ARCHAEOMETALLURGICAL STUDY OF ARGENTINIAN RAILWAY PARTS

Analysis of two historical railway parts reveals the techniques and treatments used on these metals that helped them endure centuries of use.

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The railroads have been of great importance for the growth and prosperity of the Cuyo region of Argentina. A recent metallographic and historical analysis of two pieces from the Buenos Aires to Pacific Railroad (BA&P) railway looked at possible manufacturing techniques of the parts in question. The information collected is useful for comparison with techniques and materials used at that time as well as with current techniques. The analysis questioned whether the material itself has varied or evolved from the metallurgical point of view, and confirmed the quality of raw material used to construct the historic railway line. The information obtained sheds light on how the pieces were manufactured and their similarity to some steels that are currently used for the same purposes, that is, to support large loads.

ARGENTINIAN RAIL HISTORY

The Buenos Aires Pacific Railway (BA&P) was the British capital company that operated a network of wide gauge railways (1676 m) in Argentina during the latter part of the 19th century and the first half of the 20th century. Its objective was to unite the city of Buenos Aires with the Pacific Ocean, specifically, the Port of Valparaíso, Chile. For this, it acquired the existing company of the Great Western Argentine Railroad in 1907. The Argentine Great Western Railway was created in 1887, the same year in which it acquired the state-owned Andean Railroad, which held 518 km of railways between Saint Louis and Mendoza (Fig. 1). This network expansion in this region facilitated an easier way to transport regional fruits and vegetables products. In this way, the railway transformed itself into a regional system that met the needs of the area[1,2].

The Buenos Aires Pacific Railroad was called to be prosperous, crossing the provinces of Buenos Aires, Santa Fe, Córdoba, San Luis, and Mendoza. It played a key role in the emergence of dozens of towns and cities, in agricultural activity and, especially, in the wine industry of the province of Mendoza. The arrival of the railroad contributed to the colonization of the provincial south and its development due to a fast and economic connection with the rest of the country. Prior to the expansion of the railways in Argentina, the main means of transport consisted of carts that circulated on roads to transport the products of the country and from other places. It took approximately 60 days to get from Mendoza to Buenos Aires. The trains, on the other hand, shortened these times to 36 hours and accelerated international transit between Chile and Argentina. In addition, having reduced transport times for passengers, another way in which trains managed to integrate the localities was through postal services.

Fig. 1 – The emblematic Palermo station in Buenos Aires in 1930. Note the inscription "BAP" after the name.

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These services also included the distribution of the most important newspapers of that time, making information more accessible.

Beginning in 1860, the railroads experienced rapid growth, connecting several capitals in the provinces and other production points with Buenos Aires. The system was not without obvious disadvantages, one being that the ends of its most important lines did not join, and several important cities were not connected. By 1910, the rail system in Argentina consisted of four main lines, all of which started at the port of Buenos Aires. These four lines were the Ferrocarril Oeste, Ferrocarril del Sur, F.C. Argentine Central, and the Buenos Aires Railroad to the Pacific. Due to the large investment of British capital in the construction and expansion of the railroads in Argentina, these were representative of the close ties between the two nations[3].

HISTORIC RAILWAY COMPONENTS

This research work consists of studying two typical railway elements: a threaded bolt and a fixing nail; both are a constitutive part of any railway track. The railroad tracks examined in this case study were built by the Argentine Great Western Railway, a company that was later acquired by the Buenos Aires and Pacific Railways and today these pieces (threaded bolt and fixing nail) belong to the San Rafael Railway Museum, Mendoza-Argentina.

"Fixing" is defined broadly as the main small material used to attach or fix rails to the sleepers (Fig. 2). The main functions of these rail fasteners were to:

- ensure the consistency or invariability of the rail
- facilitate the transfer of the static and dynamic loads to the infrastructure of the track (platform) exerted by the rolling stock on the structure of the track (railway package)
- possess mechanical strength and constant elasticity throughout the long life of the fixation
- contribute to good electrical insulation between both rails

Fig. 2 — Example of a hook-type fixing nail.

Fig. 3 — Example of a gauge-lock (Pandrol clip).

TABLE 1 – CHEMICAL COMPOSITION OF MODERN FIXING NAILS

%C	%Mn	%Si	%P	%S
0.37 – 0.75	0.86 – 1.74	0.30 Max	Less than 0.05	Less than 0.05

The number of required fixing pieces should be small to facilitate their manufacture, placement, and conservation, and minimize cost. The fixings for wooden sleepers can be divided into rigid and elastic defined by the way of carrying out the support and by the type of support: direct (without saddles) and indirect (with saddles). Rigid fixings (without saddles) include the nail hook and the screw. Elastic fixings (without saddles) include the single and double elastic nail, the shun, and gauge-lock (Pandrol clip) as shown in Fig. 3.

