Analysis the optimal damper angle for a furnace to reduce the energy cost and CO_2 emission

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Abstract

In this research, the Grey Relational Analysis method is implemented to develop a model for analyzing the optimal pre-heated air temperature in order to operate a full-scale heating furnace in a refinery plant. Results of using the Grey Relational Analysis as a mathematical method for conducting factor analyses show that the optimal damper angle is 42.5^{o}. This damper angle is close to the actual optimal operational temperature, and if applied, the annual fuel savings will be 1.2×10^6 m^3 and 1.4×10^3 ton /year of CO_2 emission will be reduced.

Keywords: Grey Relational Analysis, Furnace, Damper angle

INTRODUCTION

Commonly used statistical methods include regression analysis and fuzzy theory analysis. Unlike the fuzzy theory analysis method, the gray theory method requires fewer data to carry out simpler operations with better predicting results. It has been widely applied in many fields including economics, production, and power consumption and management, among the many others. The analysis applies quantifying data to discuss the relationship between the factor sequence of operational variables and the factor sequence of responding variables. In this research, the gray relation analysis method is used to develop an analytical model that can be used to analyze the parameters for achieving the optimum damper angle when operating the finance used in a full-scale petroleum refinery plant.

THEORETICAL CONSIDERATIONS AND EXPERIMENTAL METHODS

When the gray relation analysis is applied as the mathematical method to carry out the factor analyses, the pre-heated air temperature is assumed to be the specific sequence x_0, and the expected value for sequence x_0 in the analytical model is substituted with a series of values varying from the maximum to the minimum values. Hence the average correlation between specific sequence x_0 and other factors at each expected values.

RESULTS AND DISCUSSION

Influence of damper angle on the furnace temperature and thermal efficiency

Reducing the damper opening will cause a lower degree of vacuum, slower uprising velocity of the hot gas flow, and a longer residence time for the heat energy to stay in the furnace so that more heat is absorbed by the liquid to be heated to raise the furnace thermal efficiency. Table 1 indicates the damper angle is reduced from 45 % to 39 %, the radiation section temperature increases 42.3 ^{o}C from 755.5 ^{o}C to 797.8 ^{o}C; the convection section temperature drops 34.3 ^{o}C from 949.3 ^{o}C to 909.0 ^{o}C ; and the flue gas temperature drops 27.8 ^{o}C from 357.8 ^{o}C to 330.0; and the furnace thermal efficiency is raised on the average 2.0 % from 82.2 to 84.2 %.

Table 1 Influence of damper angle on the various temperatures

Damper opening (^{o})	45	43	41	39
Radiation Temp. (^{o}C)	755.5	766.9	776.8	797.8
Convection Temp. (^{o}C)	949.3	934.7	921.8	909.0
Flue Gas Temp. (^{o}C)	357.8	343.9	337.6	330.0
Efficiency (%)	82.4	83.3	83.8	84.2

Influence of damper opening on fuel flow rate

Reducing the damper opening the furnace internal hot gas heat has higher temperature, the time for the fuel to reach the burning point is reduced leading to savings of fuel consumption. Fig. 1 shows that the fuel flow rate in the furnace has a decreasing tendency with smaller damper openings. The average fuel flow rates are decreasing from 751.2 m^3/hr to 490.6 m^3/hr for damper angle of 45 % to 39 %.

