ANY MATERIAL COMPOSED OF FIBRES IS A TEXTILE, AND THIS DEFINITION covers an extremely wide range of products in everyday use. Worldwide, over 35 million tonnes of textile fibre is consumed annually, ending up not only as clothing, upholstery, bed linen and carpets, but also in such items as ropes, seat belts, nets, road stabilisation mats, drainage pipes and tents. It is not surprising that, when a crime takes place, the ubiquitous textile is nearly always present and is very often directly involved.

The successful use of textiles in such a broad range of applications is due in part to the great variety of fibres and fabric constructions that are available. Most textile items are compound structures composed of up to four levels—fibre, yarn, fabric and the final article—and within each level, there are many choices available. There are more than fifty types of textile fibre in commercial use of various lengths and diameters; for example, cotton, wool, flax, jute, nylon, polyester, acrylic and polypropylene. Normally, these fibres are formed into yarns of various types (for example, monofilament or multifilament; ring, rotor or air-jet spun; single, plied or cabled), and then the yarns are interlaced into fabrics, either by weaving, knitting, braiding or even knotting (in the case of nets).

In addition to the great many woven and knitted constructions, so-called 'non-woven' fabrics may also be formed directly from fibres, without the intermediate yarn form. Furthermore, while paper and leather are usually not considered as textiles, they are nonetheless fibrous structures, and the same damage analysis techniques can be applied to them.

It is this very variety which often makes textiles such an important element in forensic investigations (such as in matching of evidence), yet it also makes it difficult to devise a 'recipe book' approach to the interpretation
of physical damage. While fibre identification can usually be performed by a technician with general laboratory skills, the analysis of textile damage is usually left to a textile expert.

**Physical Damage**

There are various forms of physical damage which may be found on textiles; for example, ‘normal wear-and-tear’ resulting from normal use of textiles. This usually takes the form of a thinning of the fabric prior to a hole forming, but seams may also come undone, threads can catch and be pulled out from the fabric, or the fabric may even be torn. It must also be remembered that the fabric will probably have been cut in order to make the textile item. In forensic investigations, these forms of ‘normal’ physical damage must be distinguished from other forms which may be related to the crime.

In a violent scuffle, a fabric may be torn, and the seams often fail; the structure of the fabric may also be distorted. Fabrics may be neatly cut, either with scissors or by slicing with a knife. They may also be punctured by relatively sharp (for example, a screwdriver) or blunt (for example, a hammer) objects, and the nature of the damage will depend on the supporting material (if any) beneath the fabric. Note that the stabbing action of a knife may have features of both puncturing and cutting.

Pure tensile failure may occur, especially in ropes and webbing (such as seat belts and slings), although this can often be precipitated by some other form of damage which has weakened the textile.

Abrasive damage, normally considered to be due to ‘normal wear and tear’, can also be of forensic importance. For instance, a seat belt may fail to protect a passenger in an automobile accident if it has been previously caught in the door and allowed to drag along the road. Damage may also be inflicted by insects, such as moths and carpet beetles, which bite the fibre and digest the fibre pieces internally. Micro-organisms, such as some forms of bacteria and fungi, can inject enzymes onto the fibre to break it down.

There are many chemicals which can weaken, modify or completely dissolve some textile fibres. The exact nature of the damage depends on the chemical structure of the fibre and the local conditions, such as temperature and presence of other agents such as oxygen. Textiles may also be damaged by excessive heat, for example in fires or ovens. Heat damage could be localised if inflicted by a cigarette or blow-torch.

Thus, when examining a damaged textile item, the textile technologist is usually confronted by a wide range of possible general causes. This range must first be narrowed before any particular scenario can be evaluated.

Only physical damage caused by mechanical means which has led to a hole (or more generally ‘severance’, implying the breakage of yarns or fibres in the fabric structure) will be considered in detail in this paper.
Examination Techniques

Most of the information that can assist in determining the cause of some severance lies in the physical ‘morphology’ of the fibres, yarns and fabric at and near the severed edge of fabric. Information on this morphology is obtained by observation at varying levels of magnification, ranging from direct viewing by eye without magnification, up to the use of a scanning electron microscope with magnifications up to 10,000X. The majority of inspections are done using the optical stereo microscope at magnifications between 20X to 100X. The following general features are examined.

At the fabric level

- Distortion of fabric surrounding the severance, such as buckling or folds out of the fabric plane or tight threads.
- Changes to the normal thread spacing, including runs in knitted fabrics.
- Direction of the severance line relative to the thread directions in the fabric; for example, tears usually propagate parallel to one of the thread directions.
- The relative positions of the severed yarn ends. In cuts, the yarn ends usually line up quite well, whereas a puncturing action may rupture neighbouring yarns at different positions.

