Automated Ladle Pouring in the Steel Industry

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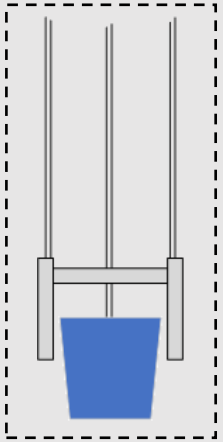
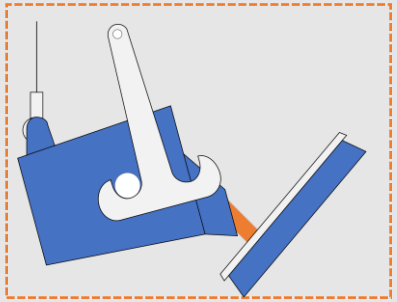
1.1 Process Background

Hot Metal (HM) Charging Gantry Cranes



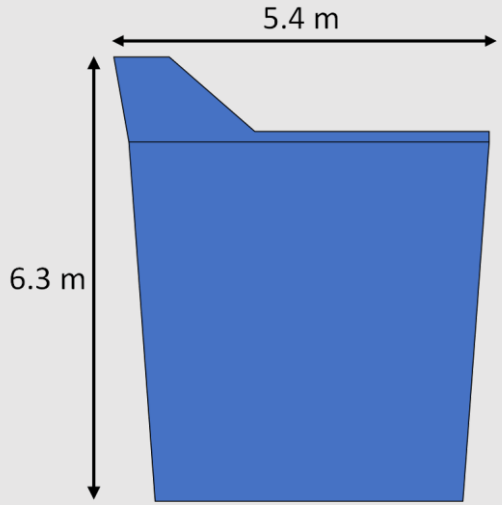
HM Pouring into Basic Oxygen Furnace (BOF) Vessels



BOF Vessel

Hot Metal Ladles

- Holding capacity upwards of 330 tonnes.



Charging Cranes

- Lifting capacity upwards of 500 tonnes.
- In constant operation (upwards of 250 weekly charges).

1.2 Process Drawbacks

Excess flame and fume release:

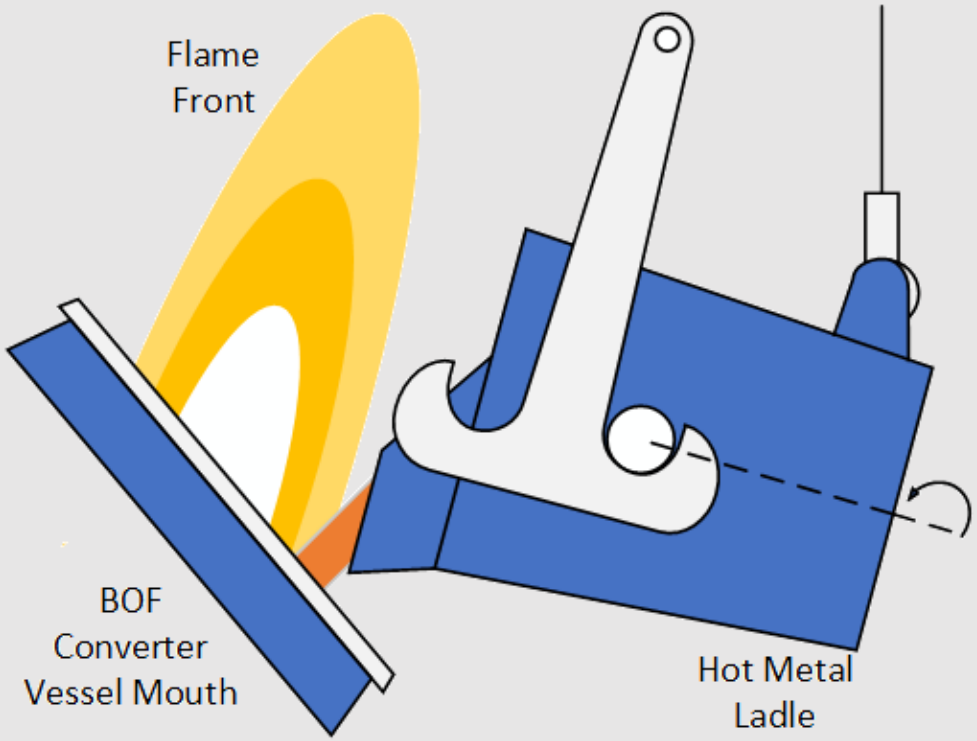
- Damage to surrounding components.
- Environmental constrains.

