Flexible solutions to decrease greenhouse gas emissions from heating furnaces in the steel industry

Workshop/seminar 28 june 2018

Jernkontoret, Kungsträdgårdsgatan 10, Stockholm

The purpose of this project is to contribute to the elimination of the use of fossil fuels in steel reheating furnaces by the steel industry in order to become CO_2 neutral by 2045. The goal of this initial investigation is to deliver a roadmap over the possibilities, combined options and the technical challenges which can exist to reach a high flexibility for the use of various energy carriers within the steel industry which offer CO_2 emission reductions. This initial investigation will begin with the existing infrastructure in Sweden as it applies to the production of steel and energy, plus it will consider future scenarios regarding the production of steel together with the market situation for various energy carriers. Furthermore, fuel flexibility will be studied regarding various combinations which are possible when using electrical energy – hydrogen – oxyfuel combustion and other gaseous fuels.

As a step in the work we are preparing a workshop with invited speakers to present and discuss current research and technologies on flexible heating solutions for heating ovens.

09.00-09.20	**Welcome and Introduction -**
09:20-11:00	**Gaseous fuel** <u>Oxyfuel Solutions in Reheat furnaces for Higher Throughput with Less Emissions</u> *Ola Ritzén - AGA* <u>Clean and Efficient Gas Heating of Industrial Furnaces</u> *Dr. Joachim Wünning - FLOX* <u>Experience with flexible fuel in heating ovens (LPG/LNG)</u> *Jonas Engdahl – SSAB* Open discussion
11:00-12:20	**Electric heating** <u>Resistive heating technology</u> *Fernando Rave – Kanthal* <u>Inductive heating technology</u> *Antti Järvenpää – FMT* <u>Experiences on electric heating at Fagersta Stainless</u> *Richard Ålberg – Fagesta*
13:00-15:30	**Open discussion and brainstorming** - What is needed for a successful implementation in industry, experiences and success stories - Need for research
14:30-14:45	**Coffee Break**
15:30-16:00	**Concluding discussion**

<u>Oxyfuel Solutions in Reheat furnaces for Higher Throughput with Less Emissions</u>

Oxyfuel is an important combustion technology. Replaces ballast of nitrogen, resulting in more heat available for reheating, improved heat transfer due to decreased gas flows results in longer retention time in the furnace, transforms recuperative zones into active zones, possibility to use less calorific gases.

- Flexifuel (gas, liquid), bio fuels
- Optimelt – regenerator for CH_4 to CO and H_2 prior to vombustion
- H_2 as fuel is used today, small quantities and niche products e.g. melt of surfaces of glas (polish)
- H_2-O_2 burners exists, however not on market yet. Main research question (what happens within the furnace, steel properties etc.)
- Several applications of oxygen (REBOX and flameless technologies). E.g. HLL in borlänge.
- Challenge today:
    - price of O_2, large furnaces requires large volumes of O_2, price dependendant and will depend on situation,
    - BREFs not currently treating O_2 combustion. O_2 combustion concentrates emissions In flue gases, disadvantage compared to diluted flue gases (emission/nm3).

Summary: AGA knows hydrogen business, can deliver biogas, LNG, O_2 saves fuel and reduces CO_2 emissions, O_2 can be used to facilitate low calorific balancing LHV values, develops new burner technologies

Clean and Efficient Gas Heating of Industrial Furnaces

FLOX develops burner technologies (flame less operation) that combines Air preheat through heat exchange. Potential High efficiency and fuel efficiency and low NOx. Challenge equipment cost and more sophisticated controls

- FLOX combustion have the possibility reduce CO_2 emission through higher efficiency and reduced fuel consumption.
- Important to understand future electric market development
- Cost for fuel will be important in the future.
- Cost of fuel vs cost of emission, where is the break even
- Several applications with different type of fuels, low calorific fases
- Recuperative burner, high burner efficiency, decreased NOx (50 ppm to 9ppm, fast transition to FLOX mode)

Summary: FLOX fuel flexible (Bio-Syngas, waste gas…), hybrid solutions (electric heaters and combustion) depending on varying prices for fuel, introduction to market requires partnership between actors

Experience with flexible fuel in heating ovens (LPG/LNG)

SSAB have converted furnace 302 to LPG/LPG from oil to minimize cost and reduced environmental impacts.

