

The previous issue of *World Footwear* contained an article by CTCP that included details of a new construction from Spanish company Simplicity Works that assembles the upper and completes the shoe using injection moulding. The possibilities of the process are such that it is worth taking a further look.



Skeleton and sole for an AMF safety shoe.
CREDIT: SIMPLICITY WORKS

An alternative to upper stitching?

Although shoemaking has undergone many changes in recent years, on the whole it is still a difficult and labour intensive process with numerous skilled operations. This is because it involves turning a number of two-dimensional components into a complex three-dimensional final product. It can of course be simplified by injection moulding a complete shoe or boot, or three-dimensionally knitting an upper to which a moulded sole is attached. However, techniques such as these are relatively limited as to what can be produced.

The vast majority of footwear worn today still requires upper components to be cut from flat materials and stitched together to form a partially shaped upper which is then either

conventionally lasted over an insole or has a flexible insole sewn in to form a 'bag' which then has a last or foot-form forced into it to produce the final three-dimensional shape. In both cases the upper sections still have to be stitched together which is expensive and time consuming.

An alternative to stitching has long been sought. Medieval shoemakers reduced the number of sections and seams to the barest minimum in order to save time and improve output. Modern manufacturing techniques, particularly where force lasted sports shoes are concerned, have led to as much shape as possible being built into the upper by the use of multiple 'sprung' seams. While this could be achieved economically by producing in low cost Asian countries, there was no problem.

Exponential wage increases since the Millennium have provided an incentive to find a practical alternative.

Having worked in the shoe industry in various countries for 25 years, Adrián Hernández was aware of this and, in 2009, came up with the idea of joining upper sections together three-dimensionally in a single operation using injection moulding that eliminated the need to stitch the upper together. Having carefully thought it through, he wrote a full description of the process called 3D Bonding and applied for a patent. Then, in 2011, he formed Simplicity Works located at the Parque Científico Universitas Miguel Herdandez at Elche in Spain, which offers facilities and advice for SMEs.

Clearly, Simplicity Works has not been able to develop this technology on

its own and in fact has a number of impressive partners who have all contributed technical input and equipment to the project. Desma has been the lead partner and provided a single injector for Simplicity's laboratory as only a single station machine was needed in order to develop the 3D Bonding technology.

This was then developed further at AMF in Portugal which had a large multi-station rotary machine for producing footwear using direct PU injection to bring the two processes together. Other high profile partners include Romans CAD, Rhinoceros, Wacker, Huntsman, Comelz, Fagus-Grecon, Durnkopp Adler, INMAGO, Pfaff and Optron.

THE PROCESS

Put simply, 3D Bonding technology replaces conventional stitched seams by joining upper sections together three-dimensionally in a mould by injecting a polymer skeleton that bonds them together edge-to-edge. Cut sections are placed in matching recesses located in the main mould. These cavities contain a number of holes through which air is sucked in order to create a vacuum between the individual sections and the surface of the mould so that they are held firmly in place. A last is then introduced, the mould is closed by a top plate and the

skeleton and sole injected.

