Internal ballistics

The term 'Ballistics' is derived from the Latin word "Ballista" which refers to a crossbow like device for throwing stone by means of twisted ropes. In order to understand elements of ballistics, it is divided into three parts as described below:

1. Internal ballistics
2. External ballistics
3. Terminal ballistics

Internal ballistics is the study, which deals with the motion of projectile/s in the bore of the weapon whereas external ballistics deals with the fight from the muzzle of the weapon to the target. This, indeed is, terribly complicated subject involving parameters such as shape of the bullet, sectional density, atmospheric conclusions and even rotation of earth in larger-caliber weapons. With the advent of powerful personal computers the complex calculations have become quick and accurate. The terminal ballistics deals with the behavior of missile once it reaches the target such as wounding capabilities and includes its performance in water, soil, brick, concrete, wood and other bullet resistant materials.

In order to understand the factors affecting the projectile in the barrel, certain terms need to be explain such as smooth bore weapons, rifled firearms, lock time, ignition time and barrel time etc.

Shotguns and improvised firearms (country made) are smooth bore weapons and fire a spherical ball, slug or a charge consisting of a considerable number of lead pellets (shot) having spherical shape. They make a perfect circle at any point of cross section.
A rifle has lands & groove as well as rifling marks. Rifled weapons fire bullets, which are not spherical in nature but elongated. Thus behaviour of projectiles inside the barrel in the two cases would obviously be different. The following diagram showing barrels of smooth bore guns & rifled firearms will make the position clearer.

Internal ballistics, which deals with the motion of projectiles, commences as soon as the first grain of the propellant is ignited and subsists till the projectile leaves the muzzle end of the weapon.

The study includes all details concerning the impulse, which makes the projectile move out from the muzzle in the air. As a matter of fact, a projectile obtains its energy during the period it remains in the firearms. This period can be divided under the three main heads.

- **i. Lock time**
- **ii. Ignition time**
- **iii. Barrel time**

Lock time
is the time interval between release of the sear and the impact of the striker on the percussion cap. A short time internal is advantageous in rapid fire. The lock time can be measured in a number of ways, in one such system the use of linear Motion sensors and an oscilloscope is made.

Ignition time
is the duration or interval between the striking of the firing pin to blow the ignition of the first grain of powder. The ignition, under the normal conditions, takes place at an interval of about 0.002 seconds.

Barrel time
is the time interval from the pressing of the trigger to the exit of the bullet from the muzzle end. In case of most of the weapons Lock time + Ignition time + barrel time varies from 0.003 to 0.007 seconds.

Phenomenon of Internal ballistics

Internal ballistics includes study of several phenomena, some of which are as follows and would be discussed in two parts, i.e. in Internal Ballistics -I &Internal Ballistics - II.

1. Ignition
2. Burning of propellants and geometry of gun power
3. Pressure and its measurement
4. Atmospheric conditions like temperature etc.
5. Shape of cartridges
6. Density of loading
7. Twist of rifling
8. Bullet fit & velocity of bullet at muzzle
9. Heat generation and problems
10. Strength of barrel
11. Erosion
12. Corrosion or rusting of barrel
13. Bullet of the weapon
14. Recoil of the weapon
15. Phenomenon of bursting of barrel

1. Ignition

When the firing pin strikes the hammer, the priming compound explodes with great velocity causing jet of flames ofan extremely high temperature to pass through the flash hole into propellant chamber. This jet of flame with a temperature of about 2000°C ignites the propellant which burns at high speed to form a large volume of high pressure gas which accelerates the bullet down the barrel and out of muzzle end.

2. Burning of Propellants

Nitrocellulose propellants, if ignited in an unconfined space, will burns gently. The heat and pressure built will accelerate the rate of burning exponentially if it is in a confined space. The products of combustion in case of Nitroglycerine are as detailed below:

Nitroglycerine®Carbon dioxide + water Vapours + Oxides of Nitrogen + Nitrogen + Heat

One gram of nitroglycerine will produce one thousand cubic centimeters of gases at normal temperature (0°C) and pressure (760 mm). The heat given by the reaction is also tremendous- about one thousand calories. The temperature may cross 3000°C. Only a portion of this energy is converted into kinetic energy of the projectile. Most of it is wasted.

In a weapon, the propellant is confined in a cartridge case, the mouth of which is closed with a bullet. The round of ammunition is then supported by the chamber walls and the standing breech of the weapon. Under these conditions, the pressure build-up will continue until it is sufficient to overcome the inertia of the bullet and starts its acceleration down the bore. The heavier the bullet, greater the resistance and higher the pressure.

When the propellant burns, it gives rise to gases (as already explained) and they remain confined completely with in the cartridge case and pressure is exerted equally on the base of the cartridge, its walls and the base of the bullet.

Once the bullet starts to move the volume filled by the gases increases and the pressure starts to fall in accordance with gas laws.

In modern propellants, moderating the propellant grains can compensate this fall in pressure. This moderation involves the addition of grains. In some propellants, the grains are also pierced with holes. There are different types of powders namely progressive powders, degressive powders and constant burning propellants as explained below:

2.1. Progressive Powder—

For some weapons, particularly in respect of shoulder arms, it is desirable that pressure should not develop suddenly and the increase in pressure should be gradual. Dense and bulk powder, when ignited, burn rapidly with the result that the projectiles receive a big push. Gradual development of pressure not only provides better velocities but also prevent quick wearing out of the barrel.

Progressive powders are manufactured to suit the needs of a particular weapon by controlling the shape and size of powder grains. Example: Powder grains having multiple perforations.

