The ultimate goal of any footwear test is to provide accurate predictions of service performance in as short a timescale as possible and in an efficient and cost effective manner. It has long been an ambition to invent a 'walking machine' capable of behaving exactly like the human foot so that shoes can be tested as realistically as possible, short of actually being worn by a human being. SATRA soling specialist Mike George describes the UK-based technology centre's solution to the problem.

Biomechanical abrasion resistance tester

It is often very difficult to find enough willing and reliable wearers close to hand who are able to give the required degree of use to test shoes in the intense timescale involved in a wear trial. It is also extremely difficult for the wear trial co-ordinator to know the exact amount and circumstances of wear and to monitor what is happening. Although wear trials involving human subjects are still used, it is much easier to take out the human element and replace it with the tireless consistency of a machine.

In practice, the biomechanical complexities of the human foot and the walking action are so great that it is all but impossible to combine all the foot actions into a single test machine. SATRA therefore has many different whole shoe tests, each focusing on one particular aspect of the walking or running action and testing for just one or two properties. The closest it has probably yet come to developing the ultimate walking machine is with the 'biomechanical abrasion resistance' tester.

SATRA's biomechanical abrasion tester showing walking boot at heel strike.

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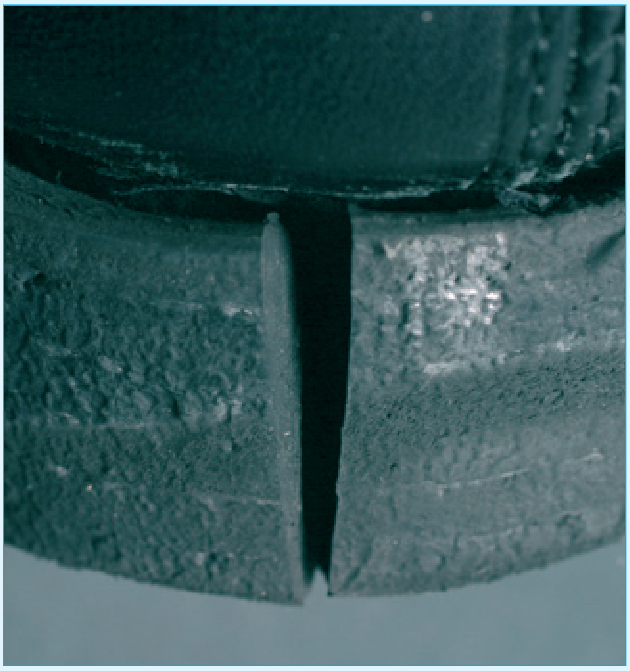
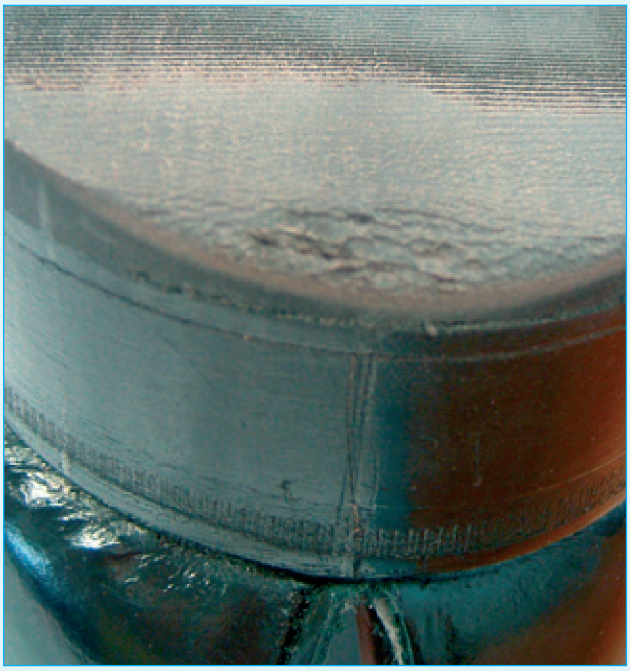


This heel has split, probably at the mould flow line, due to the realistic compression applied by the tester.



