Optimisation of Neural Network for Charpy Toughness of Steel Welds

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Contents

Introduction

Neural network

Empirical equation → unphysical values

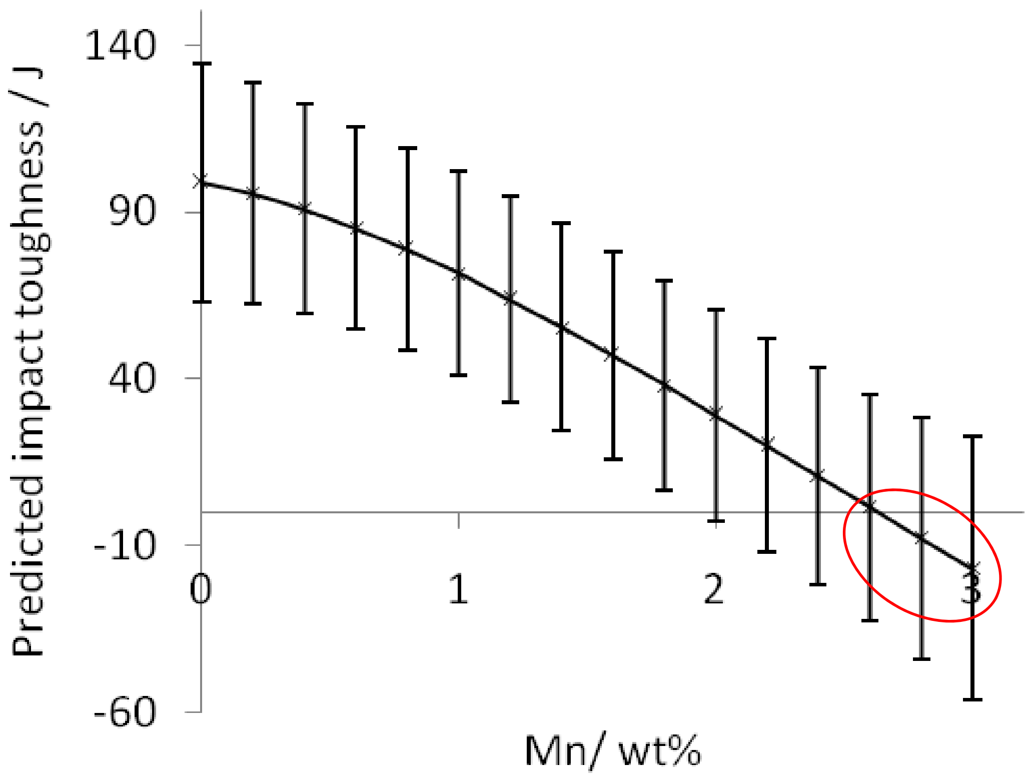
Possible

Charpy toughness (Impact toughness)

Measured energy absorbed by a standard sample during fracture

Never be negative !

Example of non-physical prediction



Modelling of output (Yescas *et al.* 2001)

Volume fraction from Avrami theory

$$\xi = 1 - \exp\left(-kt^{n}\right)$$

ξ: volume fraction k, n: constants t: time

$$\ln\left[-\ln\left(1-\xi\right)\right] \propto n \ln t$$

$$0 \le \xi \le 1$$

Double logarithmic function for output

Modelling of output (this work)

New output form

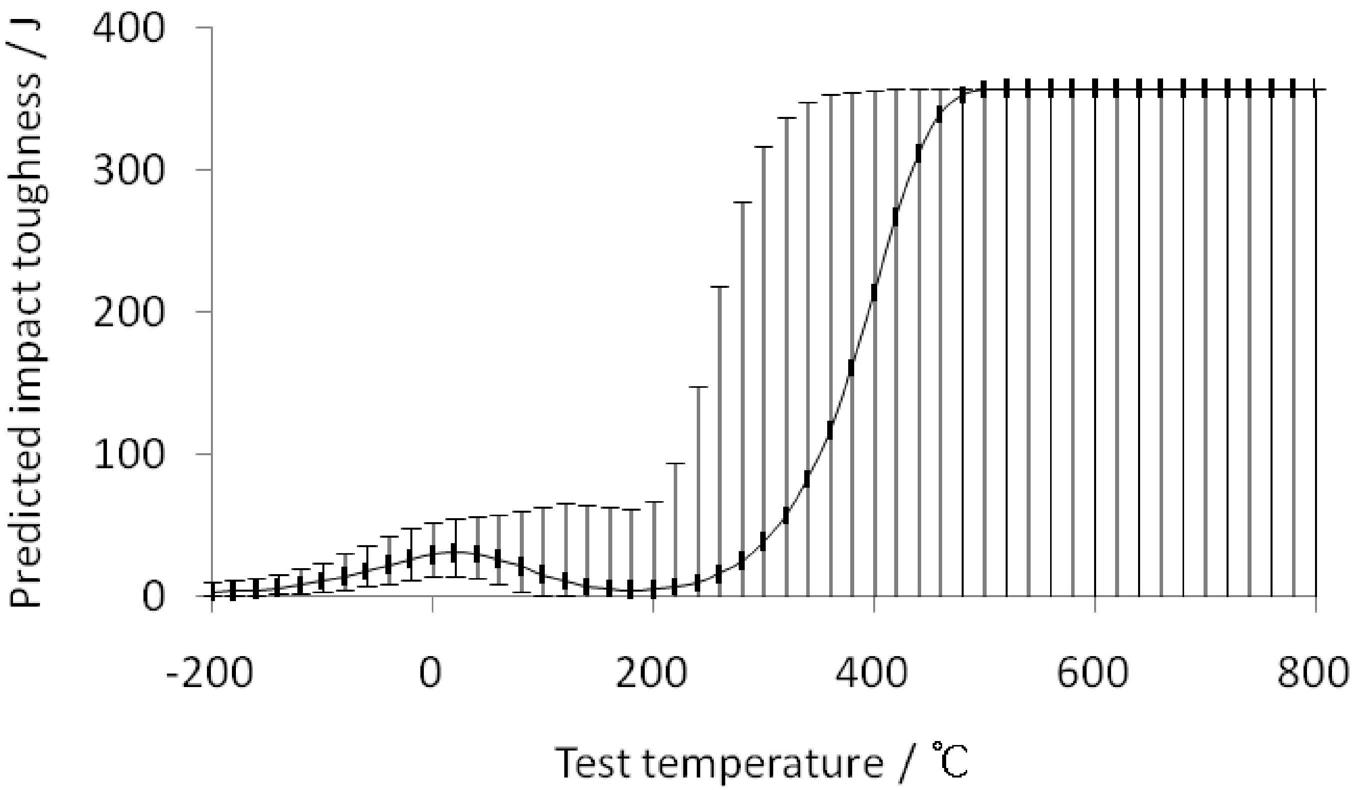
$$y' = -\ln\left\{-\ln\left(\frac{y - y_{min}}{y_{max} - y_{min}}\right)\right\}$$

