Overview of equations for estimating Ms

Model	Equation for estimating *Ms* in ℃
Ingber [1]	$Ms = 530.2 - 290.3x_{\mathrm{C}} - 35.5x_{\mathrm{Mn}} - 6.8x_{\mathrm{Si}} - 17.2x_{\mathrm{Ni}} - 20.8x_{\mathrm{Cr}} - 10.4x_{\mathrm{Mo}} + 7.1x_{\mathrm{Al}} + 4.8x_{\mathrm{Co}} - 75\left[1 - e^{-0.96x_{\mathrm{C}}}\right]$
Payson & **S**avage [2]	$Ms = [(930 - 570x_{\mathrm{C}} - 60x_{\mathrm{Mn}} - 20x_{\mathrm{Si}} - 50x_{\mathrm{Cr}} - 20x_{\mathrm{Mo}} - 30x_{\mathrm{Ni}}) - 32] \cdot 5/9$
Kung & Rayment (mod. P&S) [3]	$Ms = [(930 - 570x_{\mathrm{C}} - 60x_{\mathrm{Mn}} - 20x_{\mathrm{Si}} - 50x_{\mathrm{Cr}} - 20x_{\mathrm{Mo}} - 30x_{\mathrm{Ni}}) - 32] \cdot 5/9 + 10x_{\mathrm{Co}}$
Rowland & **L**yle [4]	$Ms = [(930 - 600x_{\mathrm{C}} - 60x_{\mathrm{Mn}} - 20x_{\mathrm{Si}} - 50x_{\mathrm{Cr}} - 20x_{\mathrm{Mo}} - 20x_{\mathrm{W}} - 30x_{\mathrm{Ni}}) - 32] \cdot 5/9$
Kung & Rayment (mod. R&L) [3]	$Ms = [(930 - 600x_{\mathrm{C}} - 60x_{\mathrm{Mn}} - 20x_{\mathrm{Si}} - 50x_{\mathrm{Cr}} - 20x_{\mathrm{Mo}} - 20x_{\mathrm{W}} - 30x_{\mathrm{Ni}}) - 32] \cdot 5/9 + 10x_{\mathrm{Co}}$
Grange & **St**ewart [5]	$Ms = [(1000 - 650x_{\mathrm{C}} - 70x_{\mathrm{Mn}} - 70x_{\mathrm{Cr}} - 50x_{\mathrm{Mo}} - 35x_{\mathrm{Ni}}) - 32] \cdot 5/9$
Kung & Rayment (mod. G&S) [3]	$Ms = [(1000 - 650x_{\mathrm{C}} - 70x_{\mathrm{Mn}} - 70x_{\mathrm{Cr}} - 50x_{\mathrm{Mo}} - 35x_{\mathrm{Ni}}) - 32] \cdot 5/9 + 10x_{\mathrm{Co}}$
Nehrenberg [6]	$Ms = [(930 - 540x_{\mathrm{C}} - 60x_{\mathrm{Mn}} - 20x_{\mathrm{Si}} - 40x_{\mathrm{Cr}} - 20x_{\mathrm{Mo}} - 30x_{\mathrm{Ni}}) - 32] \cdot 5/9$
Kung & Rayment (mod. N) [3]	$Ms = [(930 - 540x_{\mathrm{C}} - 60x_{\mathrm{Mn}} - 20x_{\mathrm{Si}} - 40x_{\mathrm{Cr}} - 20x_{\mathrm{Mo}} - 30x_{\mathrm{Ni}}) - 32] \cdot 5/9 + 10x_{\mathrm{Co}}$
