TESTS ON THE PROTECTION AFFORDED BY VARIOUS FABRICS AND LEATHERS IN A SIMULATED IMPACT OF A MOTORCYCLIST ON A ROAD SURFACE

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ABSTRACT

A life size dummy has been used to test the response of fabrics and leathers in a simulated accident, in which the rider skids and falls off his machine on to the road surface. The results have been correlated with laboratory tests on the materials. On the road surface used, clothing materials would require a breaking load of above 1200 N/50 mm wide strip, or a tearing load above 100 N when tested according to BS 3144, and an abrasion resistance of more than 10,000 revolutions of a Taber Abrader with H18 wheels and a 1 kg load, if they are to remain intact in a 112 $km.h^{-1}$ impact. An exception is Kevlar fabrics which would have adequate strength to withstand 112 $km.h^{-1}$ impacts if they resist 600 revolutions of the Taber Abrader. Major impact points like knees, elbows, hips and shoulders would probably need two layers of material to prevent injuries. No material or sewing thread would be acceptable if it degraded or softened when its temperature was very briefly raised to 300°C. Some cotton or Kevlar fabrics, and some bovine, goat or pig leather may be of adequate strength to prevent soft tissue injuries at 112 $km.h^{-1}$; they certainly should at 56 $km.h^{-1}$.

INTRODUCTION

These experiments were performed in order to determine if any clothing can prevent open soft tissue injuries to motorcylists in accidental impacts on road surfaces and to correlate laboratory test data with road test data. Various woven fabrics and leathers have been tested on a dummy in a simulated accident and also examined by laboratory tests. Feldkamp et al. (1) reported that protective clothing reduced injuries. This was emphasised by Kalbe et al., (3) who showed that the bone infections following skin and muscle contusion, open wounds or disturbances of bone blood supply, are particularly significant complications of fractures and not infrequently lead to amputation. Otte et al., (4) found nearly half of motocyclists' injuries were to soft tissues, and that 73% occurred during the run out phase of accidents. Our dummy simulates this phase of accidents. The possibility that suitable clothing could prevent many soft tissue injuries was emphasised by the Folksam study (2) which concluded that goat leather was the best material available for motorcyclists' suits.

Our experiments have only concerned clothing materials. Actual garments will have to be made with care if the inherent strength of the materials is not to be negated by inadequate sewing techniques or seam placement. There are also other important characteristics of motorcyclists' clothing that must be taken into account such as windproofing and insulation(5).

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METHODS

Road Tests

A life-size dummy weighing 70 kg was built. It has a square section welded steel tube frame, high tensile steel bolt or universal joint articulations. It was fleshed with polyurethane foam, neoprene foam sheet, and hessian strip bound together in successive layers with 50 mm wide duct sealing tape. Bony protuberances at the shoulders, elbows, hips and knees were machined out of solid nylon stock or hockey balls. The head was based on a polypropylene tank float. The dummy was dressed in a cotton jacket and trousers, and over these were fixed the test samples or protective cotton canvas sheets. The dummy's flexibility with the samples attached is, we believe, similar to that of a motorcyclist in heavy leathers.

