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

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**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

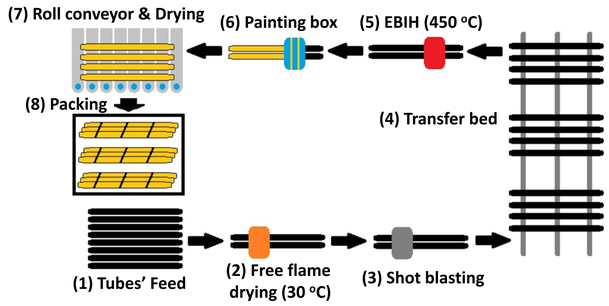


Figure 1: Schematic of a typical powder-based coating process of steel tubes

- The powder-based coating process of steel tubes uses an electric-based induction heater (EBIH) to heat the tubes to 240 $^{O}$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 ($D_{jet}/D_{target}$).

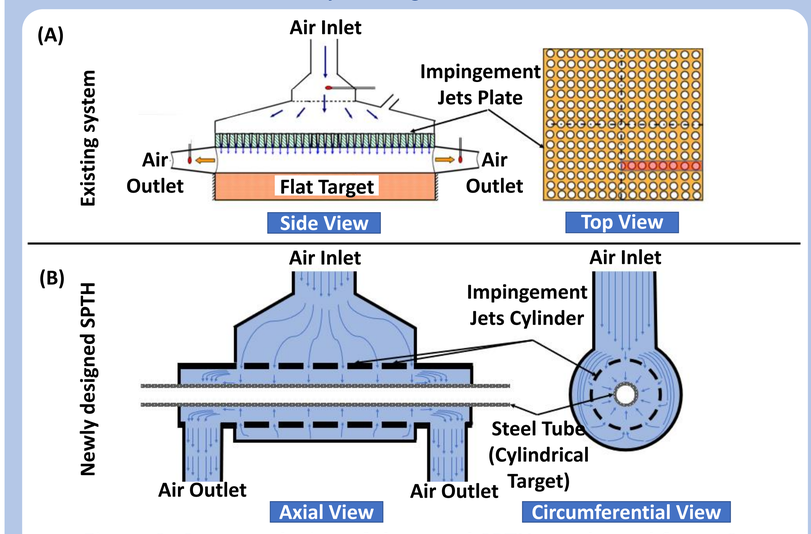


Figure 2: Concept design of the novel SPTH as adapted from [3]

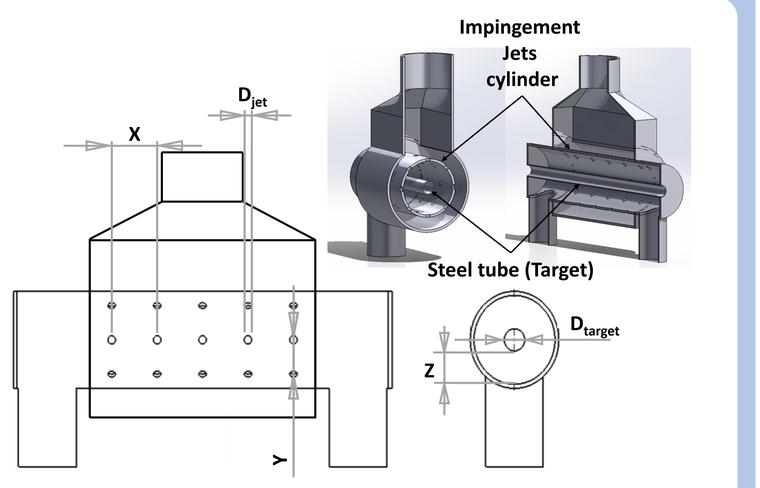


Figure 3: Drawing of the SPTH in SolidWorks with its critical parameters

## 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

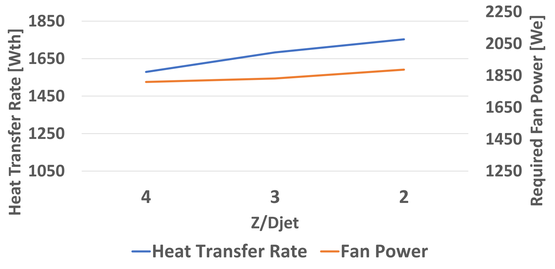


Figure 4: Effect of $Z/D_{jet}$ on heat transfer rate and required fan power

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

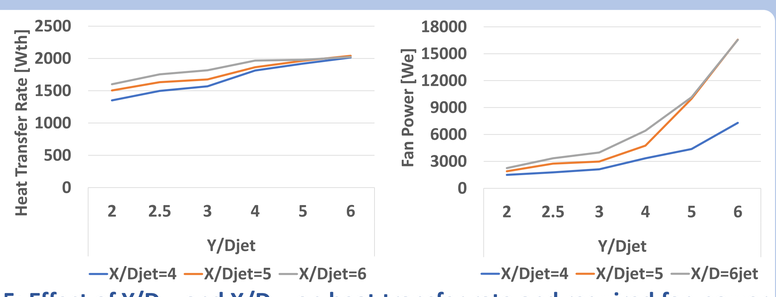


Figure 5: Effect of $Y/D_{jet}$ and $X/D_{jet}$ on heat transfer rate and required fan power

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

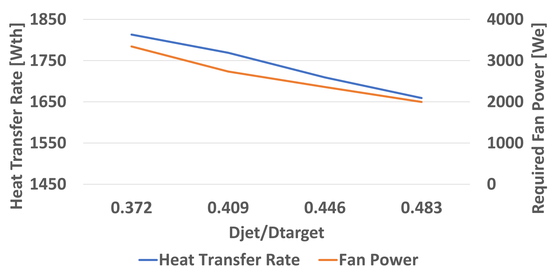


Figure 6.: Effect of $D_{jet}/D_{target}$ on heat transfer rate and required fan power

## 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.

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## References

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