THE DEVELOPMENT OF HIGH TEMPERATURE RECIRCULATING PUMP (HTRP) FOR ENERGY SAVINGS IN AN INCINERATOR

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ABSTRACT

Tremendous increase in generation of Municipal Solid Waste (MSW) has become a major concern for the Malaysian government as the country experiencing rapid development. It was estimated about 16000 tones/day MSW is produced at national level and in Kuala Lumpur alone about 2500 tones/day. Annually, it was predicted to rise about 2%. Incineration, being one of the Integrated Waste Management Solution (IWMS) was found to be a best option to overcome the waste management problem; it is proven by the number of incinerators available in developed country such as Japan, which exceeding 1000 units. This is clearly confirmed, that incineration has become one of the best options because it gives volume and weighs reduction of the MSW by 83% and 91% respectively. Currently, an incineration pilot plant called Thermal Oxidation Plant (TOP) has been installed in Malaysia Institute for Nuclear Technology Research (MINT) and it is experiencing delay in ram up time in primary chamber which has results more auxiliary fuel from design value is being consumed before the chamber reach the combustion temperature. The presence of high moisture level (60%) was found to be a reason of this phenomenon. Therefore, a High Temperature Recirculating Pump (HTRP) has been developed to overcome this problem and therefore some energy saving could be realized through flue gas recirculation method in an incinerator. The experimental results of HTRP from cold fluid and hot fluid tests have confirmed the potential of application of HTRP as a recirculation engine to overcome the current problem. Integration of these results into starved air incinerator model has result in reduction of auxiliary fuel consumption in primary chamber up to 25.91 %.

KEYWORDS

Municipal Solid Waste, Incineration, High Temperature Recirculating Pump

1. INTRODUCTION

The incineration of MSW in starved air incinerator involved the use of primary chamber to partly gasify the solid waste, followed by burning the gaseous product in a secondary chamber. Malaysian waste have up to 60% moisture [1], thus a substantial amount of fuel is needed to dry out the moisture from this waste in the primary chamber. Thus, it is very important to recirculates the hot flue from secondary chamber back to primary chamber to help the drying process. Currently, typical to the plant in MINT, there is no heat recovery involved, thus all heat generated is released into the environment. It is envisaged that, if part of the heat generated in the secondary chamber could be reused or recycled into the primary chamber, some form of energy saving could be realized.

Therefore, a High Temperature Recirculating Pump (HTRP) has been designed to recirculate part of combustion products (flue gases) that have been generated in the secondary chamber back to primary chamber. Flue gas recirculation methods have been studied in various research institutions to treat the flue gases and to control formation of NO, in combustion chamber of incinerator, boiler and turbines. Godridge [2] reviewed much work on flue-gas recirculation (FGR) in a study of oil-fired plant. The conventional method of external recirculation relies on mechanical means and typically consists of up to 30% of flue gas being cooled prior to being pump back into system by fan. The disadvantage of the fan-recirculation system is the need to cool the flue gas and the possibility of fan failure [2].

This recirculating device was developed based on jet pump concept and it was named High Temperature Recirculating Pump (HTRP) due to its function to entrain hot flue gases. HTRP has potential to suit many applications in various fields and it is simple in term of operations. The absences of moving parts attract researchers to maximize its potentials [3]. The HTRP has been subjected to two different test namely, cold fluid test and hot fluid test. The results obtained from the experiments were used to calculate the flue gas recirculation process. However, the working principle is not discussed here.

2. MATERIALS AND METHODS

Incineration of MSW generally involves three basic processes: drying, pyrolysis which takes place at absence of air and gasification in primary chamber and followed by complete combustions in secondary chamber. The primary chamber operates at 450°C and secondary chamber sustain above 1000°C with residence time 2 seconds. Flue gas recirculation (FGR) is a method of entraining combustion products in the form of gases which possess high energy at extreme temperature from secondary chamber and delivered back to primary chamber. In order to recycle the product gases, a device that can work at high temperature environment is required. Therefore, a HTRP has been designed and tested. The compressed air acts as motive fluid where it will entrain part of the flue gas and together they will go back to the primary chamber. Figure 1 shows a schematic diagram of starved air incinerator with HTRP. The energy saving through HTRP design was obtained by incorporating experimental results from hot fluid test and cold fluid test into starved air incinerator model which was developed based on work conducted by Yunus [4]. Cold fluid test involves the experiments on HTRP at ambient conditions. Here, the HTRP has been tested with various size of driving nozzle which was characterized by area ratio (ϕ).Area ratio (ϕ) is a ratio between cross sectional area of driving nozzle (A_{nozzle}) to cross sectional area of mixing throat (A_{throat}) in the HTRP. The performance of HTRP is characterized by entrainment ratio (R_m) which is defined as the ratio of mass of entrained fluid over the motive fluid. The experiment was conducted by varying the motive or driving pressure from 151.98 kPa to 455.96 kPa (absolute pressure) for fixed size of nozzle (ϕ). Similar to cold fluid test, the entrainment ratio (R_m) and the driving nozzle area ratio (ϕ) of 0.0829 has been studied to identify the potential of High Temperature Recirculating Pump (HTRP) during the hot temperature environment. In the hot fluid test, the nozzle was subjected to test with driving pressure ranged from 151.98 kPa and 253.31 kPa.

