The Use of Multiple Impingement Jets in a Solar-Powered Tube Heater for Decarbonization of the Steel Industry

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GEM-2023

March 06-10, 2023 | Boston, MA

The aim of this study is to numerically develop a novel tube heater that employs multiple impingement jets to effectively heat steel tubes and reduce the environmental impact of their powder-based coating process

Background

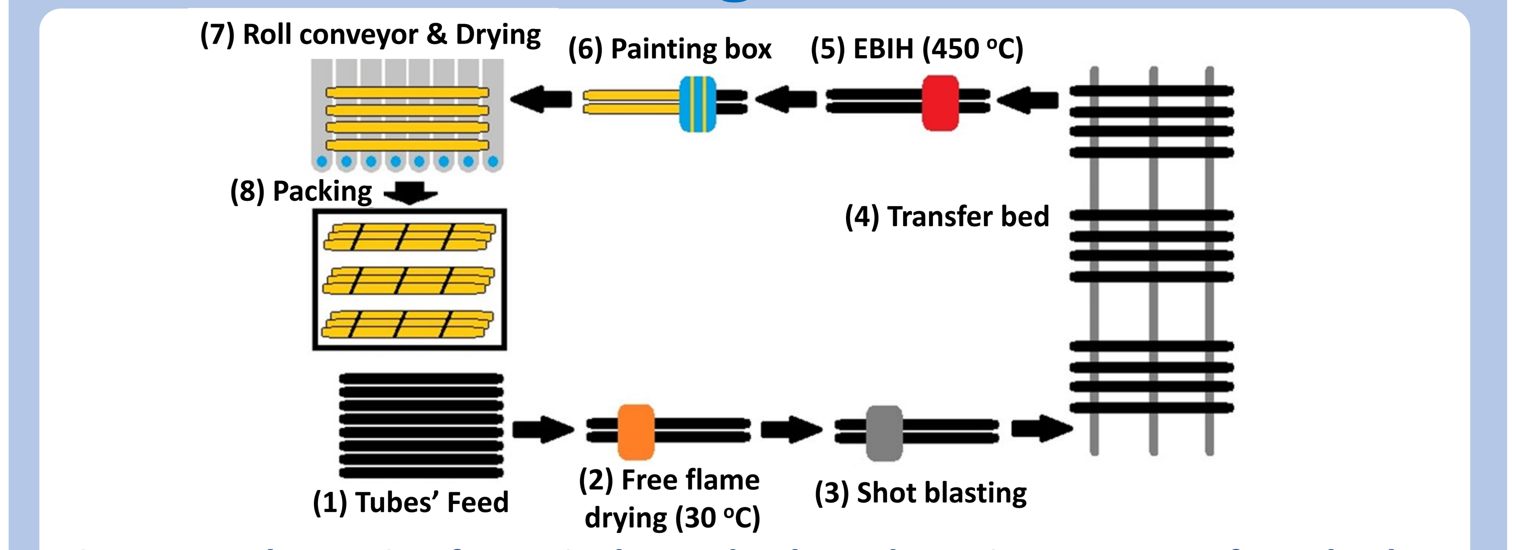

Figure 1: Schematic of a typical powder-based coating process of steel tubes

- The powder-based coating process of steel tubes uses an electric-based induction heater (EBIH) to heat the tubes to 240 °C [1].
- The EBIH has high electricity consumption and environmental impact.
- A novel solar-powered tube heater (SPTH) was developed to reduce the use of the current EBIH.
- It employs multiple air impingement jets to effectively heat the tubes without interrupting their coating process.
- The main challenge of multiple impingement jets systems is optimizing their critical parameters to enhance the efficiency of the SPTH.
- This is achieved by increasing the heat transfer rate to the tubes while maintaining a low required air fan power [2].

