A Perspective on the Manufacture of Modern-Day High-Strength Steel Rail

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Word count: 3913

ABSTRACT

Since the first Bessemer steel rails were commercially introduced in 1867 in the U.S., steelmakers have made continuous improvements to produce rails of the highest quality to meet railroad specifications. This paper describes the path which has led to rails with over 400 Brinell hardness for heavy-haul service. Metallurgists learned to apply fundamental principles to design rails that are safe while extending the life-cycle. Rails with a pearlitic microstructure have proven to provide the best wear resistance under severe wheel-rail interaction in heavy-haul application. The hard iron carbide (cementite) phase of the pearlitic microstructure, imbedded in the soft iron (ferrite) phase, is the reason for this special attribute. However, controlling the spacing of the iron carbide phase in the pearlite lamellar microstructure and minimizing the formation of grain boundary networks of either ferrite or excess cementite is crucial to maintain the balance between rail hardness and ductility (safety). Employing high-magnification electron microscopy, the fine detail of the cementite morphology has been carefully studied to assure that the optimum microstructure is maintained. Minimal use of alloying elements combined with the flexibility of a sophisticated water-spray accelerated cooling system achieves this goal. The current paper describes the unique combination of rail steel composition and processing taken to develop a 400HB rail that has consistently led the way with the least wear in the 5-degree curve of the Section 7 premium rail test at FAST.
INTRODUCTION

The commercial manufacture of steel for rails in the U.S. began in 1867 at the Pennsylvania Steel Company; a steel mill built to supply rail for the Pennsylvania Railroad. Before that date, steel rails could be procured from England at great cost. Steel was far superior to available wrought iron and cast iron rails which were too soft and too brittle, respectively. The breakthrough that made steel cost effective was an invention known as the Bessemer converter. Henry Bessemer, an English businessman, discovered that blowing air through molten pig iron (crude liquid iron from a blast furnace) in a refractory-lined open-top vessel would remove (oxidize) the chemical elements carbon, manganese and silicon and produce a “purer” form of molten iron. William Kelly of the U.S. is also credited for inventing the process. The steelmaker would then add the necessary alloying elements back to form rail steel. A typical Bessemer converter of the time at the Pennsylvania Steel Company is shown in Figure 1.

In this photo the converter is going through its “blow” where the carbon in the pig iron is oxidized to carbon monoxide as a bright flame. Once the blow was finished, usually in about 10 minutes, the converter was tipped forward and the liquid iron content poured into a refractory brick lined ladle for further processing to add back the correct amount of each element required (e.g., carbon and manganese). The first commercial application of Bessemer steel in the U.S. was to produce rail. Once in full production, expensive steel rails from England were no longer competitive. From this point on, the America’s railroad industry rapidly expanded. Figure 2 shows the miles of track laid in the U.S. during the last 7 decades of the 19th century; most of it due to Bessemer steel.
It was the lower cost Bessemer steel that allowed for the rapid expansion of America with track connecting all the major cities, especially in the Eastern U.S. By 1882 there were 35 Bessemer converters in the U.S and the Pennsylvania Steel Company had two 7 ton and three 8 ton converters (1). In the last few decades of the 19th century, the open hearth furnace was introduced and provided an improved steel rail. The open hearth process was eventually replaced by the basic oxygen furnace (BOF) and the “greener” electric furnace is now surpassing BOF production. The U.S. railroads quickly expanded to 1917 when track saturation occurred with about 250,000 miles of track.

THE EVOLUTION OF RAIL STEEL

If we compare the characteristics of rail steel in the Bessemer era with today’s rail steel we see some major differences. First of all, the carbon levels were much lower in the 1800’s than they are today. The table below shows a typical chemical analysis in early and modern steel rail.

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<th>Date (type of steelmaking)</th>
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<tr>
<td>1890 (Bessemer Converter)</td>
<td>0.58</td>
<td>1.33</td>
<td>0.074</td>
<td>0.072</td>
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<tr>
<td>2013 (Electric Furnace)</td>
<td>0.84</td>
<td>1.00</td>
<td>0.010</td>
<td>0.008</td>
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The second noticeable difference is the high levels of phosphorus and sulfur. It was learned that these two elements were not desired in rail because they impart poor ductility. These impurity elements were not effectively removed from the molten pig iron by the Bessemer converter. Later, the open hearth furnace was able to lower both sulfur and phosphorus through a longer refining time and a lime-based slag practice. Another difference is the lower silicon level. Today, silicon is an essential element for deoxidation of the molten steel. Silicon is also added to increase hardness (other important attributes will be discussed later).
The manganese level in the Bessemer steel was higher compared with modern-day rail steel. As the Bessemer process was phased out, refining the steel was the advantage of the open hearth furnace. During this process several hours were required to remove impurity elements and to permit the individual ferroalloying additions to achieve an accurate rail steel composition.