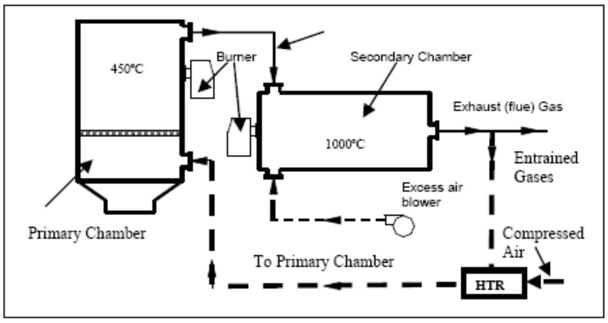
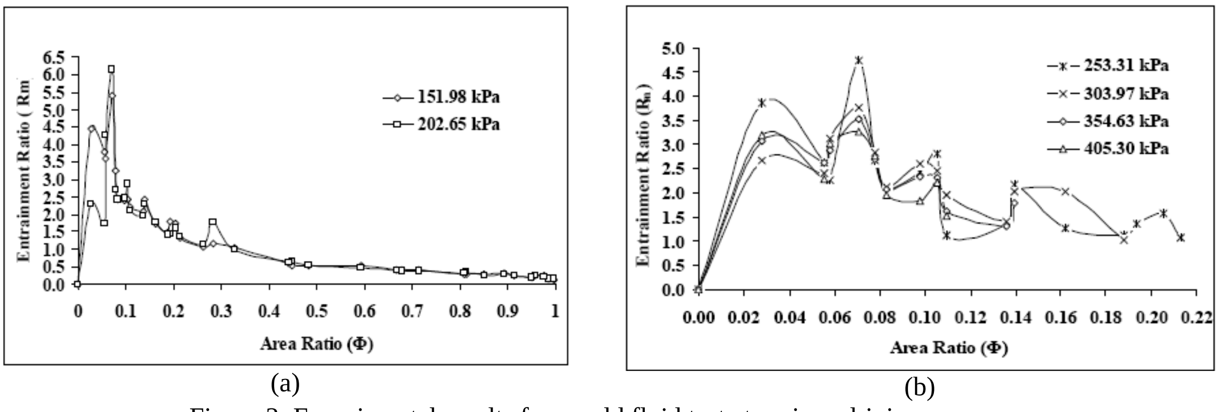


Figure 1: Schematic diagram of starved air incinerator with HTRP

3. RESULTS AND DISCUSSION

3.1 Cold Fluid Test

The result of cold fluid test is shown in Figure 2. Figure 2(a) shows that at constant driving pressure, for an example, 151.98 kPa, the entrainment ratio (R_m) increases as the nozzle size or area ratio reduces (ϕ). At higher driving pressure (202.65 kPa), more entrainment take place. The highest entrainment ratio (R_m) of 5.38 and 6.16 was documented at area ratio (Φ) of 0.071 for 151.98 kPa and 202.65 kPa driving pressure respectively. Overall it can be said that each area ratio (ϕ) behave uniquely according to the driving pressure. The result for greater driving pressure is shown in Figure 2(b). The fluctuation in the entrainment ratio (R_m) shown may be due to the recirculation effect in the mixing throat of HTRP and blockage effect.



(a) (b)

Figure 2: Experimental results from cold fluid test at various driving pressure

3.2 Hot Fluid Test

The result of the hot fluid test is shown Figure 3. The highest temperature documented in the entrainment section of HTRP is about 480°C. For driving pressure of 151.98 kPa, the initial entrainment value at temperature 39.4°C is about 2.67 and this increases as the operating temperature rise gradually to 450.30°C and results the entrainment ratio to 2.94, which amount to 10.11% increments. The fluctuation in entrainment was observed due to the recirculation effect in the mixing throat. Generally it can be concluded that the entrainment ratio (R_m) increase linearly with temperature as shown in Figure 3. The thermal efficiency of HTRP was calculated by dividing the measured temperature at exit section of pump with input temperature at entrainment port and from the experiment, the calculated average thermal efficiency of HTRP is about 62 %. From here, it could be deduced that if we want the exit temperature to be about 500°C, the entrainment temperature shall be at least 500 °C /0.62 = 806.45 °C. Therefore it can be concluded that the HTRP was successfully tested working at high temperature environment.

