Heraeus

Electro-Nite

SUSTAINABILITY CASE STUDY

CELSA Group Green Steel: Every Degree Counts

A STUDY INTO THE IMPLEMENTATION OF CASTEMP SUPERHEAT A CUTTING-EDGE TECHNOLOGY TO IMPROVE CASTING EFFICIENCY AND REDUCE CO2.

05/04/2023

Steelmakers are constantly looking for ways to reduce carbon emissions due to steelmaking contributing 7% to global CO2 output. The quickest, most cost-effective way of reducing environmental impact is through a reduction in the temperature steel is cast at, continuous temperature "CasTemp" can help.

INTRODUCTION

It is critical in the current climate that steelmaking is as efficient as possible, current practises must be challenged to ensure they are sustainable long term. We looked for answers to the following questions:

Are you in control of casting Superheat? How accurate is your Superheat? How much Superheat do you cast with on average? Superheat must be benched marked to be challenged.

How much energy can you save by reducing casting Superheat? How do you define your secondary steel send temperatures and how often do you hit this target? Is this target dynamic?

Once Superheat is reduced, how does this product quality improve? What process benefits are seen? What is the value of this energy?

SUMMARY

Celsa UK adopted CasTemp in 2014 and the steelmaking process was benchmarked to fully understand the thermal profile of the casting process with continuous temperature, this also included analysis of secondary steel making's ability to successfully hit send temperatures, this investigation allowed for small calculated incremental reduction of casting Superheat. The Superheat adjustments were then analysed, allowing for changes in casting speed and secondary cooling to optimise the process. This process was repeated multiple times with each repeat analysed for process impact.

RESULTS

7°C

Celsa UK has demonstrated a reduction in casting temperature of 7°C by consistently using CasTemp as a means of controlling casting speed.

$<CO_2$

This energy saving equates to a reduction of 1515 tonnes CO2, with a financial gain in 2022 of circa. £1M through energy saving and carbon credits.

85%
REDUCTION

Superheat reduction doubled the tonnes cast between strand breakouts, as well as reducing product scrap due to defects by ~85%.

CONCLUSION

Steel makers using spot measurement for temperature control on continuous casting machines are casting with too much Superheat. Adopting CasTemp Superheat have been proven to reduced casting temperature, and therefore save energy and significantly reduce costs.

CELSA Group Green Steel: Every Degree Counts

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Summary

Every tonne of steel melted takes a specific amount of energy. Any decrease in temperature at the continuous caster saves energy during steel processing, resulting in cost and CO2 savings.

Through the use of continuous tundish temperature measurement, the requested temperature from the secondary steel making stations have been lowered over several years with the benefits being monitored and proven.

Combining continuous temperature and world class liquidus measurement to give accurate Superheat has allowed further improvements to been realised. Access to big data has allowed confidence to continue to strive for process improvements through reduction in Superheat at the continuous caster.

Introduction

The UK steel industry is an important sector of the country's economy, providing employment and contributing to the growth of various industries. However, the steel industry is also a significant contributor to carbon emissions, which has a negative impact on the environment. In light of the global push to reduce emissions and combat climate change, the UK steel industry must take steps to become as efficient as possible. This will not only reduce its carbon footprint but also enable it to compete more effectively on a global scale.

In recent years, the demand for sustainable and environmentally-friendly products has increased, and the steel industry must respond to this demand. The production of steel releases large amounts of carbon dioxide into the atmosphere, and reducing these emissions is essential for the industry to remain competitive. The use of new technologies, such as electric arc furnaces, and the implementation of energy-efficient processes can help reduce emissions and increase efficiency.

Additionally, the use of recycled steel can also reduce the amount of energy needed to produce steel, thereby reducing emissions.

Furthermore, the UK steel industry can take advantage of the growing demand for low-carbon steel products. With the increasing awareness of the impact of carbon emissions on the environment, many companies are looking to reduce their carbon footprint by using low-carbon steel in their products. The UK steel industry can tap into this market by investing in the production of low-carbon steel, which would increase its competitiveness and contribute to the reduction of emissions.

The UK steel industry must become as efficient as possible to reduce its emissions and remain competitive in a rapidly changing global market. The adoption of new technologies, increased use of recycled steel, and investment in low-carbon steel production are all strategies that can help achieve this goal. By reducing its carbon footprint, the UK steel industry can play a vital role in the fight against climate change and contribute to a more sustainable future.

Celsa Group

CELSA Group™ is the largest circular supply chain in Europe and the second largest recycled steel producer in Europe and the most vertically integrated manufacturer of long steel products, upstream through recycling hubs spread across Europe to recover scrap and other materials, and downstream through steel transformation companies. The origins of the group date back to the 1960s, as Compañía Española de Laminación, S.A., in Castellbisbal, to manufacture rebar for the construction industry. In 1977, the first electric melting furnace was inaugurated in Sant Andreu de la Barca, at which time the company began to manufacture steel autonomously and with the state of the art. Over the years, CELSA Group™ became a national benchmark in the steel industry and grew by acquiring companies in the sector. Nowadays, it has 7 melt shops, 10 rolling mills, 45 recycling plants and 120 centres around the world and comprises Barna Steel (including CELSA Spain and CELSA France), CELSA UK (United Kingdom and Ireland), CELSA Nordic (Norway, Sweden, Finland, and Denmark) and CELSA Huta Ostrowiec (Poland). All are vertically integrated, so are present throughout the value chain and are engaged both in the tasks of recovering, collecting, and treating scrap, an in increasing the added value of the final product through the transformation into steel wire and high-quality calibrated bars.