The bolts are cylindrical body screws with a threaded end and varied heads, which serve to secure the plates to the rails. The head of the bolts tend to have a square or quadrangular design, and others have a diamond-shaped upper face. IRAM-FA Standard L 70-06 - June 84 - BULONS FOR ROAD, defines the technical requirements for track bolt material, manufacturing tolerances, and requirements for approval. Bolts are used for joints and other uses such as component of track apparatus.

The fixing parts for the rails are manufactured following a variety of standards that consider dimensions, materials, and tolerances. They are usually machined from a single solid piece into the required shape and treated superficially to give them better properties. Specific features will depend on the manufacturer. Chemical compositions of typical modern fixing mails are listed in Table 1.

The chemical composition of modern parts of a railroad are described below:

- Carbon (C) (0.37 to 0.73%) It increases hardness and wear resistance, but also influences fragility.
- Manganese (Mn) (0.86 to 1.74%) It has an influence on hardness, wear resistance, and toughness (not fragile), but decreases weldability.
- Silicon (Si) (0.30%) Increases hardness, wear resistance, and facilitates rail rolling.
- Sulfur (S) and phosphorus (P) (less than 0.05%) They are not desirable because they give fragility, but their elimination is very expensive.

EXPERIMENT AND ANALYSIS

This historical and metallographic research on railroad parts includes scientific analysis techniques such as metallographic analysis, hardness analysis, chemical composition study, and manufacturing process of the parts. By studying the pieces under a microscope with the acquired technical knowledge it is possible to interpret and "read" the message that the piece transmits. Using historical, geographical, and chronic bibliographies we're able to cross examine that information and approximate a little more, which is useful for museums, schools, students, and teachers.

Fig. 4 — Threaded bolt, where the letter B (BAP) is seen.

Fig. 5 — A fixing or clamping nail.

Fig. 6 — Bolt head.

Fig. 7 — Metallography obtained, 200x.

Fig. 8 — Threaded bolt.

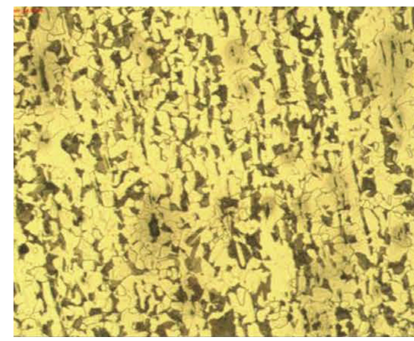

Fig. 9 — Metallography of stem zone, 100x.

The pieces received to investigate included a bolt of the threaded type (Fig. 4) and a fixing nail (Fig. 5) used in the section of the BAP railroad that connected Mendoza with San Rafael south of the Mendoza province. Both pieces belong to the San Rafael Railway Museum. The bolt would have been used to distribute the efforts (loads) on the rails and the fixing nail helped prevent variations in the gauge width and separation of the railway tracks.

In the metallography of the bolt head (Fig. 6), a ferrite-perlite structure is observed. The micrographs show that there is a decrease in the grain size of the constitutive raw material due to the machining work performed on the piece (Fig. 7). The machining that would have been used to create this kind of head is called "drop of bait," due to its final shape, and is typical of the first era of railways.

In the micrograph of the threaded bolt rod (Fig. 8), a cast iron structure of high strength, low alloy, and low carbon content (0.28%) is observed (Fig. 9). It is a structure of the ferritic-perlitic type. This suggests the bolt would have received a hot rolling or forging work with successive tempering treatments, through which the piece is shaped and which gives greater resistance to the material of the piece itself. According to the chemical composition obtained by means of the Spectro Sort Spectrometer with argon spark, it can be said that it is similar to a SAE 1030 steel of those currently used (Table 2). The hardness value of the material obtained was 80 HB[4,5].

At the time of manufacture, standardized or specified threads were not yet established, so the thread comb does not match the sample under study (Fig. 10). However, the thread it most closely resembles is the 9 G 7/8" of the current metric system (Fig. 11). By means of the stereoscopic magnifying glass, the corrosion on the thread can also be observed in greater detail (Figs. 12-13). In this sense, it is observed that the corrosive damage has not been very serious and is mainly due to atmospheric type corrosion.

From the metallographic images of the fixation nail (Figs. 14-15), a ferrite-perlite structure is observed, that is, it is low carbon (0.08%) cast iron. The ferric carbide deposited in the limits of the grain edge of the ferrite structure gives it hardness. It would correspond nowadays with a SAE 1008 steel. The hardness value obtained by the tests performed gave 90 HB[4,5]. The chemical composition is described in Table 3.