Excess wear on refractory material:

- Increased refractory replacement frequency.

Safety Constraints:

- Human error element.



1.3 Process Analysis

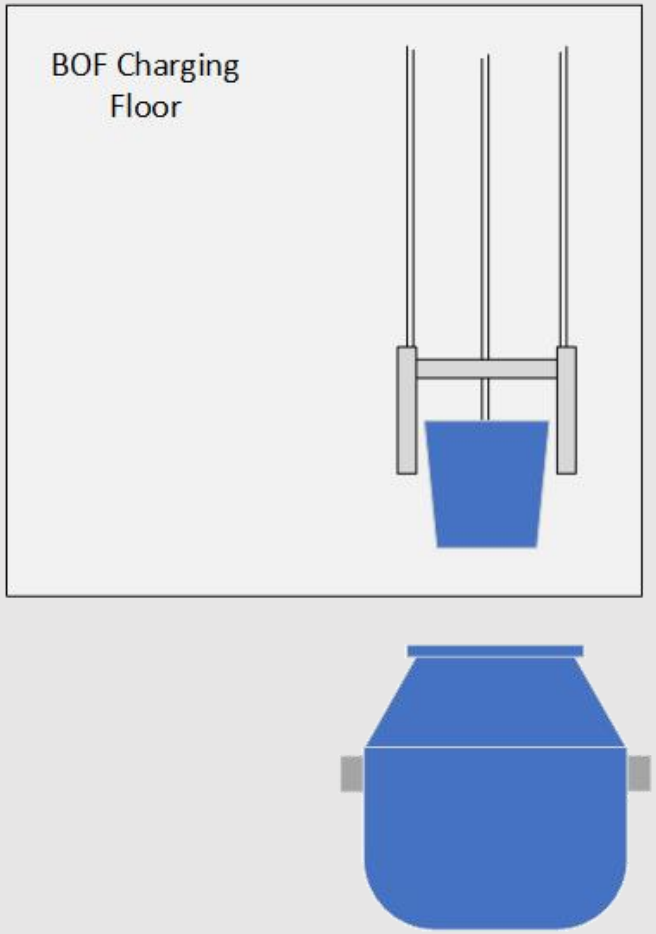
Use of video analysis for:

- Estimation of flame release during pouring.
- Estimation of pouring position.

Comparison of video analysis results with process parameters

- Scrap use and hot metal pouring rate.