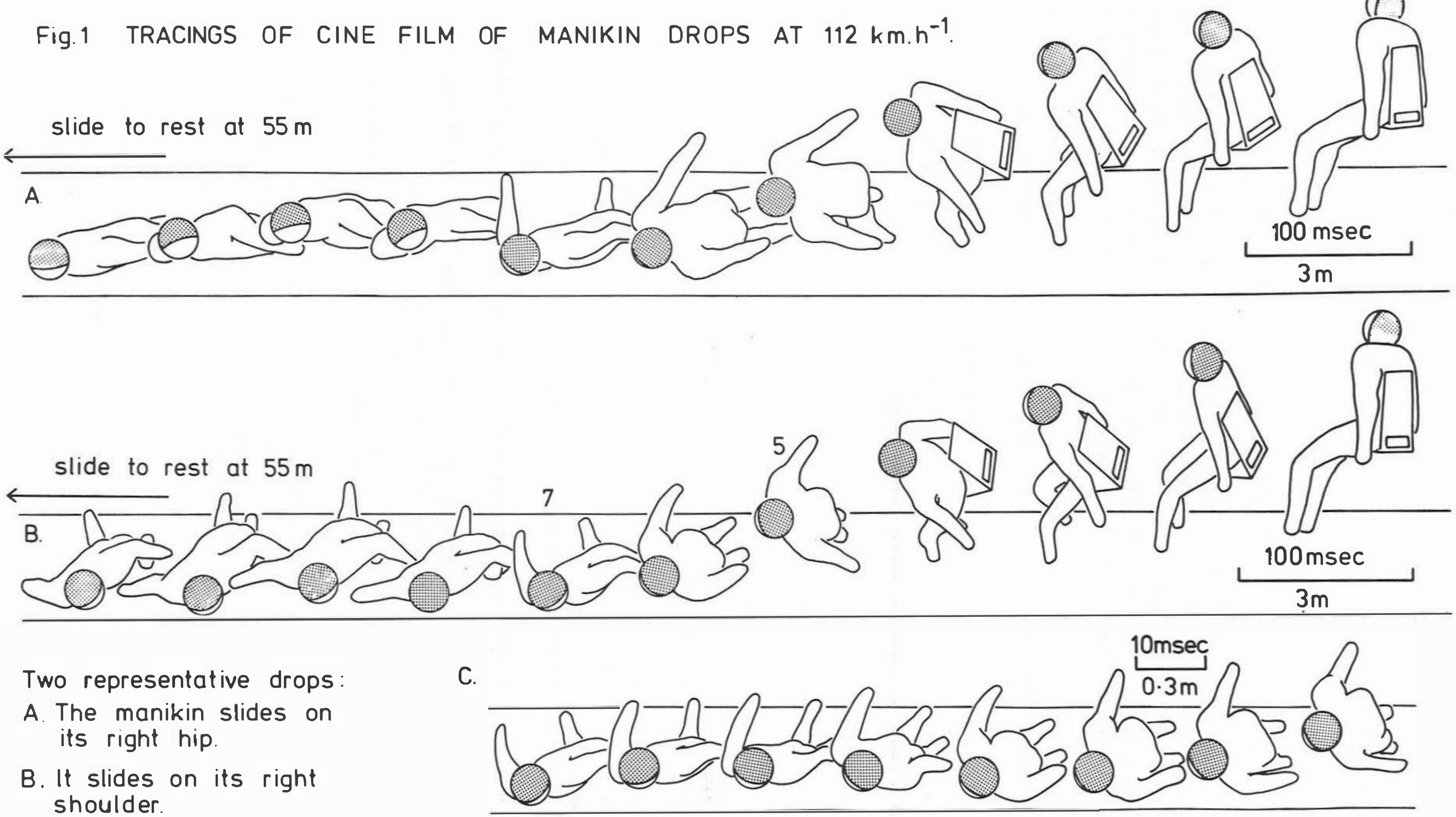
Samples were attached with 50 mm duct tape to the left knee, right shoulder and right hip. The shoulder sample is secured across the dummy's back to the left arm. The hip sample is secured to a length of cotton denim wound around the thigh beneath it. Fabric samples were 350x450 mm. Leather samples were 250x250 mm and sewn into cotton canvas sheets 450x600 mm. Cotton and Kevlar fabrics were prepared as multilayer samples because these materials are often used that way in protective clothing. For analysis of results it has been assumed that the layers perform independently and that each value obtained in the laboratory tests on one layer may be doubled for two layers. Hole sizes were determined separately on each layer. Leathers were not tested in two layers though it is possible that thin ones could be used in this way.

The dummy sat on a chair-like seat which was supported on its right side by a steel tube held in a support in the back of a laboratory van. When a catch was released the dummy rotated to its left under gravity and fell off its seat simulating a motorcyclist skidding on a left-hand corner. After leaving the chair the dummy was free of all constraint.

The impact on the road retarded the dummy's left side and as it bounced up clear of the road it rotated to its right side, struck the road with its right side, and generally slid to rest in this attitude. If it rolled over, sat up or otherwise behaved atypically the results were discarded. Figure 1 shows two common patterns of falls. The slides may be concentrated on the right hip or right shoulder or shared between them. The left knee received two injuries: the initial impact, and the subsequent slide when the dummy was on its face. Other body points received variable and sometimes severe damage, but the left knee, right shoulder and right hip gave most consistent results. The data from all three sites has been pooled for the analyses in this paper. The road surface was normally damp rather than wet, as it is very often in Britain. Samples were photographed after test, and visually examined. The holes in the samples were traced on to card with firm lateral pressure, and their areas measured on a Quantimet Image Analysing Computer.

Drops were carried out at 14, 28, 56 & 112 $km.h^{-1}$ (8.75, 17.5, 35, & 70 mph). One series on 13 March 1984 was on to a County Class B road that had been resurfaced on 5 August 1983 with 10 mm slag chippings and a binder of cut-back bitumen spread at 1.3 $l.m^{-2}$. All the other drops between 18 July 1983 and 13 March 1984 were on to a 15 year old hot rolled asphalt with flint gravel aggregate road laid to BS 594.