$y_{min} = 0$ J the least physical value of Charpy toughness

$y_{max} = ?$ larger than the maximum value in database

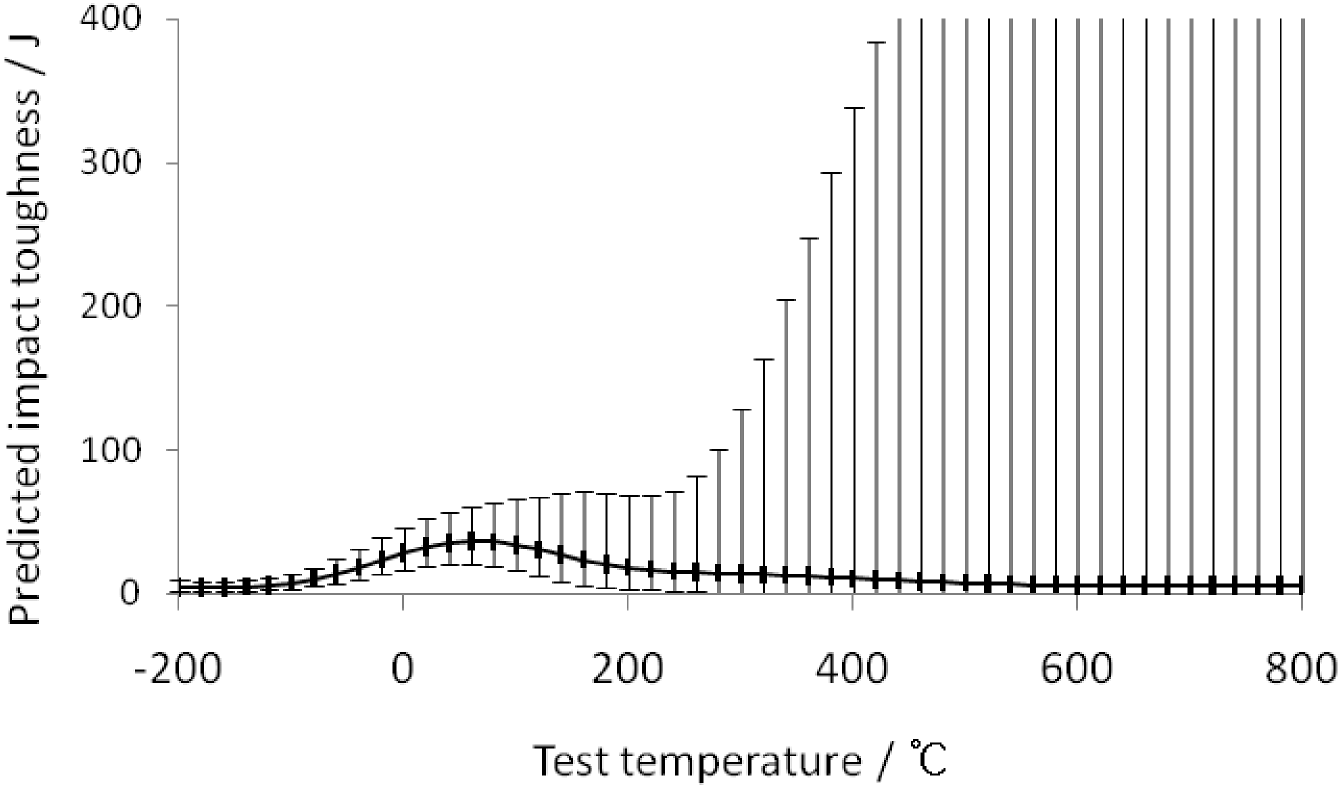
y_{max} = 357 J or 3570 J

Bias in Models



$$y_{min} = 0 \text{ J} \quad y_{max} = 357 \text{ J}$$

Bias in Models



$$y_{min} = 0\ J \quad y_{max} = 3570\ J$$

Bias in Models

The selection of y_{max} → Bias

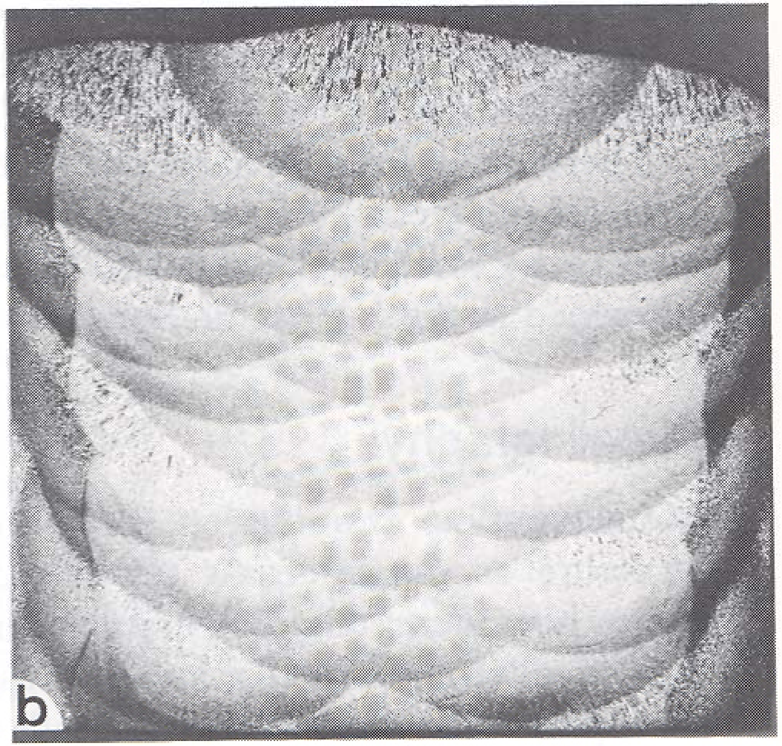
Unjustified !