1.4 Analysis Camera Locations

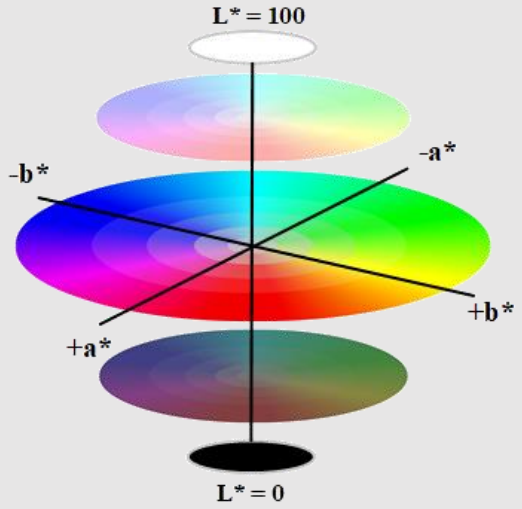


Camera 1

Camera 2

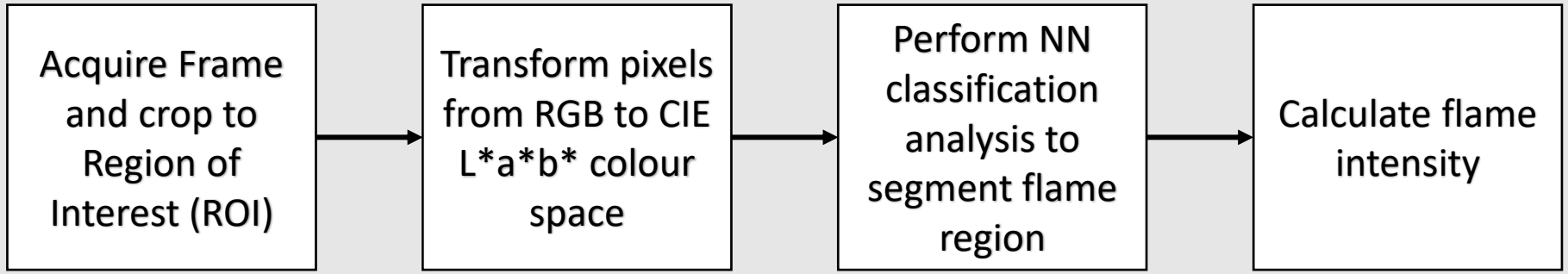
1.5 Colour Image Segmentation

- Means of separating flame image from background.
- CIE L*a*b* colour space for classification of flame.
- Image segmentation performed with Nearest Neighbour (NN) algorithm [1-2].



CIE L*a*b* colour representation

- **L*** = 99; **a*** = 0; **b*** = 0
- **L*** = 90; **a*** = -8; **b*** = 39
- **L*** = 90; **a*** = 0; **b*** = 30
- **L*** = 70; **a*** = 0; **b*** = 0



1.6 Segmentation Results

- 167 Videos of Hot Metal Charging collected and analysed.
- Average flame intensity across each video of Hot Metal Charge used in the analysis.
- Example frame shown, flame intensity = 37754.
- 2 minute pouring video ≈ 3600 frames.

1.7 Analysis Results – Scrap Use

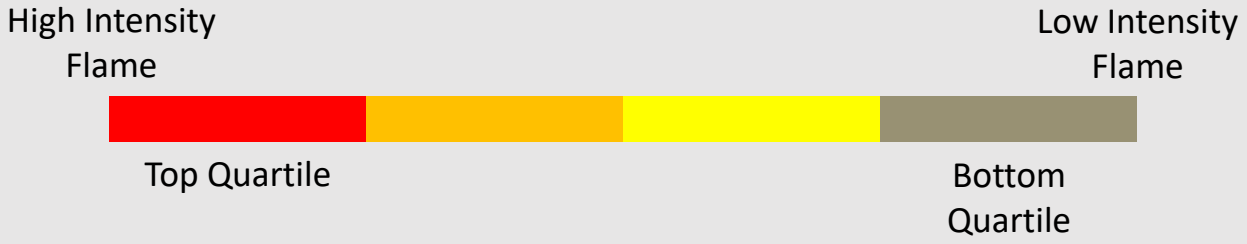
Identification of scrap types contributing to generation of flame