**Early rail specifications**

As the tons of rail steel grew in the latter part of the 19th century, the railroads began to develop specifications for rails. An excellent compendium of information on rail steel history, properties and manufacture up to 1913 can be found in reference (2). The American Railway Engineering and Maintenance-of-Way Association (AREMA) recommended specifications for rail in 1907 and Committee 1 of the American Society for Testing and Materials (ASTM) adopted specifications for rail the same year (3, 4). The very first specification for a steel product, adopted by ASTM was for rail (ASTM A1), which indicates the importance of rail manufacture and use in that era. It is interesting to compare the AREMA specification of 1907 of only 3-1/2 pages and the current AREMA Chapter 4 – Rail specification comprising over 250 pages. Obviously, the railroads greatly expanded the specifications far beyond anything considered over 100 years ago.

The 1907 AREMA specification consisted essentially of a table of temperature expansion for laying 33' rails and a table of chemical composition ranges and limits for Bessemer steel rails.

<table>
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<tr>
<th>Year</th>
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<td>0.74-0.86</td>
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<td>0.020max</td>
<td>0.10-0.60</td>
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</table>

In 1907, the only mechanical property specification involved drop weight tests. It must be remembered that the Brinell and Rockwell hardness tests were not established test methods in 1907. If we follow the evolution of chemical composition from these hypoeutectoid (C<~0.8%) levels we will see that the main element that increased was carbon. Metallurgists knew that increasing the carbon content increases rail hardness which improves wear resistance. In the 20th century, the carbon content progressively edged up to eutectoid levels (~0.8%). This was due to the continually increasing axle loads, particularly by the heavy-haul Class I railroads. Today with hypereutectoid (C>~0.8 %) rail steels, the carbon content is as high as ~1%C; a level strictly avoided years ago.
Development of high strength rail

With the advent of head hardening processes in the last 50 years, rail producers were now able to increase the hardness and strength of rail well beyond that of standard strength ambient air cooled rail while maintaining adequate ductility. These processes employ accelerated cooling to increase the cooling rate prior to and during the austenite to pearlite transformation (5). The objective is to produce pearlite with the finest possible spacing between the ferrite and cementite (iron carbide) lamella. Figure 3 shows a typical "lamellar" pearlite microstructure in a head-hardened rail head.

![Pearlite colonies in a head-hardened rail. 3,000X](image)

In head-hardened rail, the interlamellar spacing cannot be resolved using the conventional light microscope and a scanning electron microscope is required to achieve higher magnification. Figure 4 shows a schematic representation of the pearlite transforming from austenite.
The transformation of rail steel when it cools directly after it is hot rolled involves the crystal structure changing from austenite into an exact mixture of ferrite and cementite called pearlite. This reaction is called a eutectoid reaction, as shown in the equation below (6).

$$\text{Austenite (0.80\%C) } \leftrightarrow \text{ Ferrite (0.002\%C) + Cementite (6.67\%C)}$$

The 0.80\%C in the austenite phase must redistribute carbon to form cementite at 6.67\%C as the ferrite phase rejects carbon. This distribution process is called diffusion and it takes place at the growing interface between the austenite and the pearlite. Diffusion of carbon is faster at higher temperature and the consequence is a coarse spacing between the ferrite and cementite, resulting in low hardness. During the head hardening process, there is less time for diffusion of carbon and thus the diffusion distance is shortened. This results in a closer interlamellar spacing between ferrite and cementite. For rail the key is to cool the austenite fast enough to produce the smallest possible spacing without destroying the coupled growth of ferrite and cementite. If cooled too fast, the lamellar morphology will break down and undesired bainite will form (AREMA specifications require 100\% pearlite in the rail head). Pearlite is the preferred microstructure for rail in North America because the lamellar morphology of hard cementite embedded in soft ferrite is ideal for wear resistance through train wheel – rail interaction.

