Shock-wave

Shock wave research was traditionally developed as an element of high-speed gas dynamics supporting supersonicflights and atmospheric reentry of space vehicles. However, recently its scope has expanded to the comprehensive interpretation of shock wave phenomena in nature and the artificial world. In particular, many aspects of volcanoes's explosive eruptions are closely related to shock wave dynamics. One hypothesis proposes that during asteroid impact events that took place millions of years ago underwater shock waves played a decisive role in mass extinction of marine creatures. Shock waves have been successfully applied to medical therapy. Extracorporeal shock wave lithotripsy (ESWL) was a wonderful success in noninvasive removal of urinary tract stones. Recently, shock wave therapy was further developed for the revascularization of cerebral embolism, drug delivery, and other interesting therapeutic methods.

Shock wave physics

When an object (or disturbance) moves faster than the information about it can be propagated into the surrounding fluid, fluid near the disturbance cannot react or "get out of the way" before the disturbance arrives. In a shock wave the properties of the fluid (density, pressure, temperature, velocity, Mach number) change almost instantaneously. Measurements of the thickness of shock waves have resulted in values 2 micrometers (10^{-5} in), which is on the same order of magnitude as the mean free gas molecule path. In reference to the continuum, this implies the shock wave can be treated as either a line or a plane, if the flow field is 2d or 3d respectively.

Shock waves form when the speed of a fluid changes by more than the speed of sound. At the region where this occurs sound waves traveling against the flow reach a point where they cannot travel any further upstream and the pressure progressively builds in that region, and a high pressure shock wave rapidly forms.

Shock waves are not conventional sound waves; a shock wave takes the form of a very sharp change in the gas properties on the order of a few mean free paths (roughly micro-meters at atmospheric conditions) in thickness. Shock waves in air are heard as a loud "crack" or "snap" noise. Over longer distances a shock wave can change from a nonlinear wave into a linear wave, degenerating into a conventional sound wave as it heats the air and loses energy. The sound wave is heard as the familiar "thud" or "thump" of a sonic boom, commonly created by the supersonic flight of aircraft.

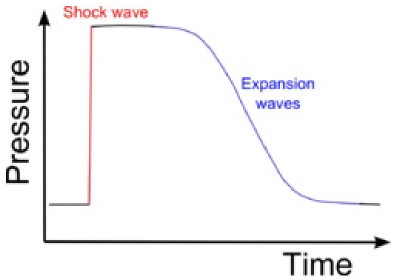

Figure:Pressure-time diagram at an external observation point for the case of a supersonic object propagating past the observer. The leading edge of the object causes a shock (left, in red) and the trailing edge of the object causes an expansion.

Shock wave physics in medicine

Extracorporeal Shock Wave Technology (ESWT) is a technological breakthrough in non-invasive surgical alternatives. ESWT offers patients and physicians benefits which traditional surgery cannot match, and the clinical outcomes prove that ESWT is just as, if not more, effective when compared to traditional open surgery.

Electrohydraulic shock wave generation (Spark gap method)

True shock waves generated for medical purposes consist of a dominant pressure pulse which climbs steeply to some tenths or even hundreds of Mega-Pascals (MPa; 1 MPa = 10 bar) within several nanoseconds (nanosecond = 1/billionth of a second) and then falls again within several microseconds (microsecond = 1/millionth of a second); this wave is followed by a weaker tensile wave portion lasting for several microseconds. The electrohydraulic source used by PulseVet's® VersaTron®, VersaTron® 4Paws, and EquiTron creates the most effective shock waves for medical purposes. These shock waves have the largest target volume and the steepest leading edge. The spark gap method, whereby a spark is generated between two electrodes, is a very effective and reproducible technique for producing shock waves of this kind. Owing to the extremely high rise in pressure at the wave front, there is a high concentration of mechanical energy in the direction of wave propagation. This technique, which is the benchmark of all shock wave generation methods, is based on the following principle: a capacitor which has been charged to a high voltage discharges electrical energy abruptly at the 1st focal point over two electrode tips located in water (underwater spark discharge). The shock wave created by the explosive evaporation of water is focused by an ellipsoid and finally releases its maximum energy at the 2nd focal point. The shock wave is conveyed into the body via a water cushion. The electrohydraulic shock wave generation method is the only method that generates a true shock wave at all energy settings.

Other types of shock wave generation

Electromagnetic shock wave generation (EMSG)

With this method, shock waves are generated on the basis of a principle similar to that used in loudspeakers. An electrical impulse is sent through an inductance coil, generating a magnetic field which repulses a metallic membrane. The acoustic impulse created by this repulsion is focused by an acoustic lens to form a shock wave. The electromagnetic method of shock wave generation requires an extensive water-based cooling system.

Piezoelectronic shock wave generation

Shock waves created on the basis of the piezoelectronic principle are generated by about a thousand piezoelectronic crystals arranged on the inside of a conical segment. The intermittent application of a high voltage to the crystals causes them to alternately contract and expands. Owing to the particular arrangement of the crystals on the conical segment, the acoustic impulses are bundled into a shock wave at the focal point. Piezoelectronic shock wave generation has not been approved by the FDA. Both electromagnetic and piezoelectric shock wave generation are popular for lithotripsy due to their small focal area, allowing most of the generated acoustic energy to be targeted at a very small object such as a kidney stone. A small focal area is not optimal, however, for treating a larger target area, as would be necessary in most orthopedic or chronic wound indications. At low-amplitude settings these technologies do not produce a true shock wave.

Radial or ballistic pressure wave generation

(Not a shock wave, but has been marketed as a shock wave)
Ballistic (Radial): This type of device has an oscillating pneumatically driven head that is applied directly to the tissue surface and mechanically impulses over the target tissue. Maximum penetration effect of this type of device is approximately 5mm. In a published study, it was found that one ballistic device investigated which was labeled as a "focused shock wave" device was neither focused nor a shock wave.

Shock wave treatment

Extracorporeal shock wave therapy in orthopedics and traumatology is still a young therapy method. Since the last few years the development of shock wave therapy has progressed rapidly. Shock waves have changed the treatment of urolithiasis substantially. Today shock waves are the first choice to treat kidney and urethral stones. Urology has long been the only medical field for shock waves in medicine.

Meanwhile shock waves have been used in orthopedics and traumatology to treat insertion tendinitis, avascular necrosis of the head of femur and other necrotic bone alterations. Another field of shock wave application is the treatment of tendons, ligaments and bones on horses in veterinary medicine. The idea behind using shock wave therapy for orthopedic diseases is the stimulation of healing in tendons, surrounding tissue and bones. This is a completely different approach compared to urology where shock waves are used for disintegration

Links

Related articles

External links

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