The wear pattern at the rear of a rubber top piece after the machine test.

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Soles need to be tough

The chief aim of this particular test is to provide realistic wear to the bottom of the sole, taking into account its complete design and shape and interaction with the rest of the shoe. Will the sole wear down in an acceptable way and at an acceptable rate? Will it stay in one piece and will anything unforeseen happen? Soles, of course, have to put up with a great deal of punishment in their serviceable lifetime. How many other articles have to withstand being simultaneously trodden on, flexed and rubbed against all manner of ground conditions once, let alone up to half a million times?

Engineering a sole to meet all of these demands in a high performance shoe is challenging in itself. Pushing the design boundaries at the same time to continue to appeal to a discerning buying public adds further scope for things to go wrong. And, when they do, the customer will not hesitate in returning the product. These days it is, therefore, more important than ever for the footwear supplier to carry out thorough testing. The biomechanical abrader is able to exert a very real combination of loading, flexing and shear force to 'walk' the sole on appropriate test surfaces.

Man and machine

The machine is the outcome of a collaborative European project undertaken in conjunction with a number of research partners. The work involved very carefully measuring all the parameters of a normal walking step and then designing equipment that was capable of reproducing them. This initially led to several prototypes and then to the first production model. When this proved successful, it was followed by a sister machine and the method's use was extended to testing the durability of flooring surfaces against the walking action of footwear soles. As a result SATRA now has two machines, one that tests footwear against standard surfaces and one that tests floors against standard soles. In both cases it has effectively brought the wear trial into the testing laboratory.

As far as footwear is concerned, testing is usually on a fairly aggressive but not unrealistic surface. To date this has been a concrete paving slab but other abradants are being investigated. The shoe itself is mounted on to the equipment by means of a foot-shaped rigid plastic last with similar dimensions to the one on which the shoe has been made in the factory. While this last will fit a range of shoe styles, it is of course necessary to have both left and right feet available in multiple sizes.

The last is therefore interchangeable and is bolted to the 'ankle' of the machine. Shoe factory lasts do not hinge where the shoe flexes so the last is modified so that it will flex against some resistance, just like the human foot. This is important to allow the wear beneath the ball of the foot to be reproduced. At the top of the steel leg shaft are a set of dumb-bell type dead weights which provide the bulk of the down force, representing an adult's body weight. This is opposed by a pneumatic cylinder in order to be able to lift the shoe.

Forcing the issue

During the test cycle compressed air is fed to and from the cylinder in rapid sequence so as to first support the shoe, then allow it to descend, then top up the dead-weight during the heel strike phase, reversing again during the mid-stance phase before again pushing down during the flexing action and finally lifting the shoe clear again. This produces the double-humped camel shape load profile which is characteristic of normal walking. Although the wearer's weight is clearly uniform, the decelerating and propulsive forces at the beginning and end of each step effectively add to the force that is transmitted through the sole, thus producing the two humps.