Celsa Group is a European producer of recycled steel and the largest circular supply chain in Europe. The company uses electric arc furnaces to recycle ferrous scrap and produce steel, which is highly valued in a global market increasingly driven by decarbonization goals. Celsa Group is committed to becoming a net positive company by 2050, contributing to the mitigation of climate change and depletion of natural resources. The company has reduced its CO2 emissions (scope 1 and 2) by 22% since its decarbonization plan in 2015 and produced 6.6 million tonnes of steel in 2021. Celsa Group's circular production system avoids the extraction and consumption of natural resources, water, and electricity, as well as reducing CO2 emissions into the atmosphere.

Celsa Group is a founding member of the newly formed Global Steel Climate Council who are a mission statement: Accelerate Progress to Reduce Emissions - Celsa have the technology to cut steel emissions by 70% today. The GSCC is leading the way to make this the standard for all steel.

Historically, steelmakers have produced steel using an extractive, blast furnace process from mined coal and iron ore. In the steel industry, this is referred to as an “integrated process.” However, in recent decades, hundreds of steelmakers have invested in Electric Arc Furnace (EAF) technology, a circular process that uses recycled steel as the primary input and produces significantly lower carbon emissions.

Steel industry stakeholders and global policy makers are currently considering a dual standard for emissions—one standard for steel made from extractive production processes and another for steel made from circular processes. Having a dual standard that rewards high-emission steelmakers, harms the environment and disincentivizes steelmakers from changing their production process. Celsa Group already have the technology to reduce carbon emissions, now our mission is to lead the way toward a truly effective low-emission steel standard that accurately counts carbon emissions – not production methods.

Background of Celsa and Heraeus Electro-Nite relationship

Heraeus Electro-Nite have been a long-standing partner with Celsa UK, being their partner of choice for all temperature and sampling needs since their acquisition of Celsa UK steel plant in 2005. This paper shows the implementation of CasTemp at Celsa UK in 2014 and the benefits it has brought, then the following implementation of CasTemp Superheat in 2021 at Celsa UK. The benefits from CasTemp Superheat implemented at Celsa Spain will also be analysed. Finally, an investigation into the activity of CasTemp through the rest of the Celsa Group and extrapolate benefits found in this paper across the Celsa Group.

CasTemp Superheat Background

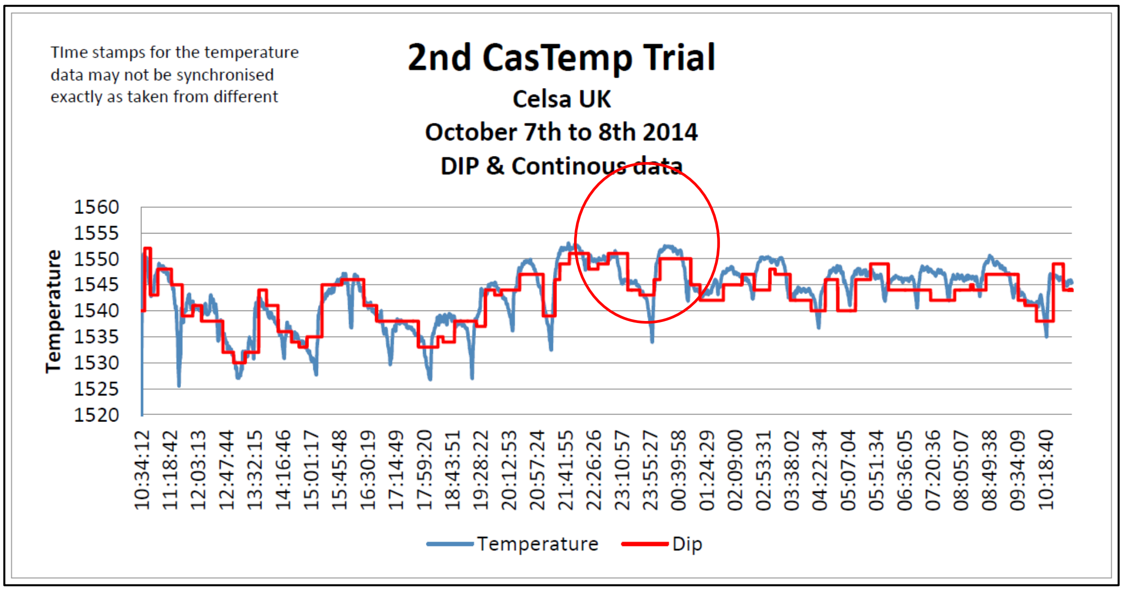
CasTemp Superheat is a combination of continuous tundish temperature (CasTemp) and a direct in situ liquidus measurement (CasTip) to give a continuous Superheat measurement (Tundish temperature – Liquidus arrest = Casting Superheat). This product combination has previously been analysed for its validity generating the following conclusion: "Good knowledge of casting Superheat in modern continuous casting requires accurate and relevant measurement of the tundish temperature and an accurate liquidus. Pikkarainen and his friends showed that there is a correlation between low superheat and final product quality in their practical studies. Casting with lower superheat enables sedimentation of globulites and negative segregation in the slab central areas. [a]. Moreover, Li and his friends proved that in billet grades with the increase of superheat, the grade of central segregation, central porosity and central pipe will increase as well. [b]

