

# TECH SPOTLIGHT

## Progress toward low-cost titanium

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The word "titanium" tends to evoke exotic visions such as that of the SR-71 Blackbird streaking across the sky at unheard of heights, exceeding the speed of a high-powered rifle bullet, protected by its heat-resistant titanium skin. Or perhaps one pictures a deadly Alfa-class Soviet submarine blasting through the water at 45 knots and at depths of more than 300 m (1000 ft), well below the crush-depth of its American counterpart, guarded from unimaginable pressures by a tough hull of titanium alloy. The senior author's first experience with titanium was more than 20 years ago while working his way through college at a foreign-car repair shop. He held in his hand a wheel lug from the legendary Porsche 911, and it felt too light to be steel.

"Aluminum?" he asked.

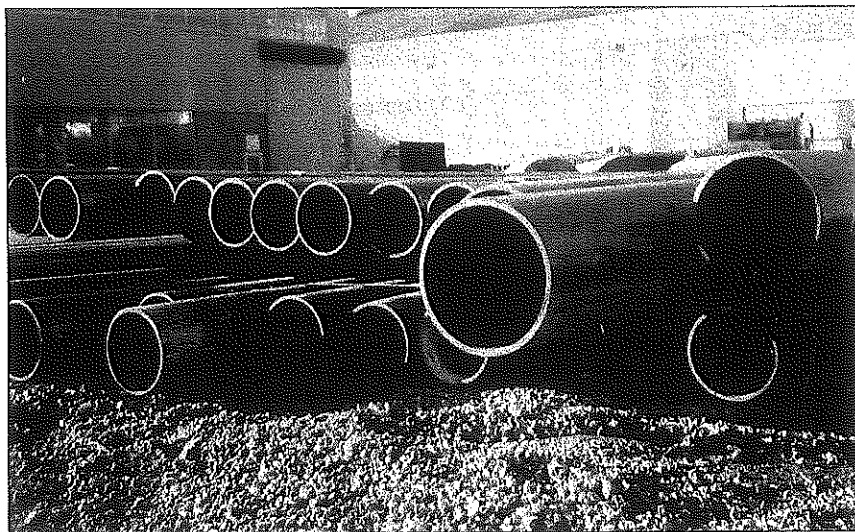
With a knowing gleam in his eye, the venerable head mechanic whispered, "Titanium."

It was a word that was almost unknown at that time, and it seemed the very definition of what we now call "high tech."

### Demand hits 10-year low

Even today, when it is being considered for new uses in industries other than aerospace, titanium is still viewed as an exotic, high-cost material. Sheets of aerospace titanium alloy are not much cheaper than similar sheets of silver. Although titanium has impressive mechanical and corrosion properties, designers and engineers simply do not think of it as a cost-effective, viable alternative to alu-

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Lower cost grades of titanium would extend use of the metal to non-aerospace applications. For example, titanium pipe can be employed in a variety of marine, offshore, and energy extractor applications. Courtesy RMI Titanium Co., Niles, Ohio.

minum and steel. Moreover, the history and use of titanium have been solidly wedded to the aerospace industry. This explains why titanium's price rises and falls cyclically with the demand for civilian and military aircraft.

Currently, with military and civilian aircraft cutbacks and an atmosphere of recession, the demand for titanium has dropped to its lowest level since 1983. The three primary titanium producers — Oregon Metallurgical Corp. (Ore-met), Albany, Ore.; RMI Titanium Co., Niles, Ohio; and Titanium Metals Corp. (Timet), Henderson, Nev. — are struggling with losses and slashing prices drastically. In addition, foreign competition is keen, and the Commonwealth of Independent States (CIS), with vast titanium resources and production capacity, poses a serious potential threat to the domestic industry.

### New uses on the horizon

Although the titanium industry is temporarily depressed, developing prospects may offer reason for optimism: Several non-aerospace industries are interested in using titanium. Unfortunately, the deci-

sion makers in these industries are more than cautious, remembering titanium's reputation for "down today, up tomorrow" seesaw prices. They want relative price stability, realizing that a substantial investment in redesign must be made to take full advantage of titanium's weight-saving potential and inherent functionality, versus simply replacing steel or aluminum on a one-for-one basis. The irony is that while serious users will not undertake major design changes without guarantees of reasonable prices, the primary titanium producers are hesitant to develop new alloys and make long-term price commitments without a market assurance.

The U.S. Army and Navy are two of the new and potentially large customers for titanium. Lessons from the recent conflict in Panama and the Gulf War have spurred interest in the development of lighter, more efficient, more maneuverable vehicles and artillery. The Army also is exploring means to lighten existing armored vehicles while increasing protection against more serious ballistic threats. The Navy is interested in increasing the corrosion

resistance and ballistic capabilities of above-deck shipboard applications while, at the same time, reducing tendencies toward top heaviness. These applications represent huge potential markets for titanium, which could conceivably double the size of the industry.