Alternative way $y' = \ln y$

→ Infinite value of y_{max}

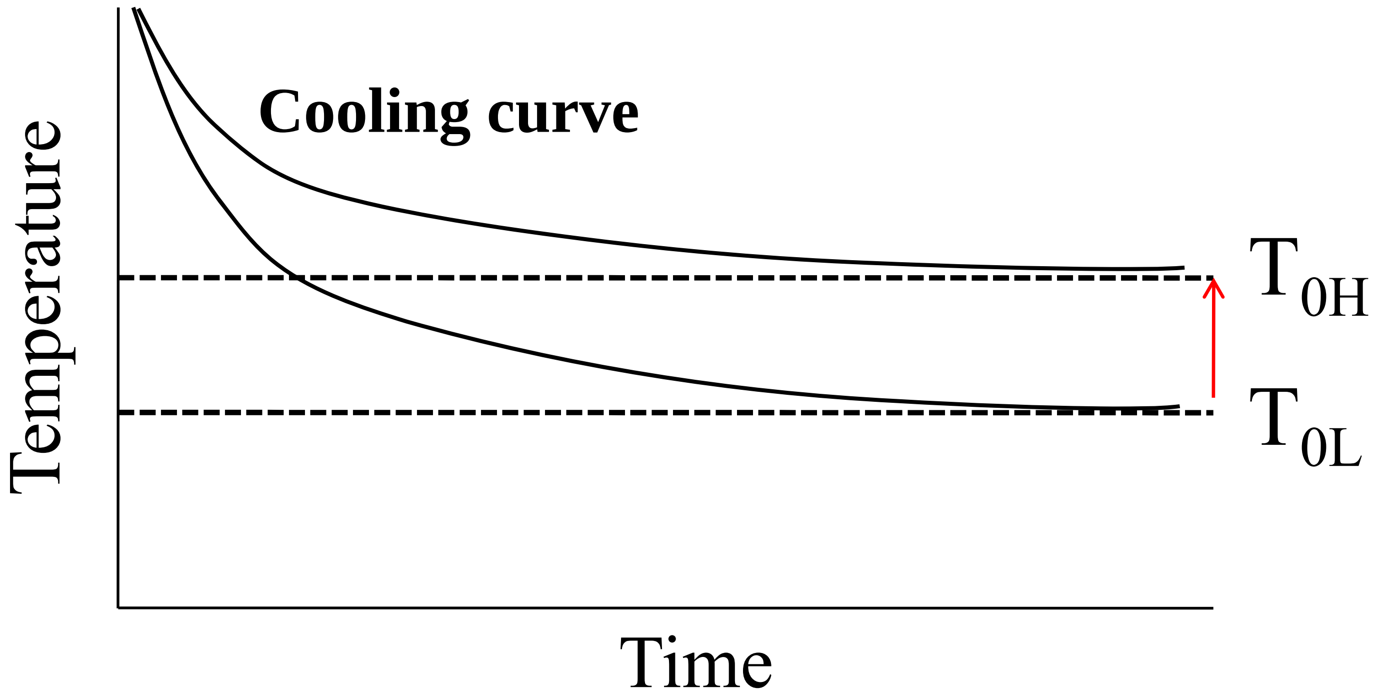
Just use raw toughness value !

Interpass temperature



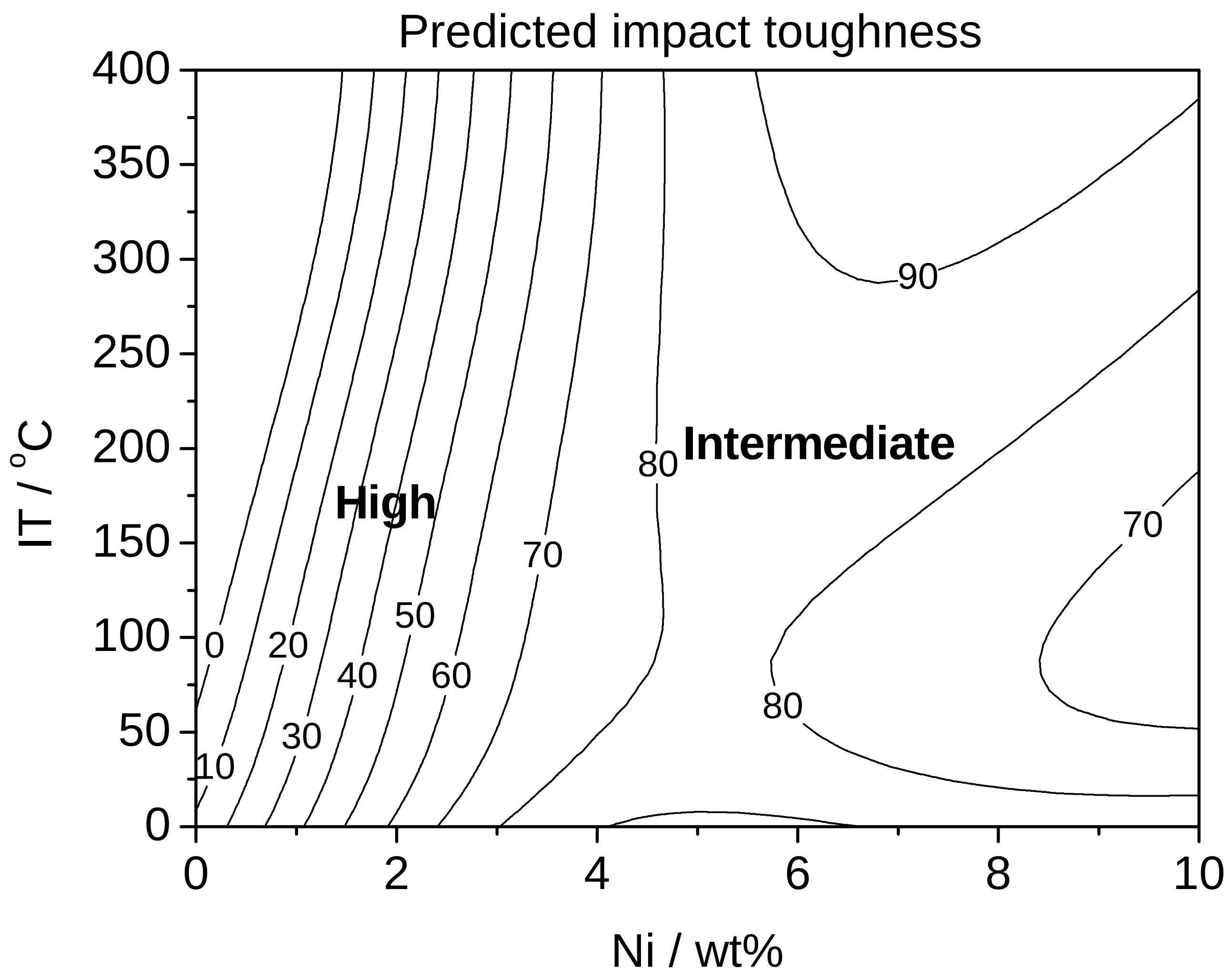
In multi-run welding, the temperature maintained immediately before depositing more metal