Steven & **H**aynes [7]	$Ms = 561 - 474x_{\mathrm{C}} - 33x_{\mathrm{Mn}} - 17x_{\mathrm{Cr}} - 21x_{\mathrm{Mo}} - 17x_{\mathrm{Ni}}$
Kung & Rayment (mod. St&H) [3]	$Ms = 561 - 474x_{\mathrm{C}} - 33x_{\mathrm{Mn}} - 17x_{\mathrm{Cr}} - 21x_{\mathrm{Mo}} - 17x_{\mathrm{Ni}} + 10x_{\mathrm{Co}} - 7.5x_{\mathrm{Si}}$
Andrews (linear) [8]	$Ms = 539 - 423x_{\mathrm{C}} - 30.4x_{\mathrm{Mn}} - 12.1x_{\mathrm{Cr}} - 7.5x_{\mathrm{Mo}} - 17.7x_{\mathrm{Ni}}$
Kung & Rayment (mod. A-lin) [3]	$Ms = 539 - 423x_{\mathrm{C}} - 30.4x_{\mathrm{Mn}} - 12.1x_{\mathrm{Cr}} - 7.5x_{\mathrm{Mo}} - 17.7x_{\mathrm{Ni}} + 10x_{\mathrm{Co}} - 7.5x_{\mathrm{Si}}$
Andrews (non-linear) [8]	$Ms = 512 - 453x_{\mathrm{C}} - 16.9x_{\mathrm{Ni}} + 15x_{\mathrm{Cr}} - 9.5x_{\mathrm{Mo}} + 217x_{\mathrm{C}}^2 - 71.5x_{\mathrm{C}}x_{\mathrm{Mn}} - 67.6x_{\mathrm{C}}x_{\mathrm{Cr}}$
Kung & Rayment (mod. A-nl) [3]	$Ms = 512 - 453x_{\mathrm{C}} - 16.9x_{\mathrm{Ni}} + 15x_{\mathrm{Cr}} - 9.5x_{\mathrm{Mo}} + 217x_{\mathrm{C}}^2 - 71.5x_{\mathrm{C}}x_{\mathrm{Mn}} - 67.6x_{\mathrm{C}}x_{\mathrm{Cr}} + 10x_{\mathrm{Co}} - 7.5x_{\mathrm{Si}}$
Tamura [9]	$Ms = 550 - 361x_{\mathrm{C}} - 39x_{\mathrm{Mn}} - 20x_{\mathrm{Cr}} - 5x_{\mathrm{Mo}} - 17x_{\mathrm{Ni}} - 30x_{\mathrm{Al}} + 15x_{\mathrm{Co}} - 10x_{\mathrm{Cu}} - 17x_{\mathrm{Ni}} - 35x_{\mathrm{V}}$
Ishida [10]	$Ms = 545 - 330x_{\mathrm{C}} - 23x_{\mathrm{Mn}} - 7x_{\mathrm{Si}} - 14x_{\mathrm{Cr}} - 13x_{\mathrm{Ni}} - 13x_{\mathrm{Cu}} - 5x_{\mathrm{Mo}} + 2x_{\mathrm{Al}} + 7x_{\mathrm{Co}} - 4x_{\mathrm{Nb}} + 3x_{\mathrm{Ti}} + 4x_{\mathrm{V}}$
Sverdlin & Ness [11]	$Ms = 520 - 320x_{\mathrm{C}} - 50x_{\mathrm{Mn}} - 5x_{\mathrm{Si}} - 30x_{\mathrm{Cr}} - 20x_{\mathrm{Ni}} - 5x_{\mathrm{Cu}} - 20x_{\mathrm{Mo}}$
Wang (linear) [12]	$Ms = 545 - 470x_{\mathrm{C}} - 37.7x_{\mathrm{Mn}} - 3.96x_{\mathrm{Si}} - 21.5x_{\mathrm{Cr}} - 38.9x_{\mathrm{Mo}}$

