Development of a low carbon vanadium-copper-chromium rail steel of improved weldability for curves and points in European railways

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In Europe, rails for normal service contain 0.4 to 0.6% carbon and 0.8 to 1.2% manganese. Higher carbon and/or manganese steels are used in track locations where severe wear occurs, such as tight curves, marshalling yards, points and switches. These higher carbon steels are more difficult to weld and are subject to fatigue failure, especially at points and switches.

A study was conducted at Ghent University to develop a lower carbon steel which would be more easily weldable and yet wear resistant enough to be used in locations of high wear. Strengthening was done with additions of copper, chromium, and vanadium, and the effects of these elements on tensile properties of 0.4% carbon steel presented.

Based on these laboratory studies, production heats were made in Luxembourg of a steel containing approximately 0.4% C, 1.4% Mn, 0.5% Si, 0.4% Cu, 0.8% Cr, 0.2% Ni, and 0.17% V. These heats were rolled into 50 and 60 kg/m rails. Yield strengths ranged from 610 to 862 N/mm^2 (88 to 124 ksi) while tensile strengths ranged from 990 to 1160 N/mm^2 (144 to 168 ksi). Service performance was evaluated over 2 years at 9 track sites in the Belgian Railway System, including severe curves.

Profile measurements of these low-carbon rails revealed that their wear resistance is at least equal to that of higher carbon as-rolled grades. The steel has also given satisfactory performance for over 2 years in points where high-carbon rails failed due to fatigue and where conventional low-carbon manganese steel rails would have to be replaced after 12 months.

INTRODUCTION

In Europe, rails for most commercial railroads are made from a carbon-manganese steel containing 0.4 to 0.6% C and 0.8 to 1.2% Mn with 0.35% Si, to the U.I.C. Specification (Union Internationale des Chemins de Fer) "Normal Quality" Rail. In locations such as sharp curves and in especially heavily used track where severe wear conditions exist, special grades, designated as "Naturally Hard" Rail, containing high carbon and/or manganese contents are employed. A summary of the compositions and properties required in these grades is given in Tables I and II.

The higher carbon and/or manganese grades, while giving greater wear resistance and longer 'in track' life than the lower carbon grades, are obviously more difficult to weld, both by flash butt techniques in the rail shops, and by Thermit welding processes in track.

Axle loads and total usage of the rails, especially for heavy freight traffic, is increasing and the necessity for rail replacements are becoming more frequent. A need therefore arises for steels having a higher resistance to plastic flow and, if possible, at the same time having equal or better weldability and toughness compared with carbon-manganese naturally hard rail.

In the course of research on the effects of copper on the properties of steels at Ghent University during the last ten years, a heavy duty low carbon weldable rail steel containing copper, chromium, nickel and vanadium has been successfully developed for rails carrying heavily loaded cranes in steelplants and other works[1]. This type of steel offered a possible route for the development of a weldable heavy duty railroad rail steel. The crane rails, however, are of a different profile to the railroad rails having, in general, heavier section thicknesses. In order to compensate for the increased hardenability resulting from the thinner sections of railway rails it was considered that the alloy content should be decreased. It was also necessary to increase the carbon content to achieve the hardness required in railroad rails,

Table I. U.I.C. specification (chemical composition) for railroad rails

		C, %	Si, %	Mn, %	P, % (max.)	S, % (max.)
Qualité Courante (Normal Quality)		0.40–0.60	0.35	0.8–1.2	0.050	0.050
Qualité Naturellement Dure (Naturally Hard rails)	Grade A	0.60–0.75	0.50	0.8–1.2	0.050	0.050
	Grade B	0.50–0.70	0.50	1.3–1.7	0.050	0.050
	Grade C	0.45–0.65	0.40	1.7–2.1	0.030	0.030