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Issue 56

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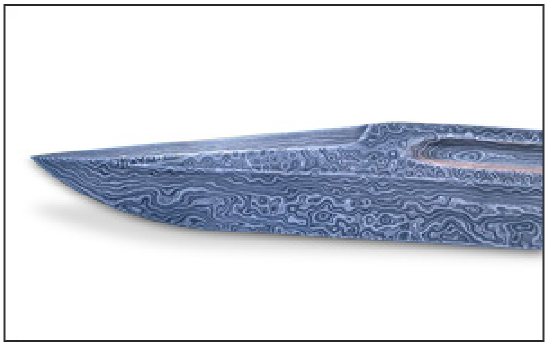
Damascus Swords - An Ancient Advanced Material



In popular culture, the Samurai sword reigns supreme as both a fearsome weapon and a work of art, a masterpiece combining hardness and flexibility in steel. However, another ancient weapon, the Damascus sword, has also been revered for centuries. Its beauty is second to none. Damascus blades have a characteristic wavy banding pattern on the blade surface known as damask. It also combines hardness and flexibility. Only recently, researchers have found some of the secrets of these competing properties. The Damascene bladesmiths were making carbon nanotubes more than 400 years ago.

Damascus blades, first encountered by Europeans in the Middle Ages in the Middle East and Asia, had features not found in European steels: extraordinary mechanical properties, an exceptionally sharp cutting edges, and a damask pattern.

Damascus blades were forged from Wootz steel from India. India has been reputed for its iron and steel since ancient times. Literary accounts indicate that steel from southern India was rated as some of the finest in the world and was traded throughout Europe, China, and the Middle East.

Steel is made by alloying iron with carbon. High carbon contents of 1 - 2% make the material hard, but also make it brittle. This property is useless for sword making since the blade would shatter upon impact with a shield or another sword. However, Wootz steel, with a carbon content of about 1.5%, showed a seemingly impossible combination of hardness and malleability.

According to an early report on Indian Wootz steel production, iron ores taken from particular mines in India contained small traces of impurities; the metals including vanadium, chromium, manganese, cobalt and nickel. Other particular ingredients were necessary in the smelting process: wood from Cassia *auriculata* and leaves of *Calotropis gigantea*.

Wootz steel was produced as small ingots and shipped to Damascus, Syria, where bladesmiths learned to forge them into the swords that displayed a beautiful surface pattern. The high carbon level of these steels plays a key role in producing the characteristic surface pattern because the pattern results from alignment of the cementite (Fe3C) particles that form in such steels on cooling.

Unfortunately, production of Damascus swords gradually declined, ceasing by around 1750, and the process was lost to bladesmiths. Several theories have been put forward for this decline, such as exhaustion of the supply of iron ore of the correct composition, disturbance of trade routes, and loss of knowledge of the smithing process through secrecy over time.

Nowadays, the term Damascus steel refers to two different types; one of which is the true ancient Wootz Damascus steel with a texture originating from the etched crystalline structure, the other is a composite structure made by welding, folding, and twisting of alternating layers of iron and steel to give a visible pattern on the surface of the final blade.

The legends associated with the excellent properties of Wootz steel and the beautiful patterns on Damascus blades caught the imagination of European scientists in the 17th through 19th centuries since the use of high-carbon iron alloys was not really known previously in Europe and hence played an important role in the development of modern metallurgy. Textured Damascus steel was one of the earliest materials to be examined at the microstructure level.

Both the internal microstructure and the chemical composition of these steels were well established by the early 1900s. The internal microstructure of a Wootz Damascus blade possessing a high-quality damascene surface pattern consists of bands of small particles of cementite clustered along the band centerline. The bands have a characteristic spacing of 30 to 70 mm and are contained in a steel matrix. The bands lie parallel to the forging plane of the blades. By manipulating the angle of the blade surface, relative to the plane of the bands, the bladesmith can produce a variety of convoluted patterns of intersection of the bands with the blade surface. After polishing and etching, the cementite bands appear white and the steel matrix nearly black, creating the surface pattern.