At the yarn level

- Relative positions of fibre ends within each yarn. A clean cut made on untensioned fabric will leave all the fibre ends ending in the same plane. This has been referred to as a planar array. On the other hand, tearing will cause the fibres to break at different positions along the yarn, leaving a less well-ordered yarn end. High tension may also cause the yarn ends to untwist when the yarn is broken, leaving a frayed appearance.
- Short segments of yarn may be created, especially by cutting actions. For example, in knitted fabric, ‘loop snippets’ are created if the fabric is cut at an angle to the thread directions.

At the fibre level

The ends of fibres may also show some characteristic features. Thermoplastic fibres develop mushroom ends if they fail in a high energy tensile failure due to localised melting, whereas most low energy tensile failures produce fibre end morphologies which depend on the morphological structure of the fibres. Some insects leave characteristic bite marks.
The end morphologies of fibres cut individually can reveal quite a lot about the implement which made the cut. Scanning electron microscopy is needed to clearly examine the fibre ends at the required magnification and depth of field. Scissors usually flatten the fibre end and give a somewhat roof-shaped end, while sharp knives may even leave tool marks characteristic of the particular blade. However, the situation is not so clear when many fibres are cut simultaneously, as occurs when a fabric is cut, since the fibres may crush each other under the pressure of the implement. Relatively few fibres may have been subject to the pure action of the implement, and it must also be remembered that there usually are many fibre ends already in the yarn, which may have been created by one of a number of processes in manufacturing. Consequently, there is some disagreement about the value of fibre end morphologies in some forensic work.

*Other*

Contaminants may help or hinder the investigation. Heavy contamination with body fluids can make the yarn end morphologies difficult to see, but can often give a clue as to whether a severance occurred before or after exposure to the contaminating fluids. Liquid contaminants also tend to bind the ruptured fibre ends together, restricting any tendency to fray. Some contaminants and debris can give clues as to the cause of damage. For instance, moth eggs would suggest searching for further evidence of attack by moth larvae.

Where multiple layers of fabric may have been damaged, a comparison of the damage features in the various fabrics can be very informative, especially if they are of different fabric types.

*Simulation*

Because of the great variety of possibilities, the forensic textile technologist frequently tries to reproduce the damage in a controlled simulation experiment. Care must be taken to reproduce as many of the known variables as accurately as possible. The test fabric should be the same as or very similar to the crime scene fabric (in fibre, yarn and fabric characteristics). Since the mounting and supporting of the fabric can have a major influence on the damage morphology, these aspects of the test conditions must also closely simulate the proposed scenario.

*Stabbed Fabrics*

Stabbing accounted for 26.7 per cent of the homicide cases which passed through the Sydney Coroner’s Courts from 1982 to 1986 (Bonney 1987). Generally, interpretation of the stab wound is left to pathologists, but this is only possible if there is a body, and if the body is in reasonable condition. Consequently, textile technologists are usually only called in when the body is badly decomposed or missing altogether, but in many cases there would be merit in examining both the wound in the body and the damage to the garment.
The morphology of stabbed fabrics has been investigated by Heuse (1982), Monohan (1975), and Stacy (1989), with a view to being able to identify the general shape of a knife which might have caused a particular severance. These workers used simulation experiments with either pork flesh or synthetic skin to simulate the support given to the fabric by the human body. Heuse (1982) suggested that four different actions can occur as a knife penetrates a fabric:

- **pushing**: moves yarns out of the plane of the fabric, or relative to each other within the fabric plane;
- **cutting**: due to sharp transverse pressure on the fibres;
- **shearing**: due to blunt transverse pressure on the fibres; and
- **tearing**: caused by the fibres being extended to break.

As the point of a knife engages the fabric, it will either push into a yarn or between neighbouring yarns. In either case, it will eventually start to push the fabric into the body beneath, tensioning the fibres and yarns and either tearing or cutting them. The cutting edge may then slice through yarns in its path until a reasonably long cut is produced.

The blunter the tip of the knife, the more the fabric distorts before the yarns sever, and the more the yarns will fray because of the tension developed in them. This distortion due to the initial penetration, found at only one end of the severance for smooth single-blade knives, is useful for deducing that the cut was produced by a stab, the likely orientation of the knife (and hence where the assailant was standing in relation to the victim) and the sharpness of the knife tip. Very sharply-pointed knives do not produce this distortion. A number of general points from these investigations are summarised below:

**The tip**

In general, the blunter the point of the knife, the more difficult it is to make the initial penetration of the fabric. Consequently, the blunter the point, the more the fabric distortion around the penetration point, due to pushing of the threads, and the more the broken yarns in this region will fray because they fail under tension rather than by being cut.