Fig. 1 TRACINGS OF CINE FILM OF MANIKIN DROPS AT 112 $km.h^{-1}$.



Two representative drops:

A. The manikin slides on its right hip.

B. It slides on its right shoulder.

C. Shows every frame at 64 fps of a sequence between figures 5 and 7 of B. The manikin bounces, rotates and impacts its rightside at the end of the sequence.

Laboratory Tests

1. Sample thickness was measured with a micrometer gauge with a 0.5 $kg.cm^{-2}$ jaw pressure according to BS 3144. 25 measurements on each leather square and 10 on each fabric were averaged.

2. Tearing load was measured according to BS 3144

3. Breaking load was measured according to BS 2576 on 50mm wide strips. Breaking load was also measured according to BS 3144 on 10 mm wide specimens. The results obtained on leather and tightly woven fabrics by the BS 3144 and BS 2576 methods were in close agreement, but loosely woven, and Kevlar fabrics, could only be tested adequately by the BS 2576 method.

4. Abrasion resistance was measured with a Teledyne Taber Abrader using H18 carborundum wheels and a 1 kg load, according to Revised BS 1651*.

RESULTS AND A DISCUSSION OF THE RESULTS

Table 1 summarises all the data from the tests at 56 & 112 $km.h^{-1}$. Seven types of damage were observed:

1. Progressive loss of thickness by abrasion. (Only on very thick wovens and leather)

2. Non-penetrating surface cuts - particularly on leather.

3. Tearing and exposure of underlying materials by folding back (weak wovens and sheep skins).

4. Melting or softening of the fabric with possibly large scale loss of material (thermoplastics like Cordura, Nomex, Acrylan and Nylon).

5. Apparent heat hardening of leather.

6. Glazing of the surface on fatty leather or very waxy fabrics.

7. Fabric distortion producing a hole by the sliding of warp on weft or vice versa. (Only seen on Kevlar materials).

Notes on the damage to individual materials

1. TEXTILES

A. Waxed Cotton Canvas 0.73 mm thick. This was the most predictable material tested. It did not tear. Surface abrasion thinned the fabric until holes appeared, which then extended as the fabric wore away. At the edges of holes the warp and weft fibres parted slightly. Repeated drops of the same samples merely extended the hole area. This material was used to protect all impact points not under study. The fabric is hard and stiff. The wax has a high melting point.

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*Revision in course of preparation.

