Rationalisation of steel grades and specifications

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Introduction

Aim

Provide an analytical basis for reclassification of steels into a significantly smaller number of grades, to improve recyclability without compromising performance and production costs using machine learning techniques.

Background

According to the World Steel Association, steel production has been on the rise, with an estimated annual production of 1.96 million metric tons in 2021 [1]. However, it is becoming clear that the way we have been producing and consuming steel is not sustainable in the long term. The current linear model is causing a strain on resources, environmental damage, and generating a lot of waste. Research suggests that at least twelve per cent of steel produced does not re-enter circulation [2].

Problem Statement

In the existing steel groups, some of the steel grade's performances are slightly the same in the production phase and differ in composition and processing conditions [3].

Research

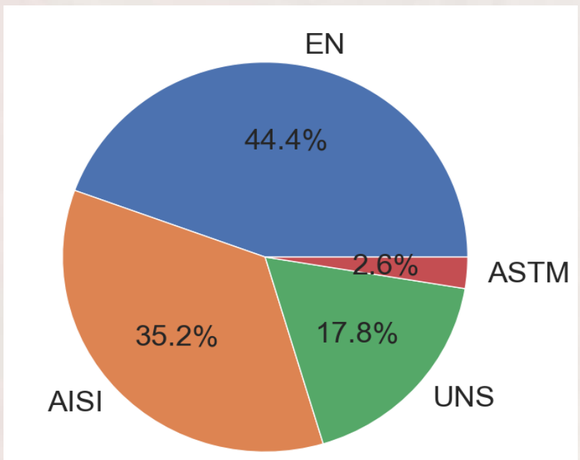
Materials

The present study focuses only on carbon and stainless steels, using the data available on MatWeb.

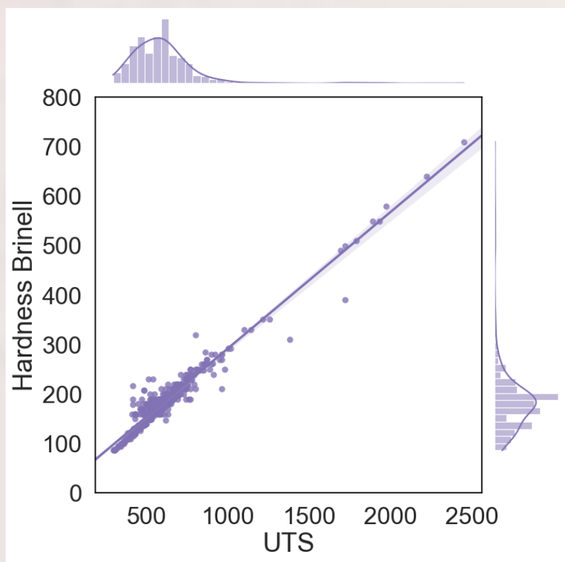
Attribute	Example
Chemical Composition	C, Cr, P, S
Mechanical Properties	Hardness, YS, UTS, Elongation
Processing Condition	Annealing, Quenching
Standard	ASTM, AISI, EN

About Data

Distribution of Examined Grades by Different Standards.



Strong linear relationship between UTS and Brinell Hardness.

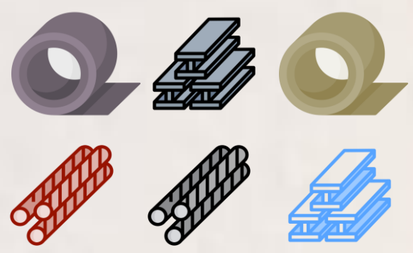


Methodology

This study uses a multistep machine learning approach to categorise steel grades into groups, providing a basis to reduce the number of grades while maintaining property coverage.

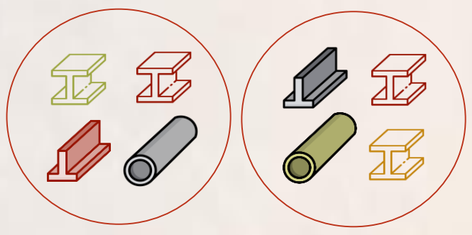
1 Data Analysis

The first step is to explore the data beyond formal modelling or hypothesis testing to uncover potential insights.



2 Classification based on properties

The classification of steel grades is performed using PCA and K-Means based on their dependent properties.

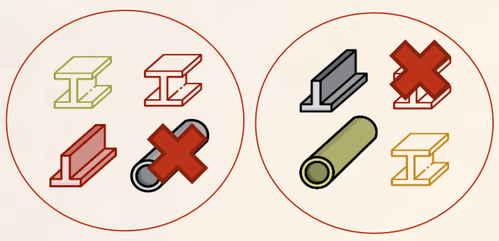


3 Finding overlaps and characteristics

This step evaluates overlaps, gaps, and property coverage among the generated groups.

