CHAPTER 12

HEMs: Constructive Applications

12.1 HEMs Have Shaped Our World

Ever since Alfred Nobel invented dynamite about 140 years ago, the world has undergone an incredible transformation. Population has increased tremendously and so have the global materialistic demands. Technology has, in different fields, grown to amazing levels. The march toward better technologies and better products goes on unrelentingly. There have always been remarkable milestones in the history of development of science and technology, and the achievement of each milestone changed the very face of our life on this earth. Some of the milestones achieved in the field of HEMs have literally shaped our world. It is an undeniable fact that explosives have wreaked untold havoc and horrors (and are still wreaking sporadically!) in the guise of a number of wars since last two centuries or more. But it is also an undeniable fact that the explosives or generally HEMs have shaped the world what it is today. The object of this chapter is to highlight this "other side of the coin," namely, the role of HEMs for constructive purposes.

Advancement in science and technology would have been almost impossible but for the fact that HEMs paved the way to easily tap the earth's resources. Among many constructive applications of HEMs, the following stand out undoubtedly.

12.1.1 Mining and Quarrying

Coal mining has been feeding the vast energy requirements of the mankind, although today we are nervously aware that this fossil fuel will not last forever. All metals and minerals (which play important roles in materials and equipments of everyday use, be it toothpaste or talcum powder, medicine, cosmetics or color TV, and computer chips) have made our life richer and more comfortable.

12.1.2 Construction

Amazing augmentation of infrastructure throughout the world has changed the very face of the earth in the last many decades and is still continuing with unabated speed. Construction of huge multistoried structures, roads, tunnels, bridges, etc. has been contributing greatly to the economy of many nations.

Demystifying Explosives: Concepts in High Energy Materials. http://dx.doi.org/10.1016/B978-0-12-801576-6.00012-4

12.1.3 Oil Well Perforation

Today, there are frenzied efforts to find alternative sources of energy driven by the fear of exhausting all the fossil fuel resources. Still, the fact remains that the oil, aptly called black gold, is the lifeline of our existence today. Imagine today's world without oil just for a week: everything would come to a grinding halt!

It is not hard to guess that the very basic requirement for the above vital activities is HEMs. In the past, humans had also been mining out coal, iron, copper, and other minerals. However, after the invention of dynamite and subsequent civil explosives, there was a 100-fold increase in their production. So was the case with quarrying. There was a tremendous increase in the production of cement and concrete and huge leap in the construction activities. Between American Civil War (1776) and end of the World War II (1945), no single engineering tool surpassed the achievement of dynamite. Today, Explosives Engineering is a specialized field and is undergoing continuous improvement (some of the basic aspects of Civil Explosive have been covered in Chapter 4). It is a multidisciplinary field that involves chemistry of explosives, detonics, structural engineering, etc.

In the following section, let us briefly see the application of HEMs in certain other not-so-common areas.

12.2 Controlled Demolition

Imagine a situation like this: A thirteen-story building that has outlived its utility needs to be demolished. The hitch is that there is a massive hospital complex with even an organ transplant facility in close proximity apart from other high-rise structures. Conventional methods of demolition using hammering, bursting, etc. will not only take enormous time, labor, money, etc., but will also involve a host of problems like traffic dislocation in the nearby area, continuous emission of noise, and enormous amounts of dust and debris. Such a process is very likely to cause serious pollution problems and potential infection to the patients in the adjoining hospital complex. Moreover, the conventional methods of demolition call for a large number of machineries like cranes, which pose severe problems of space and logistics while demolishing a structure in a congested area. Actually, the above situation was faced by an Irish hospital complex a few years ago, and that is when the controlled demolition by explosives became quite handy.

12.2.1 Explosion or Implosion?

We know that if we want to blast a multistoried structure by explosives in the conventional way, the shockwave created as well as the flying debris of steel and concrete will wreak

unimaginable havoc on life and property all around. But in the controlled demolition by explosives, it is necessary to *implode* the building so that it collapses down into its footprint. An implosion can be defined as an event where something *collapses inward*, because of the external/atmospheric pressure. For example, if you pump out the air out of a thin glass vessel, it might implode. Strictly speaking, controlled demolition of a building is not truly an implosion: atmospheric pressure does not pull or push the structure inward. Here, the explosives are used to weaken the supporting structures like columns/pillars, thus allowing the gravity to pull the structure down by the virtue of its own weight. The resultant huge piles of debris are not "laid out," but they fall very close to the foundation of the structure.