TABLE 1

MATERIALS	MEAN THICKNESS mm	MEAN BREAKING LOAD N/50 mm	MEAN TEARING LOAD N	TABER REVOLUTIONS TO HOLE OR TEAR	FRACTION OF SAMPLES TEARING AT 56 & 112 $km.h^{-1}$ POOLED	ROAD TESTS WITH SIMILAR IMPACT PATTERNS: 56 $km.h^{-1}$ – NUMBER OF SAMPLES	56 $km.h^{-1}$ MEAN HOLE AREA mm^2: LEFT KNEE	56 $km.h^{-1}$ MEAN HOLE AREA mm^2: RIGHT SHOULDER AND HIP POOLED	56 $km.h^{-1}$ MEAN HOLE AREA mm^2: ALL SITES POOLED	112 $km.h^{-1}$ – NUMBER OF SAMPLES	112 $km.h^{-1}$ MEAN HOLE AREA mm^2: LEFT KNEE	112 $km.h^{-1}$ MEAN HOLE AREA mm^2: RIGHT SHOULDER AND HIP POOLED	112 $km.h^{-1}$ MEAN HOLE AREA mm^2: ALL SITES POOLED
350 $g.m^{-2}$ COTTON CANVAS	0.73	1850	149	1420[2]	0/34	-	-	-	-	24	667	1940	1510
" " 2 LAYERS	1.53	-	-	-	-	-	-	-	-	24	41	32	35
MOTORCYCLE CLOTHING WAXED COTTON	0.38	1100	70	305	44/60	9	1.3	1070	713	24	1930	6830	5200
" " 2 LAYERS	0.79	-	-	-	-	9	0	13	9	24	546	946	812
AS ABOVE WITHOUT WAX	0.35	953	65	198	9/12	-	-	-	-	12	1740	7920	5910
" "	0.75	-	-	-	-	-	-	-	-	12	183	1850	1290
WAXED CUPRAMMONIUM TREATED COTTON	0.34	909	39	-[3]	12/12	-	-	-	-	12	3270	10300	7940
" " 2 LAYERS	0.70	-	-	-	-	-	-	-	-	12	488	4220	2980
NYLON/POLYURETHANE WATERPROOF FABRICS	0.20	1100	96	120	3/3[5]	3	2079	2340	2250	-	-	-	-
CORDURA/PTFE/NYLON LAMINATED FABRIC	0.52	1630	235	583	1/36	12	595	662	594	24	1190	4500	3400
NOMEX/PTFE/ACRYLAN LAMINATED FABRIC, TYPE 2	0.60	1000	77	708	2/9	-	-	-	-	-	-	-	-
" " TYPE 2	0.64	1090	135	363	1/24	26[6]	205	1170	919	24[6]	3580	7850	6430
" " TYPE 4	0.74	1140	157	295	4/18	-	-	-	-	-	-	-	-
KEVLAR, FOTHERGILL & HARVEY, D235	0.34	7180	-[1]	247	0/24	-	-	-	-	24	1010	2070	476
" " 2 LAYERS	0.68	-	-	-	-	-	-	-	-	24	135	6	49
KEVLAR, ARVILLE TEXTILES, FKV 269	0.36	4660	[1]	110	0/9	-	-	-	-	9	1890	1560	1670
" " 2 LAYERS	0.67	-	-	-	-	-	-	-	-	9	253	586	541
KEVLAR/NOMEX/GLASS. TBA, KC600	1.53	1440	[1]	186	0/9	-	-	-	-	9	746	1180	1030
" " 2 LAYERS	3.39	-	-	-	-	-	-	-	-	9	51	0	17
BOVINE HIDE A	1.29	505	40	2710	4/14	6	0	40	27	8	742	2530	1850
" B	1.02	1260	132	1610	0/8	-	-	-	-	8	334	156	186
" I	1.19	644	86	2940	0/18	-	-	-	-	18	276	96	156
" P	1.09	758	76	2690	7/15	-	-	-	-	(15[7]	1078	1700	1500)
" Q	1.40	1100	129	4210	0/18	-	-	-	-	(6[7,8]	401	2787	1990)
" R	1.27	1410	216	4810	1/12	-	-	-	-	12[8]	40	425	294
" S	1.71	1770	146	7370	0/15	-	-	-	-	12	199	33	72
PIG SKINS FROM 8 ANIMALS	1.31	998	78	12500[4]	5/24	3	18	0	6	21	335	108	113
GOAT SKINS FROM 3 ANIMALS	1.14	1470	86	5210	0/12	3	0	0	0	9	17	96	70
SHEEP SKINS FROM 9 ANIMALS	1.17	765	41	1420	14/38	20	180	3020	1720	18	540	418	459

NOTES: (1) SAMPLE PULLED APART
(2) SAMPLE DEGREASED TO PREVENT WHEEL CLOGGING
(3) WHEELS ALWAYS CLOGGED
(4) NINE SAMPLES DID NOT HOLE IN 12000 REVOLUTIONS. END POINT ESTIMATED FROM THICKNESS LOSS AT 12000 REVS
(5) PROBABLY MELTED NOT TORN
(6) DATA FROM NOMEX TYPES 2,3 & 4 POOLED
(7) ALL SAMPLES TESTED ON SLAG CHIP SURFACE
(8) SAMPLES FROM Q & R COMBINED

B. Waxed Cotton

(i) Waxed Cotton 0.38 mm thick. This is a traditional motorcycle clothing fabric in Britain. The wax is liquid at room temperature and the fabric is sticky. It behaved as canvas except that the holes extended by tearing. The fabric was used in several layers and the lower layers suffered much less damage than the surface one. Two layers performed well at 56 $km.h^{-1}$

(ii) Waxed cotton - before waxing 0.35 mm thick. This is the above material without the wax. It behaved slightly worse than the waxed product.

(iii) Waxed cotton, previously treated in a Cuprammonium bath 0.34 mm thick. This was a hard fabric and it was considerably weakened by partial conversion to 'rayon'. Where surface abrasion had not quite penetrated the fabric the surface fibres were flattened and fused together. They remained stuck after de-waxing. This was never seen with pure cotton. A fusing temperature was not determined in the laboratory as charring occurred first.

C. Nylon coated with polyurethane 0.20 mm thick. This was the only fabric tested at 14 $km.h^{-1}$. Holes occurred particularly on the left knee and the hole edges and fabric surface showed melting. A similar appearance was produced in the laboratory at 230°C with pressure and tension.