Methodology

- A novel concept of the SPTH was designed using the multiple impingement jets system [3].
- The impingement jets plate (Figure 2A) was amended into impingement jets cylinder (Figure 2B) using SolidWorks (UMass, USA) to suit with the shape of the steel tube (Figure 3).
- The efficiency of the SPTH in terms of the heat transfer rate and required air fan power was evaluated using ASNYS FLUENT (ANSYS Inc., USA).
- The following critical parameters were considered: (i) distance between the jets and the target (Z/Djet); (ii) distance between the jets circumferentially (Y/D_{jet}) and axially (X/D_{jet}) and (iii) size of the jets' diameter with respect to the target's diameter (D_{jet}/D_{target}).

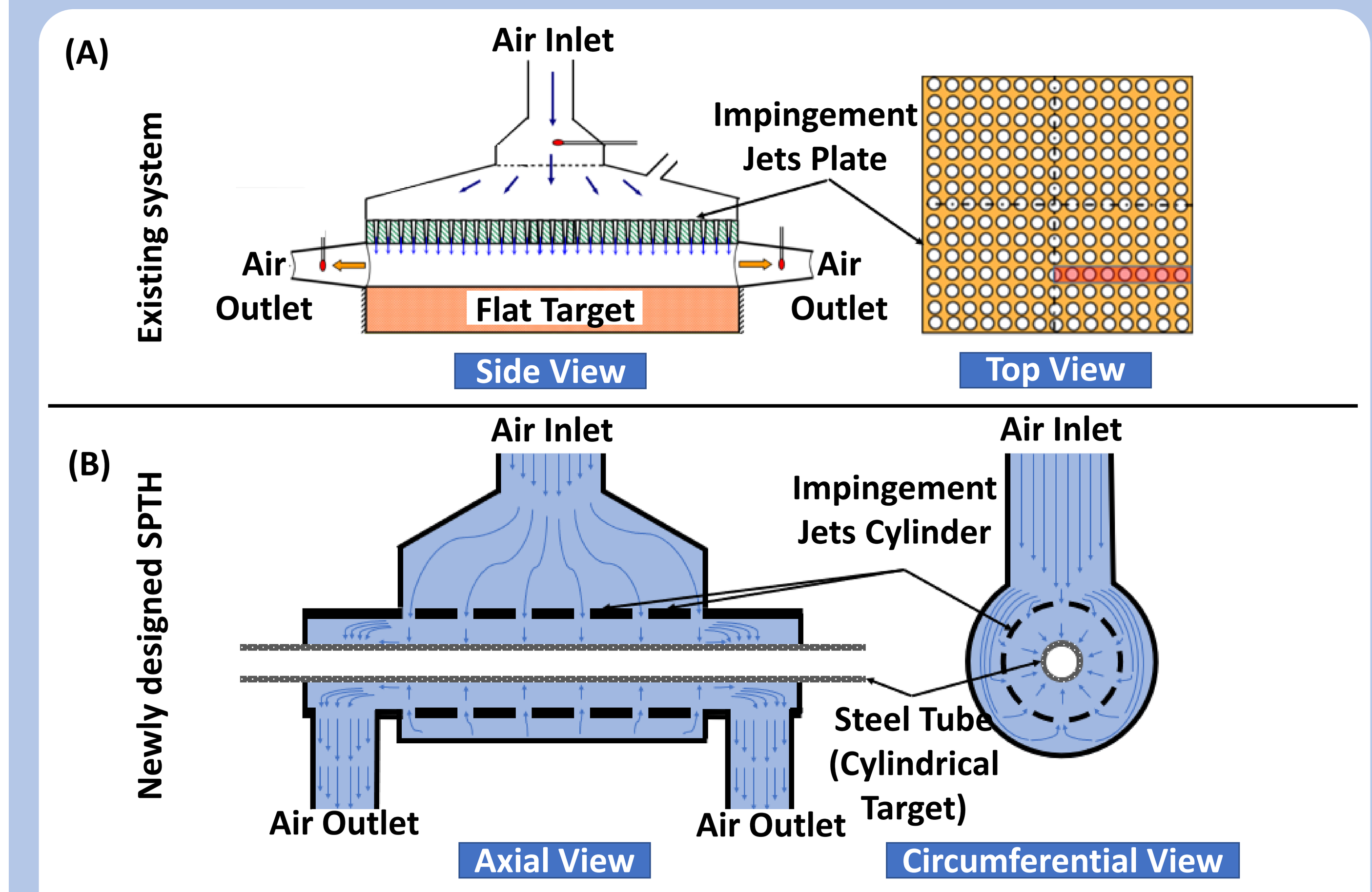

Figure 2: Concept design of the novel SPTH as adapted from [3]