Model	**Equation for estimating *Ms* in ℃**
Wang (non-linear) [12]	$Ms = 540 - 584.9x_{\mathrm{C}} - 23.1x_{\mathrm{Si}} - 117.1x_{\mathrm{Mn}} - 42.5x_{\mathrm{Cr}} + 49.9x_{\mathrm{Mo}} - 62.5(x_{\mathrm{C}} \cdot x_{\mathrm{Si}})^{1/2} + 178.3(x_{\mathrm{C}} \cdot x_{\mathrm{Mn}})^{1/2}$ $- 10(x_{\mathrm{C}} \cdot x_{\mathrm{Cr}})^{1/2} + 52.5(x_{\mathrm{C}} \cdot x_{\mathrm{Mo}})^{1/2} + 117.2(x_{\mathrm{Si}} \cdot x_{\mathrm{Mn}})^{1/2} + 50.9(x_{\mathrm{Si}} \cdot x_{\mathrm{Cr}})^{1/2} - 142.2(x_{\mathrm{Si}} \cdot x_{\mathrm{Mo}})^{1/2}$ $- 29.2(x_{\mathrm{Mn}} \cdot x_{\mathrm{Cr}})^{1/2} - 9.7(x_{\mathrm{Mn}} \cdot x_{\mathrm{Mo}})^{1/2} + 69.9(x_{\mathrm{Cr}} \cdot x_{\mathrm{Mo}})^{1/2}$
Kunitake [13]	$Ms = 560.5 - 407.3x_{\mathrm{C}} - 37.8x_{\mathrm{Mn}} - 7.3x_{\mathrm{Si}} - 14.8x_{\mathrm{Cr}} - 19.5x_{\mathrm{Ni}} - 20.5x_{\mathrm{Cu}} - 4.5x_{\mathrm{Mo}}$
van Bohemen [14]	$Ms = 565 - 600(1 - e^{-0.96x_{\mathrm{C}}}) - 31x_{\mathrm{Mn}} - 13x_{\mathrm{Si}} - 18x_{\mathrm{Ni}} - 10x_{\mathrm{Cr}} - 12x_{\mathrm{Mo}}$
Trzaska [15]	$Ms = 541 - 401x_{\mathrm{C}} - 36x_{\mathrm{Mn}} - 10.5x_{\mathrm{Si}} - 18x_{\mathrm{Ni}} - 14x_{\mathrm{Cr}} - 17x_{\mathrm{Mo}}$
Gramlich [19]	$Ms = 517 - 423x_{\mathrm{C}} - 30.4x_{\mathrm{Mn}} + 37x_{\mathrm{Al}} - 14x_{\mathrm{Cr}} + 82x_{\mathrm{Mo}} - 700x_{\mathrm{B}}$
Capdevila [16]	$Ms = 491 - 302.6x_{\mathrm{C}} - 30.6x_{\mathrm{Mn}} - 14.5x_{\mathrm{Si}} - 8.9x_{\mathrm{Cr}} - 16.6x_{\mathrm{Ni}} + 8.58x_{\mathrm{Co}} + 2.4x_{\mathrm{Mo}}$
Mahieu [17]	$Ms = 539 - 423x_{\mathrm{C}} - 30.4x_{\mathrm{Mn}} - 7.5x_{\mathrm{Si}} + 30x_{\mathrm{Al}}$
Lee & Park [18]	$Ms = 475.9 - 335.1x_{\mathrm{C}} - 34.5x_{\mathrm{Mn}} - 1.3x_{\mathrm{Si}} - 13.1x_{\mathrm{Cr}} - 10.7x_{\mathrm{Mo}} - 15.5x_{\mathrm{Ni}} - 9.6x_{\mathrm{Cu}} + 11.67\ln(d_{\gamma})$
Mikuła & Wojnar [19]	$Ms = 635 - 549.8x_{\mathrm{C}} - 85.4x_{\mathrm{Mn}} - 69x_{\mathrm{Si}} - 18.1x_{\mathrm{Cr}} + 69.3x_{\mathrm{Mo}} - 31x_{\mathrm{Ni}} - 1746.5x_{\mathrm{B}}$
Kaar [20]	$Ms = 692 - 502(x_{\mathrm{C}} + 0.86x_{\mathrm{N}})^{1/2} - 37x_{\mathrm{Mn}} - 14x_{\mathrm{Si}} - 11x_{\mathrm{Cr}} + 20x_{\mathrm{Al}}$
Liu [21]	$Ms = 550 - 361x_{\mathrm{C}} - 39x_{\mathrm{Mn}} - 5x_{\mathrm{Mo}} - 20x_{\mathrm{Cr}} + 30x_{\mathrm{Al}} - 17x_{\mathrm{Ni}} + 16x_{\mathrm{Co}} - 35x_{\mathrm{V}} - 10x_{\mathrm{Cu}} - 5x_{\mathrm{W}}$