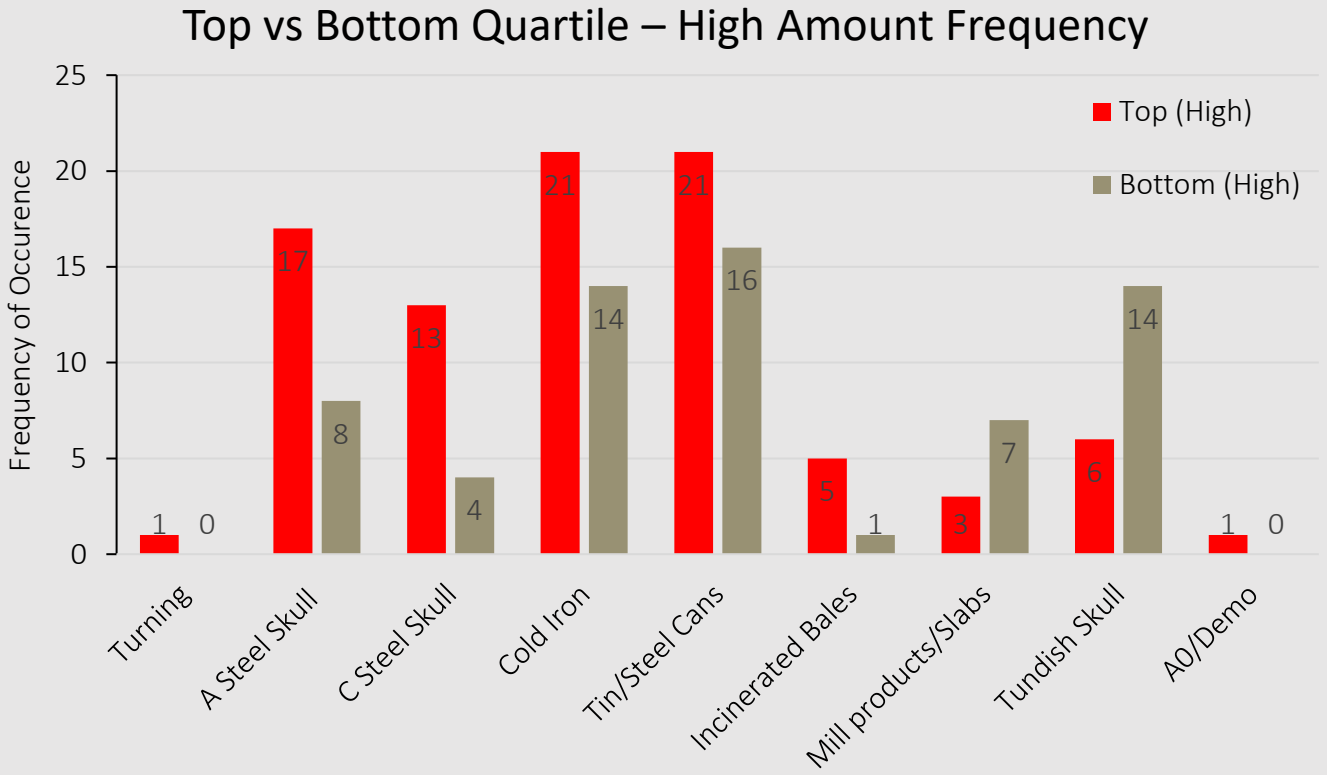
Scrap classified into 9 groups:

- ***Internally sourced scrap***: A Steel Skull, C Steel Skull, Cold Iron, Mill Products/Slabs and Tundish Skull.

- ***Externally sourced scrap***: Turnings, Tin/Steel Cans, Incinerated Bales and A0/Demo.