Other promising nonmilitary, non-aerospace applications include suspension springs and engine parts for cars and trucks, marine and offshore oil-rig components that currently are made of stainless steels and nickel-base alloys, and piping and reactor parts for the pulp-and-paper and chemical processing industries. Existing markets, such as tubing for shell-and-tube heat exchangers, are expected to grow.

### New low-cost alloys

The titanium industry is testing and producing new, low-cost alloys for non-aerospace users. They were introduced 30 Oct. 1991 during a meeting at the Bureau of Mines Albany (Ore.) Research Center. Costs were cut, without significant property reductions, through modifications to arc melting and subsequent fabricating steps. However, some tradeoffs may exist for such properties as high-cycle fatigue and high-temperature strength.

Arc melting and fabrication costs are major factors in the total cost of producing Ti-6Al-4V (the workhorse alloy of the industry), as can be seen in these unit costs compiled by the Bureau of Mines with the assistance of Oremet and Timet:

- Rutile, 96% TiO<sub>2</sub> . . . . . 4%
- Chlorination to TiCl<sub>4</sub> . . . . . 9%
- Magnesium-sodium reduction . . . . . 25%
- Arc melting:
  - Preliminary with master alloy addition . . . . . 12%
  - Final . . . . . 3%
- Fabrication to 25 mm (1 in.) thick plate . . . . . 47%

The new Oremet alloy, Auto-grade, is directed at the automotive industry. Cost savings were obtained by relaxing the melting, nondestructive testing, and chemistry (oxygen in particular) specifications that are normally applied to aerospace alloys. Ingot and billet forging and rolling were done in the beta range (~1065°C, 1950°F), allowing a significantly greater re-

## Properties of low-cost titanium alloys

Alloy	Yield strength, MPa (ksi)	Ultimate tensile strength, MPa (ksi)	Elongation, %	Reduction in area, %
Ti-6Al-4V <sup>1</sup>	950 (138)	985 (143)	14	37
Oremet				
Auto-grade <sup>2,3</sup>	1025 (149)	1115 (162)	15	38
RMI RM <sup>2,3</sup>	1005 (146)	1070 (155)	13	ND <sup>5</sup>
RMI VM <sup>1</sup>	895 (130)	1000 (145)	19	40
Timetal-62S	1040 (151)	990 (144)	15	34

1. Beta rolled. 2. Alpha-beta rolled. 3. Average. 4. Alpha-beta annealed. 5. Not determined.

duction per pass than is used with aerospace-grade titanium, which is forged at lower temperatures within the alpha-beta region. Final bar rolling was done in the alpha-beta temperature range.<sup>1</sup>

RMI has examined two methods for producing low-cost titanium alloys: scrap utilization and elemental substitution. RMI's RM (recycled material) alloy is produced from scrap titanium chips, but retains a nominal Ti-6Al-4V composition. A second alloy, VM (virgin material), is a "substitutional" alloy (Ti-6.4Al-1.2Fe), in which iron is used as a replacement for the more expensive vanadium.<sup>2</sup>

Timet has concentrated on producing a new substitutional alloy, Timetal-62S (Ti-6Al-1.7Fe-0.1Si). Its mechanical properties are equal to or greater than those of Ti-6Al-4V.<sup>3</sup> This alloy is probably the closest to production of all the low-cost alloys. Timet estimates that Alloy 62S will cost a minimum of 25% less than Ti-6Al-4V.

As shown in the table, the mechanical properties of all the low-cost alloys compare very favorably with those of Ti-6Al-4V. Current technology is adequate to produce these alloys.

### Research programs

The Bureau of Mines is working on reducing the cost of titanium even further through modifications to magnesium-sodium reduction, as well as arc melting and fabrication. Ongoing research consists of two projects to produce titanium powder or granules directly and continuously from TiCl<sub>4</sub>. The new technologies, if successful, will replace conventional batch-type Kroll and Hunter processes with a continuous process that will be used to make titanium granules suitable

for melting and a high-purity powder for P/M applications.

For the future, the Bureau of Mines — in cooperation with the U.S. Army Tank/Automotive Command, Warren, Mich., and other government and industry organizations — is planning a comprehensive, five-year program on low-cost titanium that will consist of several projects that seek not only to further reduce costs, but to improve ballistic protection and other mechanical and wear properties. For now, progress has been made to lower the cost of conventional and near-conventional titanium alloys. All domestic titanium producers have excellent, low-cost alloys either in final testing or close to production. ■

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### References

1. "Meeting on Low-Cost Titanium," by D. Hiatt: presented at the Low-Cost Titanium Conference, Albany, Ore., 30 Oct. 1991.
2. "RMI Titanium Company Approaches to Low-Cost Titanium," by S. Seagle: presented at the Low-Cost Titanium Conference, Albany, Ore., 30 Oct. 1991.
3. "Timetal-62S, Program Status," by P. Bania: presented at the Low-Cost Titanium Conference, Albany, Ore., 30 Oct. 1991.

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