Interpass temperature

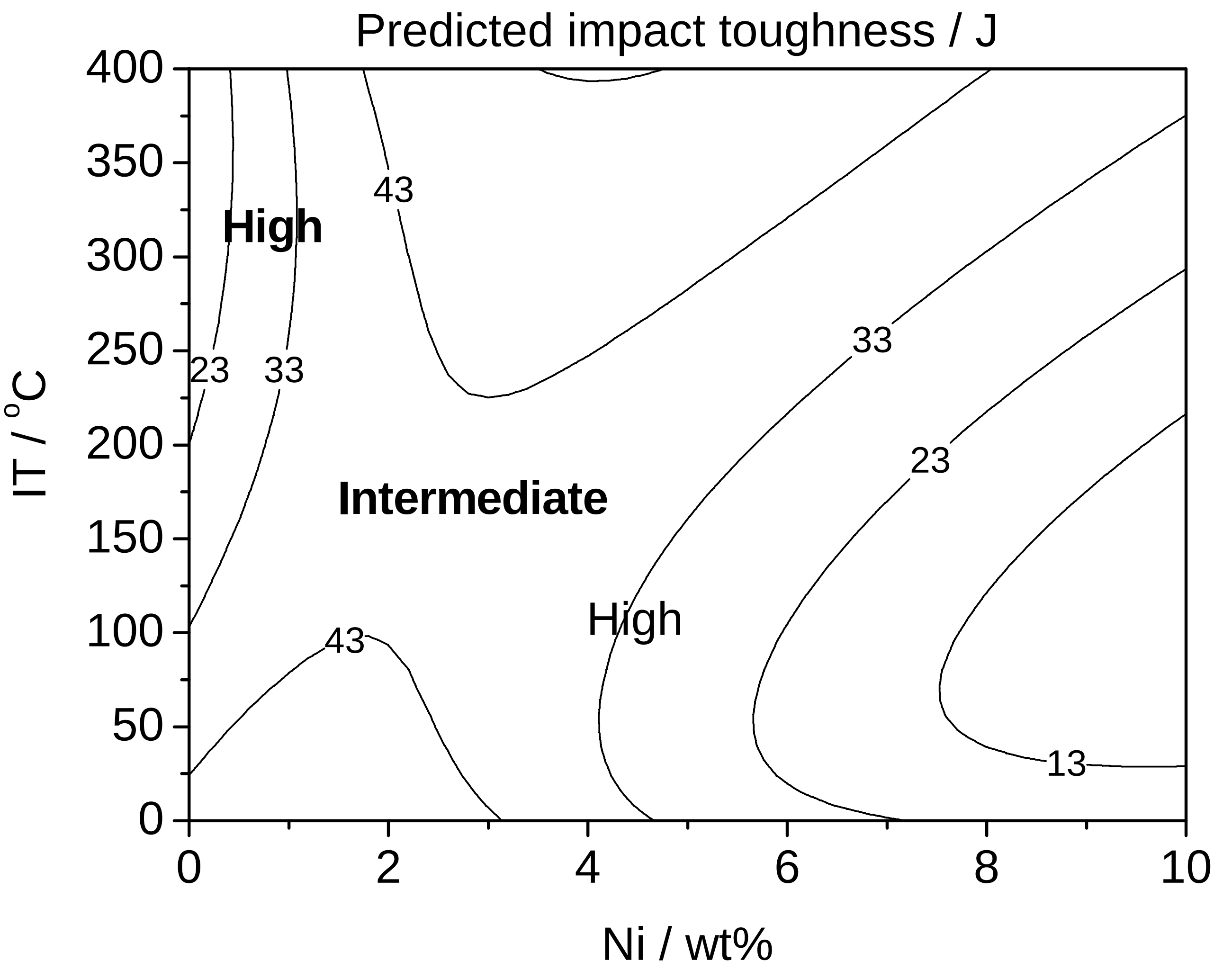


Higher interpass temperature
→ lower cooling rate

Results (0.5Mn)

