

Gearing for sports shoes

In the human skeleton, an MTP joint is one that connects a toe bone to a metatarsal bone and allows the toe to bend away from the foot. It is an extremely important joint as it allows us to walk with a balanced gait. Among the many ways that footwear can affect the human body, is that of 'gearing' at the ankle and knee joints during running. This gearing alters MTP joint bending as a function of forefoot bending stiffness and has been suggested as a way to improve athletic performance and reduce the risk of injury in a number of sports, especially football or soccer.

The theory is that as the shoe or boot moves through greater amounts of bending, forefoot stiffness should increase in a non-linear manner to shift the centre of pressure forward to improve performance, while still restricting forefoot bending in areas where turf-toe injury might result. The latter refers to a sprain of the big toe joint resulting from excessive upward bending caused by either stubbing the toe on the ground or from pushing off repeatedly when running or jumping and is a common sporting and athletic injury. The problem is that with most materials used in footwear, stiffness increases in a linear rather than a non-linear fashion.

TUNEABLE CARBON FIBRE

Although carbon fibre has previously been tried in footwear, due to the stiff nature of traditional composites, its usage was limited and somewhat short-lived. Things are changing however. American company Carbitex produces a range of proprietary carbon fibre materials which allow for stiffness modifications as a function of flexion angle. In simple terms, it has developed a way to 'tune' the degree of flexibility of carbon fibre to suit different requirements. The company claims that this exclusive technology is well-suited to the function of many aspects of athletic footwear, including footwear gearing.

Furthermore, it can also produce it with variable directional stiffness which it says is particularly relevant to football boots as it provides support for the foot during kicking by preventing excessive MTP flexion. When kicking the ball, excessive joint flexion can cause injury or, alternatively, reduce kicking performance as it causes a loss of energy at the MTP joint. As kicking the ball is an integral part of the game of football, controlling MTP flexion could therefore have potential advantages.

Carbitex in fact produces three main types of material all aimed, in the words of the company's founder and Chairman, Junus Khan, to "allow the foot to do more of what it wants to do and to help prevent it from movements that can cause issues". Its AFX is designed to provide a high level of stability and protection without limiting forefoot flexibility. For example, trail runners need a combination of comfort, support and flexibility to rapidly traverse uneven terrain. Minimalist shoes do not offer enough support, while 'maximalist' shoes can be bulky and heavy. The company says that AFX eliminates this compromise. The CX6 is used in the upper to control stretch in order to enhance power transfer, enable more efficient use of energy and more

precise control.

The DFX insole and midsole plates are able to exponentially increase stiffness to optimise performance in changing scenarios. For instance, they are said to offer the flexibility of a sneaker when walking and the stiffness of a track spike when sprinting. Carbitex says that "put simply, DFX enables shoes to have a truly dynamic midsole for the first time". To prove the point, it asked the University of Calgary, Canada, to carry out tests. Specifically, it wanted to see if the changes in bending stiffness that the material provided were sufficient to limit excessive forefoot bending to reduce injury and shift the centre of pressure to alter the lever arm and so improve performance. For instance, what was the influence of gearing technology in the form of variable and directional forefoot bending stiffness in a shoe; first on the amount of forefoot bending and the position of the centre of pressure under the foot during locomotion and, second, on the amount of forefoot bending taking place when kicking?