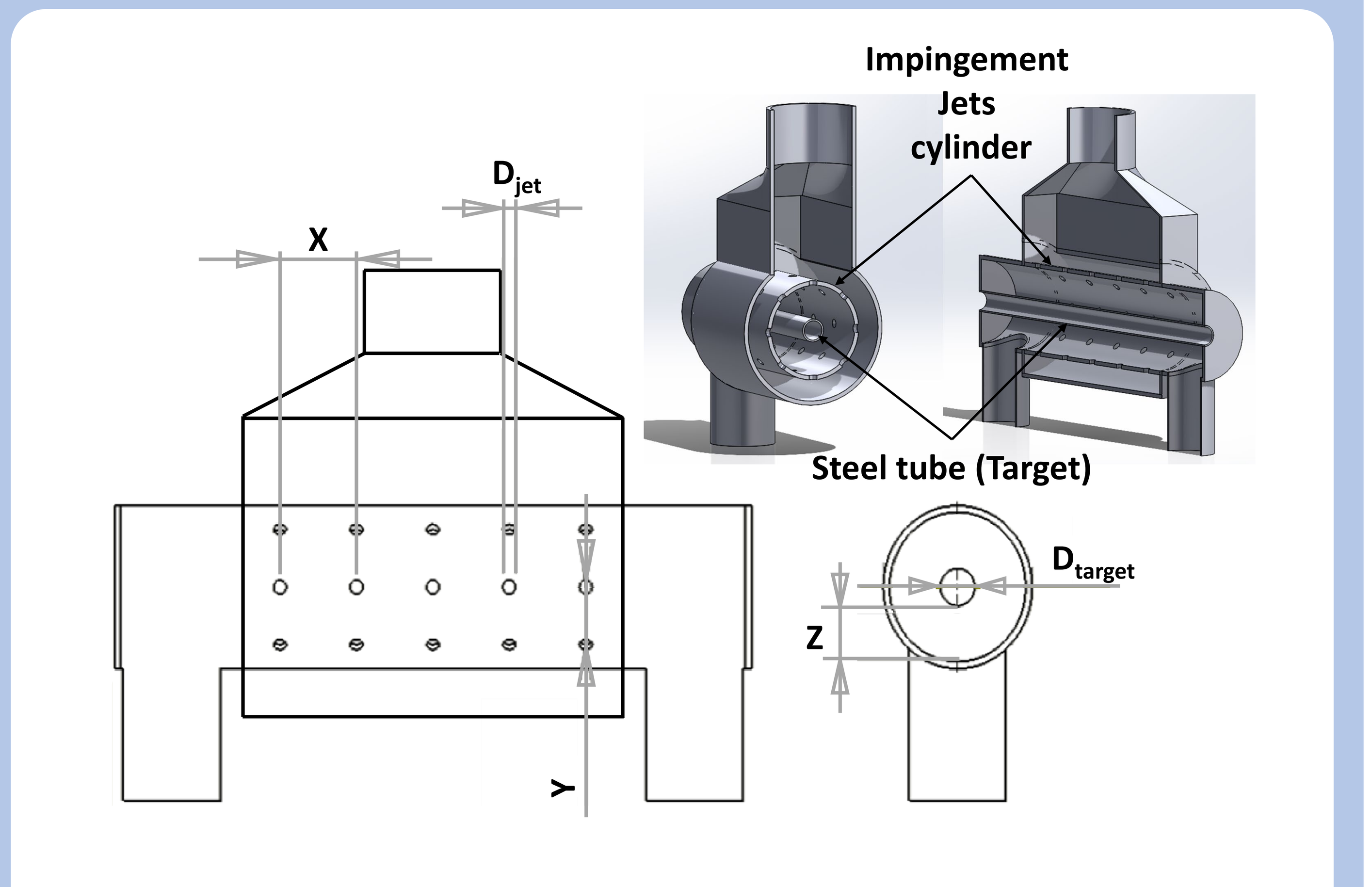

Figure 3: Drawing of the SPTH in SolidWorks with its critical parameters

Results

Figure 4 presents that the distance between the jets and the target (Z/Djet) has:

- Directly proportional effect on both aspects; heat transfer rate and required fan power
- Optimum value that obtained the maximum difference between the two aspects of Z/Djet=2

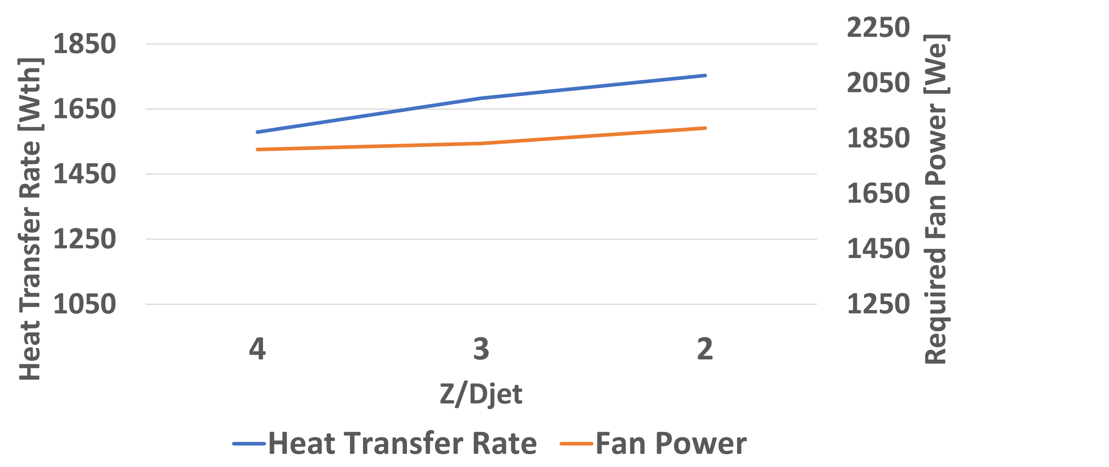

Figure 4: Effect of Z/D_{jet} on heat transfer rate and required fan power

Figure 5 presents that the distance between the jets circumferentially (Y/D_{jet}) and axially (X/D_{jet}) has:

- Directly proportional effect on both aspects
- Optimum values of Y/D_{jet}=4 and X/D_{jet}=4