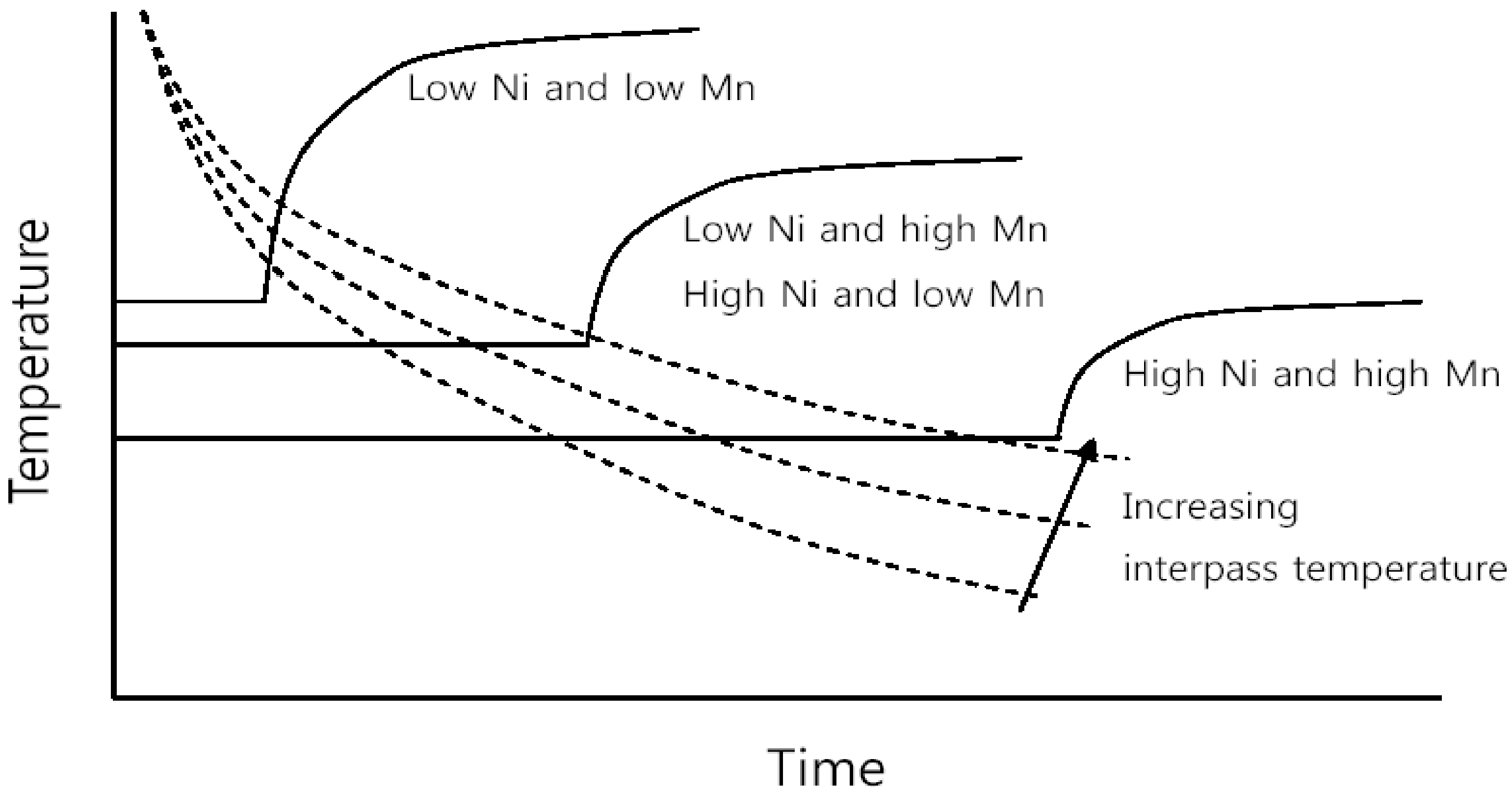


Results (2Mn)



Predicted impact toughness / J
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
IT / °C
Ni / wt%
High
Intermediate
High
43
43
33
23
33
23
13

Discussion (CCT and cooling curve diagram)



Conclusions

Using logarithmic representation of Charpy toughness introduced unjustified bias.

Interpass temperature cause different effect to Charpy toughness with respect to Ni and Mn.

Thank you

Input data (modelling bias)

All elements are in wt% unless otherwise specified.

C	Si	Mn	S	P	Ni	Cr	Mo
0.034	0.27	2.14	0.008	0.01	7.3	0.5	0.62
V	Cu	Co	W	O / ppmw	Ti / ppmw	N / ppmw	B / ppmw
0.011	0.03	0.009	0.005	330	80	120	10
Nb / ppmw	HI / kJ mm^{-1}	IT / ℃	PWHTT / ℃	PWHTt / h	D_{fe}		
10	1	250	20	0	0		

HI: Heat input IT: Interpass temperature

PWHTT: Post-weld heat treatment temperature

PWHTt: Post-weld heat treatment time

D_{Fe}: A variable considering iron diffusion during post-weld heat treatment

Input data (Ni-IT prediction)

All elements are in wt% unless otherwise specified.

C	Si	Mn	S	P	Ni	Cr	Mo
0.025	0.37	0.65 / 2	0.006	0.013	6.6	0.21	0.4
V	Cu	Co	W	O / ppmw	Ti / ppmw	N / ppmw	B / ppmw
0.011	0.03	0.009	0.005	380	80	180	1
Nb / ppmw	HI / kJ mm^{-1}	IT / ℃	PWHTT / ℃	PWHTt / h	D_{Fe}	TT / ℃	
10	1	250	20	0	0	-60	

Calculation of $t_{8/5}$ (Svensson *et al.*, 1986)

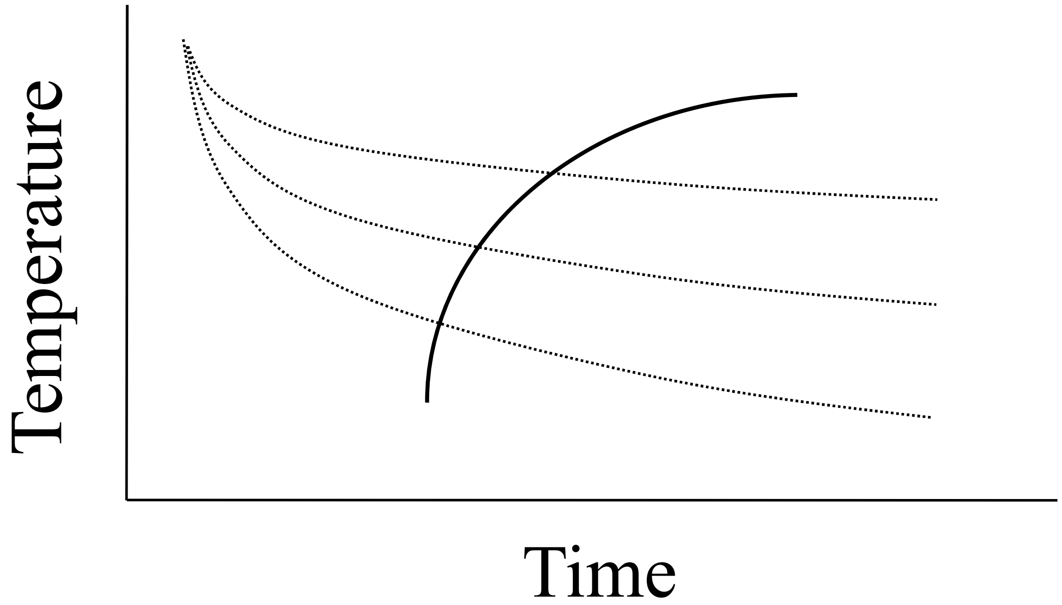
$t_{8/5}$: cooling time from 800 ℃ to 500 ℃