It you have a four-legged table and you remove two legs from one side, the table will fall over. You can control the direction of fall by choosing the appropriate two legs that are to be removed. A large building generally has many "legs" or columns that support it. In an implosion, first you remove the columns from within the building, thus causing the initial collapse to start from that point. The initial collapse of the inner columns helps to drag the structure down toward the center.

Remember the catastrophic collapse of the World Trade Center structures in the infamous 9/11 attacks at New York? Two of the tallest buildings in the world collapsed just vertically without causing much damage to the nearby structures. It is probable that the high temperature flames made the supporting structures give way. The rest of the job was done by gravity.

12.2.2 Step-by-Step

The actual process of implosion may take place in less than 60 s. However, prior to the implosion, on-site preparation operations will take several weeks to complete. Key structural supports are identified and exposed by removing interior, non-load bearing walls and piping. Small diameter holes will be drilled at specific locations to act as explosive receptacles equipped with internal non-electric timing devices that will fire on queue. Some of the important measures to be taken include the minimization (total elimination is not possible) of dust production and vibration.

The extent to which the nearby buildings or facilities will be affected by dust depends on the wind speed and direction at the time of implosion. Dust-producing materials from the building such as dry wall plaster, ceramic tiles, etc. are to be removed initially. The implosion will be designed to minimize the amount of vibration. Other precautions include closing of windows/doors/exhaust fans/air conditioners, etc. in the neighborhood during the implosion followed by some period.

Explosive (or implosive) demolition of buildings is safe, cheap, and quick, but caution! This needs to be carried out only by professional and competent personnel in this field.

Figure 12.1
Controlled Demolition of a Multistoried Structure. *Courtesy/with permission from: The Loizeaux family & Controlled Demolition Inc., Phoenix, Maryland, USA.*

This type of demolition is known to be carried out in Europe and the United States for several years. In India, it is now becoming very prevalent. Figure 12.1 depicts the controlled demolition of Biltmore Hotel in Oklahoma City, USA, in the year 1977. Note that the collapse is inward, i.e., directed toward the center of the structure. As seen in the last photograph, hardly any major debris is noticed outside the perimeter wall of the building after its collapse.

12.3 Air Bags

Air bags have become a primary safety device in automobiles today. They complement with the seat belt and save the life of the driver in case of a crash. How the air bag saves his life is given in the following picture:

In the case of Figure 12.2(a), where the automobile is not equipped with an air bag, when there is a crash, the body (mostly the chest/ribs area) hits the steering wheel directly. The force of impact is of high order (depending on the momentum of the vehicle when it crashes), whereas the area of the human body (chest/ribs) receiving the impact is quite

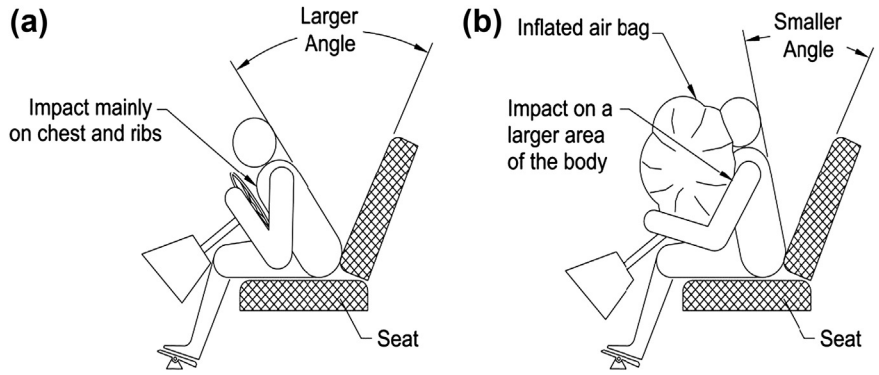


Figure 12.2
(a) Automobile Without Air Bag. (b) Automobile Equipped with Air Bag.

less. Such a high ratio of impact/area immediately kills the driver. In case of Figure 12.2(b), the automobile has been fitted with an inflatable air bag just at the center of the steering wheel. The uninflated air bag contain gas-generator HEMs, mostly a mixture of azides (like NaN_3), an oxidizer (e.g., KNO_3), and other ingredients (like SiO_2). When there is a crash, a crash sensor sends an electrical signal that ignites an initiator (Figure 12.3). The initiator ignites the gas generator mixture at the time of impact producing large volumes of nitrogen in *less than 0.05 s*, and this inflates the air bag faster than the movement of the driver's body toward the steering wheel. When the body is restrained by an inflated air bag, the force of impact is distributed over a much larger area of the body (including face and hands) resulting in less severe injuries. There is a mechanism by which the air bag gets deflated within a second after saving the life of the driver. It has been estimated that the fatality in automobile accidents has been reduced by more than 60% due to the seat belt/air bag combination.