A "through the wall" continuous temperature measurement provides a superior means of following this trend than the traditional immersion thermocouple spot measurement (reduced ΔT). As it has not been possible up to now to practically assess the liquidus of steel, there has been little incentive to review the method of liquidus determination, resulting in a range of equations in use, some of which share a common lineage; but giving very different values for the same composition. A new liquidus sensor has been developed for the tundish, based upon the long established solidification chamber measurement principle; and has been verified against a newly developed liquidus model, using thermodynamic data in its derivation. This combination provides significantly improved assurance as to the validity of the liquidus value (reduced ΔL) particularly at higher carbon levels, and allows it to be combined with the continuous temperature measurement to provide a dynamic superheat determination of consequent reduced ΔSH, integrated into a single measurement system. Wireless technology to deliver the measurements improves reliability and accuracy. A steel plant is already exploiting dynamic superheat to automate casting speed, but can see further advantages through delivering an improved visualisation package to aid operator decision making."[1]

Celsa UK – Application of CasTemp

In 2015 Celsa UK trialled continuous temperature in the tundish and were successful in adopting the technology within a few weeks of initial tests, totally eliminating the use of manual spot temperature measurement. Figure 1 shows a very early set of trial data from the UK plant, clearly showing the differences between continuous measurement and spot measurement.

Figure 1



An example of the differences seen is shown in Figure 1b – this data is from another plant.

Figure 1b

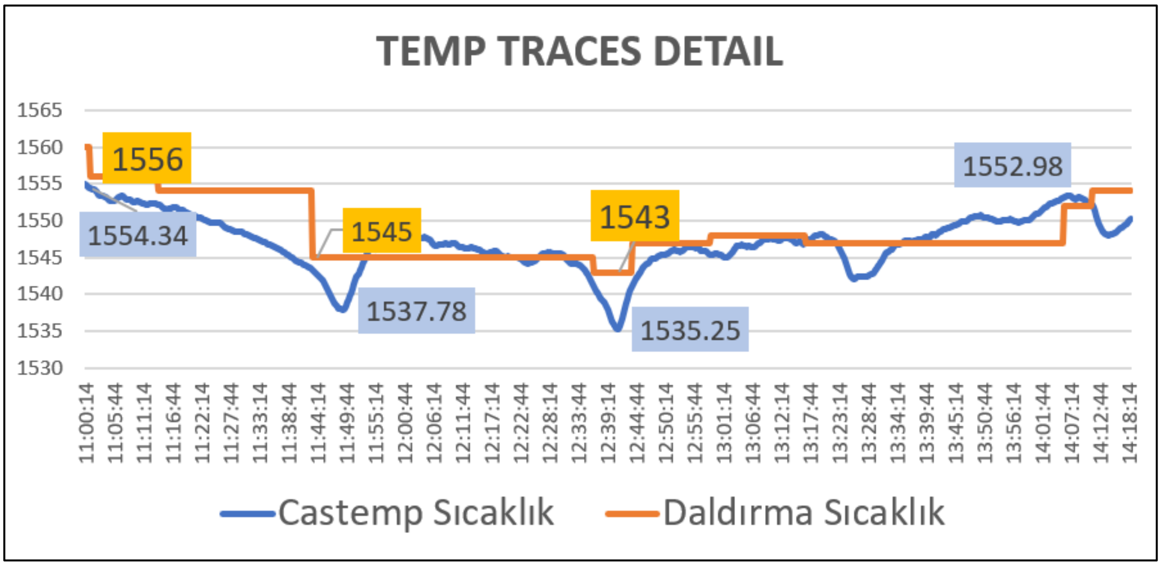
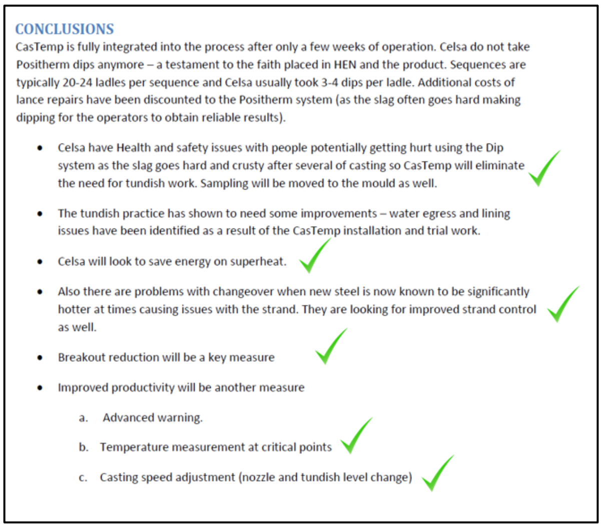


Figure 2 shows the trial conclusions from 2015, with additional annotation of green ticks in 2022 to show the conclusion that have continued to be achieved.

Figure 2


CONCLUSIONS

CasTemp is fully integrated into the process after only a few weeks of operation. Celsa do not take Positherm dips anymore – a testament to the faith placed in HEN and the product. Sequences are typically 20-24 ladles per sequence and Celsa usually took 3-4 dips per ladle. Additional costs of lance repairs have been discounted to the Positherm system (as the slag often goes hard making dipping for the operators to obtain reliable results).