The head hardening process described in this paper involves a 100 meter-long water spray system that accurately cools the rail as it passes through adjustable cooling zones (7). The process has been optimized since start-up in 1994 to produce intermediate strength head-hardened (ISHH), head-hardened (HH) and advanced head-hardened (AHH) grades with a minimum running surface...
hardness at 350HB, 370HB and 400HB, respectively. Accelerated cooling will eventually make SS and IH rail rails obsolete.

<table>
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<th>Grade</th>
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<tr>
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<td>0.75-1.10</td>
<td>0.020max</td>
<td>0.020max</td>
<td>0.40-0.60</td>
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<tr>
<td>AHH*</td>
<td>0.86-1.00</td>
<td>0.66-0.76</td>
<td>0.020max</td>
<td>0.020max</td>
<td>0.50-0.60</td>
</tr>
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</table>

* V added to AHH and all three grades contain chromium (0.20-0.25%).

All three steel grades are produced at Steelton by melting 100% steel scrap in a 140 metric ton DC electric furnace followed by refining in a ladle furnace where alloy additions are made and the liquid steel temperature is controlled. The ladle is then placed in a tank where it is vacuum degassed with argon stirring to reduce dissolved nitrogen, oxygen and hydrogen. At a precise temperature, the steel is teemed into a 3-strand bloom continuous caster where it solidifies. The bloom cross-section is 14.6" x 23.6" (370 mm x 600 mm). This cast bloom is the largest in the rail producing industry and is beneficial because during subsequent rolling to rail, the hot reduction ratio of 25 to 1 homogenizes the dendritic cast macrostructure. Rails produced from smaller cast blooms may still have portions of dendrites remaining in the rail head. The Steelton blooms are reheated and reduced in a blooming mill, roughing mill, intermediate roughing mill and a finishing mill to form the final rail.

**The head hardening process** Described previously (7), the head hardening facility (Figure 5) is in-line with the rail mill. This means that the as-rolled hot rails proceed directly to the facility in order to maintain the rail in the austenite state.

![Figure 5. Head hardening facility at ArcelorMittal Steelton.](image)
The water-spray head hardening system is ideally suited for developing refined pearlitic microstructure and properties. Hot rails from the rail mill wait in queue to enter the facility at a constant entry temperature. Once in the head hardening facility, the rails are tracked with pyrometers where exact control of the cooling path is maintained. Cooling is achieved by adjusting the water flow to the spray nozzles in independently controlled zones. Adjusting the water flow to these zones:

(a) Allows the rail to cool quickly to begin the pearlite transformation temperature at the lowest temperature possible for fine pearlite,
(b) Continues the pearlite transformation at this low temperature,
(c) Removes the extra unwanted heat of transformation by additional cooling
(d) Continues cooling to obtain greater depth of hardness in the rail head.

After exiting the facility, the head-hardened rails are sent to a packing bed where they are subsequently placed in control cooling boxes to further lower hydrogen level.

**Latest technology.** Although the Steelton head hardening facility has been producing head hardened rails for the past 20 years, the process is still improving by utilizing advances in technology. A sophisticated rail head hardening simulator in place at our Global R&D laboratory in Aviles, Spain (Figure 6) allows for the study of pearlite transformation kinetics.

![Figure 6. Head hardening simulator.](image)

Here short lengths of hot rails move by spray nozzles and are cooled with the same nozzles, speed and water flow parameters as if a rail were passing through the 100 meter-long production head hardening machine. Thermocouples embedded internally record the cooling curves in various parts of the rail head thus recording vital data on the pearlite transformation. The Global R&D Laboratory in East Chicago characterizes the water spray pattern produced by the various nozzles on a low impact testing bench (LITB). The force of the water
droplets from the nozzle is measured as they impinge on the special flat surface of the LITB. The testing bench and a resulting spray distribution pattern can be seen in Figure 7.

![Figure 7. (a) Low impact testing bench and (b) spray nozzle pattern.](image)

This characterization is used to select the optimum nozzle used in the zones of the head hardening machine. Heat transfer coefficients have been developed for the various spray nozzles at the Centre for Metallurgical Research (CRM) in Liege, Belgium. The data are incorporated into a sophisticated computer model of the head hardening process. This model can predict the cooling curves at various depths in the rail head.

**Advanced head-hardened 400HB rail**

In order to keep pace with extending the life-cycle of rail for heavy-haul service, rail producers are breaking-free of conventional 370HB high strength rail as defined in the AREMA specification to produce rails with a minimum 400HB on the running surface. In the following sections we describe the new advanced head-hardened (AHH) rail being produced at Steelton.