1.8 Analysis Results – Scrap Classification





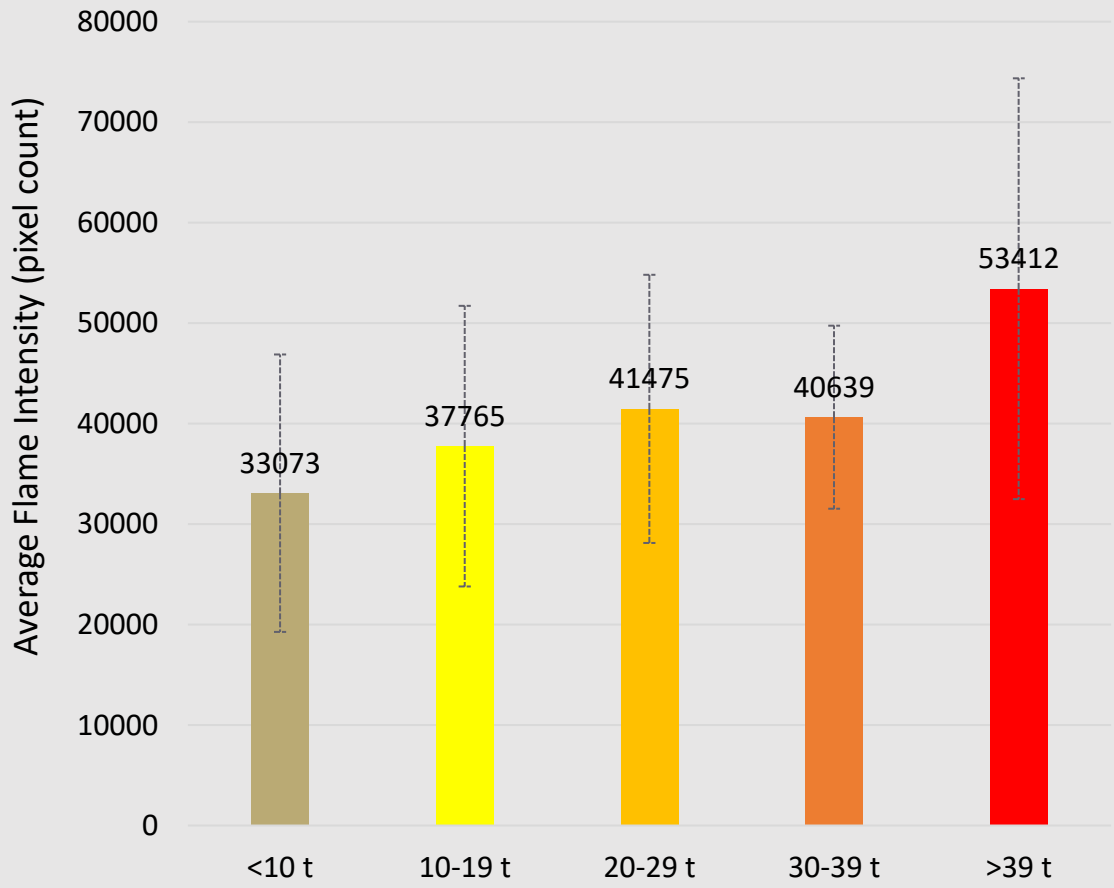
High/Low amount classification values

Scrap Type	Median (t)
Turnings	7
A Steel Skull	9
C Steel Skull	7
Cold Iron	14
Tin/Steel Cans	9
Incinerated Bales	9
Mill Products/Slabs	20
Tundish Skull	12
A0/Demo	2

1.9 Scrap Weight Classification

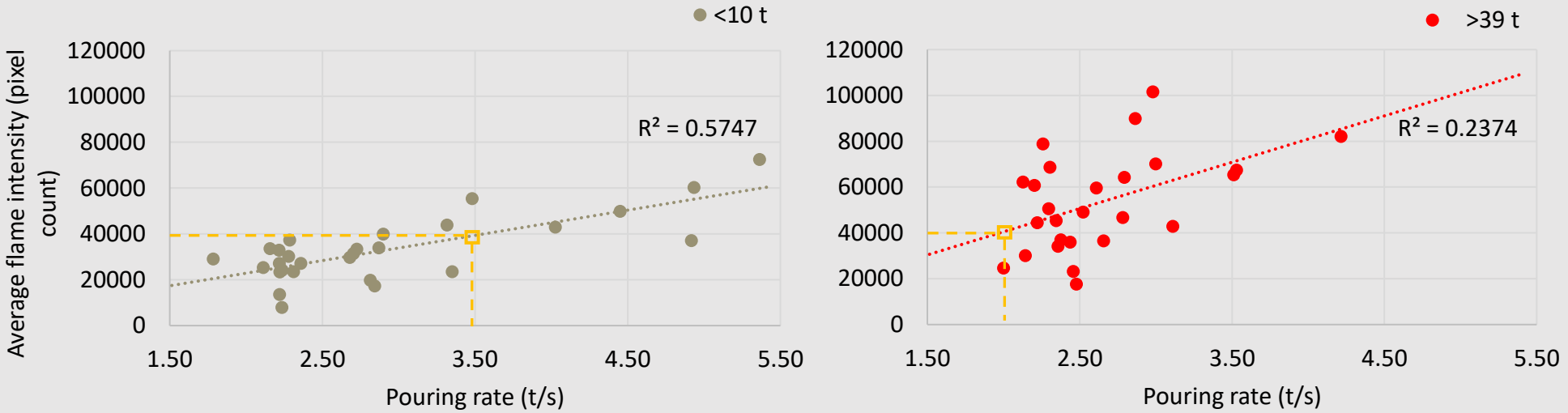
High flame scrap weight classification:

- Sum of **High** amounts of A - C Steel Skulls, Cold Iron, Tin/Steel Cans and Incinerated Bales
- 5 weight groups: <10 t, 10-19 t, 20-29 t, 30-39 t and >39 t.



