VOLUME 137 ISSUE 1 JANUARY 1990

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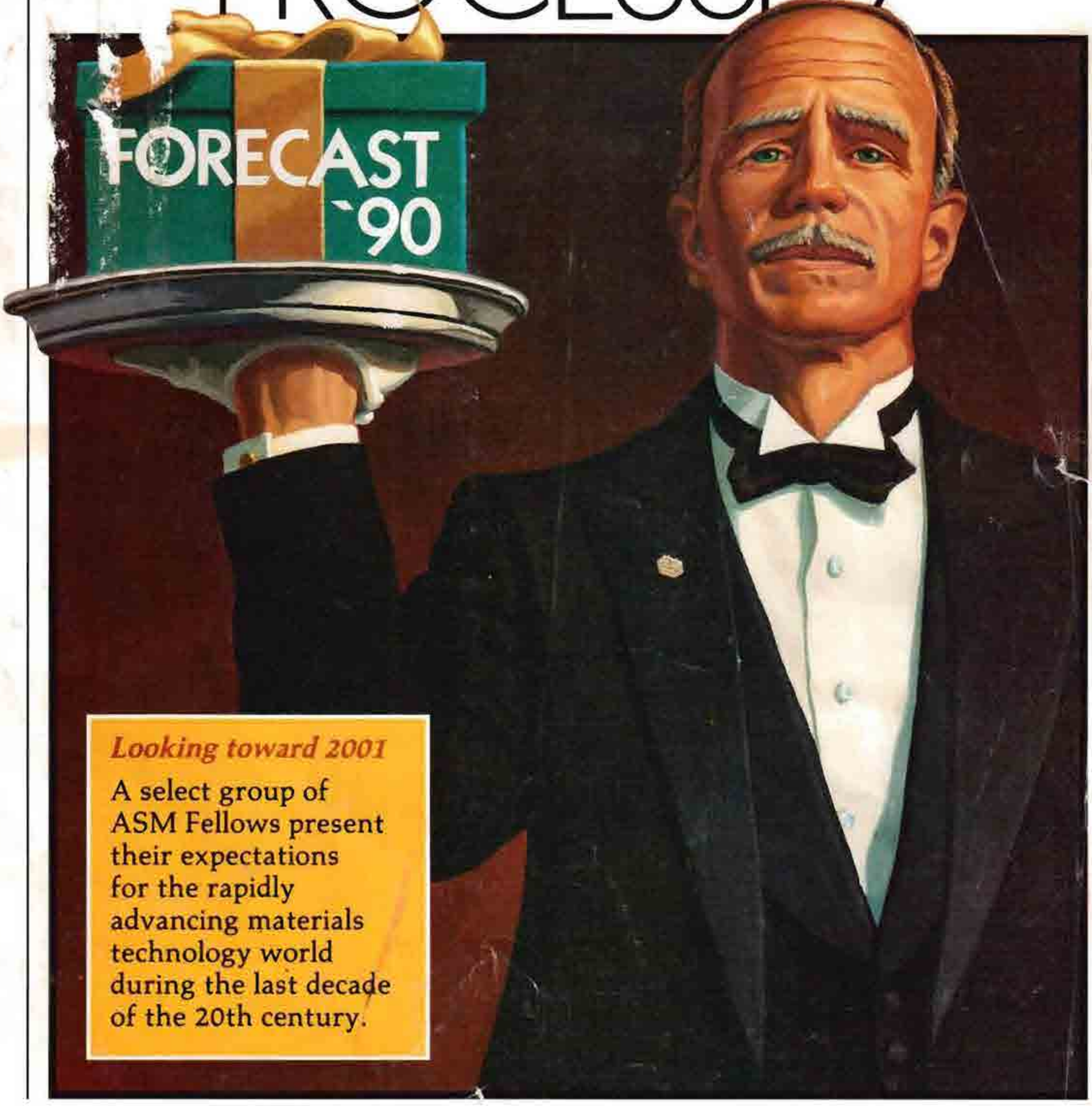

Looking toward 2001

A select group of ASM Fellows present their expectations for the rapidly advancing materials technology world during the last decade of the 20th century.

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Cover illustration by David W. Fogle

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Advanced Materials & Processes *(ISSN 0882-7958, USPS 762080) is published monthly by ASM INTERNATIONAL®. Publication and editorial offices: Materials Park, Ohio 44073; telephone 216/338-5151. Second-class postage paid at Novelty, Ohio and additional mailing offices. Vol. 137, No. 1 January 1990.* *Subscription rate is $48 per year (plus $20 Overseas Service Fee for non Western-Hemisphere subscribers). Single copies: $3.50 U.S. only, $4.50 international. POSTMASTER: Send all 3579 forms to ASM INTERNATIONAL, Materials Park, Ohio 44073. ASM is a not-for-profit educational society dedicated to the advancement of technical knowledge through the exchange of ideas and information on engineering related-material.*