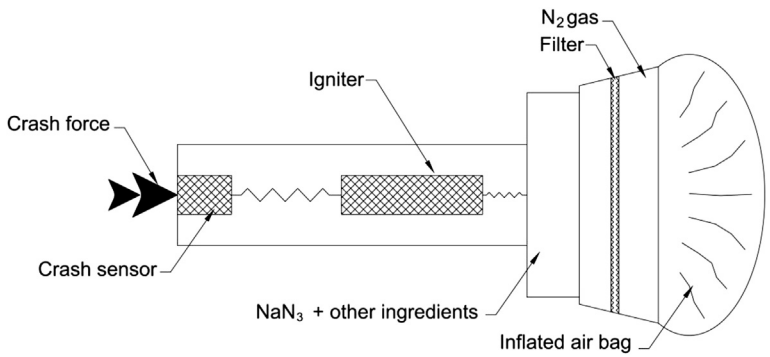
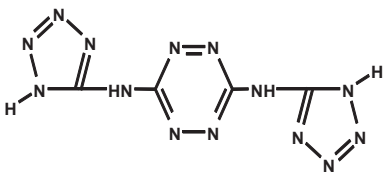


Figure 12.3
Components of Air Bag System (Schematic).

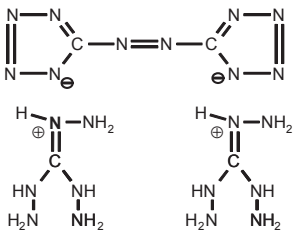
The reactions involved in an NaN_3 based gas generator are given below.

$$2NaN_3 \rightarrow 2Na + 3N_2$$
$$10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$$
$$K_2O + Na_2O + SiO_2 \rightarrow K_2Na_2SiO_4$$

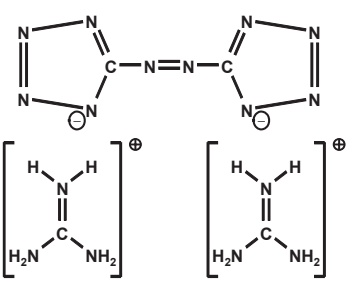
Due to the toxicity and possible risks involving NaN_3, research is on to develop alternative HEMs/gas generators. A few of the potential candidates are:



BTATz



TAGAT



GAT

Where

BTATz	Bis tetrazolylaminotetrazine (BTATz)
TAGAT	Triamino guanidinium azotetrazolate
GAT	Guanidinium azotetrazolate

12.4 Explosive Welding

Welding of certain dissimilar metals or alloys by conventional welding is a challenging task and often impossible. This, however, has been made possible by the process of explosive welding (see Figure 12.4(a)–(c)). Let us say that we want to weld a Ni-alloy plate (cladding plate) on to a carbon steel plate (parent plate). The surfaces of the plates are cleaned and dried and the cladding plate is kept at a predetermined inclination, as shown in the figure. A layer of plastic explosive with a detonator is embedded on the cladding plate (Figure 12.4(a)). On initiation of the explosive, the detonation pressure impacts the cladding plate (also called "flyer plate") on to the parent plate with huge impact pressures (in the range of a few millions of psi, with plate speed that may vary from 100 to 300 m/s) (Figure 12.4 (b)). The interfacial pressure of the collision exceeds the yield strength of the materials, resulting in momentary plastic deformation. This results in atom-to-atom type of bonding between both the materials, giving a perfectly welded material (Figure 12.4(c)).

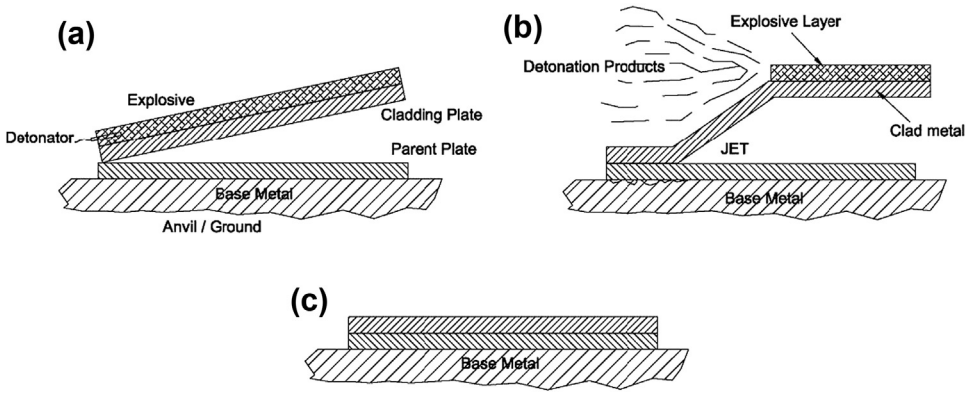


Figure 12.4
Explosive Welding of Dissimilar Metals. (a) Initial Set-up. (A Lug Support to Keep the Inclination is not Shown in the Figure). (b) After Initiation of Detonation, Huge Detonation Pressure Impacts the Cladding Plate on to the Parent Plate Resulting in Instantaneous Bonding Between the Plates. (c) Explosive-Welded Plates.