Higher $t_{8/5}$ → lower cooling rate

Under the heat input of 1.53 kJ

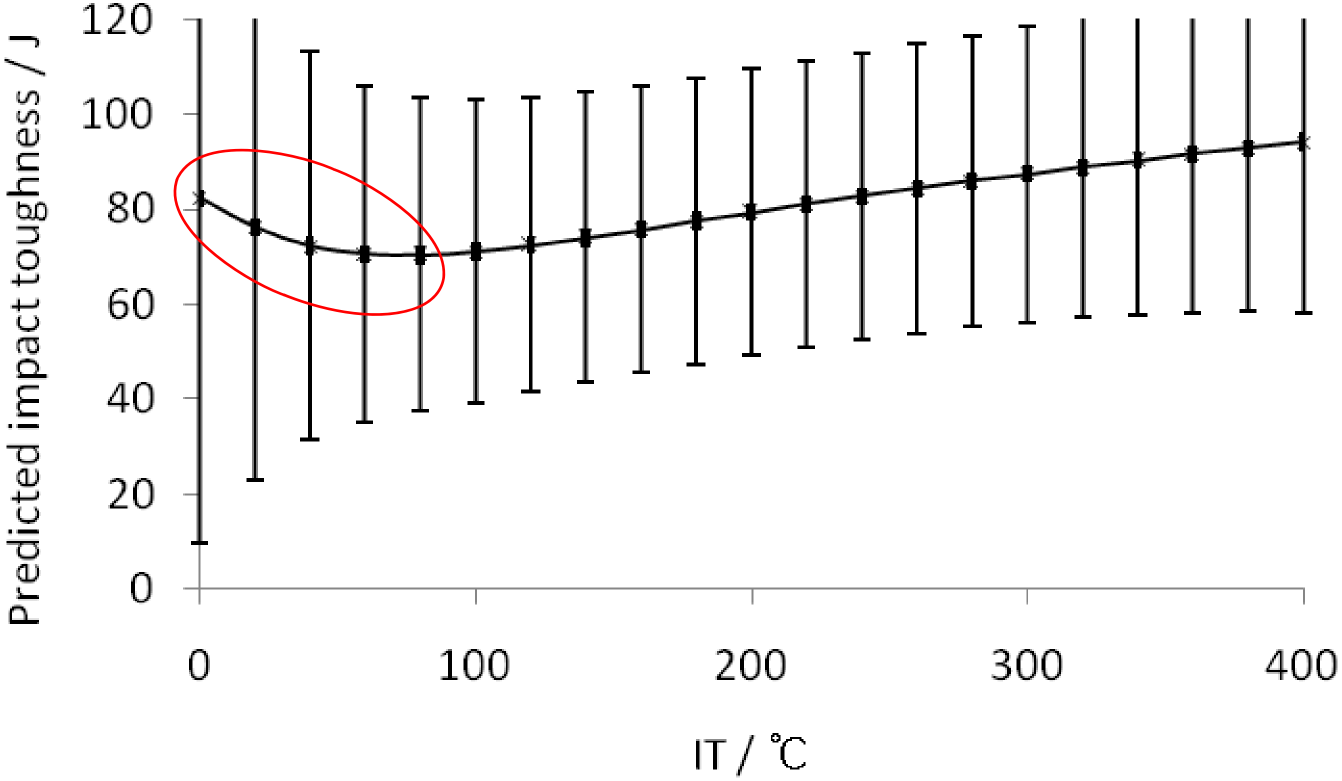
Interpass temperature (℃)	100	200	300	400
$t_{8/5}$ (s)	11.7	16.6	26.3	53.1

Discussion

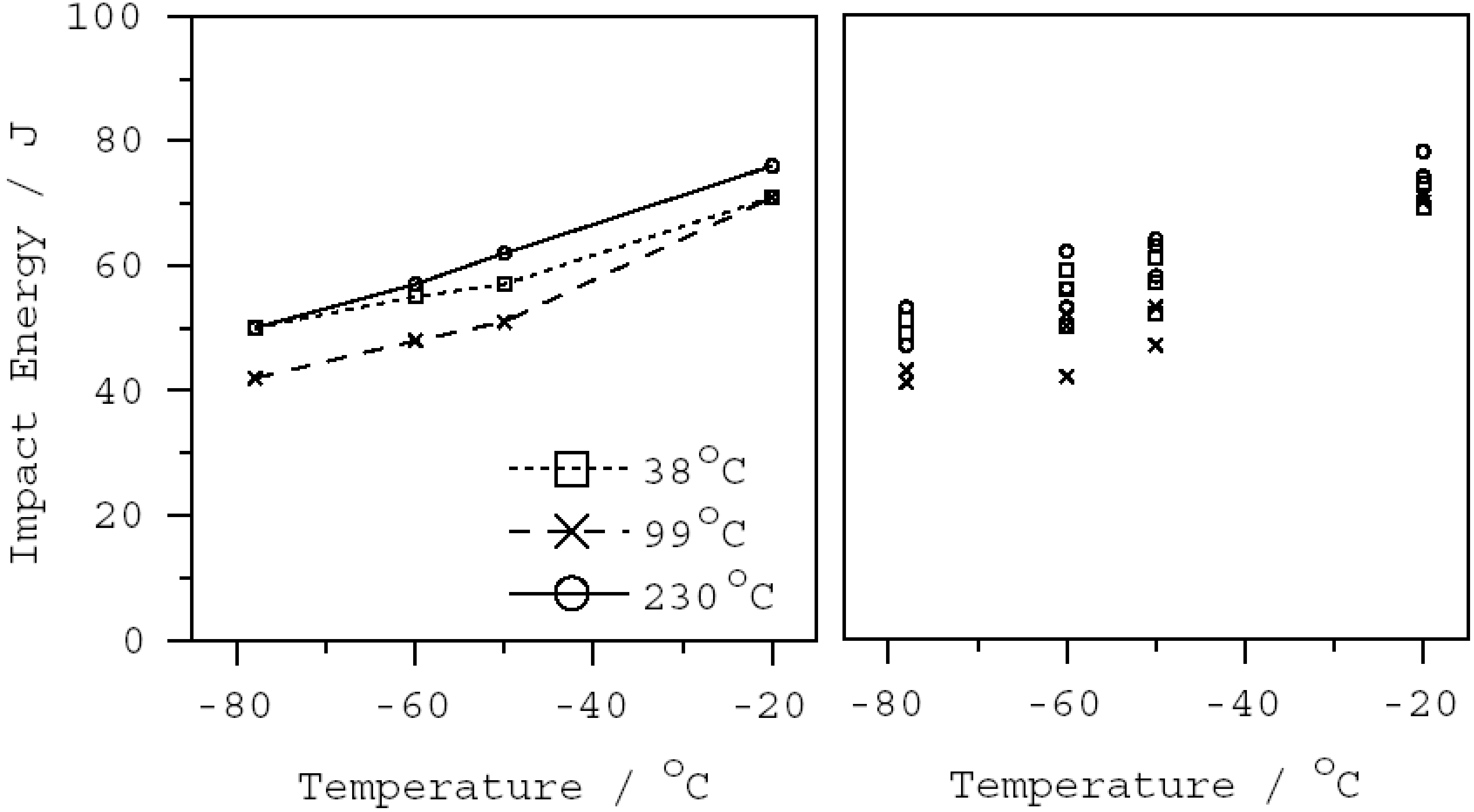


High transformation temperature
→ coarser microstructure (Lord, 1999)