- Celsa have Health and safety issues with people potentially getting hurt using the Dip system as the slag goes hard and crusty after several of casting so CasTemp will eliminate the need for tundish work. Sampling will be moved to the mould as well.
- The tundish practice has shown to need some improvements – water egress and lining issues have been identified as a result of the CasTemp installation and trial work.
- Celsa will look to save energy on superheat.
- Also there are problems with changeover when new steel is now known to be significantly hotter at times causing issues with the strand. They are looking for improved strand control as well.
- Breakout reduction will be a key measure
- Improved productivity will be another measure
  a. Advanced warning.
  b. Temperature measurement at critical points
  c. Casting speed adjustment (nozzle and tundish level change)

Celsa UK – Health and safety benefits

Man-less casting is a growing topic in steel production, with strong commitments to remove operators from steel. Continuous temperature moves tundish temperature from being an operator activity to man-less. Prior to continuous temperature Celsa UK took on average 20,000 spot measurement dips per year on the casting machine, taking an estimate of 1 minute per dip this equated to 330 hours of an operator placed in a high-risk zone to take manual spot dips and freed up the operator for other tasks. Continuous temperature has removed 100% of this high-risk activity making temperature measurement man-less.

Celsa UK – Temperature reduction

Celsa UK casting machine is supplied with molten steel from a single EAF station to a single LF station before arriving to be cast. Celsa UKs continuous caster operates by the caster requesting a temperature from the LF. The challenge at the LF is then to get as close to this requested temperature as possible. Historical data shows that the LF station is proven to have excellent temperature control, on average in 2021 the difference between requested temperature and LF post temperature was 0.6°C, with a SD of 1.8°C. This gives Celsa UK to confidence to make small incremental changes to the requested temperature knowing on average the LF will meet their expectations.

Figure 3

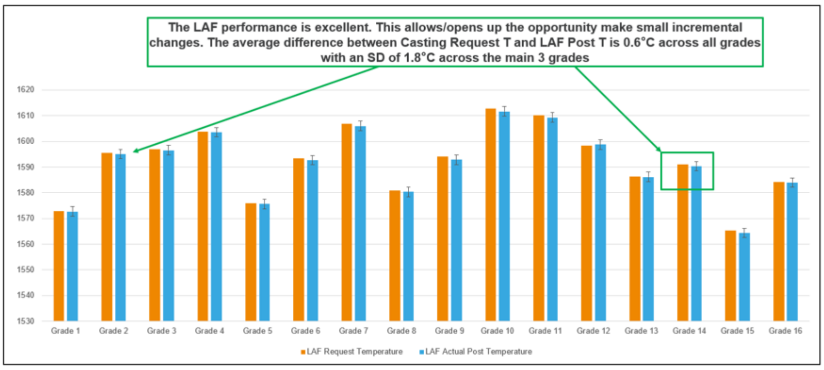
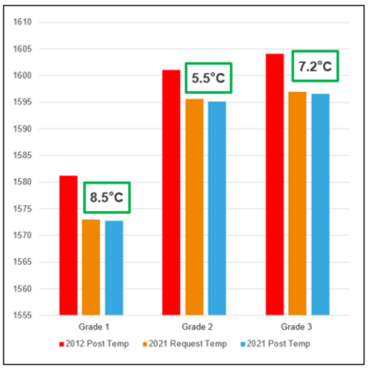


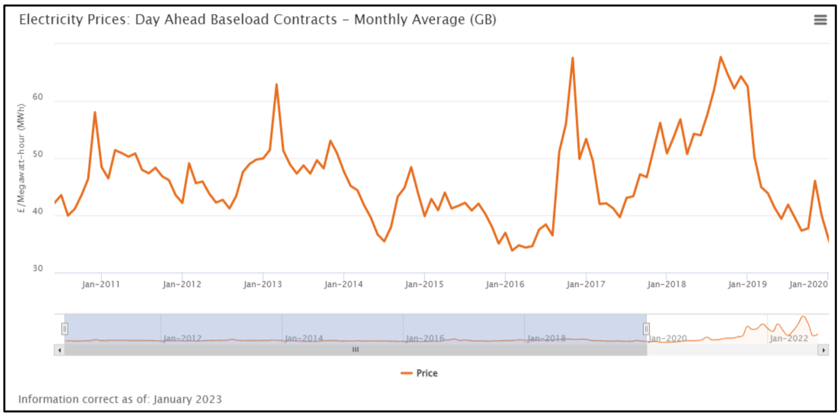
Figure 4



This confidence to make small changes matched with the improved temperature control in the tundish through continuous measurements has allowed over 7 years for the requested temperature to drop significantly. 88% of the steel produced by Celsa UK is across 3 grades, figure 4 shows the temperature reduction on these 3 grades in detail. This temperature reduction weighted for volume of steel produced against the grade equals 7.5°C temperature reduction average across all grades.

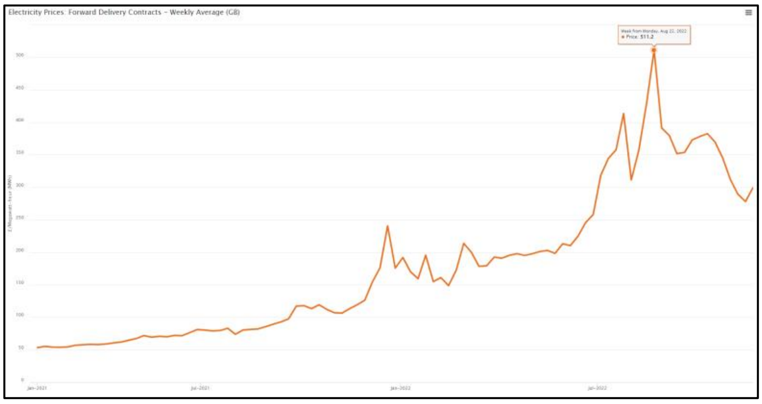
The UK steel industry since 2020 has been under increased pressure due to extreme cost of electricity. Historically, 2011-2019, the whole sale cost of electricity was in the range of £40-70 per MWh, figure 5.