D. 'Cordura'/PTFE/Nylon '66' laminate 0.52 mm thick. The Cordura high tensile nylon outer surface behaved like normal nylon, but only damaged at higher speeds. Both the Cordura and the Nylon '66' inner layer melted at some hole edges even at 28 $km.h^{-1}$. In the laboratory this occurred at 230°C. On the right shoulder the Nylon '66' inner often fused to the denim cotton beneath without any hole appearing in the 'Cordura' outer. A temperature of 250°C at the Nylon '66'/cotton interface was required to produce fusing under pressure in the laboratory. After road tests at 112 $km.h^{-1}$ areas of fabric were shredded or missing.

E. Nomex/PTFE/Acrylan laminates 0.60-0.74 mm thick. At 28 $km.h^{-1}$ and above the Acrylan and Nomex layers showed melting and fusion of fibres. The inner Acrylan layer often fused and shrank and distorted the outer layer without any hole occurring in the outer layer. In the laboratory the Acrylan fused at 125°C and the Nomex at 280°C under pressure and tension. Large areas of fabric were lost at 112 $km.h^{-1}$.

F. Kevlar fabrics

(i) TBA Fortamid KC 600 1.53 mm thick. This is a thick fabric of composite Kevlar, Nomex and Glass fibre yarn. Some holes appeared in the outer layer and the fibres appeared to have snapped. The holes did not extend much by warp and weft separation and second layer holes were very small. Considerable surface abrasion appeared to have occurred before the fibres snapped.

(ii) Arville Textile Ltd. FKV 269 0.36 mm thick. This is a very loose weave fabric of untwisted pure Kevlar yarn. Abrasion holes occurred and also considerable fabric distortion due to slippage of warp on weft and vice versa.

(iii) Fothergill and Harvey D235 0.34 mm thick. This is a tightly woven untwisted pure Kevlar yarn fabric. Some holes were abraded in it. There was little fabric loss. Usually broken fibres were frayed. A few fibres showed flattening, and had globular ends and a curly shape. They may have snapped while hot. Similar appearances were produced in the laboratory when tightly stretched yarn was snapped while it was pressed firmly against a soft support with a soldering iron. This was not achieved below 320°C.

2. LEATHERS

Unlike manufactured products leather is a non-uniform material. It varies according to the species and age of the animal, the tanning process used and the precise site of origin on the animal. The finished thickness of the leather and the above variables determine the physical properties of the leather. This variability is reflected in the range of values obtained in laboratory and road tests. Small skins from pigs, goats and sheep provided so few samples that all the data from each species has been pooled.

A. Sheep Leather 0.95-1.4 mm thick.

(i) Wool Sheep. The grain* layer of wool sheep skin tended to tear away from the corium. Once holed there was a tendency to tear also. As expected from the low tearing loads and abrasion resistances of wool sheep skins, their performance was unsatisfactory at 112 $km.h^{-1}$. Many were severely damaged at 56 $km.h^{-1}$.

(ii) Hair Sheep Hair sheep skins were stronger but usually thinner than wool sheep skins and tended to abrade to a hole at 112 $km.h^{-1}$

B. Goat Leather 1.05-1.18 mm thick. None of the samples tested tore in road tests. Goat Leather usually stretched and occasional abrasion holes occurred where it folded. The goat skins used, which had been supplied for motorcycle leathers were strong and abrasion resistant.

C. Pig Leather 1.09-1.70 mm thick.

(i) Grain Pig skins. Some grain pig skins exhibited small tears but they lost little thickness during road testing.

(ii) Suede Pig skins. Suede Pig skins rarely tore but often appeared glazed and compressed after road testing. They too lost little thickness during test. Pig skin has the same dense structure throughout its thickness unlike the other leathers tested. It is a promising material for motorcycle leathers.

D. Bovine Leather 1.02-1.71 mm thick Seven hides from three different sources were tested:

(i) SOURCE 1. Hide A. This hide's tearing load and breaking load were both low, and it tore extensively in road testing.

(ii) SOURCE 2. Hides B, I and P. Hide B was thin and therefore had a low abrasion resistance and was holed during road testing. Hides I and P which had similar characteristics in laboratory tests, were road tested on different road surfaces (see Table 1). The grain was cut by the stones and also abraded. Once the grain had been abraded away the corium tended to stretch and tear. Some right hip specimens showed linear shrinkage and hardening due to compression, friction or impact heating.

(iii) SOURCE 3. Hides Q, R, & S. These all had high breaking loads. Leathers Q and R were particularly soft and flexible and appeared to impact down between road stones and suffer more damage than leather S. Leather S was considerably thicker than leathers Q and R and was much more abrasion resistant. It performed well in road tests and its corium was not rapidly revealed in road tests in which it performed well at 112 $km.h^{-1}$.

