# Study of Various Technical Systems Incorporated in a Metro Rail System

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**Abstract**— This paper emphasizes on some of the essential technical systems that are incorporated in a metro rail. Broadly, the mechanical systems, pneumatic systems, braking systems and door mechanism have been dealt with in detail. The information presented is a result of extensive study performed at the Delhi Metro Rail Corporation (DMRC's) rolling stock department.

## 1 Introduction

Since the inception of the Delhi Metro, the network has been expanding rapidly across the region. This has called for establishment of various maintainence centers on different lines to deal with repair activities pertaining to the rolling stock. Such maintainence centers keep a regular check on the state of coaches from time to time and carry out necessary changes to maintain the quality and safety of the metro rail system. These centers deal with the mechanical, pneumatic, braking, electrical as well as the air-conditioning systems installed in the metro rail. Besides maintainence activities, the rolling stock department is also responsible for the assembly of coaches.

## 2 Train Formation

There are two types of train coaches in the metro rail namely the Driver-Trailer (DT) car and Motor (M) car. Both the DT and M car serve as one unit. They cannot be used separately. This is because the M car consists of the main motor (three-phase induction motor) which serves the purpose of tranmission. Whereas the DT car consists of the pantograph assembly which is connected to the 25kV over-head extention for power supply purposes. Hence, the DT and M car cannot be used separately. As a result of this, the metro rail runs with even number of coaches only (4,6 and now 8 coaches are common). Also, it is essential to have the DT car at the ends of the metro rail. This is because the DT car consists of the train operator's cabin. A general arrangement of coaches in a four-coach metro train is shown below.


Fig. 1. Four coach train arrangement

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## 3 Types of Couplings Between Coaches

There are three different types of couplings used in between different coaches of a metro train. These are:-

- Front Automatic Coupling (FAC)
- Semi- permanent Coupling (SPC)
- Intermediate Automatic Coupling (IAC)

### 3.1 Front Automatic Coupling (FAC)

This coupling is used at both ends of the metro train i.e., in front of the DT car. The FAC is automatic in operation and hence is very useful in case of rescue operations. During rescue operations, the FAC of the rescue train couples with the FAC of the train to be rescued automatically on impact. No manual effort on part of the train operator is required to couple the two trains.

### 3.2 Semi- permanent Coupling (SPC)

This coupling is incorporated between the DT and M cars. Since the DT and M cars serve as one unit, they are not usually required to be separated. Hence, a semi- permanent coupling is used between the two.

### 3.3 Intermediate Automatic Coupling (IAC)

This coupling is used between two M cars in order to facilitate easy engagement of coaches especially when the number of coaches has to be increased.

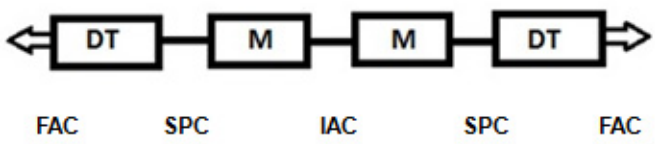


Fig. 2. Types of couplings between different coaches

## 4 PNEUMATICS

A large chunk of operations in the metro train are performed with the help of pneumatics. These operations include the application of brakes, variation of pressure in the air suspension system, variation of pressure for the movement of pantograph etc. Such operations are performed with the help of compressed air which is stored and supplied with required pressure to various units.

### 4.1 Advantages of Compresses Air

- Explosion proof
- Clean
- Abundantly available
- Easy to transport
- Easy to store and remove

### 4.2 Components Used in Air Supply System

- Air compressor
- Oil separator
- Air dryer
- Main reservoir tank
- Governor
- Safety valves

### 4.3 Functions of Various Components

Air is compressed to a pressure of about 8 to 10 bar through the air compressor. The oil separator helps in filtering the air of any unwanted particles. Air dryer removes moisture from air while a micromesh filter removes any kind of foreign particles that may be present in the air.

The compressed air after being properly filtered is stored in a 200 litre reservoir. It is further supplied to different pneumatic systems with pressure regulated as desired. The governor regulates the starting and stopping of the compressor. When the pressure in the reservoir reaches 10 bar, the governor cuts off the supply. When the pressure falls below 7.5 bar, it starts the compressor again.

### 4.4 Air Suspension

There are two types of suspension systems in the metro rail namely the primary suspension and the secondary suspension. Out of the two, the secondary suspension utilizes the compressed air stored in the 200 litre reservoir for its operation.