Figure 5



Since 2020 the electricity price has continued to rise, peaking in August 2022 at £511 per MWh [2]. This is around a 10x increase for steel produces. For example, if Celsa UK EAF takes around 50 MWh to melt 150 tonnes of scrap, this would normally cost £2,500 to melt the scrap, this peaked at £25,000 to melt the same amount of scrap. This is clear that any improvements that can reduce the amount of electric consumption by the plant would reap large rewards.

Figure 6



Calculating what a 7°C reduction in casting temperature is worth for the plant directly in electricity costs. Table 1 shows the average electricity price per year with the temperature reduction during that period with the electricity saving per 1M tonne produced. Celsa UK produce around 1M tonne a year. The saving is based upon a 50% LAF reheating efficiency. Refractory/electrode savings will be seen also but are excluded from this analysis.

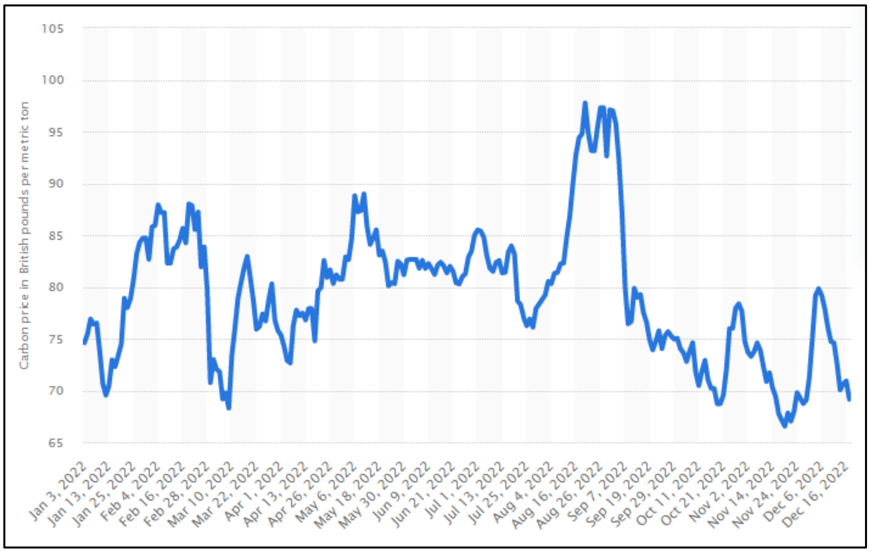
Table 1

Year	Temperature Reduction	Saving per 1M tonnes
2014	0	0
2015	2	£37,000
2016	2	£38,000
2017	4	£84,000
2018	4	£106,000
2019	6	£119,000
2020	7	£117,000
2021	7	£399,000
2022	7	£837,000

Table 1 clearly shows that Celsa UK benefited from over £837,000 worth of electricity saving through 2022 from investment in better tundish temperature control to bring confidence to make the casting process more efficient through lower casting temperatures.

Also, the UK operates an emissions trading scheme (ETS) where the amount of CO2 emitted is limited to a CAP, any additional emissions need to be paid for and this CAP is decreased over time. The 7°C temperature reduction equates to 1515 tonnes of CO2 emission saving per year, each tonne of CO2 has a value in the ETS, the latest price for 1 tonne of CO2 is £69.15, figure 7, but this did peak at £97.75. The allowance in the ETS can also be traded between emitters so have added value even if the company is below the CAP. 1515 tonnes saving of CO2 equates to £104,762 ETS savings per year, this again is an indirect saving. This also is aligned to Celsa Group's mission statements, around green low-carbon steel.

Figure 7

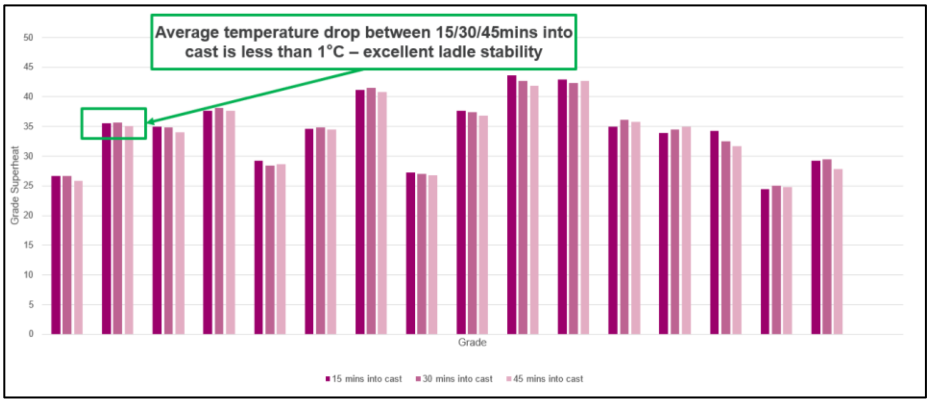


Celsa UK – Superheat Trial

In 2022 the improvements made through the implementation of continuous tundish temperature measurement were again reassessed to see if more improvements could be brought using CasTemp Superheat, (combination of casting temperature and liquidus measurement to give casting Superheat).