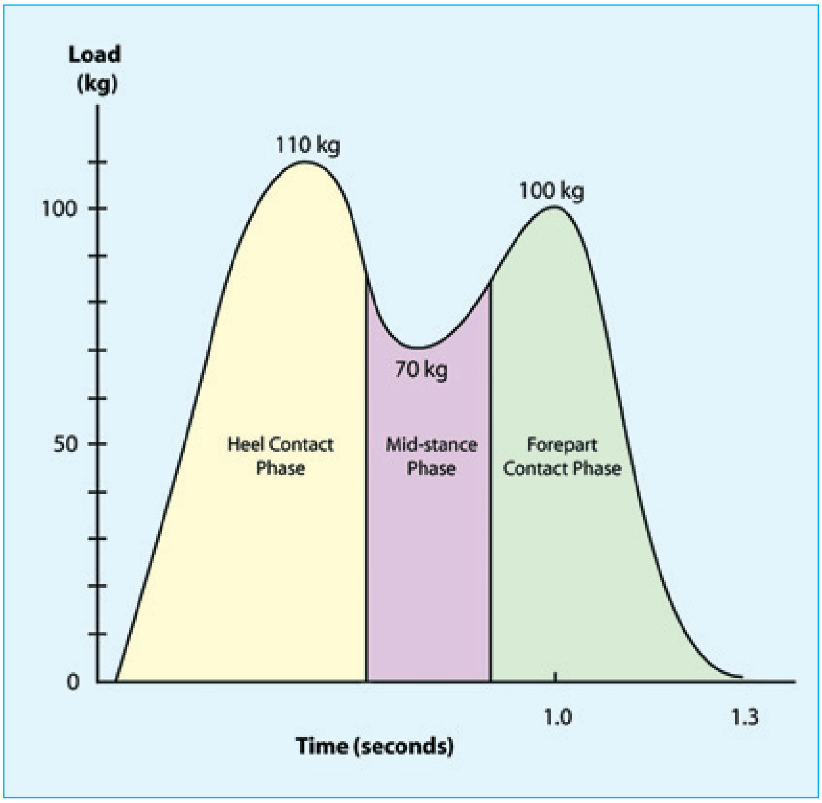
The machine has linear bearings and a screw drive so that the attitude of the shoe can alter from angled heel strike, through flat, to flexing and toe-off. During each step the drive has to accelerate the dead weights along the bearings, stop, and then return them to the start position. The leg starts with a forward angle of 25° and ends with a rearward one of 30°. Each full cycle is completed in less than two seconds.

Achieving all of this requires a complex piece of engineering. But this is not the end of the story as a turntable is also incorporated which allows the flooring to advance to a fresh position every other step and also twists beneath the flexing sole as though the walker were turning a corner. Wear to the front part of the sole is accelerated by cornering in a similar way that tyres wear faster on cars. To help to speed up the wear in the test, this action is reproduced every second step.

A test of endurance

In a typical test, the machine is operated for 18 hours which represents about 45 miles of walking. While a test can run for longer, this is usually enough to give a good indication of the wear performance of the test sole. Weight or thickness reduction can be used to assess abrasive loss to the sole and reduction in tread depth at key locations is also a useful measure.

If required, the rate of loss can be extrapolated to predict the life of the sole in miles on the surface being used before it wears down. If time permits, the test can run indefinitely until this actually happens. Apart from this ordinary type of wear, surface delamination or melting of the sole, separation or delamination of sole components or coloured inserts, breakage or tearing of pattern elements and splitting of the heel wall or other compression-related damage can be looked at.



Load profile during walking step.

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This is where the machine really comes into its own as there is no other way, aside from real wear, of predicting these types of breakdown. The soles of active sportswear—more than any other type of footwear—feature complex designs assembled from multiple materials which, far from being just cosmetic, have to perform under some of the toughest conditions.

SATRA now has experience of testing a wide range of footwear types with this method. The soles involved mostly tend to be those considered 'high risk' by virtue of complex or novel design or heavy intended use. In practice, the materials from which the sole is made will first be evaluated separately with simple traditional bench test equipment including scouring-action machines for abrasion resistance. Once the materials have been screened for potential suitability, a completed shoe is submitted for whole product testing.

The biomechanical abrasion resistance tester is the nearest thing to real wear that is now available and has the added benefits of speed and controllability. Although the project has moved well beyond the prototype stage and the present equipment is considered sufficiently standardised and robust for the footwear industry, SATRA is still keen to continue its research and development. The current thrust is towards more sophisticated computerised control, 24/7 operation with reduced supervision, and the use of alternative test floors and test floor maintenance procedures. As the shoes themselves continue to advance, so must the test equipment.