Prediction of mechanical properties of hot rolled steel using neural network & iGATE statistical method

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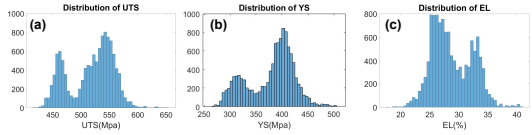
Introduction

The aim of this study is to build reliable data-driven models to predict mechanical properties of hot rolled steel plates. 48 input variables of chemical composition and process parameters were used as input to predict UTS, yield strength and elongation, with a total dataset of 12312. Results using neural network & iGATE statistical methods have been obtained and are compared here. Influential variables are identified.

Data

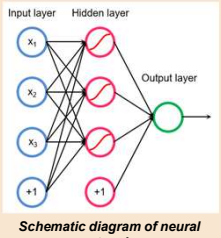
No.	Variable	No.	Variable
1	Slab thickness(mm)	27	Width of rolled plate(mm)
2	Slab width(mm)	28	Length of rolled plate(mm)
3	Slab length(mm)	29	Rolling reduction ratio
4	Temperature before reheating(°C)	30	Slab weight(t)
5	Temperature of heating zone(°C)	31	Weight of rolled plate(t)
6	Total time in heating section(min)	32	C(wt%)
7	Temperature of soaking zone(°C)	33	Mn(wt%)
8	Total time in soaking zone(min)	34	P(wt%)
9	Total time in reheating furnace(min)	35	S(wt%)
10	Rough descaling pressure(Mpa)	36	Si(wt%)
11	Finish descaling pressure(Mpa)	37	Cr(wt%)
12	Rough rolling temperature(°C)	38	Cu(wt%)
13	Rough descaling frequency	39	Ni(wt%)
14	Rough rolling pass	40	Nb(wt%)
15	Rough rolled thickness(mm)	41	Mo(wt%)
16	Rough rolled width(mm)	42	V(wt%)
17	Rough rolled length(mm)	43	Ti(wt%)
18	Inlet temperature in finishing mill(°C)	44	Ceq(wt%)
19	Finish rolling temperature(°C)	45	B(wt%)
20	Finishing descaling frequency	46	Al(wt%)
21	Finishing rolling pass	47	Ca(wt%)
22	Finishing rolled thickness(mm)	48	As(wt%)
23	Finishing rolled width(mm)	49	UTS(Mpa)
24	Finishing rolled length(mm)	50	YS(Mpa)
25	Accelerate cooling temperature(°C)	51	EL(%)
26	Thickness of rolled plate(mm)		

Variables sourcing from rolling mill, total dataset 12312



Histograms of pre-processed data (a)tensile strength, (b) yield strength, (c)elongation

Methodology

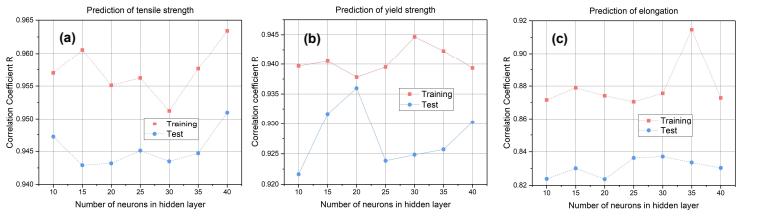


Schematic diagram of neural networks

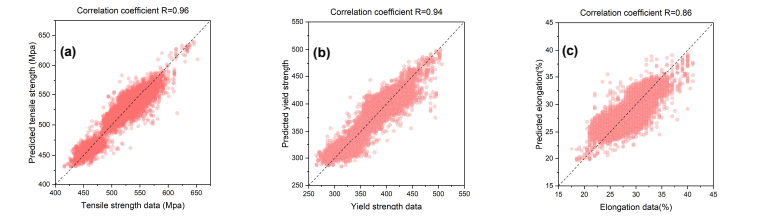
Mathematical expression

$$y = \sum_j \varphi\left(\sum_i w_{ij}x_i + b_j\right) + b$$

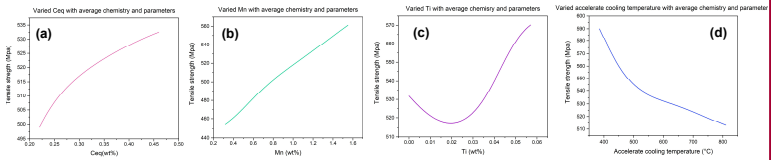
y - output,
x_i - i^{th} input
w_{ij} - weight of x_i in j^{th} neuron in hidden layer
φ - activation function
b_j - bias of j^{th} neuron in hidden layer
b – bias of output layer



Accuracy of neural network prediction vs. number of neuron in hidden layer (a) tensile strength, (b) yield strength, (c) elongation



Comparison of predicted and actual properties (a)tensile strength, (b)yield strength, (c)elongation



Key influential variables for tensile strength predicted by neural network (a) Ceq, (b) Mn, (c) Ti, (d) accelerate cooling temperature (ACT)

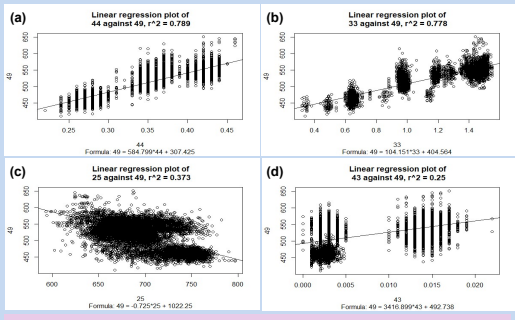
Key variables recognized by iGATE

Tukey-Duckworth test → Wilcoxon rank sum test → Regression plot

IGATE Selected 16 variables as influential to tensile strength

Variable No.	R^2
44	0.789
33	0.778
25	0.373
43	0.25
35	0.177
45	0.169
40	0.156
46	0.139
26	0.071
17	0.055
30	0.046
24	0.036
48	0.009
47	0.009
11	0.003
9	0.003

Influential variables selected by iGATE and corresponding R^2 in linear regression



Regression plot of tensile strength versus (a) Carbon equivalent, (b)Mn, (c)accelerate cooling temperature, (d)Ti

1. Stein, Stefan, et al. "A guided analytics tool for feature selection in steel manufacturing with an application to blast furnace top gas efficiency." *Computational Materials Science* 186 (2021): 110053.

Conclusion:

- Neural network with more than 10 neurons shows its capability to predict UTS and YS of hot-rolled steel plates with a high accuracy.
- Both neural network and iGATE statistical methods identify Ceq, Mn, accelerated cooling temperature and Ti as key influential variables to UTS.
- Our work reveals that chemical composition, geometry of the rolling plate and reheating process are the key variables affecting UTS of hot rolled steel plates, in particular chemical composition plays a dominant role.

Future direction:

- Develop prediction models for impact energy.
- Investigate the influence of key variables on yield strength, elongation and impact energy.
- Apply the developed models with new data.

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