More recently, materials researcher Peter Paufler and his colleagues at Dresden University (Germany) using high-resolution transmission electron microscopy, have detected carbon nanotubes in a specimen taken from a genuine Damascus sabre produced by the famous blacksmith Assad Ullah in the 17th century. The nanotubes appear after dissolution of the sample in hydrochloric acid. Incompletely dissolved cementite nanowires were also identified, indicating that these wires could have been encapsulated and protected by the carbon nanotubes.

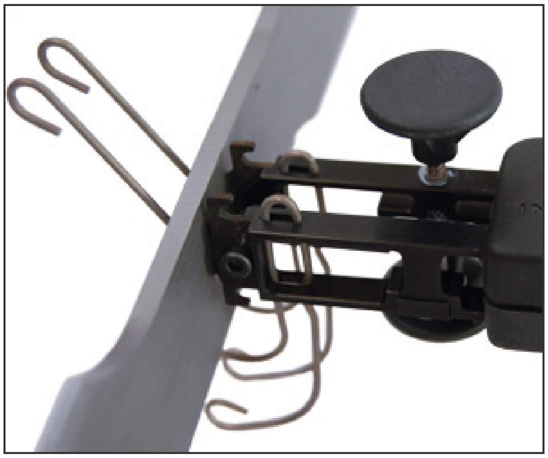
Carbon nanotubes are cylinders made of hexagonally-arranged carbon atoms. They are among the strongest materials known and have great elasticity and tensile strength. The team theorizes that the nanotubes were protecting nanowires of hard and brittle cementite. That may be the answer to the steel's special properties; at a nanometer level, it is a composite material. The malleability of the carbon nanotubes compensates for the brittleness of the cementite formed by the high-carbon Wootz steel.

It is not clear how ancient bladesmiths produced these nanotubes, but the researchers believe that the key to this process lay with the unique combination of impurities in the Wootz. Alternating temperature phases during manufacture caused these impurities to segregate out into planes. From there, they would have acted as catalysts for the formation of the carbon nanotubes, which in turn would have promoted the formation of the cementite nanowires.

Using the unique properties of Wootz steel, and their unique blade-treatment procedures, Syrian craftsmen may have been making that most modern of material, carbon nanotubes, more than 400 years ago.

Sources: *Wootz Steel: An Advanced Material Of The Ancient World*. Updated November, 18th 2000. S. Srinivasan and S. Ranganathan. Department of Metallurgy, Indian Institute of Science, Bangalore.
The Key Role of Impurities in Ancient Damascus Steel Blades J.D. Verhoeven, A.H. Pendray, and W.E. Dauksch JOM, 50 (9) (1998).
Carbon Nanotubes in an Ancient Damascus Sabre. NATURE, Vol 444, 16 November 2006.

Extensometer Slippage



Some of our customers are frustrated when they experience slippage of their strain gauge extensometers. Close examination of their extensometer knife-edges often reveals wear that has rounded the edge, increasing the likelihood of slippage. If you are experiencing extensometer slippage, take a close look at your knife-edges. For replacement parts, please contact your local Instron representative.

Note that the knife-edges are precision engineered to ensure an accurate gauge length, so we do not recommend that you attempt to sharpen the edges yourself.

Q. What is the Best Way to Grip Thin-walled Steel Tubes for Tension Testing?

A. For testing most tubular specimens, you should use vee-serrated grip jaws. They hold the specimen securely and the vee face ensures that the specimen is centered. However, the grip forces can deform thin-walled tubes. You should manufacture close-fitting mandrels with a tapered end to insert into the tube ends before gripping the tube. The mandrel will ensure the tube cross-section does not deform, and the tapered ends will accommodate any necking of the tube during testing.

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