Interpass temperature effect

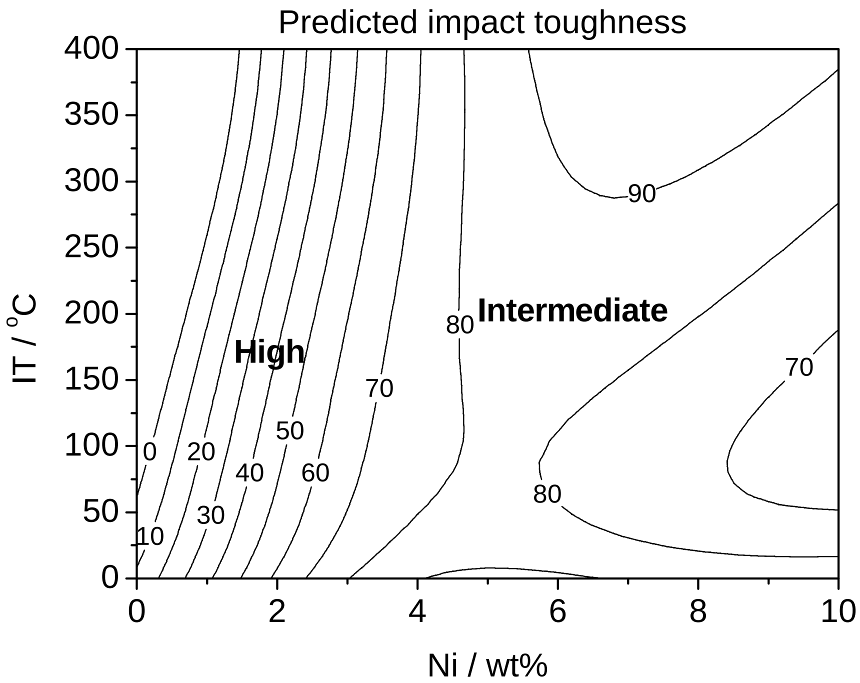


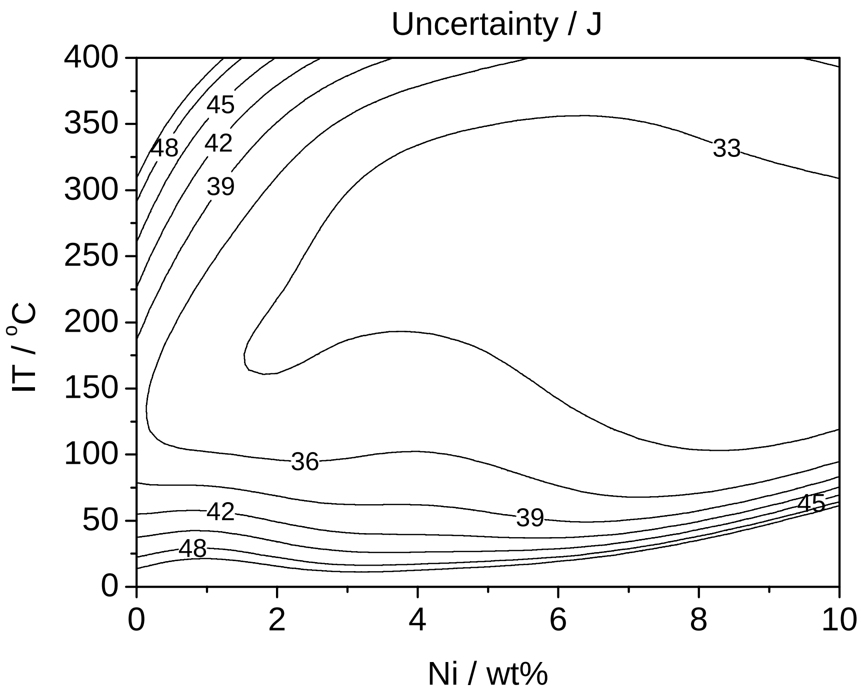
Evidence (Lord, 1999)



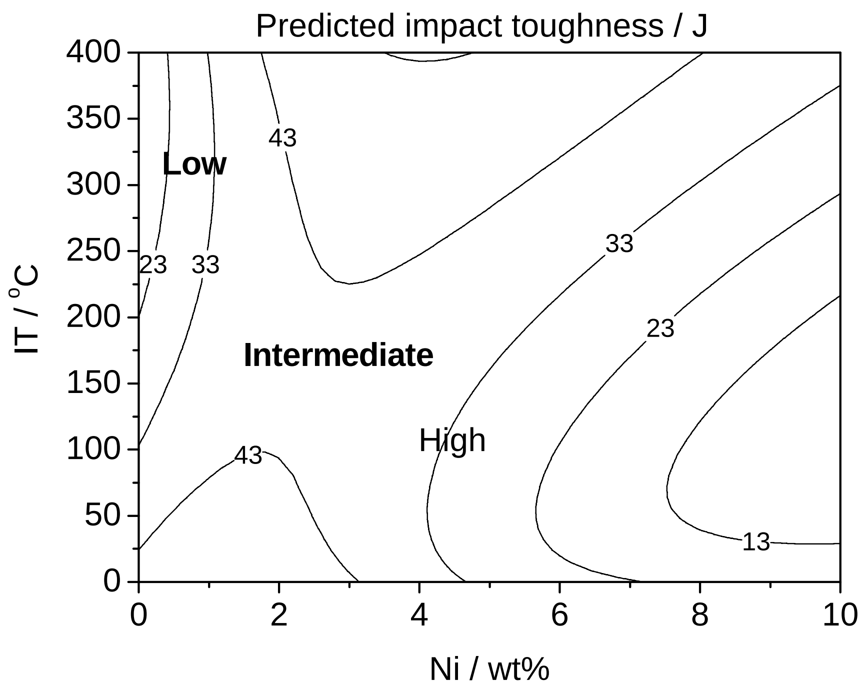
CHV (99 ℃ IT) < CHV (38 ℃ IT)

Results (0.5Mn)





Results (2Mn)



