A chromium-vanadium alloyed rail steel for heavy duty requirements

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Additions of 0.12 to 0.18% vanadium have allowed the production of rail steels with strengths between 1100 and 1200 MPa (160 to 175 ksi). The production and rolling of these steels are described in this paper. In addition, the properties of these steels are correlated with their performance on proving track in tests conducted by the Railway Association.

Rail steels standardized in the most common national and international specifications are essentially based on carbon and manganese. These steels with natural hardness have, depending on their chemical composition, a minimum tensile strength of approx. 690, 790 and 880 N/mm^2 (100, 115 and 128 ksi). According to the terms of the U.I.C. standards the latter has become primarily known in Europe as the wear-resistant rail steel. In its chemical composition, the wear-resistant grade U.I.C. grade 90 A more or less equals the common U.S. grades defined by the AREA specifications. Table I provides a general survey of rail steel specifications for chemical composition and mechanical properties for different countries.

Generally the above mentioned rail steels meet the requirements of the individual railway companies. However, in particular cases of heavy loads, particularly in tight curves of the railways companies' network and in tracks carrying iron ore and brown coal for mining companies, even the wear-resistant rail steel with its minimum tensile strength of 880 N/mm^2 (128 ksi) was found to be inadequate in meeting the requirements in some cases.

Occurrence of wear such as frictional wear of the guiding surface on the outer rails of a curve and shelling of the inner rails of a curve cause the rails to be removed prematurely, even before their wear reserve is used up, after a service life as short as one to two years. A new rail grade was therefore developed by Thyssen AG, formerly August-Thyssen-Hutte AG, based on systematic research in the early 1960's with the object of increasing the resistance of the rail to general wear.

The research work and the general theories developed on the relationship between composition, structure and properties, together with a description of the production, properties and performance in service of the new rail grade are set out in this Paper.

POSSIBILITIES OF IMPROVING THE RAIL STEEL

An improved resistance of the rail steel to wear and shelling may be achieved by increasing the yield point, tensile strength and fatigue resistance in combination with pearlite having a fine lamellar structure. This objective can be achieved in two ways:

(a) Heat treatment of the rail throughout the entire cross-section of the profile or, alternatively, only on the running surface.

(b) Alloying the steel by the addition of grain refining and hardening elements so that, for normal production, a self hardening rail quality with improved mechanical properties and a fine lamellar pearlitic structure is obtained.

The first route is primarily used today in U.S.A., Russia and Japan.

The development of self hardening, highly wear-resistant rail steels with improved behaviour in service by selecting a suitable chemical composition was started in the early 1960's primarily in the Federal Republic of Germany.

DEVELOPMENT OF A SPECIAL ALLOYED GRADE

Increasing the carbon content beyond 0.82% with a view to obtaining higher yield points and tensile strengths in the rail steel is feasible, but unacceptable because this would result in too great an embrittlement of the steel. Increasing the manganese content beyond 1.70% is not practical either, because the welding of such steels becomes more difficult.

Therefore, laboratory heats were first used to study the effects not only of carbon and manganese, which are common elements in a rail steel, but also of silicon, chromium, vanadium, niobium and molybdenum, as single and as combined additions.

An improvement in mechanical properties was found to be possible through several combinations of these elements, with the most favourable transformation behaviour for good weldability being that of a combination of 1% chromium and up to approximately 0.15% vanadium. The effect exerted by vanadium on the tensile strength as determined from data arising from experimental heats is shown in Fig. 1.

The use of niobium and niobium plus molybdenum severely retarded the transformation of the steels into the pearlite and also impaired weldability and the manufacture of highly wear-resistant rails based on these elements was not pursued.

Production heats of the compositions given in Table II were made with the object of making rails with the properties obtained in the experimental heats.

PRODUCTION OF SPECIAL GRADE RAILS

Thyssen AG uses the BOF process to make crude steel for the manufacture of rails. Converters having a capacity of up to 400 tonnes (441 short tons) each are available for this purpose. The entire production cycle, i.e. making of the crude steel, deoxidation and alloying are controlled by means of computers.