**The blade**

The sharpness of the blade affects the shape of the severance. A sharp blade will neatly cut the yarns as it travels through the fabric, with little or no fabric distortion, whereas a blunt blade will tend to pull the yarns before eventually cutting them, resulting in distortion along the sides of the severance and increased fraying of the severed yarn ends.
**Blade irregularities**

The presence of scallops on a blade will increase fraying and distortion, as each scallop point strikes undamaged yarns at a high angle, pushing them out of the plane of the fabric in the same way as the penetration of a blunt blade tip. Imperfections such as notches have a similar effect, and may even ‘pull’ single threads in some fabrics.

**Blade dimensions**

The thickness of the blade influences the width of the severance, as the broken yarn ends are pushed apart by the passage of the blade. Consequently, single-edged blades with a thick, blunt back edge produce a tapered severance, because the blunt back pushes yarns away from the severance near the point of initial penetration. However, the yarn ends may spring back to varying degrees after the blade has been removed.

The width of the blade influences the length of the severance; however, this is also affected by the depth of penetration and whether there is any ‘slashing’ (movement of the knife parallel to the fabric plane) in the stabbing action. The tendency to slash is determined largely by the resistance offered by the support below the fabric. Because of the likelihood of slashing, the width of the knife should be determined from the shortest severance, although this may underestimate the knife width if the knife only partially penetrated the fabric.

**Stabbing angle**

The severances are usually straight unless the blade is tilted at an angle to its direction of motion. This may occur if the knife is held at an angle in the stabbing action, if it bends or deviates under the force of impact, or if the fabric is moving laterally to the knife. In these cases, various forms of curved or multi-directional severances are produced.

**Secondary cuts**

In many cases, the knife may draw the fabric into the wound, causing a fold. The fabric can be cut at the fold, giving a small additional cut in line with the main severance.

**Fabric effects**

The same knife can produce different severance morphologies depending on the type of fabric that is penetrated. For example, a denser fabric like denim is harder to penetrate than an open structure like lace. This is another reason why it is not possible to fully characterise fabric severance morphologies; it is necessary to examine the effect of a particular knife on fabric identical to that involved in the investigation.
While these descriptions may appear quite clear, there are so many variables in most situations that great care must be exercised in drawing conclusions about the cause of a severance. In many cases, it is necessary to proceed by eliminating possibilities, bearing in mind that similar morphologies can be created by different means.

**Handling Damaged Textiles**

It is important for crime scene investigators to know how to collect and handle damaged textiles that may require forensic examination. Since handling can alter the relative positions of fibres, it is useful to record the shape of the severance and its relation to the body, photographically if possible, before disturbing the fabric.

Great care should be exercised when removing any implement from the fabric and in removing the fabric from its environment, so as not to disturb the fibres or threads in the vicinity of the damage. The area should be inspected and any loose fibre or thread fragments collected and recorded. This applies also to any implements suspected of having caused the damage.

The fabric should be handled very gently and folded carefully to avoid distortion to the damaged region, preferably with the damaged area left flat and folded inside other layers of the fabric.

Any subsequent damage that may occur must be recorded. For example, if the severance is propagated by tearing during removal of the fabric from the scene, then this must be recorded, as the torn region could otherwise confuse the investigation. The taking of samples from the fabric, such as for blood analysis, must also be recorded to save the textile technologist having to identify cuts made by the pathologist’s scalpel or scissors.

*Washing the fabric will effectively destroy the evidence.* The mechanical action rearranges the yarn positions and frays the severed yarn ends, so any removal of contaminant should be left to the textile examiner.

**Summary**

Both textiles and the damage which can be occasioned to them are many and varied. Nonetheless, armed with a knowledge of textile properties and a stereo microscope, the textile technologist is often able to gain insight into likely causes of the damage by studying the morphology of the damaged material. However, as a general rule, possible causes can be eliminated with greater certainty than they can be confirmed.

**References**


"Physical Damage" redirects here. For the passive skill, see Physical Damage (passive skill). Physical damage is one of the five damage types. It is the most common and the only one reduced by armour, rather than by a resistance. Most physical damage comes from weapon attacks, but some spells deal physical damage as well. Every 10 points of strength give a 2% bonus to physical damage from melee attacks. The Iron Grip keystone passive extends this bonus to also apply to physical damage from projectiles.