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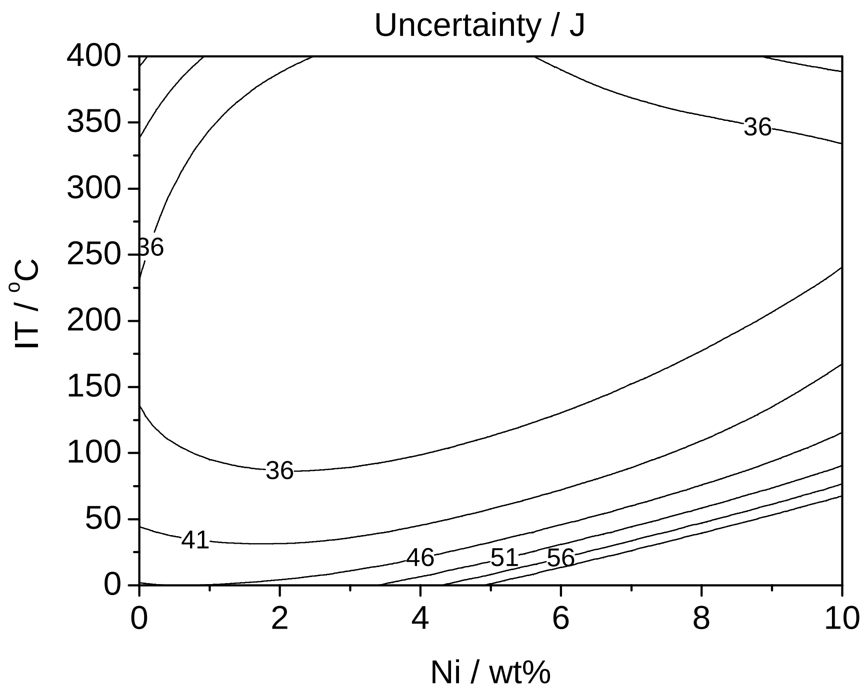
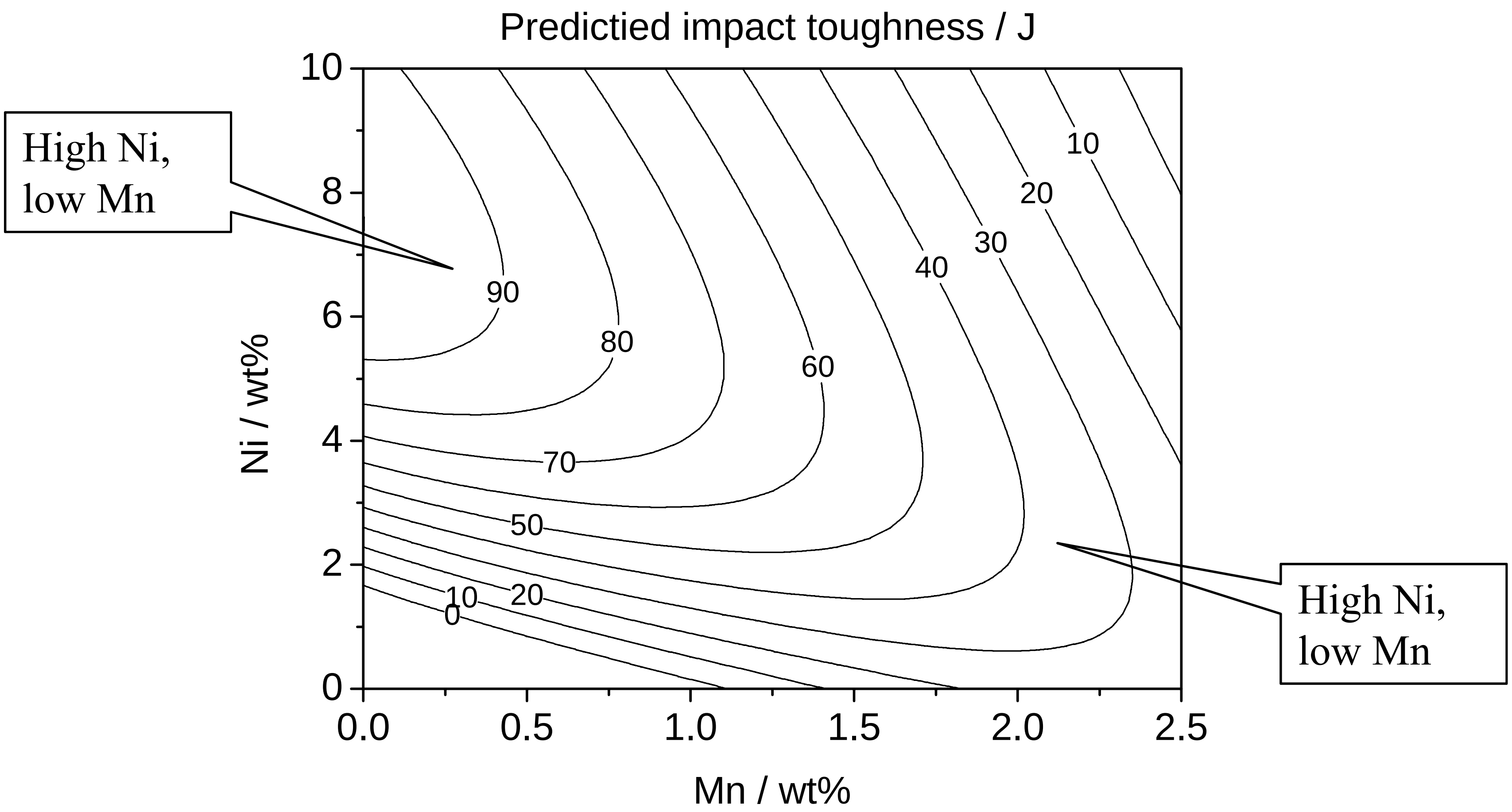


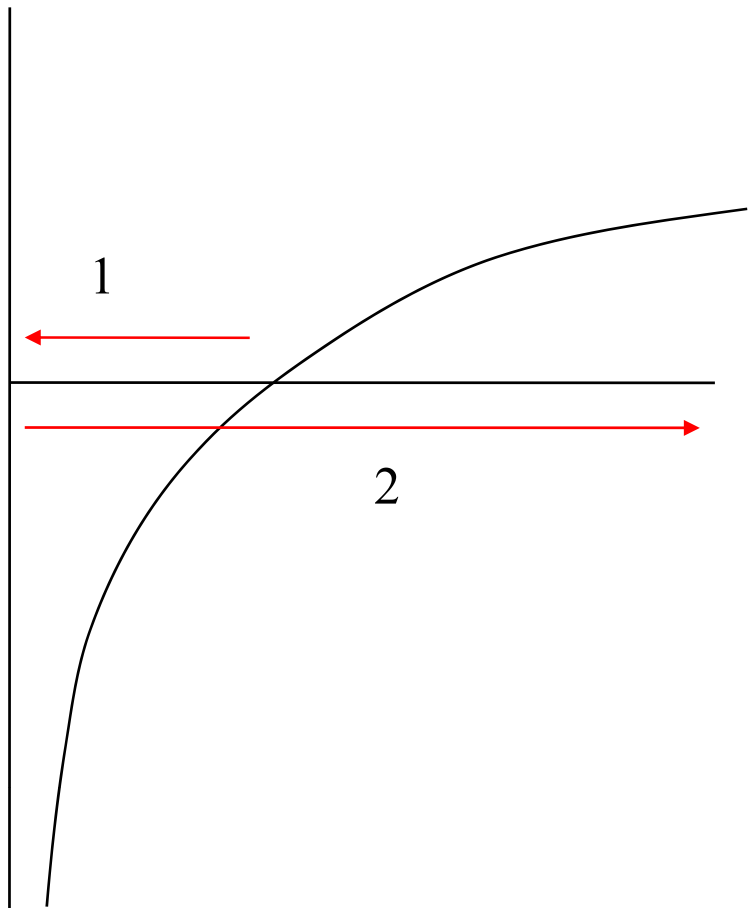
Uncertainty / J
IT / °C
Ni / wt%
36
36
36
41
46
51
56
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10

Discussion (Ni-Mn prediction)



Double logarithms

Yescas's work



This work