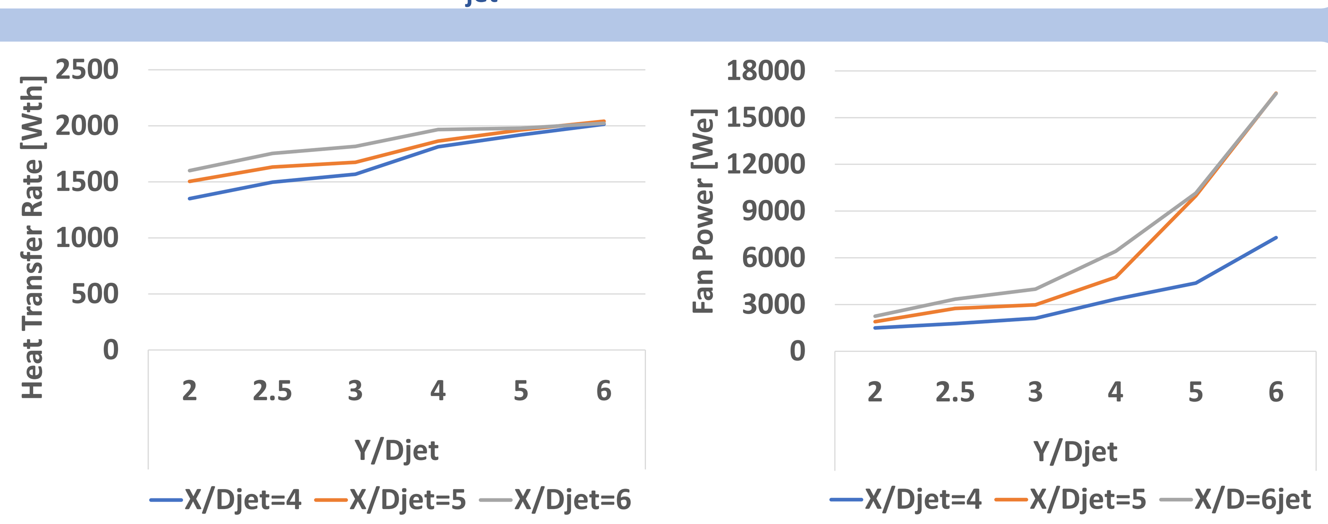

Figure 5: Effect of Y/D_{jet} and X/D_{jet} on heat transfer rate and required fan power

Figure 6 presents that the size of the jets' diameter with respect to the target's diameter (D_{jet}/D_{target}) has:

- Inversely proportional effect on both aspects
- Optimum value of D_{jet}/D_{target}=0.409

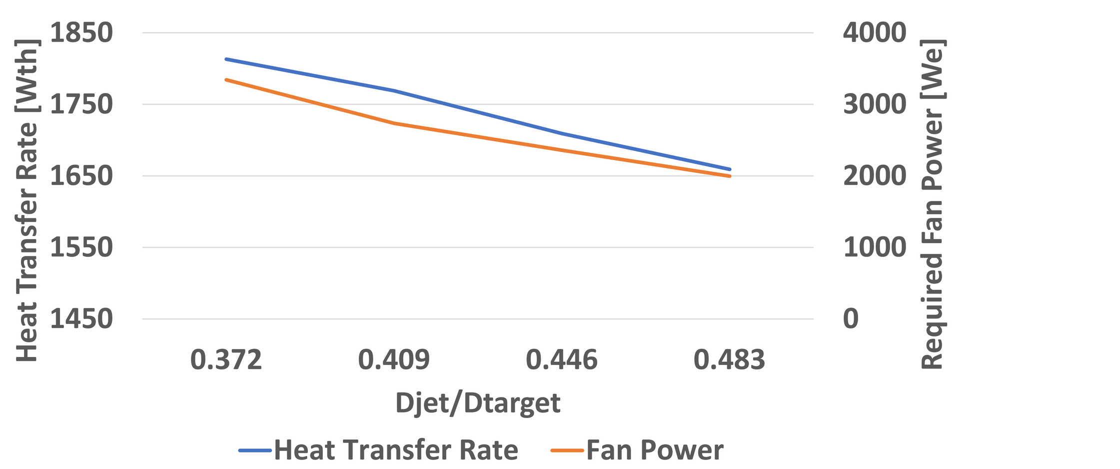

Figure 6.: Effect of D_{jet}/D_{target} on heat transfer rate and required fan power

Summary

- A novel SPTH for heating steel tubes in the powder-based coating process was designed.
- The system uses multiple impingement jets to heat the steel tubes resulting in high-quality coating and reduced energy consumption.
- In order to enhance the efficiency of the SPTH, critical parameters of the design were identified and numerically optimized.
- The critical parameters included: Z/D_{jet}, Y/D_{jet}, X/D_{jet} and D_{jet}/D_{target}.
- The results showed that Z/D_{jet}, Y/D_{jet} and X/D_{jet} have a directly proportional effect whereas the D_{jet}/D_{target} had an inversely proportional effect on the heat transfer rate in the SPTH.
- The optimum values of these parameters included: Z/D_{jet}=2, Y/D_{jet}=4, X/D_{jet}=4 and D_{jet}/D_{target}=0.409.
- The optimization of these parameters led to improving the heat transfer rate in the SPTH by 12%.
- Future work includes validating these results experimentally using a real-life prototype.

Acknowledgment

This project is funded from the EU Horizon 2020 research and innovation programme, Application of Solar Energy in Industrial processes (ASTEP), under grant agreement No 884411 (https://astepproject.eu/).

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