TABLE 2 – CHEMICAL COMPOSITION OF THE THREADED BOLT

% C	% Si	% Mn	% P	% S	% Mo	% Ni	% Al	% Cu	% Fe
0.28	0.043	0.83	0.017	0.042	0.003	0.014	0.004	0.03	98.6

TABLE 3 – CHEMICAL COMPOSITION OF THE FIXING NAIL

% C	% Si	% Mn	% P	% S	% Mo	% Co	% Cu	%Al	%Fe
0.083	0.005	0.61	0.026	0.062	0.003	0.014	0.017	<0.003	98.6

Fig. 10 — The threaded bolt that was studied.

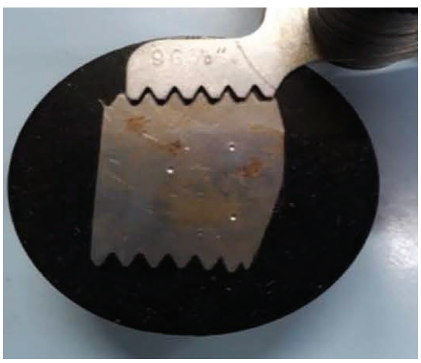

Fig. 11 — A thread comb is used to measure the type of thread.

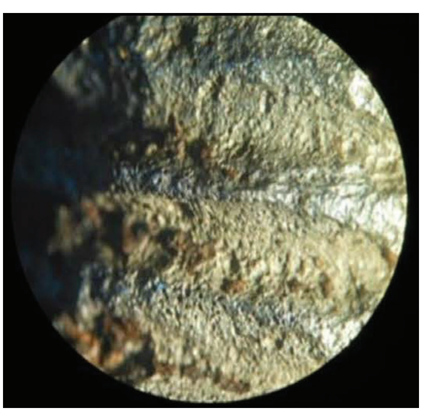

Fig. 12 — Corrosive damage to threads.

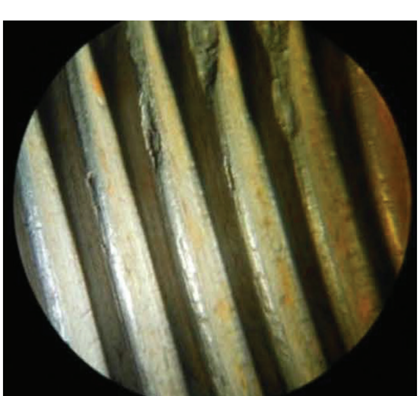

Fig. 13 — Thread detail with binocular stereomicroscope.

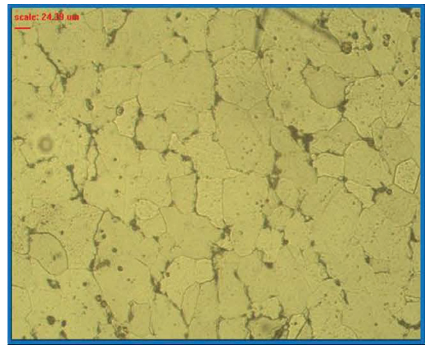

Fig. 14 — Nail metallograph at 100x.

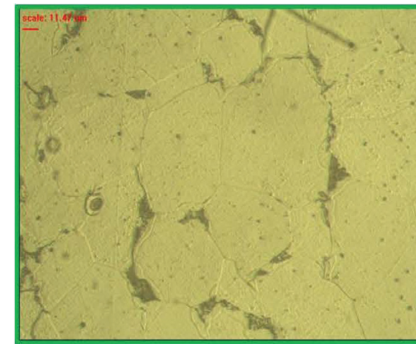

Fig. 15 — Nail metallograph at 200x.

CONCLUSIONS

The objective of this study is the metallographic and historical analysis of two pieces from the Buenos Aires to Pacific Railroad. The threaded bolt is a connecting element, and there is a difference in the size of grain between the parts of the head and the stem. These differences are due to the various types of machining in the production process. These production processes give the pieces the necessary strength to withstand the mechanical stresses to which they would be subjected. Manganese, one of the chemical elements with the greatest presence, provides greater and better ductility characteristics.

On the other hand, the fixing nail has a metallographic structure where the carbon is deposited at the borders of the grain edge, which gives it strength and functional characteristics. This deposited carbon would form a kind of shell or shield to protect the material and make it more resistant. It is similar to a modern thermochemical treatment called cementation, where the material retains a soft heart, and its surroundings are hardened as a protective shield. Being a clamping piece, it needs to behave elastically, therefore the Mn provides these characteristics with greater ductility and elastic behavior. That is, the material is able to support bending loads without breaking, and return to original form when the load is removed. In this way a fixing nail transmits efforts, deforms, and recovers, maintaining the invariability of the gauge width, the fixing of the sleepers, and electrical insulation. **~AM&P**

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