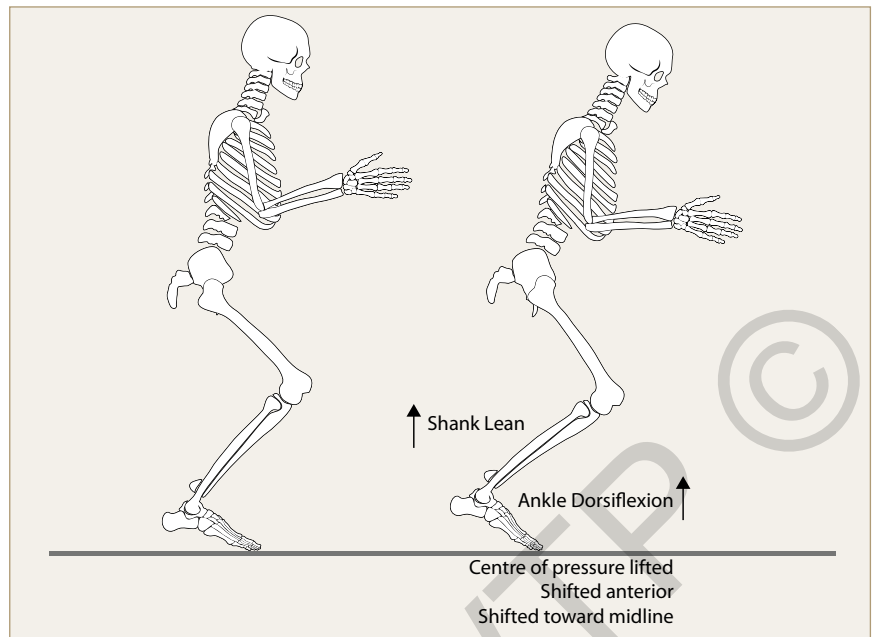
ALL CREDITS: CARBITEX

SEEKING PROOF

Trials were carried out using a standard adidas football boot with various inserted Carbitex DFX carbon fibre insoles to provide different degrees of gearing, including a special kicking insole designed to resist hyper-flexion of the toes. Participants were made to perform linear locomotion at five different speeds: walking, slow run, medium run, fast run and sprint measured against a control boot with no insert. Additional data was also collected during maximum effort kicking.

From the information gathered, it became clear that at the MTP joint, as both running speed and normal MTP bending range of motion increased, the stiff insoles reduced the amount of bending and shifted the centre of pressure more anteriorly, while also reducing medial-lateral movement of the centre of pressure. Participants' movement patterns also changed so that they increased their body lean and so improved their ability to generate higher knee joint moment. The inserts also reduced key biomechanical injury risk variables such as non-sagittal plane joint loading at the knee and ankle joints. As body lean increased, sagittal plane joint loading at the knee joint also increased while that at the ankle remained constant, regardless of running speed. As sagittal plane joint loading is thought to influence the performance of linear movement, this increased loading at the knee could assist in flexing and extending the leg, and so enhance performance.

In addition to analysing performance variables, biomechanical ones associated with injury risk were also investigated. It has been suggested that increased non-sagittal plane joint loading can lead to joint injury. Joint loading is estimated by calculating resultant joint moments, which represent net torque or twisting loads on the joint and joint angular impulse. This in turn represents the cumulative loading experienced by the joint throughout the stance phase of a movement. While joint moments and angular impulse calculated from inverse dynamics cannot determine the exact loading on actual joint structures, these measures can nevertheless be used to predict total load across a given joint.



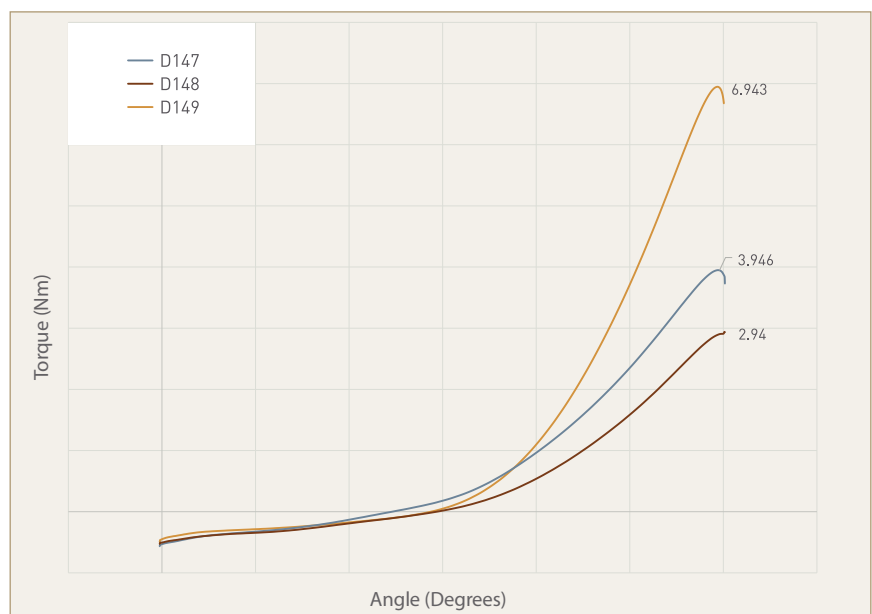
Overview of movement pattern changes of participants.