The major advantages of the method of explosive welding are:

1. Dissimilar and normally unweldable metals can be welded.
2. Can be done at room temperature in air/under water/vacuum.
3. The process is compact, portable and inexpensive.

However, there are a few disadvantages:

1. Metals/alloys should have high impact resistance and ductility.
2. The plates should have simple geometries flat/cylindrical/conical (for symmetrical travel of the shock wave).

12.5 Avalanche Control

An avalanche (a huge mass of snow and ice falling rapidly down a mountainside) often causes disasters to life and property. When snow strength (bonding between snow crystals) can no longer support its own weight, the entire mass starts sliding down causing an avalanche.

An avalanche control is a measure to intentionally trigger an avalanche using explosives (before it occurs naturally) after taking necessary precautionary measures like clearing the area from people, traffic, ski-resorts, etc. An avalanche control expert has to be conversant with mountain (snow) safety as well as explosive safety. He/she can predict the time and place of avalanche occurrence. He should be able to determine the type and quantity of explosive to be used to clear an avalanche and also the proper means of initiation.

Avalanche control prevents disasters such as people, tenements, and vehicles being buried under snow (*please refer Chapter 4, Figure. 4.14*).

12.6 Life Saving Applications

HEMs find a life-saving application for emergency exit of fighter pilots. In case the pilot wants to abandon the aircraft during an emergency, an explosive device severs and dislodges the canopy, following which a propulsion device under his seat ejects the pilot and parachute from the aircraft. The design and development of the explosive system for canopy severance and the propellants/propulsion system for seat ejection is a very critical job, as it involves the life of the pilot. Many lives have been and are being saved by a combination of seat ejection and canopy severance devices where the HEMs play a very critical role.

In the field of medicine, nitroglycerine—a well-known explosive—has saved the lives of many patients suffering from coronary heart disease. NG-based tablets are known to prevent or stop the chest pain (angina) among such patients. NG dilates the blood vessels, leading to more blood flow and oxygen supply to the heart. NG-based tablets are strictly prescribed medicines and should be taken only as per strict medical advice.

There has been an interesting and rather weird application of explosives in tenderization of meat! It was discovered by Morse Solomon, a meat scientist, and John Long, that huge quantities of meat kept under water get tenderized by subjecting them to underwater explosion. It has been estimated that this method of tenderization of meat is far cheaper than methods involving electrical power. Probably some of the potential applications by HEMs are yet to be discovered.

Suggested Reading

[1] E.G. Mahadevan, Ammonium Nitrate Explosives for Civil Applications Slurries, Emulsions and Ammonium Nitrate Fuel Oils, first ed., Wiley-VCH, 2013.
[2] The Explosive Engineer: Forerunner of Progress in Mining, Quarrying, Construction, vol. 20, Contributor Hercules Powder Company, Publisher Hercules Powder Company, 1942.
[3] E.G. Baranov, A.T. Vedin, I.F. Bondarenko, Mining and Industrial Applications of Low Density Explosives, Taylor & Francis, 1996.
[4] D.E. Davenport, Explosive Welding, American Society of Tool and Manufacturing Engineers, 1961.
[5] T.Z. Blazynski, Explosive Welding, Forming and Compaction, first ed., Springer, 1983.
[6] E.O. Paton, Explosive Welding of Metal Layered Composite Materials Welding and Allied Processes, International welding Association, 2003.
[7] R.A. Patterson, Fundamentals of Explosion Welding, ASM Handbook, vol. 6, Welding, Brazing, and Soldering (ASM International), 1993.
[8] B. Crossland, Explosive Welding of Metals and its Application, Clarendon Press, 1982.

Questions

1. What are the important factors to be considered in the controlled demolition of high-rise structures?
2. How does an automobile air bag work?
3. What is an avalanche and how can it be controlled using explosives?
4. What do you understand by canopy severance system? How does an explosive and propellant system save the life of an aircraft pilot during an emergency?
5. What is meant by explosive welding? What are its advantages over conventional welding?
6. How does nitroglycerine help in relieving angina?