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*The grain layer of a leather is the natural surface layer and it is usually denser than the corium which forms the bulk of the thickness of finished leather. In most species of animal the deeper corium layers are progressively looser. A Suede leather consists entirely of corium.

COMPARISON OF ROAD DATA AND LABORATORY DATA

Graphical analysis of mean hole diameter against tearing load (Figure 2) suggests that leather and woven materials behave differently but that either would require a tearing load of above 300 N to remain without any holes on impact above 112 $km.h^{-1}$. The Kevlar fabrics are not included in this graph as they pull apart in the laboratory test.

Graphical analysis of mean hole diameter against breaking load (Figure 3) again suggests that leather and wovens behave differently. Without considering the pure Kevlar fabrics, a breaking load in excess of 3,500 N/50mm wide strip appears necessary if the materials are to remain intact in impacts on the road. However D235 has a breaking load of 7180 N and this still develops holes in the top layer on impact, which suggests other factors may be important in addition to tensile strength.

Graphical analysis of mean hole diameter against abrasion resistance on the Taber Abrader (Figure 4) suggests that with this measurement leathers and wovens behave similarly, if the Kevlar fabrics are excluded. It appears that a material needs to withstand, over 10,000 revolutions of the abrader if it is to resist holing on impact at 112 $km.h^{-1}$.

Tearing load and breaking load determinations measure similar strength characteristics of materials, except for thread sliding such as occurs in some woven Kevlar fabrics which was only revealed in tear testing. Abrasion resistance, tearing load and breaking load all increase with an increase in the thickness of a material. Behaviour on impact with a road will depend on tearing and breaking loads and abrasion resistance of materials and these are partly dependent on thickness. A material which tears at a low load will tear whatever its abrasion resistance properties. A fabric with a high breaking or tearing load fails if it has a low abrasion resistance, or if removal of part of its thickness disproportionately weakens it. A satisfactory material needs to have a certain strength, to abrade slowly and to retain a reasonable proportion of its strength while abrading.

From Table 1 it can be seen that significant tears are not often found in materials which tear at a load above about 100 N or break at a load above about 1200 N/50 mm wide strip, see also Figure 6. These values are much lower than those predicted from figures 1 & 2 (300 N & 3000 N) and suggest that tensile strength as determined in the breaking and tearing tests is only one factor. It possibly can be partly eliminated by excluding all fabrics and leathers with low tearing and breaking loads. If those with tearing loads below 100 N or breaking loads below 1,200N/50mm wide strip are removed from figure 4, figure 5 is obtained. A much clearer relationship of hole size to abrasion resistance is then seen. Woven fabrics and leather lie on one line with all the Kevlar fabrics quite separate. Figure 5 suggests that lack of abrasion resistance is indeed a major factor in hole formation in impacts on road surfaces.

The leather points in Figures 4 & 5 show considerable scatter and this could be related to the differences between the road and laboratory tests. In the Taber test the leather is only minimally subjected to tension and does not heat. The scatter may also be due to interaction between tearing and breaking, and abrasion resistance properties. The points marked 'P' are pig skins which fall below the chosen breaking load threshold of 1200 N, but