**In-track testing.** 400HB rails from world-wide producers were installed in the 5-degree, 39 ton/axle load, Section 7 test site at the FRA Facility for Accelerated Service Testing (FAST) in Pueblo, CO in early 2010. The AAR Transportation Test Center, Inc. (TTCI) is monitoring the wear and changes to the running surface of the various rails approximately every 30 to 60MGT. The test results at 380MGT are shown in Figure 8 (8).
The rail with the “Mittal” brand is the patented (9) 400HB advanced head-hardened grade produced at the Steelton, PA rail mill. After several measuring sessions by TTCI, the AHH rails performed with “statistically less wear than control” (10). AHH rails are also installed in the Eastern and Western mega sites and at customer test sites. Note that in Figure 8, the 400NEXT rails were included after the test began and are three measurement stages behind the rest.

Microstructure. As seen in the above table, the 0.86-1.00%C level of AHH rail makes the steel hypereutectoid. Hypereutectoid rail steels may develop continuous or semi-continuous cementite on the prior austenite grain boundaries during cooling. Continuous cementite networks theoretically reduce the ductility and fracture toughness of the rail. However the combination of silicon and vanadium additions of the AHH rail coupled with the cooling path during head hardening at Steelton, there are 40% fewer grain boundary cementite deposits than other widely used hypereutectoid rail steels (quantitatively measured on the scanning electron microscope at our Global R&D Laboratory in East Chicago). Since the element silicon does not form a carbide phase in steel it alters the activity of carbon in the austenite to suppress grain boundary cementite formation. A micro-addition of vanadium also assists in the suppression process and forms submicron vanadium carbide particles during the pearlite transformation that take excess carbon from the austenite grain boundary areas (10-12). A view of fragmented cementite particles on a prior austenite grain boundary of AHH rail can be seen in the center of Figure 9 (enlarged view on the right with arrow).
The small fragments are the same thickness as the cementite lamella and are almost indistinguishable from the pearlite itself. Cementite in this morphology does not present a continuous path for potential crack propagation.

**Pearlite interlamellar spacing.** It is well known that there is an inverse relationship between pearlite interlamellar spacing and rail hardness. Employing the scanning electron microscope at our Global R&D Laboratory in Esch-Sur-Alzette, Luxembourg, in one typical rail head the interlamellar spacing measured at a location 2 mm below the running surface was 85 nanometers (see Figure 10) and at 35 mm deep was 167 nanometers. These spacing dimensions equate to measured hardness values of 420HV and 360HV.
In addition to pearlite spacing, alloy additions to AHH contribute to hardness and strength. Silicon contributes solid solution strengthening and vanadium contributes precipitation hardening of the ferrite in the pearlite. Dark-field transmission electron microscopy conducted at our Global R&D Laboratory in East Chicago, Indiana shows a uniform distribution of submicron vanadium carbide particles in the ferrite (Figure 11) as well as in the interlamellar locations.

Figure 11. TEM images of pearlite in AHH rail showing (a) bright field image of ferrite and cementite, (b) bright field image of vanadium carbides in interlamellar ferrite and (c) dark field image of vanadium carbides in ferrite locations.
**Hardness.** Rockwell hardness was measured at 1/8" (3.2 mm) increments below the rail surface at three locations, the centerline and at diagonals on each side of the advanced head-hardened rail head starting at the top corners. Typical hardness measurements in the head of an advanced head hardened rail are shown in Figure 12.

![Hardness Graph](image)

**Figure 12.** Rail head hardness for advanced head-hardened rail.

**Tensile properties.** ASTM A370 standard 0.500" (12.5 mm) diameter, 2" (50 mm) gage length tensile specimens are tested from the rail head top corner location as specified by AREMA. Production records on over 1000 tons of AHH rails show they have a remarkably consistent (standard deviation <3ksi) yield strength of 134 ksi (924 MPa) yield strength and 197 ksi (1360 MPa) tensile strength with 10 % elongation.