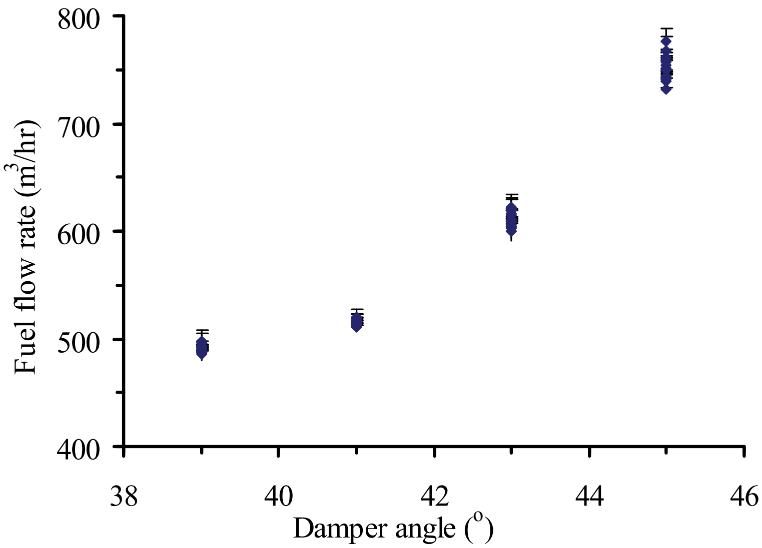

Fig.1. Relationship between damper angle and fuel flow rate

GRAY RELATION ANALYSES

The "damper angle" is designated as a single specific sequence x_0 for evaluating the average relational grades between the expected value of the specific sequence, and the sequence of the parameters to be analyzed. As shown in Fig. 2, when the damper opening is reduced from 45% to 38%, the average relation for the parameter analyzed reveals an increasing tendency. For the damper angle range between 42 and 42.5^o, the average relation increasing rate gradually decreases. When the damper angle exceeds 42^o, the average relation appears gradually decreasing. Hence, based on the results obtained using Gray Relation Analyses, the optimum damper angle is found to be between 42 and 42.5^o. This is also confirmed by the on-site results obtained with the full-scale furnace that when the damper angle is controlled at 42^o, the maximum fuel savings (186 m^3/hr) are observed among all other damper angle studied.

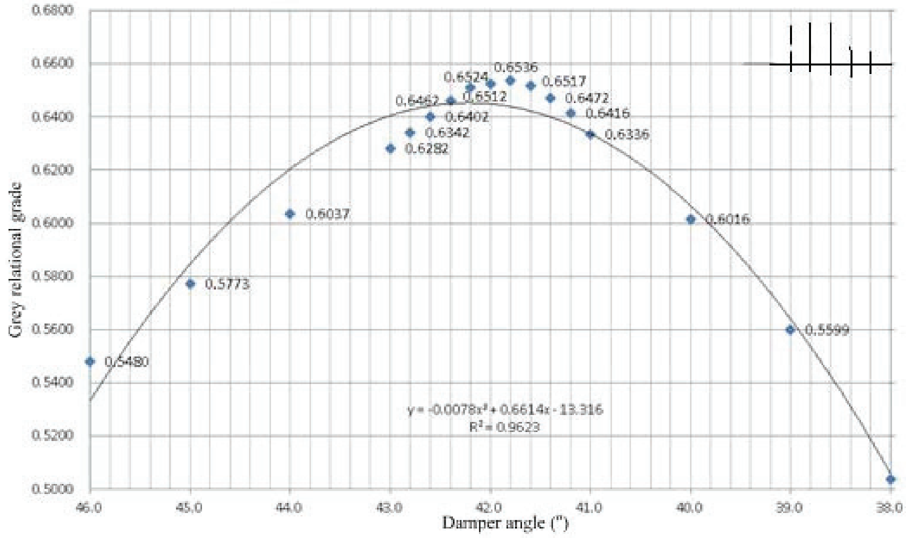

Fig. 2. Correlation between the average relations for the damper angle and the parameters to be analyzed (distinguished coefficient ζ 0.1)

CONCLUSIONS

The results indicate that when the damper angle is reduced from 45 to 39^{o} the average temperatures increase 42.3 ^{o}C in the radiation section, 34.3^{o}C in the convection section, and 27.8^{o}C for the flue gas.

Additionally, the on-site study results using a full-scale furnace are confirmed with the results obtained using the Gray Relation Analysis that the optimal damper angle range is between 42 and 42.5^{o}. If the full-scale furnace is operated at the optimal damper angle, the annual savings of fuel consumption is 1.2×10^6 m^3 and 1.4×10^3 ton /year reduction of CO_2 emission.