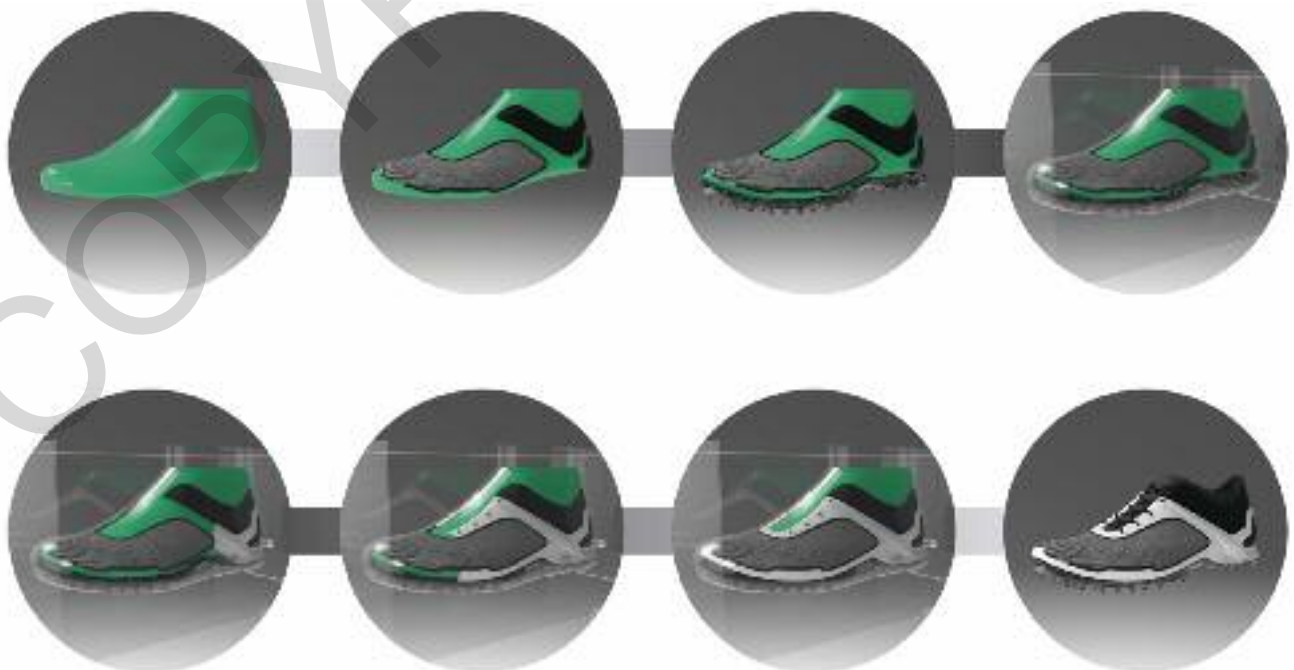
The first stage in the process involves sketching out the design characteristics of a shoe in the normal manner, modelling it using a 3D CAD package and then using that data to produce a graded set of moulds and matching lasts. The same data is also used to perform the flattening of the upper material patterns and create a file that can be transferred directly to a CNC cutting table for the cut components needed for the upper. The fact that the upper components are joined edge to edge means the patterns are simplified and extremely accurate as there is no need for any underlay allowances etc., to be included.

A set of moulds (left and right) consists of three sections: a top plate and two lateral moulds. Once the injection stage has been completed, the top plate lifts and the two lateral moulds open by around 2cm allowing the last and finished shoe to be removed. A specially made last fits inside the mould cavity leaving only space enough for the upper pieces and the channels between them, and between the last bottom and the mould top plate, for the injected skeleton.

There are two types of top plate depending on whether single- or two-stage injection is involved. In the case of the former, it contains a cavity for a pre-moulded outsole which is bonded to the

upper skeleton by a single injection of PU. The latter involves a more complicated two-part mould which allows the skeleton to be formed on its own by the first-stage injection. Once the PU has cured, a different top plate, again containing a pre-moulded outsole with a cavity left for a midsole, is locked in place. A second injection creates the midsole and bonds it to both the skeleton and outsole to complete the process in what Simplicity says is a completely new philosophy using a totally new generation of moulds for the manufacture of footwear with new materials and functions.

It also says that it has not been easy to develop the technology necessary to inject PU through channels that are sometimes less than 5 mm² in cross section. Simplicity considers it to be an important and complex scientific achievement due to the fact that the material's viscosity and density change progressively from a liquid state to foam in only a few seconds. It is indeed impressive as not only have the parting lines associated with traditional direct PU injection been eliminated, but also constant smooth surfaces without micro-bubbles have been achieved as a result of the new generation of moulds. Huntsman has played a key role here, providing support from the very beginning with chemical formulations most suited to the different



The process sequence involved in 3D Bonding. CREDIT: SIMPLICITY WORKS



The micro-bubbles often associated with direct PU injection (left) has been eliminated with 3D Bonding (right). CREDIT: SIMPLICITY WORKS

requirements of the technology, technical advice based on its extensive experience with PU and by carrying out material testing.

MATERIALS

During the course of developing the process, Simplicity has tested many different types of PU, changing both the polyol or isocyanate compound involved. The main objective of the material used for the skeleton is to obtain a resistant bonding between it and the cut upper pieces. However, obtaining a good strength to weight ratio is also important. At present, a modified ESD (electrostatic discharge)

light polyester PU with a final density of 230kg/m^3 is being used for both skeleton and sole as this is necessary in order to meet electrical discharge resistance requirements in the safety shoes AMF produces. It also offers an excellent strength to weight ratio and high bonding strength so that it is equally suitable for other types of footwear.

This material also offers quite good expansion, reducing the total quantity of material needed, thus making the shoe lighter and giving it a smooth touch underfoot for comfort in wear without reducing its durability. However, for the first injection, the

priority is achieving the best possible bonding and durability. For the second one—the midsole—the priority is to use a PU with high expansion to save weight. Further weight can be saved by adding sections of EVA to act as a filler. Needless to say PU is, in any case, an excellent soling material in terms of both physical performance and durability.