**Fracture toughness.** Four AHH rail specimens were fracture toughness tested according to EN 13674-1 and ASTM E399 procedures. The average measured KIc values of the rails was 36 MPa•m$^{1/2}$ (33 ksi•in$^{1/2}$). There is no significant difference between fracture toughness values at room temperature and at -20 ºC (-4 ºF). As shown in Figure 13, the fracture toughness of the new rails is the same as the fracture toughness of conventional head hardened rails as reported in the literature.
Figure 13. Histograms of ksi•in$^{1/2}$ fracture toughness values of AHH rails compared to values reported in the literature for head-hardened rails.

Rolling contact fatigue. In addition to wear resistance, all pearlitic rails experience surface damage with time under heavy axle loads. This surface damage is a form of “cold work” where the pearlitic microstructure deforms and aligns parallel to the running surface. The higher the hardness and strength, the more resistant the rail is to this cold work condition. This shallow region eventually delaminates and shallow surface cracking occurs. The phenomenon is called rolling contact fatigue (RCF). If this layer is not removed by grinding it begins to spall and generates deeper cracks that can develop into transverse defects. For this reason railroads lubricate the rails in curves and inspect and grind the rails periodically to remove surface damage. Recently some laboratories have built facilities to test actual rail under simulated rolling contact fatigue condition. One such facility is available to the ArcelorMittal Global R&D Center (and ITMA) in Asturias, Spain. The simulator, shown in Figure 14, can create conditions to simulate the same kind of damage experienced in track.
In this photo, a U.S. railcar wheel (Grade B) is applying both longitudinal and lateral forces on the running surface of a 136RE rail. Although now in its early stages of use, the simulator will eventually allow the study of RCF that will lead to the development of rails with improved RFC resistance.

SUMMARY

The hardness and wear resistance of pearlitic rail steels have progressively increased over the past century as steelmaking methods have improved along with increases in carbon level, selected alloy additions and advanced accelerated cooling processes. With proper maintenance by the railroads (periodic grinding, selected lubrication, etc.), modern-day hypereutectoid rails should last for many years.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Shaun Elder (Global R&D East Chicago), Boris Donnay and Filippo Cialini (Global R&D Luxembourg) for their detailed electron microscopic evaluation of the rails. Thanks also go to Jose Arancon (Global R&D, Asturias) for conducting head hardening and RCF simulations, Rudolf Moravec (Global R&D, East Chicago) for water spray characterization studies and Raymond Uhrin, Jason McCullough, Michael Muscarella, John Nelson, Adam Peter and Richard Perry of Steelton for various contributions.
REFERENCES


List of figure captions

Figure 1. Photo of a Bessemer converter circa 1880.

Figure 2. Miles of railroad track in the U.S. in the 1800’s.

Figure 3. Pearlite colonies in a head-hardened rail. 3,000X

Figure 4. A schematic representing the growth of pearlite into austenite.

Figure 5. Head hardening facility at ArcelorMittal Steelton.

Figure 6. Head hardening simulator.

Figure 7. (a) Low impact testing bench and (b) spray nozzle pattern.

Figure 8. Wear test results of 400HB rails at FAST.

Figure 9. Fragmented cementite on prior austenite grain boundary. 3000X

Figure 10. Pearlite spacing measured at 100,000X.

Figure 11. TEM images of pearlite in AHH rail showing (a) bright field image of ferrite and cementite, (b) bright field image of vanadium carbides in interlamellar ferrite and (c) dark field image of vanadium carbides in ferrite locations.

Figure 12. Rail head hardness for advanced head-hardened rail.

Figure 13. Histograms of ksi•in$^{1/2}$ fracture toughness values of AHH rails compared to values reported in the literature for many different rails.

Figure 14. Rolling contact fatigue simulator.
A Perspective on the Manufacture of Modern-Day High-Strength Steel Rail

by
Bruce Bramfitt
ArcelorMittal Steelton

ArcelorMittal

September 29 - October 2, 2013
Indianapolis, IN
**HISTORY**

Early Rail Steel Composition:

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<td>1.33</td>
<td>0.072</td>
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**Early “Bessemer” rail:**
- Low carbon
- High manganese
- High phosphorus/sulfur
- Low silicon
- Low hardness ~250HB

**PSCo. CIRCA 1880**

Henry Bessemer

The Pennsylvania Steel Company in Steelton, PA was the first in the U.S. to commercially produce steel rails in 1867 using the Bessemer process.

**AREMA Specifications:**

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<td>2013</td>
<td>0.74/0.86</td>
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<td>0.020max</td>
<td>0.10/0.60</td>
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**Current rail:**
- Higher carbon for wear resistance
- Restricted phosphorus and sulfur
- Higher hardness; 250HB in 1890 vs. 310HB min for standard strength rail 370HB min high strength rail.

