Fast-welding chromium-molybdenum-vanadium extra-high strength rail steels

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A series of experimental rail steels was prepared to identify a composition that exhibits a tensile strength greater than 1250 MPa (180 ksi) and a Brinell hardness of 350 to 400. At the same time, the steel was to be properly alloyed so that no extraordinary procedures are required for flash-but welding. The preferred composition that best met these requirements was 0.70 to 0.80% C, 0.50 to 0.70% Mn, 0.50 to 0.70% Cr, 0.22 to 0.27% Mo, and 0.08 to 0.125% V. In this steel, vanadium appears to interact with molybdenum to promote a fine lamellar-pearlite microstructure.

INTRODUCTION

The steadily increasing axle loads experienced by railroad track structures throughout the world have led to more-rapid deterioration of rail profile, especially in curves. Often, the magnitude of the applied stresses causes plastic deformation (yielding and flow) of the rail head of conventional pearlitic rails[1]. It is possible to improve the resistance to plastic deformation in rails by increasing their yield strength: this is accomplished by treating the rail steel in such a way that the usual pearlite microstructure is refined. Heat treating and quenching the rails has been used for some time to produce a steel rail with greater yield strength and hardness. An alternate method of achieving the same end is to alloy the steel with relatively small quantities of chromium, molybdenum or vanadium, or combinations of these elements. Many steel companies and research organisations have been actively searching for improved alloyed rails in recent years. The general objective has been to develop rails which, when processed with the same practice as conventional carbon steel rails, will have a yield strength greater than 690 MPa (100 ksi). Such rails are referred to as high strength rails and typically exhibit hardnesses in the range of 321–388 HB.

High strength and hardness in rails is achieved by reducing the pearlite interlamellar spacing, either by austenitizing and quenching or by alloying. When the pearlite spacing is reduced to about 1000Å, the strength of the steel reaches the desired 690 MPa (100 ksi) level. Further refinement of the pearlite is possible, but below about 750Å the lamellae become very short and twisted; this structure has been called transitional pearlite[2]. The limit of yield strength in a fully pearlitic steel is about 830 MPa (120 ksi), while transitional pearlite steels can have yield strengths between 830 and 1030 MPa (120 and 150 ksi). Rail steels which fall in this yield strength range are called extra-high strength rail steels.

One of the established high strength rail steels is an alloy steel containing chromium and molybdenum. Rails of chromium-molybdenum steel have been in test tracks and revenue service since 1976 and have shown excellent wear

Table I. Comparison of chromium-molybdenum and chromium-molybdenum-vanadium steel rails

Steel	Composition, wt. %						0.2% Yield Strength		Ultimate Tensile Strength		Elongation, %	Reduction in Area, %	Hard Hardness, HB
	C	Mn	Si	Cr	Mo	V	MPa	ksi	MPa	ksi			
Cr–Mo[a]	0.75	0.81	0.26	0.69	0.18	–	785	114	1210	175	11	25	350
Cr–Mo–V (I)	0.66	0.90	0.23	1.02	0.06	0.09	675	98	1100	159	12	21	327
Cr–Mo–V (II)	0.78	0.85	0.39	0.75	0.20	0.07	835	121	1260	183	9	13	376

[a] Average from eight heats

Table II. Composition of experimental steels

Steel	Composition, wt. %							
	C	Mn	Si	P	S	Cr	Mo	V
25	0.77	0.60	0.29	0.015	0.020	0.58	0.25	–
25V	0.79	0.60	0.32	0.016	0.019	0.58	0.26	0.11
30	0.76	0.60	0.27	0.015	0.020	0.58	0.30	–
30V	0.80	0.59	0.31	0.016	0.019	0.58	0.30	0.10