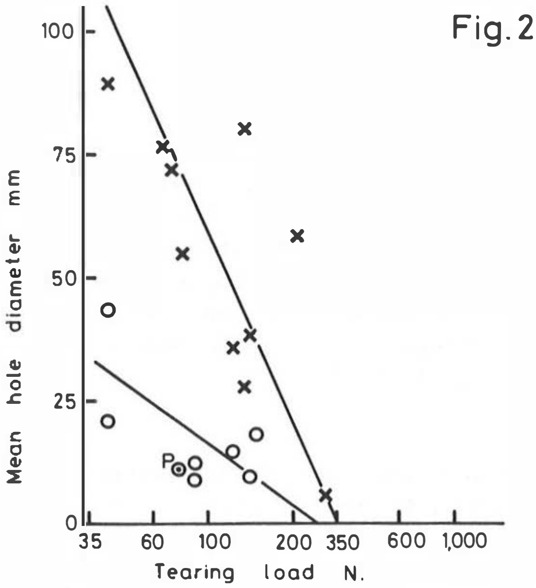

Fig. 2

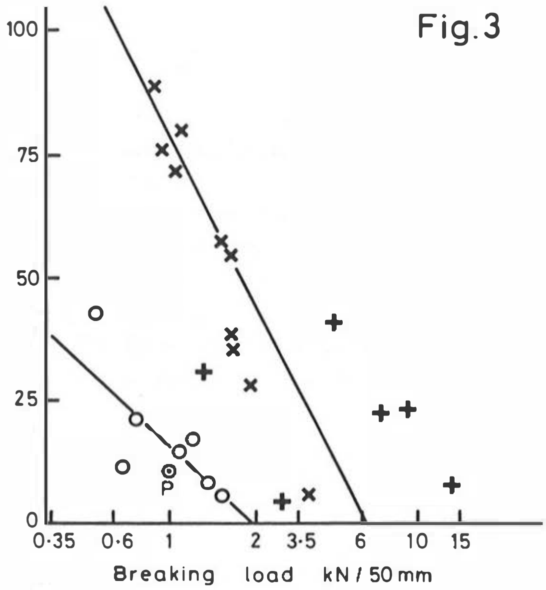

Fig. 3

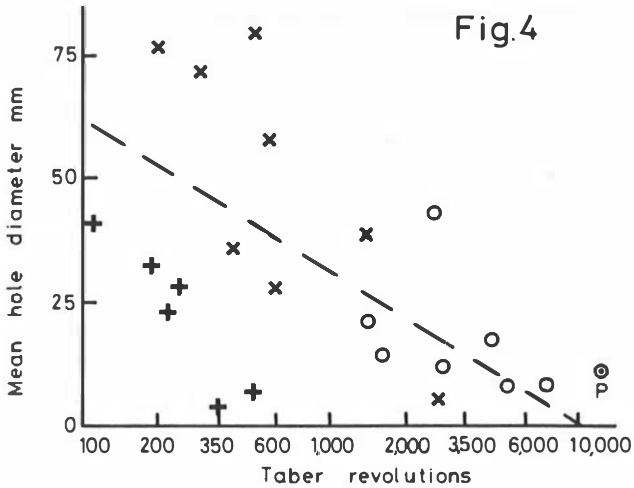

Fig. 4

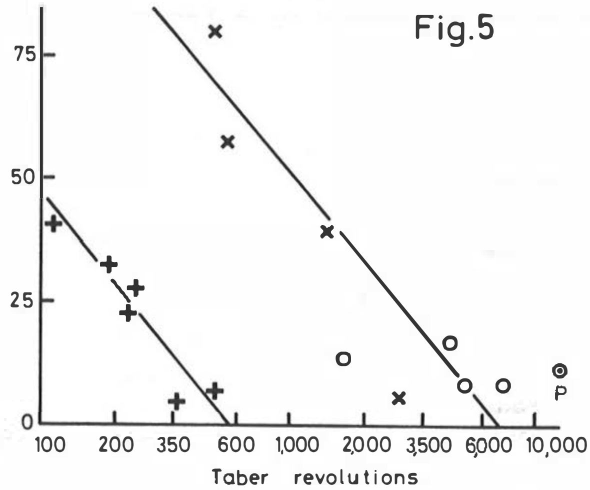

Fig. 5

Key

- O Leather. P denotes pig skins.
- ✚ Kevlar fabrics.
- ✕ Other woven fabrics.

} Includes data from the second layer of fabrics plotted as though two layers have twice the tearing load, breaking load and abrasion resistance of a single layer.

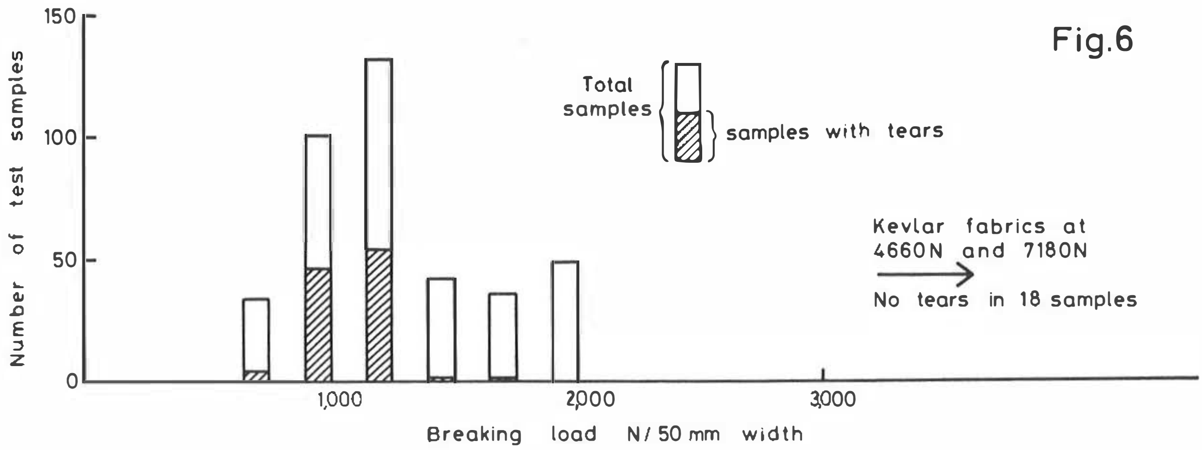

Fig. 6

performed well and lie to the extreme rights of the figures, because of their very high abrasion resistance.