**DEVELOPMENT OF HIGH-STRENGTH RAIL**

The need for even higher hardness rail has grown -- a fully pearlitic rail is proven to be ideal for heavy-haul wheel-track interaction.

Pearlite has a lamellar (eutectoid) structure consisting of alternate plates of ferrite and cementite (iron carbide).

**INTERLAMELLAR SPACING**

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<tr>
<td>0.80% CARBON</td>
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DEVELOPMENT OF HIGH-STRENGTH RAIL

Interlamellar spacing -- the smaller the spacing the higher the hardness and strength of the rail.

There is a limit due to the rate of the diffusion of carbon in maintaining the coupled growth of ferrite and cementite.

The key is the diffusion of carbon.

Ways to improve pearlitic rail:

1. Control the transformation kinetics.
2. Increase the carbon content (hypereutectoid).
3. Add specific alloying elements.

1. Control Transformation Kinetics:

Cool the austenite at a fast rate for an ultra-fine Interlamellar spacing.

The limit is ~550°C below which bainite begins to form.

Use accelerated cooling of austenite to develop a fine pearlitic microstructure.

In-line head-hardening systems:

- Forced-air cooling
- Water-spray cooling
- Immersion in a aqueous polymer solution

Water-spray head hardening process

Water-spray head hardening process

100 meter-long head hardening facility

Various top head, side head, web and base sprays
DEVELOPMENT OF HIGH-STRENGTH RAIL

ADVANTAGE
Greater flexibility as rail passes through different cooling zones of process.
- Zone 1 - Cool rail to a low pearlite transformation start temperature.
- Zone 2 – Continue cooling and remove the unwanted heat of transformation.
- Zones 3 and 4 - Continue cooling to drive hardness deeper in rail head.
- Zone 5 (air)- Self-quench central region of head.

2. Increase the carbon content:

More carbon -- more hard cementite.
However, must prevent cementite from forming continuous grain boundary networks.

[Photo shows ideal discrete cementite particles on boundary].

For over a century, rails were produced hypoeutectoid and eventually eutectoid to avoid brittleness/low ductility.
Metallurgists learned how to produce hypereutectoid rails by combining accelerated cooling with selective alloying elements.

3. Alloying elements:

- Silicon
  - Alters carbon activity in austenite and suppresses formation of continuous cementite networks.
  - Increases ferrite hardness by solid solution hardening.
  - Deoxidizes the liquid steel.

Vanadium
- Forms carbide (VC) particles that compete with cementite formation at grain boundary.
- VC is 2-1/2 times harder than Fe₃C.
- VC strengthens the ferrite by precipitation hardening.

Composition:

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Microalloyed with V plus a Cr addition

U.S. Patent #8,241,442
DEVELOPMENT OF HIGH-STRENGTH RAIL

A safe, high-strength, high-hardness rail has been developed – Advanced Head-Hardened (AHH) rail.

- Surface hardness 400HB
- Yield strength 130-140ksi
- Tensile strength 190-200ksi
- Total elongation 10% min.

Hardness:
Rail head hardness.

Electric Flash-Butt Welding:

Thermite Welding:
Using a high performance alloy charge.

Research Support:
Fracture toughness.

Research Support:
Rolling contact fatigue simulation.
DEVELOPMENT OF HIGH-STRENGTH RAIL

Research Support:
Head hardening simulation.

ArcelorMittal Global R&D
Asturias, Spain

DEVELOPMENT OF HIGH-STRENGTH RAIL

Research Support:
Nozzle spray pattern characterization.
(important for optimum cooling)

ArcelorMittal Global R&D
E. Chicago, IN

DEVELOPMENT OF HIGH-STRENGTH RAIL

In-Track Performance at FAST

FAST 5-degree curvature at 39 ton/axle load (heavy axle load environment).

TTCI data

High rail with
381 MGT accumulated load

J. LoPresti
TTCI
18th Annual Research Review

DEVELOPMENT OF HIGH-STRENGTH RAIL

In-Track Performance at FAST

SUMMARY

- Rails have progressed from 250HB of the 1890’s to over 400HB today.
- Controlling the pearlite transformation, raising the C level and safely adding key alloying elements lead to improved properties.
- With proper maintenance, today’s rails are much safer with a substantially longer life cycle.