- LPG → LNG using the same system with the new fuels.
- Change in air factors (excess air lightly higher when operating on LPG)
- NOx increase when using O_2 and LPG (at the same time), related to burner (speed issues), Lances not optimized for LPG, same MJ/h → reduced speed with 60%
- Fast pay-back (due to the price difference between fuels)
- Increased HLL-e

Summary: have today flexibility (gaseous fuels) possible to introduce bio based LNG (have made tests), quick change between fuels.

Resistive heating technology

Kanthal have several technologies for electric heating. Resistive heating technologies up to 2000 C (ceramic) and up to 1400 C (metal).

- Accurate and efficient heating (70% energy reduction)
- Several technologies (electric heating elements, panels, modules, gas heaters)

- Limitation 12 W/cm2, basic temperature corrosive issues

Summary: Several technologies available. Possibility to develop hybrid solutions

<u>Inductive heating technology</u>

- Rapid heat treatment opens for development of new steel properties. (increase in tensile strength/hardness, enhanced impact toughness, reversion (improved mechanical properties in annealed conditions)
- Energy only when there is production
- Overheating a possible problem

<u>Experiences on electric heating at Fagersta Stainless</u>

Production of stainless wire rod and wire. (from June 2018 owned by Outokumpu)

Inductive heating was installed as a consequence of their production setup. Long products (up to 50 meter long), high speed (0.5 – 5 m/s)temperature gradients from start to end (2 C/s → 200 C). Electric heating is installed within the production chain between roughing mill 2 and intermediate mill in order to reheat the material to uniform conditions.

- Makes it possible to homogenize and mitigate against large temperature deviations between start and end of material.
- High workload and power consumption when rolling colder material
- Mitigate against dimension deviation from front to back on finished wire coils.

<u>Benefits</u>: negligible scale due to short heating time, better surface temperature → longer duration of rolls (rolling mill), no idle related heating costs, no emissions compared to fuel heating

<u>Problems</u>: difficult to keel up temperature when incoming temperature is low (back end), Some materials more difficult take induce heat than others, to large distance between material and coil affects efficiency, some differences in speed and dimensions

NOTES FROM WORKSHOP 2 - FLEXIBLE SOLUTIONS TO DECREASE GREENHOUSE GAS EMISSIONS FROM HEATING FURNACES IN THE STEEL INDUSTRY

Projekt.: FlexVärmeStål
Uppdragsnr.: 51.100748
Projektledare: Mikael Larsson
Författare: Mikael Larsson, John Niska
Datum: 2019-03-19

1 SUMMARY

The purpose of this project is to contribute to the elimination of the use of fossil fuels in steel reheating furnaces by the steel industry in order to become CO_2 neutral by 2045. The goal of this initial investigation is to deliver a roadmap over the possibilities, combined options and the technical challenges which can exist to reach a high flexibility for the use of various energy carriers within the steel industry which offer CO_2 emission reductions. This initial investigation will begin with the existing infrastructure in Sweden as it applies to the production of steel and energy, plus it will consider future scenarios regarding the production of steel together with the market situation for various energy carriers. Furthermore, fuel flexibility will be studied regarding various combinations which are possible when using electrical energy – hydrogen – oxyfuel combustion and other gaseous fuels.

Table 1: Agenda for the seminar

8:30-9.30	**Registration, coffee**
09.00-09.20	**Welcome and Introduction** (appendix 1) – Mikael Larsson (Swerim)
09:20-10:20	**Electricity market Sweden** (appendix 2) **Vattenfall** - Nicklas Simonsson, - Swedish energy market, availability of power - Renewable energy in energy system (solar, wind) - Indirect electrification (hydrogen production)
10:20-10:30	**Coffee Break**
10:30-12:30	**Equipment for flexible heating** **TENOVA** - Massimiliano Fantuzzi - **Future furnace development at Tenova** (appendix 3) **UTAB** - David Muren - **Furnas design for high energy intensity and integrity** (appendix 4) **FIVES** - Emmanuel PATARD - **Hybrid solution system for long product** (appendix 5)
12:30-13:00	**Lunch**
13:00-15:30	**Open discussion and brainstorming**
14:30-14:45	**Coffee Break**
15:30-16:00	**Concluding discussion**

The seminar was held at Jernkontoret, Kungsträdgårdsgatan 10, Stockholm. Attending the meeting was representative from the project group, organisations with interest in TO51 and invited speakers. Full attendance list is found in appendix 6. Signed competition law compliance is found in appendix 7

Presentations from the day can be found in appendix 1-5.