The effect of padding beneath the sample

Two layers of waxed cotton were used in tests at 112 $km.h^{-1}$ to determine the effects of foam padding on hole formation in the fabric above the foam. No effect was seen with a hard neoprene foam No 105E* or a soft polyurethane foam No. RA52*. An effect was found with both a soft neoprene foam No. RA102E and an EPDM synthetic rubber foam No. RA25* of similar density. All the foams were 12 mm thick. The mean hole diameters for the right shoulder and hip in the outer and inner layers of waxed cotton were 83 mm and 31 mm respectively without foam, and 67 mm and 19 mm respectively with foam. 8 drops were done without foam and 8 with RA25 or RA102E.

The effect of the road surface

181 drops were done on the hot rolled asphalt surface at Oakington Barracks, and 11 on the slag chipping surface on a County Class B road. 5 bovine hides were compared: I on asphalt with P on slag chips, and separate samples of Q R & S on each surface. For all comparisons pooled the mean hole diameter increased by a factor of 4.8 on the rougher slag chippings.

CONCLUSIONS

1. (i) The materials reach surface temperatures of around 300°C in the road impacts. 250°C is reached within the material layers when the outside has not reached 230°C. Some of the heating will be due to friction. Most is probably from dissipation of the impact force, even on the right-hand side of the body which hits the road in a secondary impact.

(ii) In the experimental impacts at 112 $km.h^{-1}$ materials tend to break if their laboratory determined breaking load is less than 1200 N/50 mm width.

(iii) Abrasion of the materials consists of cuts of various depths by the road surface. Soft materials mould better to the stones, and therefore abrade more. Laboratory testing with a carborundum wheel is not a perfect substitute for road tests except for comparing materials of similar physical properties. Kevlar is renowned for the difficulty experienced in cutting it. In a suitable weave it can resist road abrasion much better than the laboratory tests used could predict.

(iv) The nature of the road surface has a significant effect, as also probably do the climatic conditions.

(v) Suitable shock absorbing padding may assist the clothing of a rider to stay intact, as well as reducing injuries to tissues beneath it.

(vi) The damage to fabrics is significantly related to velocity of the rider prior to the impact.

2. The following characteristics appear desirable in any material to be used for motorcycle protective clothing:

(i) It should not soften or degrade when briefly raised to 300°C.

(ii) It should have a breaking load above 1200 N/50 mm wide strips, or a tearing load above 100 N by BS 3144.

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*Rubber Astic & Co. Ltd., Wednesbury.

(iii) It should withstand 10,000 revolutions on the Taber Abrader if it is a leather or cotton woven, but need only withstand 600 revolutions if it is a Kevlar fabric.

(iv) It should neither be so soft it moulds into the road surface on impact nor too uncomfortably rigid to wear as clothing.

3. The following materials appear to show possibilities for development for use in this clothing: Cotton fabrics intermediate between the canvas and traditional waxed cotton material in thickness, Kevlar fabrics, and bovine, goat and pig leathers. The only suitable materials known to be available at the moment are Kevlar fabrics and bovine and goat leather. It must be noted however that not all bovine or goat leathers or even Kevlar fabrics are strong enough. Improved tannery selection procedures of leather specifically for motorcyclists' clothing are necessary to ensure that leather for this end use is of sufficient thickness and has adequate tearing load, breaking load and abrasion resistance properties. In addition purchasers of leather for motorcyclists' clothing should specify that this is the end use for which it is required. Even the best materials tested developed some holes at 112 $km.h^{-1}$, so at the moment clothing cannot be expected to eliminate open injuries in high speed accidents, but it may significantly reduce them and even prevent them at more moderate speeds such as 56 $km.h^{-1}$. Tests of whole clothing assemblies, and analysis of the injuries caused in actual accidents, and collection of data about accidents where no injuries occurred, will be required to establish the applicability of the results of experiments like those reported above, to riders involved in accidents.

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