2.2 Degressive Powder—
In the case of degressive powders the shape and size of grains are kept such that, as burning of propellant progresses, the rate of burning goes on decreasing. Example: Non-perforated powder grains.

2.3 Constant Burning Propellant—
In this type of propellant, the powder grains contain a single perforation and the total surface area burning at any instant is constant.
Example: Single perforated grains.

3. Geometry of Gunpowder
Burning of propellants is a function of geometry of gunpowder; certain terms concerning burring are briefly explained here:

***Combustion*:-** It takes place when the reaction of the burning propellant/substance arise out of its contact with the air in an open space. If the reaction takes place in an enclosed space, the space should be large enough for the heat generated to dissipate and the gases produced will disperse without generating any significant increase inthe pressure. The spreading of fire is brought out by the gradual heating of the surrounding area.

***Deflagration*:-** It includes rapid and violent burning and is intermediary step between gradual combustion and detonation. This is caused by the acceleration due to gradual heating up or by the increased pressure of the gases produced by decomposition of the mass according to the conditions prevailing in the explosive system.

Detonation:- It takes place when the explosion is extremely rapid and the formation of gases is almost instantaneous, transmitting shock waves, which are also known as explosive waves, throughout the mass. Ballistic powders are capable of producing large volumes of high temperature gases in a very short time by means of deflagration.
The propellant charge is composed of quantity of grains that are ideally of the same shapes and size. Solid cylindrical grains present smaller area as burning progresses. Cylinders with certain perforations along their length presents nearly a constant surface and propellants of this shape are called as constant burning propellants. With multiple perforations the amount of propellant burned increases as burning progresses.
In forensic terms ballistic advantage of the latter is that it generates gas at a lower rate initially when the total volume behind the projectile is small and produces gas at an accelerated rate as the projectile gathers velocity and creates greater volume behind as it moves, through the barrel towards muzzle to escape in air.

4. Combustion of Propellants and Barrel Length

There are wide variations in the rate of burning of the powders. Some powders burn quickly, while other burns slowly. Various firearms require different burning rates. For example, in pistols and revolvers, a very quick burning powder is needed so that the powder is converted into gases before the projectile is pushed out of the short barrel of the firearm. If slow burning powder is used, the projectile will not acquire the desired velocity. Likewise if quick burning powder is used in long barreled firearms, the projectile will not receive sustained pressure. Consequently, for the maximum pressure the projectile will have a lower velocity. If a powder with appropriate burning rate is used, the projectile can be given higher velocities for the same maximum pressure. The rate of burning has to be related to the length of the barrel.

The pressure in the firearm cannot be increased beyond a certain limit. And the limit is determined mainly by the strength of the barrel and action of the firearm to withstand the pressure.

5. Atmospheric Temperature

The ammunition is manufactured to give the desired velocities and pressures at a particular atmospheric temperature. If the temperature differs only slightly at the place of the use, the ballistic aspects are not seriously affected. If temperature variations are substantial (*e.g.*, in Ladakh or in Rajasthan desert), they affect the ballistics aspects of the ammunition. In hot places the pressures developed may be excessive and the firearm may burst. In cold places the ammunition may develop low velocities. Indian Ordnance Factories manufacture most of their ammunition with a temperature tolerance of —52°Cto72°C.It has been found that the variation in velocities because of the temperature is about one meter per second per degree centigrade.

6. Shape of the Cartridge Case

It has been observed that if there is an abrupt junction of the neck and the case, the rounds develop greater pressure (for the same quantity of powder). The combustion is more uniform. It appears that abrupt neck joint deflects the hot gases inward. The hot gases quickly ignite the powder charge in every nook and corner. Thus correct initiation and complete combustion of the powder charge takes place inside the cartridge. It reduces excessive heating and wear and tear of the barrel.

7. Heat Problems & Combustion of Propellants

During the combustion of propellants, the temperature often reaches to 3000°C. The steel barrels of the firearm easily melt at these temperatures, if gases at this temperature remain in the barrel for any appreciable time. But fortunately the time for which the hot gases are in contact with the barrel is about 0.001 second. Therefore, the high temperature does not create the havoc which is, otherwise, expected. Instead, there is gradual erosion, called ‘washing’, of the barrel due to continued flow of the hot gases. They carry away metal slowly but surely. Both the aim and the range are considerably affected by the increase in the diameter.

The repeating firearms (automatic or semi-automatic) are eroded more quickly. In these the barrels do not get sufficient time between the shots to get cooled. The erosion at higher temperatures is greater. The use of Nitroglycerine powders, which results in higher temperatures, wears out the barrel more quickly.

The leed of the barrel is the first part to be affected in the firearm. A widened leadgreatly affects the accuracy of the projectile. It facilitates the escape of the gases and consequently a portion of the energy is wasted. Gas cutting is another phenomenon observed in the extensively used firearms. The out-rushing hot gases, at certain points, either due to some deformity in the projectiles or erosion of the leed, come out in the form of jets, which create furrows. These furrows attain greater width & depth with the passage of time due to the ever increasing volumes of gases rushing through these channels.

8. Density of loading & Combustion rate

An important factor, which affects the rate of combustion, is the density of propellant load.

Density of propellant loading is given by the formula, $S = u/V*100$

Where, u is the volume occupied by the powder,
V is volume of the cartridge case
S is the density of loading.

In the rifle cartridge, the loading density varies from 75 to 95.

Higher densities are more useful as they permit uniform burning, proper development of pressure, economical and give rise to regular velocities. When loading density is small it may result in giving “hang fire”. Improper loading density materially affects the range and aim of a shot.