On the open discussion and brainstorming session the group was divided into two smaller groups led by Mikael Larsson and John Niska. The topics to discuss was

1. What is needed for a successful implementation in industry, experiences and success stories
2. Need for research

The groups discussed these two topics individually and the outcome was summarised for the whole group. It can be concluded that it is very likely that the infrastructure at the industrial sites will be very similar to what exists today. Disruptive change is in its nature difficult to predict. Therefore, the industry needs to be able to achieve the net zero fossil emission solution by the infrastructures and energy carriers that are available today.

What is needed and when:

1. Incentive (carrot) for the industry to be able to make the transition. Compare presentation from Vattenfall indicating that the cost the intermediate product producer is much higher than the cost increase on the final product. Needs to start as soon as possible. Several incentives probably will need to come in play. (2020-2025)
2. New infrastructure (electricity, biogas, hydrogen). Industry needs to know the different solutions available. (2030-2035), especially for the production and storage of hydrogen at multiple steel hot rolling mill sites as proposed in the HYBRIT project for replacing the blast furnace in Luleå.
3. Time to build new infrastructure: it takes time to get e.g. new electricity supply. Therefore this needs to be decided and planned for. (2025)
4. New type of cooperation and collaborations. The new solutions most definitely will require collaboration between several actors (e.g. industry user and resource supplier). This new type of business models needs to be developed. (2025)

From a technological point of view, new solutions needs to be developed and tested.

1. Induction heating (before heating oven and after heating oven, e.g. partly fuel shift to electricity
2. Hydrogen combustion technologies (w. and wo. Oxygen enrichment).
3. Waste heat recovery technologies (improvement of energy efficiency)
4. Hot charging (reducing fuel demand in primary heating oven)
5. Automation, Ind. 4.0, control to be able to steer and optimise the process for minimum energy requirement.
6. Broad perspective on fuel research and a systems perspective. There will not be one solution for all. Most definitely the solution will be site based and depending on the local requirements.
7. Implementation of new processing routes can reduce the need for steel reheating furnaces, for example, thin strip casting or thin slab casting with direct hot rolling.
8. Successful research on developing new technology like electric plasma jet burners could simplify implementing electric heating in existing furnaces.

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Projekt.: FlexVärmeStål
Uppdragsnr.: 51.100748
Projektledare: Mikael Larsson
Författare: Mikael Larsson, John Niska
Datum: 2019-04-23

1 SUMMARY

The purpose of this project is to contribute to the elimination of the use of fossil fuels in steel reheating furnaces by the steel industry in order to become CO_2 neutral by 2045. The goal of this initial investigation is to deliver a roadmap over the possibilities, combined options and the technical challenges which can exist to reach a high flexibility for the use of various energy carriers within the steel industry which offer CO_2 emission reductions. This initial investigation will begin with the existing infrastructure in Sweden as it applies to the production of steel and energy, plus it will consider future scenarios regarding the production of steel together with the market situation for various energy carriers. Furthermore, fuel flexibility will be studied regarding various combinations which are possible when using electrical energy – hydrogen – oxyfuel combustion and other gaseous fuels.

Table 1: Agenda for the seminar

09.30-10.00	**Registration, coffee**
10.00-10.10	Introduction (Mikael Larsson)
10.10-10.40	WP1,2: Slutsatser från litteraturstudie och seminarier (Mikael Larsson)
10.40-12.00	WP3: Alternativa bränslen och uppvärmning, bränsleflexibilitet, konceptuell scenariobeskrivning (Rikard Svanberg, Henry Persson)
12:00-12.45	**Lunch**
12.45-14.15	WP4 Teknoekonomisk scenarier för hur Sverige kan nå netto-0 år 2045 - TIMES – Sweden (svenska energisystemet, vad måste ske när och hur, för att nå målen) (Anna Krok-Reikkola) - TIMES – modellering omvärmningsugnar. Scenarion för omställning till netto-0 år 2045 utifrån olika uppvärmningsalternativen (Erik Sandberg)
14:20-14:40	**Coffee Break**
14.40-16.00	Slutsummering (alla) - Vad drar vi för slutsatser? Hur tänker industrin? Hur går vi vidare? (tiden är knapp), vem gör vad?