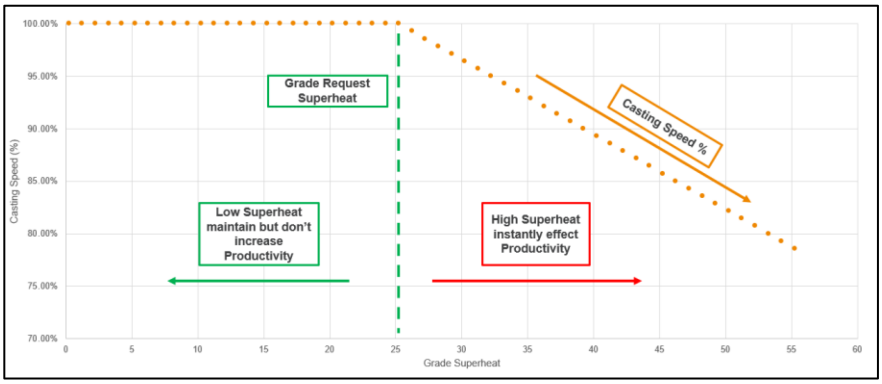
The first variable that was investigated was the thermal stability in the ladle, it is already shown that Celsa UK have good control over LF post temperatures but if the ladle were thermally unstable and dropped an excess amount of temperature during cast then dropping more temperature/superheat would not be recommended. After analysing all data from 2021 it was noted that the ladle fleet at Celsa UK had excellent thermal stability. Superheat timestamps from 15/30/45 minutes into cast were compared for each heat through 2021, giving the following results, figure 8, all 16 grades gave similar superheat loss profiles. Superheat loss from 15 to 45 minutes was less than 1°C on average, again giving confidence that Superheat can be reduced further safely.

Figure 8



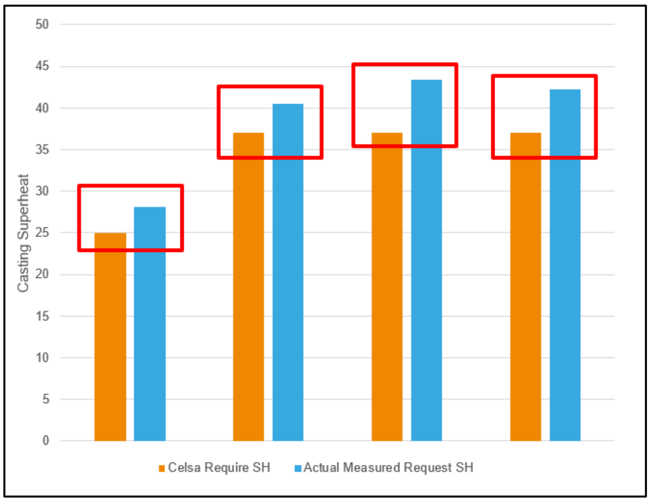
Extensive trials were conducted during March 2022 across a range of grades to assess Celsa UKs understanding of Superheat. Celsa UK now have good control of temperature within the tundish, so the next logical investigation was around Celsa UKs control over liquidus, which directly influences casting superheat. Celsa UK have a practise of using a grade book liquidus, this is a predetermined liquidus for the grade in cast, this is not dynamically changed to match the exact elemental analysis of the current heat in cast. It was found, that by dynamically measuring the liquidus of the heat in cast, a difference could be seen between the grade book liquidus and measured liquidus. On average Celsa UK were underestimating the amount of superheat they were casting on, potentially risking a casting breakout by casting at a higher speed than recommended for a specific superheat. See a casting speed example below, when a grades superheat is higher than the requested superheat, casting speed should be slowed, figure 9.

Figure 9



Four of the main grades Celsa UK make were analysed during the trial, figure 10, showing a maximum of 7.5°C difference between the superheat Celsa calculated using a grade book compared to a live in situ measurement. If these differences were address and accounted for this would save an additional £340,000 in reduction of electricity by reducing the aim temperature.

Figure 10



Unfortunately, during one of the trials an issue was seen downstream meaning casting had to be emergency stopped with a tundish full of steel. This however supplied a good opportunity to confirm the superheat findings above.

In figure 11 grade book liquidus is highlighted by the green line, CasTip live liquidus is shown by the blue changing line and tundish temperature is shown by the orange curve. The tundish was full during the abort at around 29 tonnes, the trial systems were left connected so it could monitor the liquidus arrest of the tundish, this perfectly aligned with the CasTip liquidus. This liquidus arrest event is shown in more detail in figure 12.

Figure 11

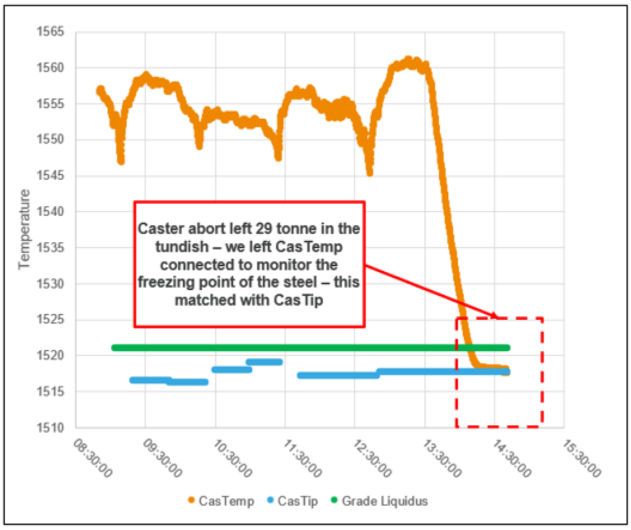
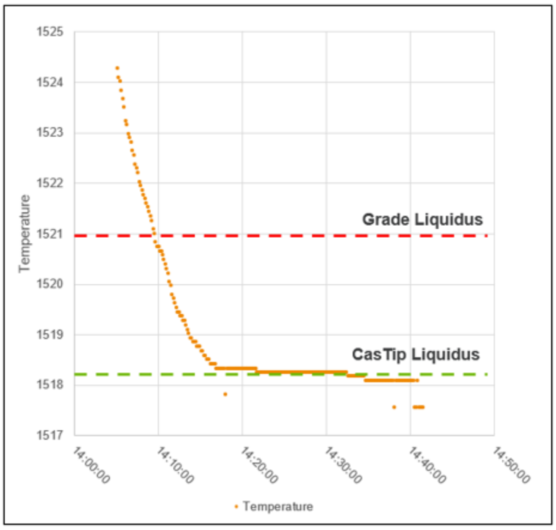