1.10 Flame Intensity and Pouring Rate

- Relationship between pouring rate, scrap type and average flame intensity.
- Leading to - identification of optimum pouring rates, for different scrap use conditions.

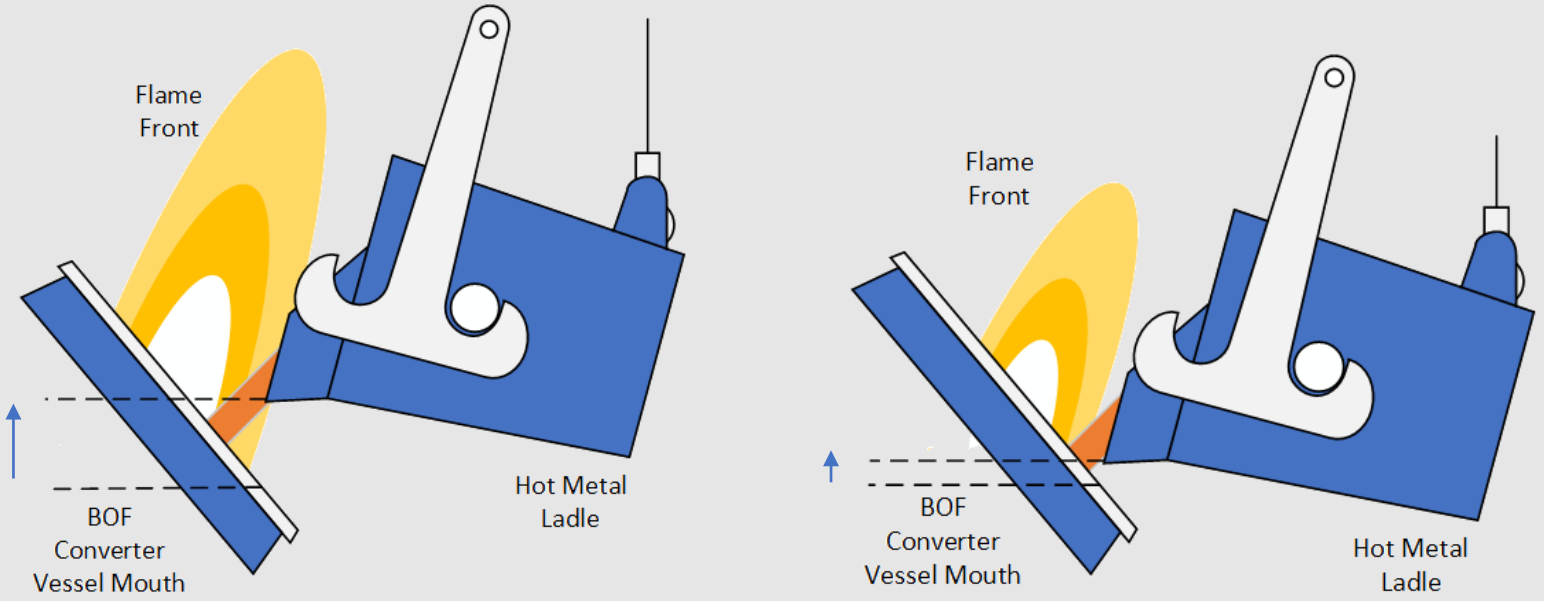


1.11 Current Work - Pouring Position Identification

Use of flame data for high and low flame release classification.

Tracking Ladle position during pouring.

- Ladle feature identification and tracking from video



1.12 Future Work

- "Digital Twin" modelling of Converter Crane/Ladle system.
- Application of position and velocity control to system model.

References:

[1] MathWorks: Color-Based Segmentation Using the L*a*b* Color Space, https://uk.mathworks.com/help/images/color-based-segmentation-using-the-l-a-b-color-space.html, last accessed 2020/11/19.

[2] Cover T., Hart P. Nearest neighbor pattern classification. IEEE transactions on information theory, 13(1), 21-27 (1967).