MATERIALS

Microalloyed Steels

J. Malcolm Gray, FASM (1987)

In the future, the entire sequence of alloy design, melting, casting, processing, and fabrication will be considered in developing and applying microalloyed steels. All of these considerations have a bearing on the cost, serviceability, use, reliability, and even applicability of these steels. Microalloyed high-strength, low-alloy (HSLA) steels have been in existence for approximately three decades, and they have permeated many sectors of the steel industry. While these steels were developed with specific mechanical properties and target markets in mind, all fabricator and end-use requirements did not receive sufficient attention. Thus, it later became necessary to improve toughness and to optimize weldability. Simultaneously, steel fabricators discovered that formability and defect tolerance were reduced as strength increased, thus, making it necessary to improve steel cleanness. Ultimately, construction of overseas state-of-the-art facilities combined with lower labor costs in these countries pressured U.S. steel suppliers to develop a competitive product.

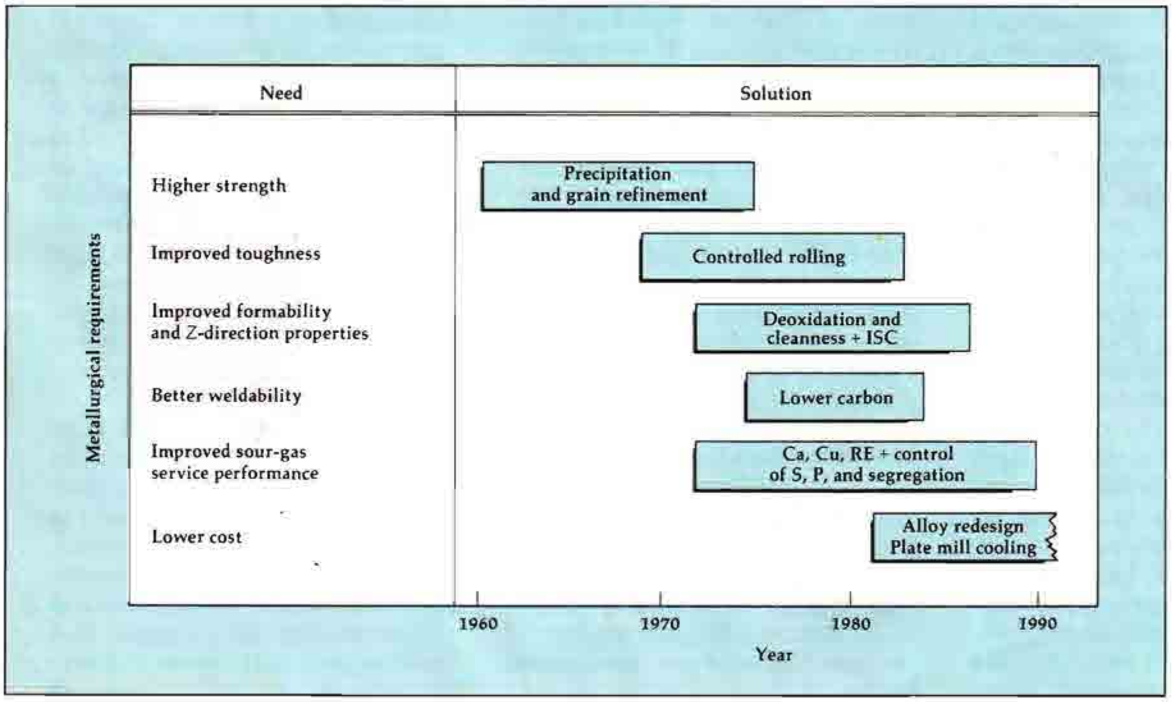
Mr. Gray is president, Microalloyin International Inc. Houston, Texas.

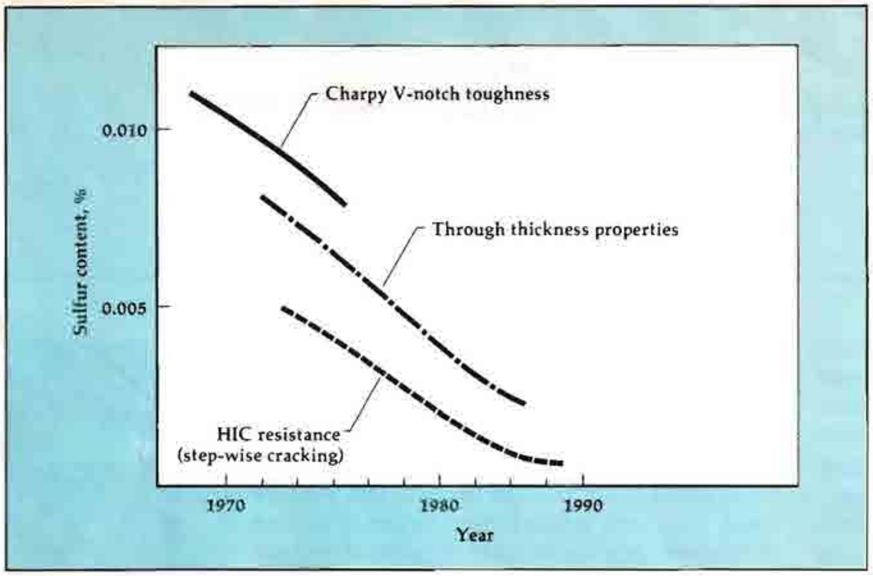
While this scenario has been repeated in several HSLA-product areas, a more comprehensive approach to product development can be expected in the next decade. An integrated total life-cycle engineering approach, such as that prevailing for aircraft structural and engine alloys, will likely be adopted for the development of future HSLA steels to make them more predictable, easier to fabricate and inspect, and affordable.