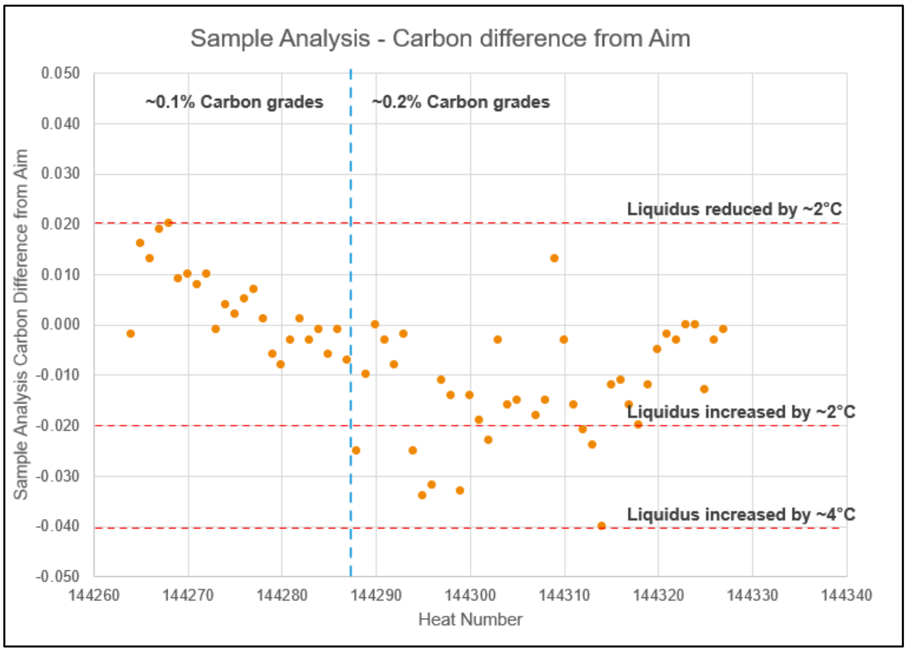
Figure 12



The tundish arrest point matching the CasTip liquidus gave validity to live casting superheat provided by the CasTemp Superheat system, this gives confidence to continue through 2023 to look at these areas for improvement to realise the further electricity/CO_2/casting speed savings.

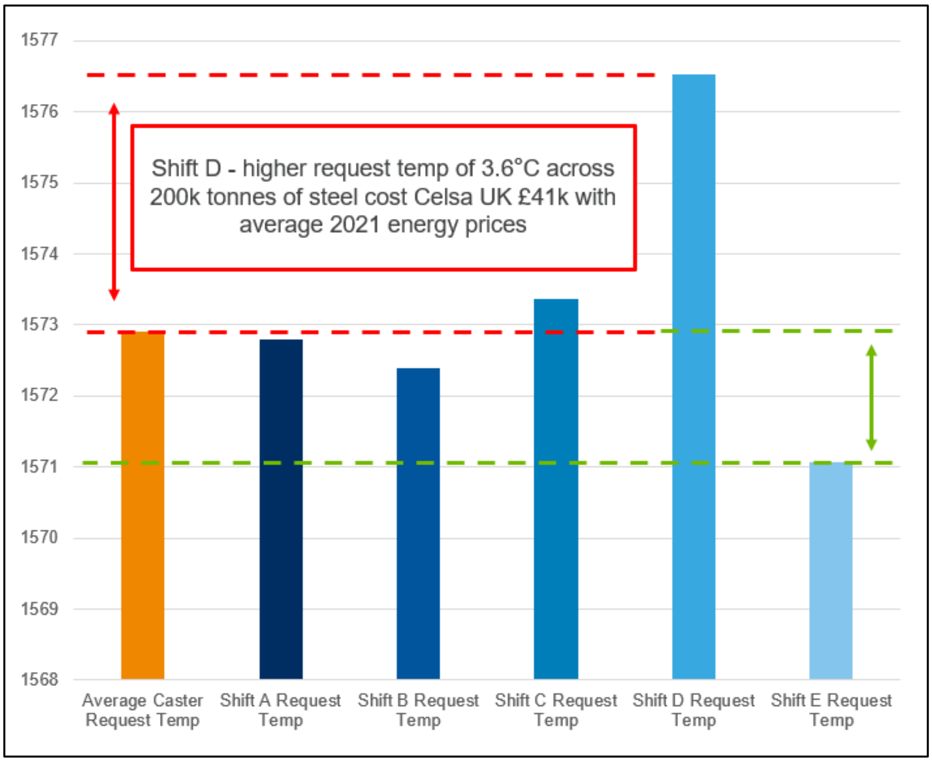
Fixed liquidus that isn't dynamically changed with the sample analysis will also see liquidus drifts for grades made within specification. Figure 12b highlights liquidus differences at differing carbon levels.

