**Abstract:** This paper proposes to present a comparative study between three Electric-Diesel High Speed Train Power car bodies; the study is oriented on design issues and is concentrated especially on the aesthetical elements and the functional role. This comparison also involves the aero dynamical properties of the shapes used in the design of the Power cars. The 3D modeling of the three car bodies is made in CATIA V5, one of the powerful tools for computer aided design.

**Keywords:** High Speed Train, Power car, Body, design, aesthetics, Intercity-Express, TGV, Shinkansen.

1. **INTRODUCTION**

High Speed Trains (fig. 1-2) are modern rail vehicles that are designed to carry out passengers at very high speeds. In conformity with the EC Directive 96/58 of the International Union of Railways, a rail vehicle is considered a high speed train if it travels at speeds higher than 200 km/h (125 mph) on regular tracks and 240 km/h (150 mph) on special build tracks [6].

Even though most of the High Speed Trains are built to carry passengers there is also a cargo train, the French TGV “La Poste” which are older TGV Sud-Est trains modified to transport mail for the French postal service.

2. **HISTORY**

Before the first real High Speed Train to enter service there have been made a few attempts made by Siemens in 1903 with an electric railcar that achieved a top speed of 203 km/h (126 mph) on a German military line. In 1945, Alejandro Goichechen, a Spanish inventor created a diesel streamline train that could take curves with higher speeds than many very fast trains at that time, 128 km/h (80 mph) against 48 km/h (30 mph).

The true revolution in High Speed Trains begins in Japan, in the 1950’s this was a country with very congested roads and railways, so it was needed for very fast means of transportation that could carry out large numbers of passengers.

After the success with the Romancer 3000 SE prototype created for the narrow gauge systems that existed in Japan, the engineers from Odakyu Electric Railway started working on a standard gauge vehicle for the special built line, Tōkaidō – Shinkansen, which began to be build in April 1959 and completed in 1963. While making tests, a train achieved a Top Speed of 256 km/h (160 mph). In October 1964, before the Olympics the line was opened for public service with trains from the 0 Series. In the next years the rail service was extended in the entire country.

The first High Speed Rail service in Europe was the British IC 125 (Intercity 125), introduced in 1976 it had a top speed of 201 km/h (125 mph) and was the fastest diesel-powered High-Speed Train at the time of its introduction, some train sets are still used today on the non-electrified lines and some have been replaced with the Italian built Pendolino trains.

The second European country to introduce High Speed Rail Service was France with its Train à Grande Vitesse - TGV, opened for public on 27 September 1981 with a line between Paris and Lyon (fig. 1). In the next years France developed its High Speed Rail network throughout the country.

In 1989, Germany introduced The InterCity-Express (ICE) High Speed Rail Service, which runs both on regular lines and special built ones.

3. **HIGH SPEED TRAIN TYPES**

Since there is only one type High Speed freight Train service, all others being made for passengers only, these trains can be categorized after their power source and the type of lines they are using. This way there are two types of power sources: electric and diesel, most of them, like TGV, Shinkansen, Acela Express, ICE, AVE, Railjet, KTX and others have an electric power source, the electric current being transmitted through overhead lines. The diesel powered trains like the British Intercity 125, the
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Australian XPT and the German ICE TD are operated mostly on non-electrified lines.

Regarding the types of lines on which many High Speed Trains are using there are three types of trains, the first type is the one using only special built lines like the Japanese Bullet-Trains, there are trains that travel only on usual lines like the Pendolino class trains and the British Intercity 125, but there also high speed trains that travel on both types of lines like the French TGV and the German Intercity-Express [3].

4. DESIGN

Regarding the role of this type of trains, they are designed considering the aspects of aerodynamics, power consumption, power to weight ratio, vibrations and the cost of production.

The aerodynamics is one of the most important aspects in the design of High Speed Trains, that is because the drag force created by the air moving on the surfaces of the train and near it increases exponentially, being directly proportional with the square of the speed.

Fig. 3 Effects of the Drag Force on a High Speed Train [7]

To reduce this force there are used curved lines and edges, also the front nose of the Power car is tilted at a sharp angle to ease the air flowing over it, many of them looking like an airplane nose (fig. 3).

Unfortunately not always a streamlined nose will look also aesthetic, there are cases like the Shinkansen E5 that have a nose shaped like a duck beak, which is very aerodynamic, especially in the tunnels where the Drag Force increases very much because of the tube effect (piston effect) created while going through the tunnel, but it makes the Power Car to look unattractive (fig. 4).

An another important element in the construction of High Speed Trains is the Weight, this affects very much the power consumption, at a bigger weight more fuel or electricity is consumed, that is why many trains like the German ICE have a body made from aluminum alloy.

Fig. 4 The Shinkansen E5 Series Bullet Train [3]

5. COMPARATIVE STUDY

Below there are shown the three bodies created by me using a 3D modeling program. The three bodies have in common the longitudinal and transversal section, what makes them different is the nose (fig. 5 - 9).

The solid models have been built in CATIA Part Design and CATIA Assembly Design modules. Also, this three-dimensional software provided the opportunity to modify and visualise complex geometric shapes.

