Testing of shanks for high-heeled footwear

MARK SOUTHAM highlights why shanks are a vital source of hidden support in footwear, and how their failure can lead to serious consequences.

The shank is a strip of stiff material made from steel, wood, plastic or composite which is used to reinforce the waist area of insoles. It is attached to the insole by a variety of methods, the most common being an eyelet or rivet through a hole in the shank. Shanks are important structural components of footwear, particularly in high-heeled styles, as they provide strength and stability where these characteristics are needed. The higher the heel, the greater the challenge to the shoemaker. This article focuses on testing shanks manufactured from steel and which are used in more difficult applications.

To be effective, the shank must be stiff enough to hold its shape when under load in wear, but must not be brittle. It also must have good fatigue resistance – that is, be capable of withstanding the repeated loading and unloading cycles that occur in wear without breaking. Failure to achieve the necessary mechanical strength in the waist can lead to a variety of problems. These range in severity from wearers experiencing a feeling of insecurity in the shoes, to breakage in the waist or heels becoming detached because of inadequate support.

The reinforcing potential of a steel shank is determined by its design and by the properties of the metal. The latter are governed by composition of the steel and by the treatments it receives in the various production processes involved. Carefully controlled heat treatments – hardening and tempering – are the key to achieving the desired characteristics. These treatments modify the internal structure of the steel and relieve any internal stresses created during the shaping processes. The result is an item that is hard, stiff and has improved fatigue resistance.

For any given steel, these properties of hardness, stiffness and fatigue resistance are interrelated. A change in hardness signals a change in stiffness and fatigue resistance. For this reason, hardness measurements provide a very useful indicator for quality control purposes. If the hardness is not in the expected range, the manufacturing process is likely to have not been carried out correctly.

Figure 1: Fluted steel shanks for waist and backpart rigidity

Measurement of stiffness

The property of stiffness is crucial. This is especially true in women's high-heeled footwear, as it is the shank which provides almost all of the rigidity in the waist region of the shoe. Stiffness is dependent on the material(s) from which the component is made. However, the design of the shank also plays a critical role in stiffness, particularly its cross-sectional shape. Generally speaking, the stiffness of the shank will increase with increasing thickness of the metal. Except for the thickest of shanks, a flat strip of metal will not be stiff enough to provide sufficient rigidity in the finished shoe. However, rigidity is significantly increased by incorporating a curve or ridge into the cross section. This is known as a flute and this can be seen in figure 1.

Measurement of the stiffness of shanks is covered in SATRA TM58:1999 – 'Stiffness of steel shanks', EN 12959:2000 and ISO 18896:2006 (both of which are called 'Footwear – test methods for shanks – longitudinal stiffness').

In these methods, the shank is clamped at its heel end and bent as a cantilever beam by adding a series of weights at its free end (figure 2). It is important at the start of the test to ensure that the side of the shank which will be on the underside of the footwear (usually the fluted side) is uppermost, and that the free end of the shank is horizontal. As the weights are added, the vertical deflection is measured using a dial gauge. The

Figure 2: Measuring the stiffness of a shank

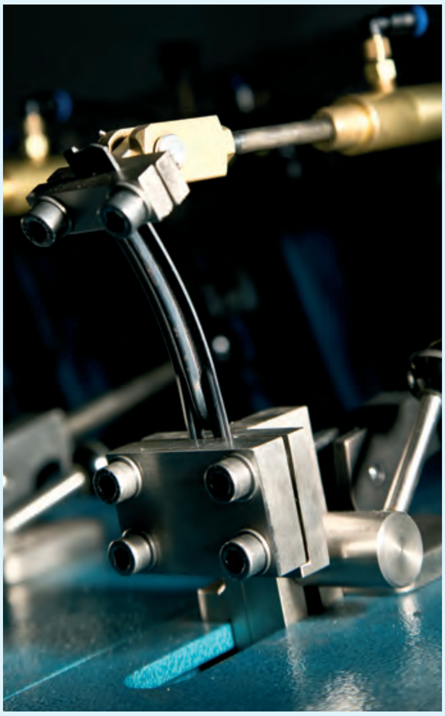

Figure 3: Assessing resistance to fatigue

average deflection value for each 2N of load is calculated.

The distance is measured between the front edge of the clamp at the heel end of the shank and the point at which the load is applied (known as the 'moment length'). This is used together with the average 2N deflection value in calculating the 'flexural rigidity' of the shank. This is a measurement of stiffness that is dependent upon the cross sectional shape and area of the shank, but is independent of its length. Three shanks are tested in this way, and the average of the three results is calculated and expressed in kN.mm^2.

Measurement of fatigue resistance

One of the main problems encountered with a shank in wear is premature fatiguing leading to subsequent breakage. This type of failure results from progressive weakening of the shank associated with the very slight bending that it experiences every time a step is taken. None of the individual bending loads would cause an unaffected shank to break. However, repeated loading will result in stresses within the shank that will increase until failure may occur. It is therefore important to be able to evaluate the ability of a shank to resist premature fatiguing and so obtain a reliable assessment of its likely life expectancy.

Test methods that cover measurement of the fatigue resistance of steel shanks are SATRA TM97:1999 – 'Fatigue test for steel shanks', EN 12958:2000+A1:2004 and ISO 18895:2006, both of which are entitled 'Footwear – test methods for shanks – fatigue resistance'.

In these methods, the heel end of the shank is held in a fixed clamp so that the shank stands vertically. A pivoted clamp is attached to the front end of the shank a known distance from the fixed clamp (figure 3). It is important to ensure that the correct test length is used, and care should be taken not to over-tighten the two clamps, as this could cause damage to the shank and lead to premature failure in the test.

Alternating forwards and backwards horizontal forces are applied to the front end of the shank via the pivoted clamp. The clamp pulls the shank in one direction until the force reaches 49N, then pushes it back in the opposite direction – once again until the force reaches 49N. This is done at a rate of four cycles per second. The number of cycles required to cause the shank to break is recorded as the 'fatigue life of the shank'. Three shanks are tested, and the average number of cycles to failure is calculated.

Measurement of hardness

For metal shanks, hardness is determined by measuring the ability of the metal to resist permanent deformation by indentation. The Rockwell test has become the most widely used technique, and this utilises a number of scales to accommodate different applications. The 'Rockwell C' test, which uses a diamond tipped cone-shaped indentor, is the preferred choice for metal shanks.

It is imperative that the area of the shank to be tested is flat on both sides and the surfaces are free from such contaminates as rust or paint. The rear end of the shank is usually suitable for testing. Hardness is often the only test that can be performed when a shank has broken in wear, since it is not normally possible to measure the stiffness or durability of an incomplete shank. A hardness measurement can be made away from the site of any failure and can identify the material as being abnormally soft or hard.

How can we help?

Please email SATRA's footwear testing team for assistance with the testing of metal shanks and advice on their use.

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