

Numerical simulation is currently used in a variety of industries such as automotive, aeronautics and plastics, where it affords important financial and quality benefits. Its potential is not fully recognised in the footwear industry and, as a result, it is seldom used as a manufacturing tool. Jean Luc Chaverot, CTC Groupe, France, explains the potential.

Numerical simulation tools

The aim of numerical simulation is to predict a material's performance by using computer science and is divided into three stages.

1. Data is fed into a calculation software program that is able to translate a process and/or its use.
2. The results are stored in a format that includes mathematical models that represent the material or process concerned.
3. This information is then presented so that a full evaluation of the material or process can be made.

Applications

Injection simulation can be used in the design of soles, heels, counters and inserts. It enables a reduction in product development stages such as machining, press tests, material tests and assessment of final quality. Simulation of the performance of certain materials and structures can also be applied to these components in order to anticipate their performance in production or during use, including heel resistance against impact (*Figure 1*), flex resistance of soles, and stretch and compression resistance of materials.

Numerical simulation can also be used with regard to biomechanics as applied to sports and comfort shoes, where it can simulate foot/shoe/ground interactions for a specific application (*Figure 2*).

Injection moulding

For injection moulding, it is possible to measure mould parameters (sole shape, material and mould temperature), the material to be used (relative viscosity and thermal performance) and the machine itself (temperature, pressure, speed of injection and force). The following is an example using a TR-SBA compound.

Fluid material flow is ruled by two equations, conservation of mass (flow conservation) and conservation of movement (balance of forces). Thermal transfer to the core of the polymer fluid is dictated by heat, so material performance must be determined by the relationship between constraint, polymer deformation and temperature.

Where there is an almost stationary flow rate, material flow can be calculated independent of injection time. Due to the fact

Figure 1: Simulation of heel structure performance

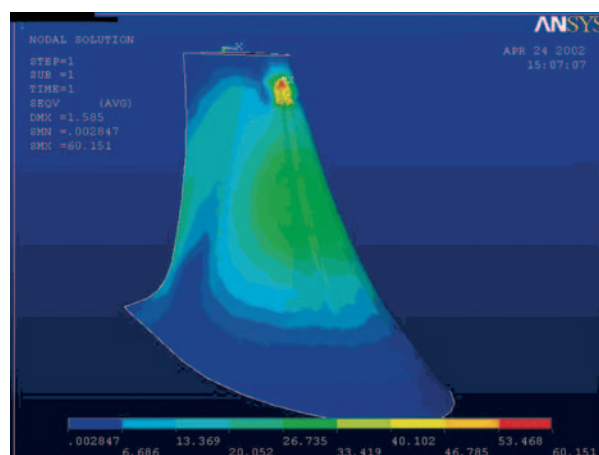


Figure 2: Biomechanical simulation of foot/shoe interaction

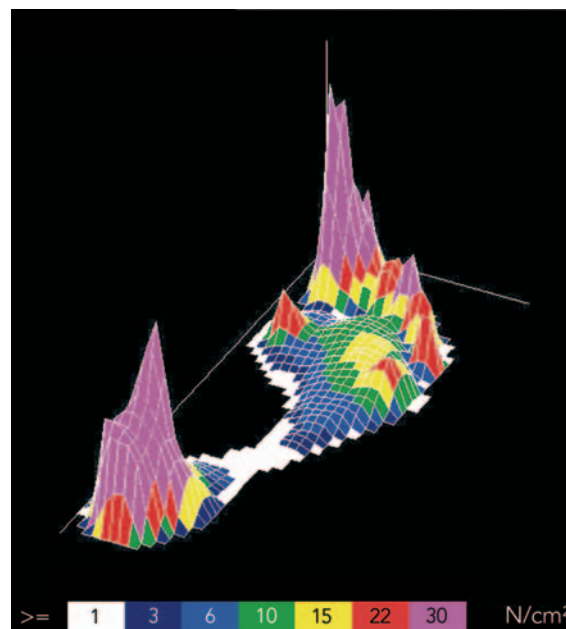


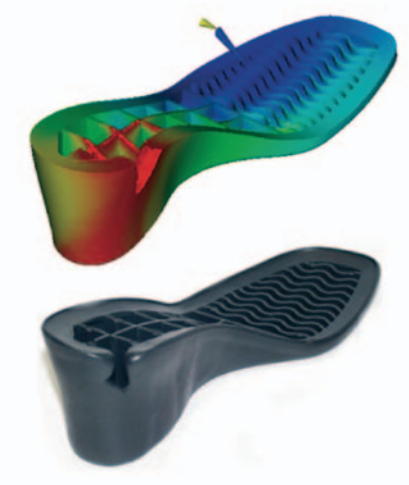
Figure 3: Start of filling process



Figure 4: Partially filled mould



Figure 5: Completely filled mould



that melted polymers are involved, the Reynolds number is weak and the following assumptions can therefore be made:

- The cavity is filled with a non-compressible material so volume is constant
- Thermal conductivity of the material does not vary according to temperature
- The material behaviour law is that of a general Newtonian fluid
- When cooled the polymer forms a solid layer close to the mould wall

Simulation process and results

First, the sole shape and general characteristics need to be defined in order to provide an element of comparison with the numerical simulation. The known machine and mould parameters are then entered as input data. Second, it is necessary to know the performance of the plastic material in terms of viscosity. Using this information, the first calculations

can be made. The results are shown here as comparisons.

This area (Figure 3), where the thickness is low compared with the rest of the sole, shows a number of grooves and a material flow close to reality.

This simulation (Figure 4) shows a material flow that is different on the medial and lateral areas of the mould.

In both of these images (Figure 5), the filling process finishes at the inside of the heel. Therefore, the correlation of the calculation and the actual performance is satisfactory at all the different stages of mould filling.

Possibilities

The global footwear industry faces many difficulties involving quality-related issues. Simulation tools are a way of responding to these problems. Furthermore, the transfer of essential know-how can be difficult as it is often based on long practical experience. Simulation tools could provide a way round this and be used as a substitute for training techniques which may be difficult to acquire and master. 



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