Each car has a secondary suspension system in the form of four air bags which are installed on the bogie. These air bags are filled with air with the help of a leveling valve. The leveling valve ensures that the floor height remains equal in any condition. If in case the floor height decreases from one side as a result of excessive load in that particular area, the leveling valve adjusts the air in the air bags installed on the other side of the bogie to level the height of the coach.

The air from the 200 litre reservoir is first supplied to a 50 litre tank from where it is further supplied to 70 litre tanks. It is then fetched to air bags as per the requirements.

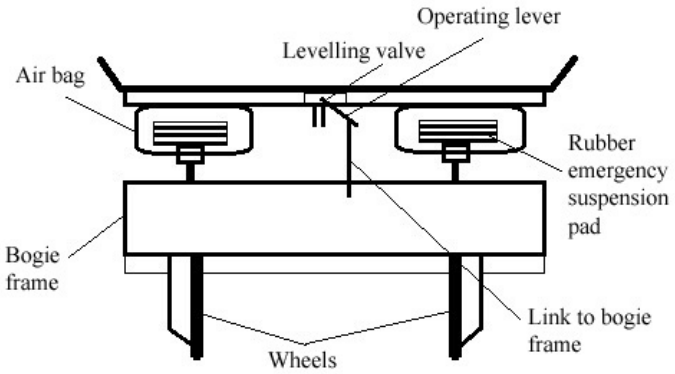


Fig. 3. Air suspension system

### 4.5 Pneumatic Brakes

Pneumatic brakes as the name suggests works on the principle of application of brakes using the force exerted by compressed air. There are five different types of brakes in the metro rail system based on their purpose of operation.

- Service brakes
- Emergency brakes
- Parking brakes
- Holding brakes
- Backup brake

**Service Brakes:** These brakes constitute the main braking system of a metro rail. They operate during normal running conditions and are also equipped with a regenerative braking system. The kinetic energy lost on account of application of brakes is converted into useful electrical energy and either stored in the battery system or supplied back to the overhead extension (OHE) in order to be used by other rails on the network.

**Emergency Brakes:** These brakes are used in case of emergency. It can be directly applied by the train operator. Besides, even if some condition is not fulfilled during operation and found potentially dangerous, a signal is sent to the Brake Electronic Control Unit (BECU) and subsequently to the Brake Control Unit (BCU) which further changes the signal into a pneumatic signal to apply brakes.

**Parking Brakes:** These brakes are used when the train is parked in a depot. Each metro car has a set of four parking

brakes, with two brakes installed on one bogie. They are installed on the DT car and can be applied either manually or automatically when the reservoir pressure is low.

**Holding Brakes:** These brakes are used to prevent the train from rolling back on a rising gradient. They are particularly useful when the train is standing on a station or in a depot. These brakes operate on a pressure which is seventy percent of the service brake pressure.

**Backup Brake:** This brake is particularly useful when the main braking system fails. The driver can operate the pneumatic brake in case of a fault in the electrically operated braking system. The pneumatic friction brake is operated using the driver's brake valve.

## 5 Brake Electronic Control Unit (BECU)

This is the main control unit that is responsible for receiving signals from the train operator to apply brakes. It also keeps a check on the load exerted on the air suspension and develops electrical signals accordingly.

When the train operator has to apply the brakes, he gives the signal to BECU. Accordingly, the BECU gives command to apply the electric regenerative braking. However, if the braking effort is not sufficient, then command for pneumatic braking is generated. The braking provided is load corrected, i.e., if the load is more, then more pressure will be applied. During braking, wheel sliding is prevented with the help of an anti-skid valve. This valve is also controlled through BECU.

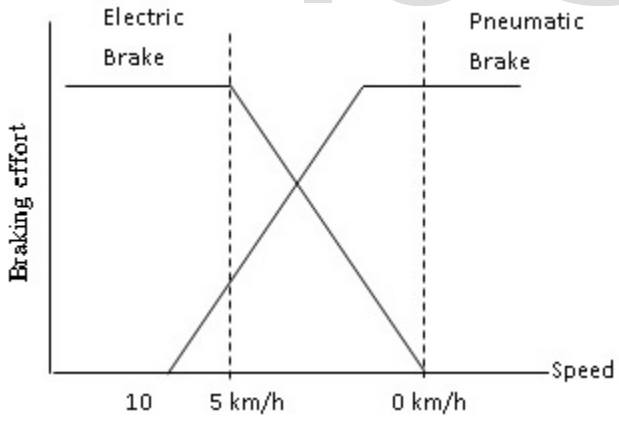


Fig. 4. Brake usage on account of variation in speed

## 6 Brake Control Unit (BCU)

This unit is responsible for receiving electrical signals from BECU and converting these signals into pneumatic signals. The BCU consists of different valves. According to the pneumatic signal generated with the BCU, a corresponding pressure is generated to apply brakes.

