Technical Note

Production of High Nitrogen Steels

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NITROGEN used as an alloying element in steel has received increased attention in recent years. Its merit as an austenite stabilizer and hot strengthener has long been recognized, particularly by European investigators.[1]

Recent work[2] indicates that nitrogen contents of ½ pct or more allow the addition of several percent of ferrite-forming hot strengtheners, such as molybdenum, without subsequent austenite decomposition at elevated temperatures. The room temperature properties of such alloys are characterized by high yield and tensile strengths with excellent ductility, even after cold working, as shown in Tables I and II. The 1350°F creep-rupture properties of Cr-Mn-Mo-N steels are comparable to those of commercial alloys such as Timken's 16-25-6, containing 16 pct Cr, 25 pct Ni, and 6 pct Mo, as shown in Table III.

Cr-Mn steel containing ½ pct N must be made under pressure if ingot gassing is to be avoided. However, there are difficulties attendant to this practice. Pressure melting restricts the ingot size, and the equipment required is costlier and more complicated than comparable air melting facilities. An effort was made, therefore, to determine more economical methods of adding nitrogen.

The pressures generated in centrifugal casting usually range from 5 to 10 atm and are sufficient to prevent the gassing of high nitrogen Cr-Mn steels. A centrifugal casting was made of an alloy containing 16 pct Cr, 18 pct Mn, 2 pct Mo, and 0.73 pct N. A disk, 8 in. diam and 1½ in. thick, was cast at 1000 rpm. It has been calculated that a pressure of 9 atm was developed at the periphery of the disk at this speed. Metallographic inspection of specimens taken from the disk revealed no gas holes or other defects. The elevated temperature properties of radial and circumferential specimens taken from this casting are given in Table IV. The creep-rupture life of this cast nickel-free austenitic steel was equivalent to that of the wrought Cr-Mn-Mo-N steels.

Although centrifugal casting appears to lend itself to the manufacture of high nitrogen austenitic steels, its applicability is limited to relatively small sizes.

A process applicable to the production of large ingots of high nitrogen steels is suggested by low carbon rimming steel practice. Gas holes formed during ingot solidification are not detrimental so long as they weld shut during hot rolling. An economic advantage of gassing ingots is the increased ingot-to-slab yield, especially if the ingots are mechanically capped. Also, it is probable that higher nitrogen levels can be achieved with mechanically capped ingots than with hot-topped ingots.

A series of gassy heats was made under both atmospheric and higher pressures, as indicated in Table V. Several of the air melted ingots were mechanically capped by chilling the molten ingot tops with a steel plate. The ingots were allowed to freeze in steel molds without hot-tops unless otherwise indicated.

A comparison of Table III with Table V shows no significant difference in the creep-rupture properties of the gassy and the nongassy ingots after hot working nor between the gassy ingots produced under different conditions.

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References

[1] F. Rapatz: Application of Stainless and Heat Resisting Steels Alloyed with Nitrogen. *Stahl und Eisen* (1941) 61, pp. 1073-1078.

[2] V. F. Zackay, J. F. Carlson, and P. L. Jackson: High Nitrogen Austenitic Cr-Mn Steels. *Trans.* ASM (1955) 48, pp. 509-523.

Table I. Room Temperature Tensile Tests of Wrought Cr-Mn-Mo-N Steels Water Quenched from 2150°F

Nominal Composition in Pct	Tensile Test Data: Yield Strength, Psi	Tensile Strength, Psi	Elongation, Pct
16 Cr-14 Mn-2 Mo-0.5 N	61,400	119,000	70
16 Cr-14 Mn-2 Mo-0.5 N	59,100	121,250	68
16 Cr-14 Mn-2 Mo-0.6 N	61,500	120,000	65
17 Cr-13 Mn-2.5 Mo-0.75 N	75,000	140,000	50

Table II. Tensile Properties of Cold Worked Austenitic Steels

Nominal Composition	Type: 301	302	CM*	Cr, Mn, N	Cr, Mn, N
Pct Cr	17	18	16	16	17
Pct Ni	7	9	1	—	—
Pct Mn	—	—	15	14	13
Pct Mo	—	—	—	2	2.5
Pct N	—	—	—	0.6	0.75
Cold Work, Pct	40	60	40	33	25
Yield Strength, Psi	150,000	180,000	145,000	183,000	176,000
Tensile Strength, Psi	200,000	195,000	185,000	207,000	205,000
Elongation, Pct	10	3	5	13	11.5

* CM represents commercial Cr-Mn steel.

Table III. Creep-Rupture Properties of Wrought Cr-Mn-Mo-N Steels Water Quenched from 2150°F

Nominal Composition in Pct	100 Hr Rupture Life in Psi at 1350°F
16 Cr-13 Mn-3 Mo-½ N	28,000
16 Cr-14 Mn-2 Mo-½ N	26,000
16 Cr-25 Ni-6 Mo	27,000

Table IV. Creep-Rupture Life of Centrifugally Cast Cr-Mn-Mo-N Steel Water Quenched from 2150°F

16 Pct Cr-18 Pct Mn-2 Pct Mo-0.73 Pct N*, Nominal Composition	100 Hr Rupture Life in Psi at 1350°F
Radial Test Specimen	28,000
Circumferential Test Specimen	28,000

* Percentage given is actual nitrogen value.

Table V. Creep-Rupture Life of Wrought Cr-Mn-Mo-N Austenitic Steels Water Quenched from 2150°F

Nominal Composition* in Pct	Casting Condition	100 Hr Rupture Life at 1350°F, Psi
15 Cr-16 Mn-4 Mo-0.50 N	Gassy, pressure melt	25,000
16 Cr-15 Mn-3 Mo-1 Ni-1 Si-0.46 N	Gassy, pressure melt	26,000
16 Cr-12 Mn-2 Mo-0.60 N	Gassy, pressure melt	29,000
16 Cr-16 Mn-2 Mo-0.62 N	Gassy, air melt	29,000
16 Cr-16 Mn-2 Mo-0.61 N	Gassy, air melt	26,000
16 Cr-14 Mn-2 Mo-0.55 N	Gassy, mechanically capped	26,000
16 Cr-14 Mn-2 Mo-0.56 N	Gassy, mechanically capped	26,000

* Percentages given are in actual nitrogen values.