POSITIVE RESULT

The fact that the Carbitex inserts had a positive effect in terms of reducing potential injury to the ankle is encouraging as it has been shown that 90% of all ligament injuries at the ankle are caused by internal rotation (transverse plane movement) and inversion (frontal plane movement) of the foot. The similar result seen at the knee joint is also a positive as increases in cumulative loading have been directly linked to chronic types of injury such as painful 'runners knee' and even osteoarthritis. While there were no significant differences in terms of kicking performance, the special stiff insole did nevertheless have the effect

of reducing the peak amount of MTP bending during the kick, suggesting that this could help to reduce kicking toe flexion injuries for footballers.

These positive results clearly indicate the potential of this type of carbon fibre material for enhancing performance and reducing injuries in sporting activities. The fact that these materials can be fine tuned to offer so many combinations of flexing and rigidity within a single component is their most remarkable feature and only goes to show how technically advanced some modern shoemaking materials have become. It is therefore perhaps worthwhile to look at the three Carbitex products mentioned earlier in more detail.



Torque/angle graphs for DFX D147, D148 and D149 materials.

CARBITEX AFX

AFX stands for asymmetric flexibility, so the material is flexible in one direction and stiff in the other. It is also multi-directional in the sense that it can be tuned to provide longitudinal, lateral-medial and torsional flexibility in a variety of flex ratios. While a number of standard materials are produced, an infinite variety of individual configurations can be created depending on what the customer wants. It has also been shown to be able to sustain repeated flexing for excessive periods of time without any loss of performance. Furthermore, whereas traditional carbon fibre insole plates can crack after extensive flexing, Carbitex says plates cut from AFX will not. Being carbon fibre, it is of course extremely lightweight.

It is available in four substances, C120 (1.3mm), C127 (2.3mm), C135 (1.6mm) and DO92 (2.6mm), and can be used in a variety of footwear types.

Cleated sports (football boots, etc.) – reduces stud pressure while still providing forefoot flexibility.

Work boots – increases stability and protection without limiting forefoot flexibility. Also helps reduce the size and weight of midsoles thus reducing wearer fatigue.

Snowboarding – provides stiffness on the board but flexibility for walking off board.

Motorcycle boots – top performance on bike combined with flexibility when walking.

Fashion – improved performance without adding bulk.

CARBITEX DFX

Traditional materials increase stiffness in a linear manner, so it is necessary to choose a material that has the right degree of flexibility that is needed. DFX plates are tuned to change stiffness so that it is possible to produce a midsole that is either stiff or flexible as required. This is because the material has the ability to increase its non-linear stiffness when flexed and, the degree to which it does this, can be tuned for almost any category of performance footwear. As in the case of AFX, the range of options for tuning is virtually limitless. At the same time, it also has all the properties in regard to repeated flexing, resistance to cracking



AFX plates incorporated in the outsole reduce stud pressure without reducing forefoot flexibility on football boots.

and lightweight.

It is available in three substances, D147 (1.3mm), D148 (1.2mm) and D149 (1.9mm), and again has a wide range of footwear applications.

Football boots – helps protect against turf toe injuries.

Running – energy conservation and helps reduce fatigue.

Basketball – increased spring when jumping.

Training – again increased spring plus gearing for flexibility when walking and stiffness when sprinting.

Both AFX and DFX can be cut by water jet (preferred method), CNC router or conventional die-cutting. In the latter instance, it is important to keep cutting dies sharp as they will wear more quickly than normal due to the tough nature of the materials. When bonding these materials, both surfaces need to be clean and dry; a light wipe with isopropyl alcohol (IPA) is effective. Aggressive scrubbing and/or more aggressive cleaning agents should be avoided as they can damage the material. If found necessary, a mild abrasive can be used to lightly scratch the surface to improve bonding.

CARBITEX CX6

Carbon fibre has the highest tensile strength of any commercially available fibre and, within its operating limits, it has virtually zero elongation. CX6 harnesses these key characteristics in an exceptionally flexible form enabling it to be used in footwear uppers where it will control stretch, increase power transfer and ensure firm support to the foot. At only 0.43mm in substance for the flat finish version and 0.53mm for the textured version, it adds little bulk but still has exceptional tensile strength. It is also highly resistant to abrasion, tongue tear and the effects of UV light. Furthermore, it is fully compatible with traditional upper construction techniques such as cutting and stitching, and requires no special equipment to process it.

The fact that CX6 is available in over 30 combinations of weave, weight, colour and finish means it again has a considerable number of potential footwear applications.

Cycling shoes – tight fit on the foot and zero energy loss to the pedals.

Water ski – highly durable and provides rapid and precise control on demand.

Fashion – lightweight durability without losing flexibility. 



CX6 provides a glove like fit and zero loss of energy to the pedals on cycling shoes.