Fig. 5 Power car, version A, tridimensional model.
\(a\) Left side view; \(b\) Left side and rear views.

Fig. 6 Power car, version A, tridimensional model.
\(a\)

Starting from a sketch (required a closed contour), which have imposed constraints it’s obtain the 3D model. This can be easily modified as shape and/or sizes by simply amending the value of one constraint.

These constraints, imposed at the entities which form the sketch (segment, circle, arc, spline) can be dimensional (relative position, length, angle, diameter, radius) or geometrical (parallelism, perpendicularity, collinearity, concentricity).

Version A has a front end that looks more like regular diesel-electric and pure electric locomotives that is why is not extremely aerodynamic, but the fact that it has an elliptical based shape and the upper part has a certain inclination make it to have some aero dynamical performances (fig. 6, a, b, c).
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Anyway the bigger Drag Force will be balanced by a high Power to Weight Ratio, thanks to the use of aluminum alloy and the use of composite materials at the manufacturing of certain panels and other components of the body.

Even though it is not extremely aero dynamical, the bigger Drag Force will help the train to stem at high speeds, which is a big problem for most High Speed Trains because modern brakes are not efficient at speeds higher than 350 km/h. The triangularly based cuttings are meant to increase the visibility for the train’s conductor. In the upper part, the small rectangular cutting is meant to be used for a monochrome headlight, not like the ones from the lower part that will have two colors. The bigger rectangular cutting will be used for an electronic display, something quite rarely used on most High Speed Trains.

The B version has a triangular shape based nose which makes it far more aero dynamical than version A (fig. 8).

Fig. 7 Power car, version A, tridimensional model. 

a) Top view; b) Front view; c) Isometric projection.

Fig. 8 Power car, version B, tridimensional model, isometric projections.

This form is very used in High Speed Trains design, but not in this way, because its height is bigger than on regular High Speed Train, this is caused by the big height of the Power car, that is designed to function in collaboration with the Romanian AVA 200 coaches, that forms the base of the Romanian national rail operator. The triangular shape has rounded corners to increase the aero dynamical effect, but is rounded also from aesthetical reasons; sharp angles being less engaging then rounded corners. The front end rounded corner has a parabolic based shape which has greater aero dynamical performances than circles but close to elliptical based shapes (fig. 9).

The upper part of the nose, where the cockpit is situated is realized from a section of a truncated cone, this one has a very steep angle that will help decrease the Drag Force thanks to its aero dynamical properties.

The cockpit has two trapezoidal base cuttings that are making the Power car’s cockpit to look like an aircraft’s cockpit. Because the two cuttings are occupying a large area they create an increased visibility for the train’s conductor. Unfortunately here there is not space to put another headlight and the electronic display like on the version A Power car, but is has more aero dynamical properties.

On the front of the nose there is a gap that will be covered with a part made form composite materials, because of the very complex geometry at the end of the two surfaces, one being parabolic and the circular, being more difficult to be manufactured from metallic materials. The longitudinal section of the rest of the body is more rectangular based, including the bottom cuttings made for easy access panels at the components situated under the chassis, but also these panels are put there to reduce the Drag Force. The transversal section is made up of a rectangle and a circular arc, following the form of the AVA 200 coaches.

Fig. 9 Power car, version B, tridimensional model.
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The Draco Flag [5] inspired body presents a new approach to the Design of High Speed Train Power Cars, since the wolf is a very beautiful animal and also a fast one, that is why Draco Flag Power Car can be considered a truly example of Aesthetics. To show as much as possible with the head of a wolf, the Power Car has a hump, the difference of level among the hump and the part from the middle of the body and the rear of it is not very big. The hump will serve as a stand for the Pantograph and the aero dynamical brakes, which will have triangular shape, similar to a wolf’s ears; this explains the 2 triangular cuttings that exist on the hump.

The Power Car will have 2 types of Power Supply, pure Electrical and Diesel-Electrical, giving it the capacity to use both electrified and non-electrified lines, but also will have the ability to work without stopping in the case of a power drop of the electrical network of the electrified lines, or it could easily travel on completely non-electrified lines.

Because is a Dual-Mode vehicle, the Power Car must be longer than most High Speed Train Power Cars, because it has to accommodate more components than the others, making it about as long as a regular railway carriage used to move people, which means a length of about 20 meters. Just like other Power Cars it has slots for the ventilations of the electrical systems and the electrical transformers, this is why are present the rectangular cuttings situated under the hump, the other ones, from the rear and the roof are for ventilations of the Diesel engine and the electrical systems. The Power Car also has a very good streamline profile thanks to the use of the 45° angle for the windshield and the inclination of 10° of the nose.

6. CONCLUSIONS

The three bodies are unique in aspect and they could be used successfully as models for other locomotives and Power cars. In both cases the shapes used in the design of the Power cars involve the functional role, especially in aerodynamics. The purpose of the 3D models is to change quickly the aerodynamic configuration in the wind tunnel in order to save time and money during the test sessions.

REFERENCES


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