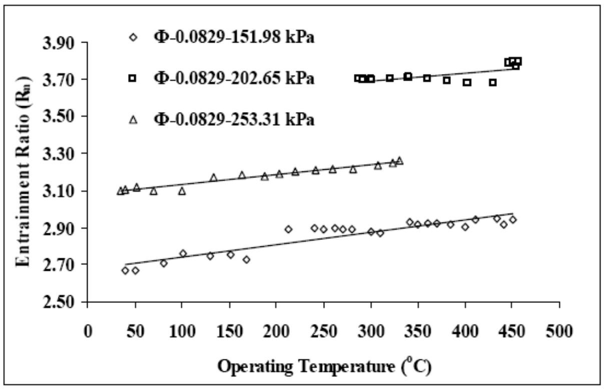


Figure 3: Experimental results from hot fluid test at various driving pressure

3.3 Energy Saving

By incorporating the results obtained from cold fluid test and hot fluid test of HTRP into the starved air incinerator model, the energy saving in primary chamber can be predicted. The developed model is capable of predicting theoretically the amount of auxiliary fuel required to perform partial combustion in primary chamber and followed with complete combustion in secondary chamber. For a 1000 kg of MSW having characteristic as in Table 1, the required amount of combustion air per hour for 12 hours operation cycles time when the primary chamber stoichiometric air ratio (X) was set to 0.3 is 83.5 kg/h. For this, the suitable driving nozzle size in term of area ratio (ϕ) is 0.0978 which has taken from combination of Nozzle-80° and Spindle-30°. At driving pressure 303.97 kPa, the corresponding entrainment ratio (R_m) during cold run test is 2.59. Generally, it was found to increase 10% during hot run and its result to 2.85. Figure 4 shows some prediction of energy saving at various sub-stoichiometric air condition and pump application condition. When the model was tested without FGR for substoichiometric air ratio (X) of 0.3, the calculated amount of auxiliary fuel consumption in primary chamber is about 85.06 kg, of which 33.3 kg of total fuel was consumed to evaporate the 60 percentage of moisture in the waste. With the incorporation of HTRP, the total auxiliary fuel consumption in primary chamber was reduced to 77.63 kg and this shows an energy saving of about 8.73 % in the primary chamber. The amount energy being saved when the primary chamber operated at sub-stoichiometric air ratio of 0.57 using 2 units of HTRP was about 25.91% of the total auxiliary fuel consumption at 54.46 kg.

Table 1: Starved air incinerator's parameter [5]

Sample: A	MSW Weight	1000 kg
Proximate Analysis :	Moisture :	60%
Ultimate Analysis :	Carbon :	56.37 % (by weight)
	Hydrogen :	8.15 % (by weight)
	Oxygen :	40.16 % (by weight)
Lower heating value (LHV) :	17,696.04 kJ/kg	
Primary chamber temperature :	450°C	
Secondary chamber temperature :	1000°C	
Combustion air :	The total air at both chamber was set to 2.0 time's stoichiometric air required.	

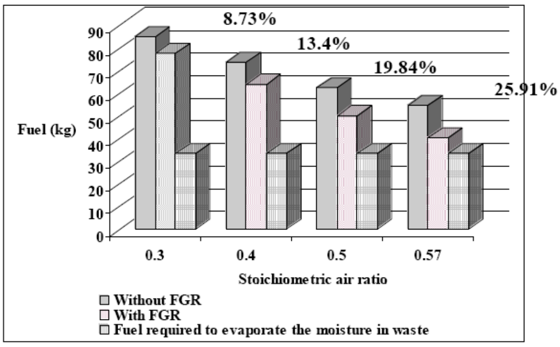


Figure 4: Fuel consumption in primary chamber for 1000 kg of MSW (LHV=17,696.04 kJ/kg) for MSW in Table 1.

4. CONCLUSIONS

Through this analysis, it can be concluded that the High Temperature Recirculating Pump (HTRP) is capable recirculate the hot flue gases generated in the secondary chamber back to the primary chamber and promote some energy savings through reduction in auxiliary fuel consumption.

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