Incentives for further development in microalloying technology will vary from one product area to another. For example, projects, such as the Alaskan pipeline, which may be marginally economical, will require the development of alloys for higher pressure, smaller diameter pipelines. The material selected will require rigorous qualification, thus, defect tolerance and fitness-for-service must be properly demonstrated, especially considering the greater tendency for welding heat-affected-zone softening in very high-strength, thermomechanically processed steels.

One such development involves controlled-cooling equipment for producing plate and pipe. The system is used to initially accelerate cooling

Metallurgical solutions to meet technological problems came about as materials structure/property relationships were developed and as property-controlling mechanisms were identified.





*Product or end use requirements often produce technological improvements (*e.g.*, sulfur reduction) in sequence over time as technology transfer leads to a broader knowledge base.*

from the austenite-phase region during planned delays in the controlled-rolling process, and after, used in the conventional sense to cool the final product. Cost-reduction pressures and stiff competition among linepipe producers will provide the incentive for wider adoption and further refinements of these sophisticated thermal treatments.

Similarly, fast air-cooling techniques used in producing hardenable alloy-steel forging bar stock produces very fine pearlitic or bainitic microstructures in medium-carbon microalloyed steels and eliminates the need for reheating, quenching, and tempering. In addition, optimization of metallurgical and processing objectives during hot rolling will be increasingly aided through the use of computer-based thermodynamic models (such as one developed at McMaster University), which take into consideration all interactions between alloying elements and their effects on solubility and precipitation kinetics during mechanical working.

Further increases in strength may not be possible by increasing cooling rate alone, but could require additional alloying. The U.S. Navy, for example, has taken the lead in applying copper-strengthened microalloyed steels at the 550-, 690-, and 900-MPa (80, 100, and 130×10^3 psi) yield-strength levels. There already are signs that a broader market for these steels will develop in railroad tank-car and offshore-platform applications. In another development, based on the Cu-Ni aging system, 550-MPa (80×10^3 psi) forgings (ASTM A 707) are being considered for heavy-section (254 mm, 10 in.) connectors in new tension-leg platform designs. The relative ease of fabrication and weld repair of this steel in underwater service compared with HY 80 are inducements for change.

Environmental cracking resistance of linepipe steels has been dramatically enhanced by improvements in steelmaking and continuous-casting practices and the introduction of reliable testing. Reduced sulfur, phosphorus, carbon, and manganese segregation, plus treatment with calcium or rare-earth metals for inclusion-shape control assure virtual freedom from stress-corrosion cracking and hydrogen-induced cracking (HIC), or step-wise cracking.

Accidents, product failures, and natural disasters also produce incentives for change. For example, after the earthquake in Mexico City in 1985, codes and government regulations were changed, eventually leading to widespread specification of tough, microalloyed concrete-reinforcing bar to replace high-carbon-manganese grades. Similar changes are expected in steel specifications for highway, bridge, and building construction in the 1990s.

The sheet steel market is another area for development of microalloyed grades. Competition from other materials, such as aluminum and plastics, has led to a proliferation of new steel grades. Very high strength levels (640-MPa, 90×10^3 psi yield strength) are possible in grades such as Mn-Nb-V and Mn-Nb-Ti-Mo-B steels developed by Thyssen Stahl, West Germany. At the opposite end of the spectrum, low-strength, highly formable interstitial-free (I-F) steels are key materials.

Intermediate-strength microalloyed steels account for the major use in automobiles. Interstitial-free steels may be stabilized using titanium or niobium singly, or in combination, called dual stabilization. The latter probably represents a realistic compromise between cost and performance. For nonexposed parts, slivers or streaking caused by titanium oxysulfide inclusions associated with titanium stabilization can be tolerated. Dual stabilization or stabilization with niobium alone is preferred for sheet to be zinc-coated to avoid "powdering" during hot-dip and Galvanneal processing.

Although these steelmaking developments relate to improvements in impurity control, equally significant are improvements in continuous-casting technology to improve surface quality. One possibility is the development of direct hot charging, which affects the microalloying-element precipitation sequence and will require modification of alloy designs. In general, direct hot-charging will reduce the microalloying levels needed to achieve the required results.

Likewise, the prospect of thin-slab or sheet casting has implications for steels that develop their properties as a by-product of the hot (or even cold) rolling process. However, the reduced deformation needed for these processes will necessitate alloy designs that develop proper textures at lower strain levels. ■