As regards upper materials, Simplicity says that synthetic textiles have shown satisfactory results so far, providing higher bonding strengths than in traditional stitched seams. Furthermore, no special pre-treatment is required. The critical factor here is that because the actual surface of the bonding area is relatively limited, the PU skeleton must be able to penetrate well into the cut edges of the upper pieces. Bearing in mind the high viscosity of PU and the openness of a textile material, this is obviously less of a problem than with nonwovens and, more particularly leather, where the presence of greases and silicones can have an adverse impact on PU's ability to bond well. Work is being carried out to find a solution to this problem and Simplicity says that some positive results have already been obtained.

A lining can be easily added in the form of a simple seamed 'bag' that is pulled over the last before it is inserted into the mould. The injected skeleton bonds to it and surplus material is trimmed off at the same time as any moulding flash. A rather novel idea, that is being used by AMF, is to make the lining separate from the shoe so that it is pulled onto the foot in the same manner as a sock before putting the shoe on and lacing it in the normal manner. The materials used are able to



AMF uses a separate and detachable 'sock' lining.

CREDIT: AMF

grip the inside of the shoe of their own accord to avoid any slippage in wear. These 'sock' linings can also be easily washed to help maintain a healthy environment within the shoe. The absence of upper seams also reduces friction and pressure points while the PU skeleton helps to increase overall stability for the foot.

IMPLICATIONS

The first thing that must be said is that judging from all the evidence so far, the 3D Bonding process appears to work extremely well. Finished shoes have a solid feel to them and are very cleanly moulded. Furthermore, they also look good. As regards performance, Simplicity says that they have been thoroughly tested by INESCOP and found to perform better in many respects than shoes with conventionally stitched uppers. The company also claims that savings of up to 70% in direct labour costs and up to 50% in upper material consumption can be achieved compared to shoes with stitched uppers and cemented soles.

It also says that trials have shown that a relatively wide selection of footwear besides safety shoes can be produced using 3D Bonding, including trekking boots, football boots and golf shoes. Further studies have also indicated that the technology is in fact able to produce many of the current models of any segment including men's, women's and children's. Moreover, it also gives the possibility of developing new designs that are impossible to obtain with traditional manufacturing methods.

The only limiting factor here might be the apparent need to have a front opening as shown in the AMF shoe shown on this page. However, as modern styling is now so orientated towards the sports or athleisure look, this would not appear to be too much of a problem. The fact that using leather for the cut upper sections could create difficulties may again not be too much of a problem as consumers—particularly younger ones—are increasingly less concerned with what a shoe is made from than how it looks and what it costs.

The philosophy behind the concept has been to create a technology that makes it possible to increasingly bring back footwear manufacture to Europe



3D Bonding is able to produce footwear simply that is nevertheless quite complex in appearance. CREDIT: AMF

so that it is closer to consumers but still offers good performance at an affordable price. Simplicity says that, in its opinion, "3D Bonding is an ideal solution for industries where labour content is high as in the case of footwear. It will be especially interesting for big companies that have their manufacturing systems in Asia or South America where labour costs have historically been low but are now rising ever higher. Together with a much reduced time to market, this makes the technology a viable and interesting solution."

Simplicity is clearly aiming to ride the growing on-shoring trend and it certainly offers real possibilities. The fact that the process can be carried out on a standard Desma rotary PU machine is one reason why AMF has become the first company to develop a range of 3D Bonded shoes as it already had a suitable machine. Starting from scratch, a fully functional self-contained production unit would have an extremely small footprint, be able to operate 24 hours per day close to its chosen market place and with a minimal labour force.

What is perhaps the most significant factor, however, is that the 3D Bonding process is able to produce thoroughly

practical footwear quickly and simply that is quite complex in appearance with hardly any stitching being involved. While upper stitching will never disappear completely due to the enormous design flexibility it offers, 3D Bonding has the potential to replace it in many types of footwear aimed at the mass market consumer. And, there are millions of those. 📌

Simplicity Works possess the patent rights of its technology and also engineers the industrial design by CAD software. Once the product is designed Simplicity Works also develops all necessary tooling and moulds for footwear production. This know-how is transferred to manufacturers along with complete machinery and polyurethane specifications determined in cooperation with Huntsman and Desma. 3D Bonding greatly reduces production costs compared with traditional methods and a portion of this reduction is collected as royalties by Simplicity Works. Desma provides all necessary machinery and automation systems and Huntsman delivers the correct PU for the 3D Bonding process.