The Heat Treatment of Vanadium-Modified Alloy Steels

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SUMMARY

The hardenabilities of four alloy steel grades modified with vanadium were determined at various austenitizing temperatures depending on carbon content. The modification was made by substituting V for Mo; results show that a 1:2 substitution of V for Mo (in weight percent) was effective. The "micro-alloying" addition of 0.10-0.15%V, alone or in combination with a lesser amount of Mo, is sufficient to attain the hardenabilities of the standard grade containing 0.15-0.40%C with higher amounts of Mo. From the results, it was deduced that vanadium carbide can be dissolved in austenite at standard or slightly higher austenitizing temperatures for all the vanadium levels studied. It was also shown that grain coarsening of the austenite is induced more by vanadium than by molybdenum.

INTRODUCTION

At a recent symposium, Robinson[1] summarized the development of and the challenges faced by alloy steels in the automotive industry. Through the years since Henry Ford revolutionized car manufacture, constant changes in alloy steel compositions, to meet the demands of the times, were prevalent. At present, it appears that the technology of heat-treated alloy steels has reached its maturity, with work concentrated on both accurately predicting hardenability from chemical composition and balancing composition to minimize cost for the application desired. However, this is far from the reality, for specific effects of the various alloying elements, individually and in combination, on hardenability, materials properties, and service performance are far from being understood.[1,2] The current use of alloy steels depends to some extent on the mystique, developed with their development, that either individual or combinations of alloying elements were considered uniquely responsible for the steel properties.

Despite this mystique, there persist changes in the selection of materials based on alloy costs and performance, i.e., response to varied and complex engineering and processing demands on the materials. The complexity of demands resulted in the establishment of an increased number of alloy grades to meet specific demands. In 1940, the SAE (Society of Automotive Engineers) listed 65 standard grades of low-alloy steels; today[7] there are 86, not including the "H band" series, plus EX grades and numerous "modified" grades specified by individual manufacturers. In the course of the years, 96 former grades[7] were deleted, i.e, no longer of major commercial use. Such continuing activity suggests that the technology of alloy steels is still in a state of flux.

Although wrought alloy steels face some competition in low-stress automotive components, they will continue to be the dominant materials for highly stressed components, such as power transmission gears and shafting, ball and roller bearings, and spring members. These components have high hardness ($\geq 50R_c$) and depend on the ability of the steel to be through hardened, case hardened by induction heating, or case carburized.

In predicting hardenability from composition, one finds no readily available factor for vanadium,[3] in spite of the fact that vanadium was used in the early alloy steel grades

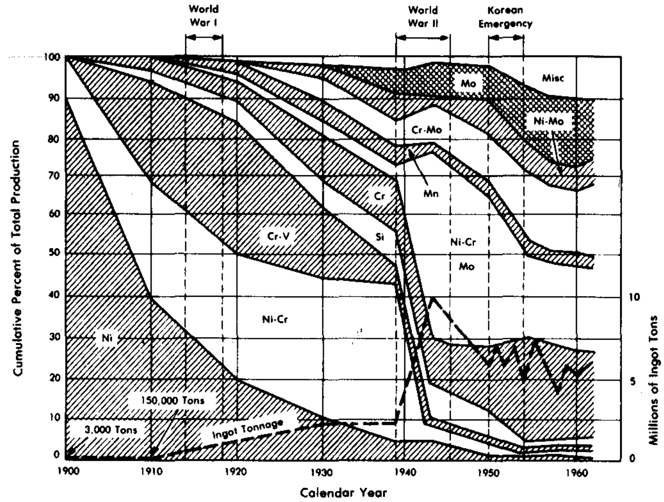

Figure 1. Alloy steel production in the U.S. showing cumulative percent of steel type produced in a given year from 1900.

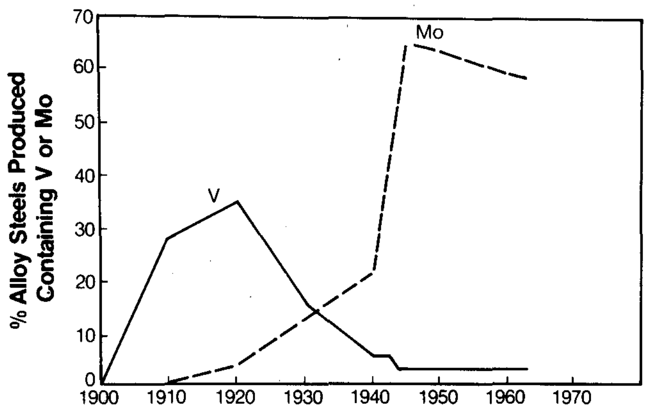

Figure 2. Relative percent of alloy steels produced containing V or Mo during same period as Figure 1.

(Figure 1). Relative to molybdenum, the percent of alloy steels containing vanadium through the years is shown in Figure 2. The unavailability of the factor for vanadium stems from vanadium's infrequent use in current alloy grades and conflicting data on its influence on hardenability. The current restricted application of vanadium in alloy steels is due mainly to the concept that during austenitization vanadium forms insoluble carbides which result in very fine austenitic grain size.[4] Both the insolubility of the carbides and the fine austenitic grain size minimize hardenability.

The present study was conducted to determine the hardenability response of vanadium-modified 4030, 4130, 4330, and 8630 alloy steels at the SAE specified standard temperature and slightly higher austenitizing temperatures. In addition, the interaction of carbon and vanadium was determined in the 8615 and 8640 steels. The modifica-