4 Elimination process

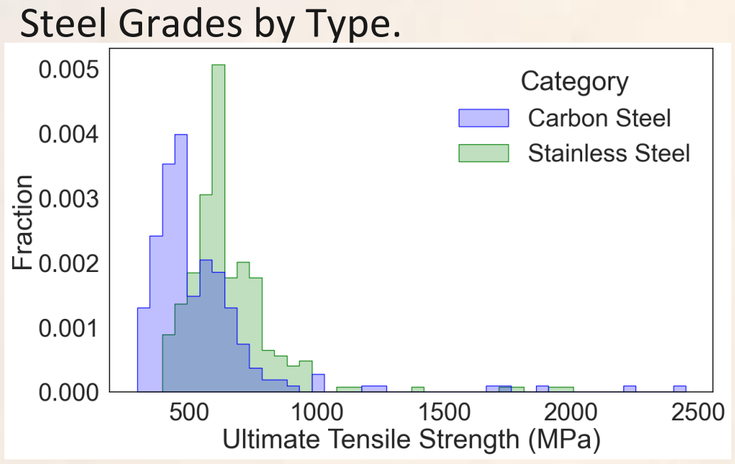
This step propose an algorithmic elimination process called KMEP to minimise grades while ensuring property coverage and fewer recyclability-limiting elements.



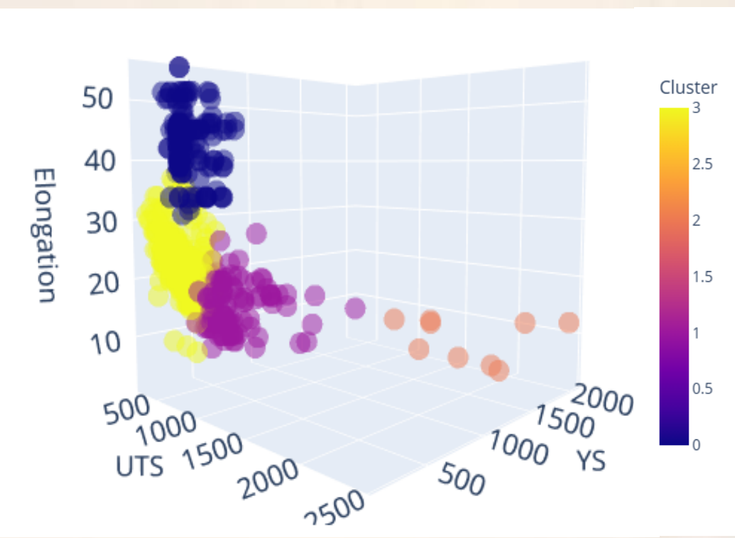
Key Findings

Results

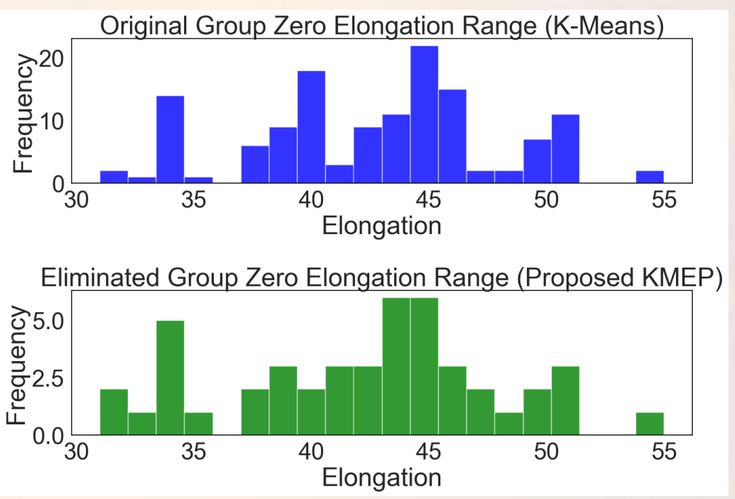
This plot shows the distribution of Ultimate Tensile Strength in Examined Steel Grades by Type.



The performance-based classification of steel grades across generated groups is shown based on key mechanical properties.



The proposed KMEP algorithm maintains property coverage with fewer steel grade options.



Conclusion

The designed KMEP algorithm could successfully reduced steel grades while maintaining property coverage within each group. In Group One, 100 grades were reduced to 25, covering both carbon and stainless steel. The process also replaced grades with fewer recyclability-limiting elements, supporting circular economy principles.

[1]: World Steel Association, “World steel production in 2021,” https://worldsteel.org/wp-content/uploads/2021-World-Steel-in-Figures.pdf.
[2]: J. Bowyer *et al.*, “Understanding Steel Recovery and Recycling Rates and Limits to Recycling,” *Dovetail Partners Outlook*, Mar. 2015.
[3]: Tiwari T, Jalalian S, Mendis C, Eskin D. Classification of T6 Tempered 6XXX Series Aluminum Alloys Based on Machine Learning Principles. JOM 2023;75:4526–37. https://doi.org/10.1007/s11837-023-06025-9.

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