Figure 12b



Another interesting finding from a deep dive into LF request temperature is that there is practise deviation between each shift, with one shift on average requesting steel with a temperature 3.6°C higher than the average of all shifts. This has a significant cost of £41,000 in 2021 and £81,000 in 2022, figure 13. Additional saving of £145k in 2021 could be made by adopting shift E practises.

Figure 13



Celsa Spain – CasTemp Superheat

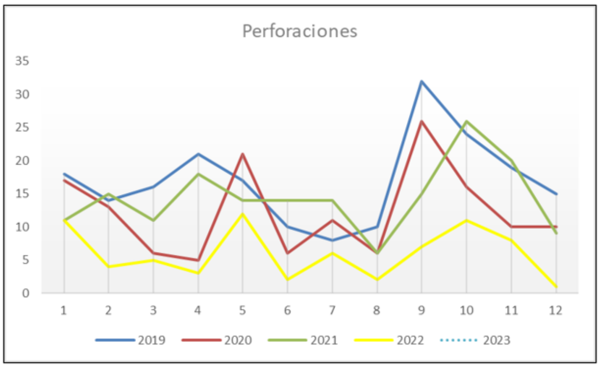
Celsa Spain completed a very similar investigation in 2021 with very similar conclusions to Celsa UK.

The following improvements were obtained through the trial work:

- Reduction in temperature
  - Casting Superheat band reduction from +20/+30ºC to +15/+25ºC
- Reduction in energy consumption through reduction in temperature (above)
- Reduction in break out rate
  - 5267 tonnes cast per strand breakout prior to CasTemp Superheat trials
  - 9073 tonnes cast per strand breakout post to CasTemp Superheat trials
  - Figure 13/14
- Reduction of scrap through reduction in rhomboidity of the billets
  - 1649 tonnes of Rhomboidity scrap prior to CasTemp Superheat trials
  - 243 tonnes of Rhomboidity scrap post to CasTemp Superheat trials
  - Figure 15

Figure 13 – Strand break out per year per month

Figure 14 – Strand break out per year per tonnes



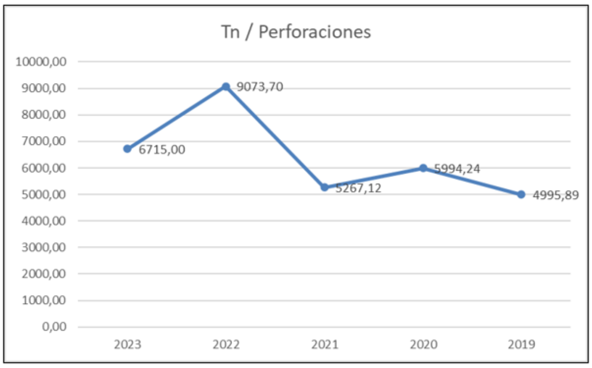
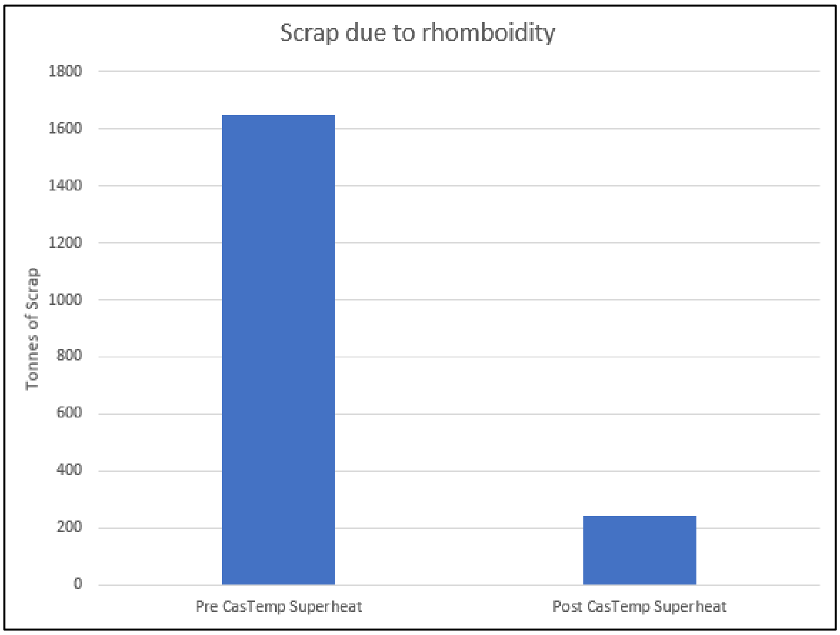


Figure 15



Celsa Group

Below is a short summary of other Celsa Group global sites and their current progress to apply the same technology on their casting procedures.

Site	CasTemp Superheat Progress
Celsa France	CasTemp user – planning CasTemp Superheat trials
Celsa Nordic	CasTemp Trials
Celsa Huta Ostrowiec	CasTemp user

Celsa group annually produce 6.6 million tonnes of steel, if the saving shown in the UK and Spain are extrapolated across the entire production Celsa Group vast electricity savings could be seen and large CO2 saving to add to their green low carbon mission statements.

Conclusions

It is clear from the data that continuous tundish temperature brings many benefits to the continuous casting process. This paper outlines the savings in quality and breakout rate, while reducing temperatures saving electricity and CO2. Safety benefits for the operators are also key.

Acknowledgments

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10.4028/www.scientific.net/AMR.317-319.361