

CLAIMS

1. Method of improving an endothermic process that takes place in a furnace containing tubes being filled with a catalyst for the chemical conversion of a gaseous feed and positioned vertically in rows inside the furnace, burners being fed with primary and secondary fuel streams and oxidizer stream and mounted in rows with rows of inner burners placed between two rows of tubes and rows of outer burners placed between a row of tubes and a side wall parallel to the rows of tubes, with heat being transferred from the burners to the tubes and with flow rates associated, where the method improves the homogenization of the temperatures of the tubes by throttling part of the burners,
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- 10 characterized in that the method comprises the steps of:
- step a) optionally calibrating the simplified physical model of step c3) by measuring one or more real tube temperature for at least a tube impacted by the throttling of a burner in standard and in throttled state,
- step b) acquiring information on a real tube temperature for the tubes present in the furnace with all the burners present in the furnace under standard non-throttled conditions,
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- step c) getting a map of burners to throttle including:
- c1) choosing at least one parameter representative of the performances of the furnace with a target of improvement,
- c2) choosing at least one or more power ratio for the burner throttling,
- 20 c3) utilizing the information of step b) and a simplified physical model of the impact of throttling a burner on the tube skin temperature for the tubes in the furnace to individually know the impact of the throttling of a burner on the chosen target of step c1), and individually identifying burners to throttle,
- c4) getting a map of burners of the furnace where the burners to throttle are individually identified,
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- step d) throttling the burners according to the map got in step c4).

2. Method according to claim 1 characterized in that said simplified physical model of the impact of burner throttling on the tube skin temperature is based on the following rules 1) to 3) of behavior :

- 5 1) throttling a burner impacts significantly the two closest rows of tubes, said two closest rows of tubes being on the same side for an outer burner and one on each side of the burner for an inner burner; throttling an outer burner has a higher impact on the closest row of tube than on the second row whereas an inner burner throttling distributes the impact on the closest rows of tubes on both sides; within any of the impacted rows, the throttling of a burner has the highest impact on the closest tubes, the impact on
10 the tubes decreasing rapidly while moving off from the throttled burner, the number of tubes impacted by the throttling of a burner is estimated at $4 \times N_{\text{tubes}} / N_{\text{burners}}$, for the impacted tubes the tube skin temperature variation is proportional to the distance from the throttled burner
- with N_{tubes} = number of tubes in the row, and N_{burners} = number of burners in the
15 row;

2) the impacts of throttled burners on the tube temperature cumulate;

3) the tube temperatures variations are proportional to the power ratio τ , with τ being:

$$\tau = \frac{P_{\text{non-throttled}} + \Delta P}{P_{\text{non-throttled}}}$$

where $P_{\text{non-throttled}}$ is the power of the burner in standard operational mode and ΔP is
20 the power variation induced by the throttling with $\Delta P < 0$ when the burner power has decreased due to the throttling of the burner and $\Delta P > 0$ when the burner power increase due to redistribution of the power among the non-throttled burners in the furnace.

3. Method according to claim 1 or 2 characterized in that the one or more parameters of
25 step c1) is chosen among the following: Maximum Tube Skin Temperature, Tube Skin Temperature Spread, Syngas Collector Temperature Spread with the target of improvement being the reduction of the parameter value.

4. Method according to any of the claims 1 to 3 characterized in that in the step c3), the
30 simplified physical model is combined with an optimization algorithm which is either an in house

optimization algorithm or algorithms for optimization known in the art, such as as black box optimization algorithms.

5 5. Method according to any of the preceding claims characterized in that the throttling of the burners is obtained by partially closing at least a valve installed on at least one of the fuel streams or oxidizer stream preferably on the fuel streams and more preferably on the secondary fuel stream.

10 6. Method according to any of the preceding claims characterized in that the power ratio $\tau\%$ of a throttled burner is between 90% and 50%, preferably between 80% and 60% .

15 7. Method according to any of the preceding claims characterized in that the information on a real tube temperature of step b) is the tube skin temperature, being preferably obtained by means of a thermocouple or a pyrometer or an Infrared camera, or deduced from the syngas collector temperature being preferably obtained by means of a thermocouple.

20 8. Method according to any of the preceding claims characterized in that the method comprises the calibration step a) where real tube temperature measurements are performed for one or more tubes impacted by a throttled burner, at least for a tube in front of said burner in non-throttled and in throttled conditions, with the burner being preferably an outer burner.

25 9. Furnace containing reforming tubes being filled with a catalyst for the chemical conversion of a gaseous feed and being positioned vertically in rows inside the furnace, burners being mounted in rows with rows of inner burners placed between two rows of tubes and rows of outer burners placed between a row of tubes and a side wall parallel to the rows of tubes, with heat being transferred from the burners to the tubes and with flow rates associated characterized in that part of the burners are individually throttled according to the map got by the method of any of the claims 1 to 8.

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