The BCU consists of the following essential components:-

- Analog converter (for service brakes)
- Emergency brake valve
- Double check valve (for backup brake)
- Pressure transducer (converts pneumatic signal to electrical signal)
- Relay valve
- Load limiting valve (for load correction)

## 7 Door

There are different types of doors installed in the metro rail to facilitate different functions. These are:-

- Passenger body side door
- Cabin body side door
- Emergency door
- Partition door

**Passenger body side door:** This door is installed on each side of the DT or M car to facilitate the movement of passengers into and out of the train. The opening and closing of this door is facilitated through electronic means.

**Cabin body side door:** This door is installed on both sides of the DT car. It is used only by the train operator to move into and out of the cabin. It is operated manually.

**Emergency door:** This door is installed on both ends of the metro train. The access to this door is through the train operator's cabin. It is operated manually with the help of a lever. This door is used as a last resort when all the attempts to open the passenger body side doors fail.

**Partition door:** This door is located between the driver's cabin and the saloon of the DT car.

### 7.1 Components of Saloon Door System

The major components of a saloon door system are:-

- Door panel
- Door Control Unit (DCU)
- Door gear assembly
- Door locking mechanism

**Door panel:** Two door panels constitute one door assembly. Both panels operate simultaneously.

**Door Control Unit (DCU):** The DCU is responsible for controlling the opening and closing of door. The signals for door opening or closing are sent from the train operator's panel to the DCU. The DCU determines whether it is safe to open or close the door accordingly. It also sends a signal back to the train operator's panel indicating the status of the door (Open/Close). However, in case of a system failure, the door can be opened or closed manually.

**Door gear assembly:** The door gear assembly is divided into two parts:-

- Mainframe Assembly
- Electric Motor and Gearbox

The mainframe assembly is located at the top of every external slider door system. It is the place where the door mounting with the car body is done.

The electric motor provides the required power for the movement of door panels. In an electronic slider door mechanism, a permanent magnet direct current motor is used.

**Door locking mechanism:** The door locking mechanism is essential in order to ensure that the door does not open accidently while the train is running.

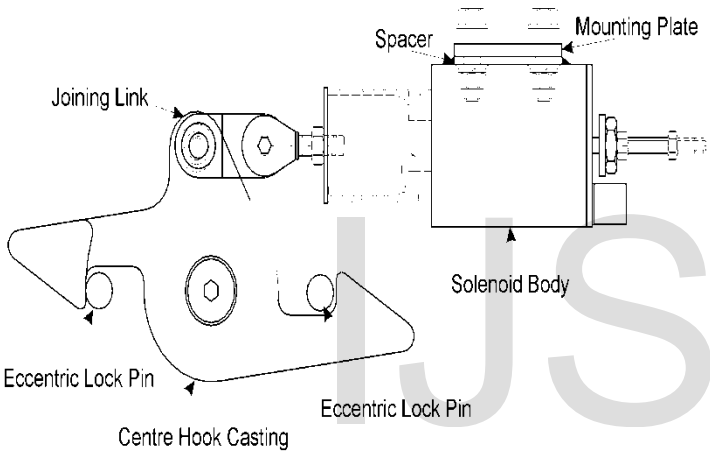


Fig. 5. Door locking mechanism

When the door is in the 'closed' position, the solenoid is activated. As a result of this, the centre hook assembly locks the two door panels as shown in Fig. 5. This firmly holds the two door panels together. The movement of the centre hook assembly in this position also sends a signal to the DCU stating that the door is locked. The DCU in turn sends this signal to the train operator's panel.

When the train operator sends a signal to open the door, the DCU processes the signal and de-energizes the solenoid of the door locking mechanism thus bringing back the centre hook assembly to its initial position. Besides, the DCU also sends a signal to operate the motor to open the door.

In case a fault occurs in the door locking mechanism due to which the locking ceases, this is indicated to the train operator through the DCU.

### 7.2 Door Working Mechanism

The DCU processes the signal received from the train operator to open or close the door. It accordingly sends an electrical signal to the permanent magnet d.c. motor which is connected to the spindle shaft with the help of a belt drive.

As the motor operates, it rotates the spindle shaft in the clockwise or anti-clockwise direction as per the signal received from the DCU. The movement of the spindle shaft is transferred to the drive brackets through the spindle nuts. The drive brackets then translate on the spindle shaft in the opposite directions, thus opening or closing the door in the process.

## 8 Acknowledgment

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## 9 References

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