stagger any notches in the layers. One manufacturer used a patented overlapping strip design that allows the greatest flexibility.

7. Garment restraint

Three major problems are seen on some existing clothing involved in accidents. The sleeves ride up the arm resulting in forearm and elbow injuries, the trouser legs rotate and ride up the shin resulting in knee injuries, and the jacket rides up the body resulting in abdominal and back abrasions. Garments that pass the tests described here should not have these problems. The lack of sleeve restraint is the most important defect, and the collaborating manufacturers report that many jackets bought ready-to-wear, are sent to them for alterations to reduce the sleeve width. Motorcyclists are obviously aware of the problem and the risks of inadequate sleeve restraint. Manufacturers and importers should make a note of the simple solution provided by a 50 mm wide cuff band secured with hook and pile fastener that can tighten the sleeve around the wrist. The design has been in use for a number of years.

8. Ergonomic assessment

The PPE Directive and particularly Annex II have significant ergonomic requirements. These are difficult to assess by laboratory measurements. User tests are the only practical method for highly specialised garments like motorcycle riders' protective suits, and only an experienced rider will know what to expect and how to use the clothing. The set of questions developed covers all the requirements of the Directive, and at the present time it is considered the best approach, despite being subjective. The questions are designed to minimise inter-subject variation. Experience will show what changes are needed in the questions, this however will take some years to accumulate.

CONCLUSIONS

CEN/TC 162 WG9 first met in August 1991 with a target date for producing a draft standard, of March 1993. This proved an impossible task. Directly applicable test methods were generally not available, and thus no test data could be called on to set performance requirements. This test data is now available from crash-damaged clothing, and from new garments specifically designed and made to meet a draft specification derived from the examination of crash-damaged clothing[5,6] The test methods and test procedures, with some modifications, are applicable to new clothing. Five manufacturers have produced garments that meet the 'high' performance requirements in all respects. They have expressed great satisfaction at the information obtained during testing, its value in assessing changes to designs, and the confidence it gives them that their products are of very high quality.

This work has been done without government or safety organisation funding. An extensive study should now be funded to correlate accident types, clothing strength, clothing damage and injuries. These data are needed to validate the work that has been done so far.

Acknowledgements

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