Eichelmann & Hull [23]	$Ms = 1350 - 1655(x_{\mathrm{C}} + x_{\mathrm{N}}) - 33x_{\mathrm{Mn}} - 28x_{\mathrm{Si}} - 42x_{\mathrm{Cr}} - 61x_{\mathrm{Ni}}$
Steim [24]	$Ms = 550 - 350x_{\mathrm{C}} - 40x_{\mathrm{Mn}} - 5x_{\mathrm{Si}} - 20x_{\mathrm{Cr}} - 10x_{\mathrm{Mo}} - 17x_{\mathrm{Ni}}$
Bott & Pickering [25]	$Ms = 502 - 810x_{\mathrm{C}} - 1230x_{\mathrm{N}} - 13x_{\mathrm{Mn}} - 12x_{\mathrm{Cr}} - 30x_{\mathrm{Ni}} - 54x_{\mathrm{Cu}} - 46x_{\mathrm{Mo}}$
Kulmburg [26]	$Ms = 492 - 125x_{\mathrm{C}} - 65.5x_{\mathrm{Mn}} - 10x_{\mathrm{Cr}} - 29x_{\mathrm{Ni}}$
Dai [27]	$Ms = 501 - 199.8(x_{\mathrm{C}} + 1.4x_{\mathrm{N}}) - 17.9x_{\mathrm{Ni}} - 21.7x_{\mathrm{Mn}} - 6.8x_{\mathrm{Cr}} - 45x_{\mathrm{Si}} - 55.9x_{\mathrm{Mo}} - 1.9x_{\mathrm{C}}(x_{\mathrm{Mo}} + x_{\mathrm{Cr}} + x_{\mathrm{Mn}})$ $- 14.4\left[(x_{\mathrm{Ni}} + x_{\mathrm{Mn}})(x_{\mathrm{Cr}} + x_{\mathrm{Mo}} + x_{\mathrm{Al}} + x_{\mathrm{Si}})\right]^{1/2}$
Monma [28]	$Ms = 550 - 350x_{\mathrm{C}} - 40x_{\mathrm{Mn}} - 20x_{\mathrm{Cr}} - 10x_{\mathrm{Mo}} - 17x_{\mathrm{Ni}} + 15x_{\mathrm{Co}} - 10x_{\mathrm{W}} - 10x_{\mathrm{Cu}} - 35x_{\mathrm{V}}$
Eldis [29]	$Ms = 531 - 391.2x_{\mathrm{C}} - 43.3x_{\mathrm{Mn}} - 16.2x_{\mathrm{Cr}} - 21.8x_{\mathrm{Ni}}$

Remark

Please note that this collection is not complete.
It represents the equations known to us. If you know of other equations, we will be pleased to add them to this collection.

Finkler & Schirra [22] published a modified Steven and Haynes equation to account for alloying contents of especially V and W, but also N, Nb, Zr, Ta and Hf. The corresponding equation in the original publication (p. 340) unfortunately contains a bracket error. We were not able to find a bracket setting to match all the calculated Ms values given in Table 3 with the chemical compositions given in Table 1. That's why we didn't consider this equation.

We would also like to point out that there are other approaches to calculate Ms values:

- Martensite Start Temperature Predictor from Northwestern University
  https://info.eecs.northwestern.edu/MsTpredictor
- STEEL_MS_EMPIRICAL_2014 from Mathew J. Peet at *Materials Algorithms Project Program Library*
  https://www.phase-trans.msm.cam.ac.uk/map/steel/programs/ms-empirical2014.html

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