The seminar was held at Jernkontoret, Kungsträdgårdsgatan 10, Stockholm. Attending the meeting was representative from the project group, organisations with interest in TO51

Full attendance list is found in appendix and signed competition law compliance is found in appendix 4

Presentations from the day can be found in appendix 1-3.

1.1 Results/discussions from WP1 and 2 (appendix 1)

The literature review have identified the need to find new solutions to be more energy efficient and carbon neutral. There are both international goals (EU) and national targets that will govern the industry.

- EU 2020 targets: 20% reduction in greenhouse gas emission, increasing the share of renewable energy (>20%) and 20% energy efficiency
- EU 2030: 40% reduction in CO2, >32% renewable, >32.5% energy efficiency
- National: 2030 - 50% energy efficiency (cw 2005), 2040 – 100% renewable, 2045 - net 0 emission,

From the literature survey it can be concluded that fuel flexibility as a concept has to be studied. Only few projects, RFCS (0), EU H2020, FP5-7, on the topic and these does not necessarily focus on fuel flexibility.

- Fuel flexibility; H_2, H_2 – Electric, Biogas, are possible alternatives
- Pilot trials and industrial furnace conversion to partial electrical heating or partial hydrogen combustion could be the most secure way to test new technology.

Fuel flexibility have been shown earlier (Celsa), but also in more recent time e.g. the SSAB Borlänge fuel shift. The examples are however dependent on infrastructure and availability of energy carrier. Future development need to take into account how different energy carriers can be combined and the infrastructure available/needed.

Electric power is a relatively straight forward energy carrier that can be combined. Therefore different combinations with electric heating (direct, indirect) are of interest to further study. From a technical perspective the following can developments have been identified from the discussions with the industry:

- Development of burner technology and electric heating concepts
- Induction heating (as preheating or after heating oven) should be analysed. Great potential for fuel shift.
- Hydrogencombustion technology (w. or wo. Oxygen) should be further studied. Hydrogen has great potential to decarbonise the heating ovens.
- Heat recovery possibilities to increase the energy efficiency
- Hot charging (reducing fuel demand in primary heating oven)
- Automation, Ind. 4.0, control to be able to steer and optimise the process for minimum energy requirement.
- Broad perspective on fuel research and a systems perspective. There will not be one solution for all. Most definitely the solution will be site based and depending on the local requirements.

There are of course future development that might significantly change the future demand for heating ovens, e.g. strip casting etc. These developments are difficult to predict.

1.2 Results/Discussion from WP3 (appendix 2)

Calculations show that there are potential in finding alternative energy carriers that fulfil the main criterion in reaching the target temperature in the furnace. Calculations made shows that, although the fuel varies in heat value and composition, with o2 enrichment and preheating degree it is possible reach a wide span in adiabatic flame temperature.

One main issue in changing fuel might though be the Wobbe index, an indicator of the interchangabillity of gaseous fuels, indicating that there are quite some differences between different fuel gases. Hence there might not be possible to change fuel without changing the burners.

Electric heating have great potential for fuel saving and can be implemented either as preheating or after heating of steel.

Hence, fuel flexibility with probably mean several systems is required.

1.3 Results/discussion from WP4 (appendix 3)

From the system analysis made with the TIMES modelling the different scenarios indicate how the steel industry heating ovens can be made Fossil CO_2 neutral in the future. From the analysis it can be seen that

- Air + fuel using hydrogen the winning concept in 2045.
- Air + fuel using gas (combination of natural gas and bio-SNG) important in the transition period 2020-2040
- Oxyfuel only relevant if existing oxygen capacity exists.

Recuperative/regenerative furnaces using hydrogen seems to be a very efficient heating option.

1.4 Conclusions

From the conducted study the following conclusions can be drawn:

- Not much research is being carried out internationally,
- There are technologies that the industry can use for the transition. However these requires research and development
- It is possible to find alternative fuels to make the fuel shift (based on furnace requirements)
- It is not likely that there will be one burner that can use all fuels, hence alternative parallel systems will be required.
- Future development should focus on hydrogen combustion and electric heating combinations
- From a fuel perspective, electricity (either direct or indirect) is a vital solution for the industry in its transition. Biogas will be important as a mediate energy carrier
- Bio oil is still very uncertain, one thing is certain, the industry is not overly enthusiastic in using oil once again.