



## Finite element analysis of MSW pyrolysis reactor

F. Polat<sup>1,a</sup>, E. Toklu<sup>1</sup>, M.Kılınçel<sup>1</sup>, M. Gur<sup>1</sup>, A. Coskun Avci<sup>1</sup>

<sup>1</sup>Duzce University, Mechanical Engineering, Duzce, Turkey.

Accepted 5 Apr 2014

### Abstract

The aim of this study was to observe the temperature distribution at the inlet of the pyrolysis reactor at different flow rates. The pyrolysis process; used in the iron and steel industry or the chemical industry and conducted in a furnace having a durable structure for high temperature and corrosive gases such as chloride and sulfite. A prototype of the pyrolysis reactor was designed in 3D CAD program (Inventor). The designed model was converted to finite element program aided by reverse engineering methodology. The finite element analyses (CFX) were performed with respect to different flow rates (50 kg/s, 55 kg/s and 60 kg/s ) at the inlet. In the first part of the work, the importance of the study, describes the purpose and scope. The second section describes issues related to solid waste and made comparable with each other. Then recycling municipal solid waste disposal methods, landfill, thermal conversion technologies and biological conversion technologies are described, respectively. Thermodynamic analysis of pyrolysis which is one of the thermal disposal methods was performed. In the last section the results are evaluated and recommendations made.

**Keywords:** Pyrolysis; finite element analysis; municipal solid waste

### 1. Introduction

As a result of industrialization in recent years, running out of natural resources with the effect of population growth occurred due to the amount of solid waste and the environment is growing rapidly polluted. But nevertheless the idea of converting the waste is also adopted as an input to economic every day and are trying to implement waste management

systems worldwide. There are several methods to convert waste into energy. Some of these are landfills, thermal decomposition (incineration, gasification, and pyrolysis) and anaerobic digestion[4,6]. There are differences in the reaction conditions of the thermal decomposition methods as can be seen in Table 1.[1-5]

Table 1. The reaction conditions of the thermal degradation method[5]

	Incineration	pyrolysis	gasification,
Reaction temperature (°C)	800 – 1450	250 - 700	500 – 1600
Combustion chamber pressure (bar)	1	1	1-45
Ambient	Air	inert - nitrogen	O <sub>2</sub> ,H <sub>2</sub> O
Stoichiometric air ratio	> 1	0	< 1
Gaseous products	CO <sub>2</sub> , H <sub>2</sub> O, O <sub>2</sub> , N <sub>2</sub>	H <sub>2</sub> , CO, H <sub>2</sub> O, N <sub>2</sub>	H <sub>2</sub> , CO, CO <sub>2</sub> , CH <sub>4</sub> , H <sub>2</sub> O, N <sub>2</sub>
State products	ash, slag	ash, coal	ash, slag
Liquid products		pyrolysis oil, water	

The amount of solid waste produced per person in consequence of the change in consumption habits is increasing every day. This challenge is increasing concern about being economical and environmentally friendly technologies used in the disposal of waste and researches on the issue are increasing. All over the world context of

sustainable development, waste management strategies aimed at converting an input is adopted for the economy [6,7]. Integrated solid waste management is a process which includes waste reduction at source, reuse, recycling and recovery, starting with applications, consisting of waste collection and ending with final disposal.

<sup>a</sup> Corresponding author;

Phone: +90-541-205-5024, Email: fikretpolat@duzce.edu.tr

Landfill waste is stored according to the principles of engineering. The resulting gas is used for energy production warehouse. In combustion technology, waste, incinerates by providing heat recovery and power generation is performed using steam turbines. Gasification technology at the first stage provides pyrolysis then followed by up to high temperature reactions and low molecular weight gases are produced. The generated gas is evaluated for power generation using internal combustion engines or boilers. This study was conducted a detailed

review of the literature on energy production technologies from municipal solid waste. Pyrolysis is the thermal decomposition process took place in an inert atmosphere[8-11]. The pyrolysis process usually takes place between 400-850 oC. As pyrolysis product gas components, volatiles, carbon and ash revealed. The resulting carbon black can be used in tire production and the resulting ash is used as construction material. Mini pyrolysis reactor showed in figure 1.

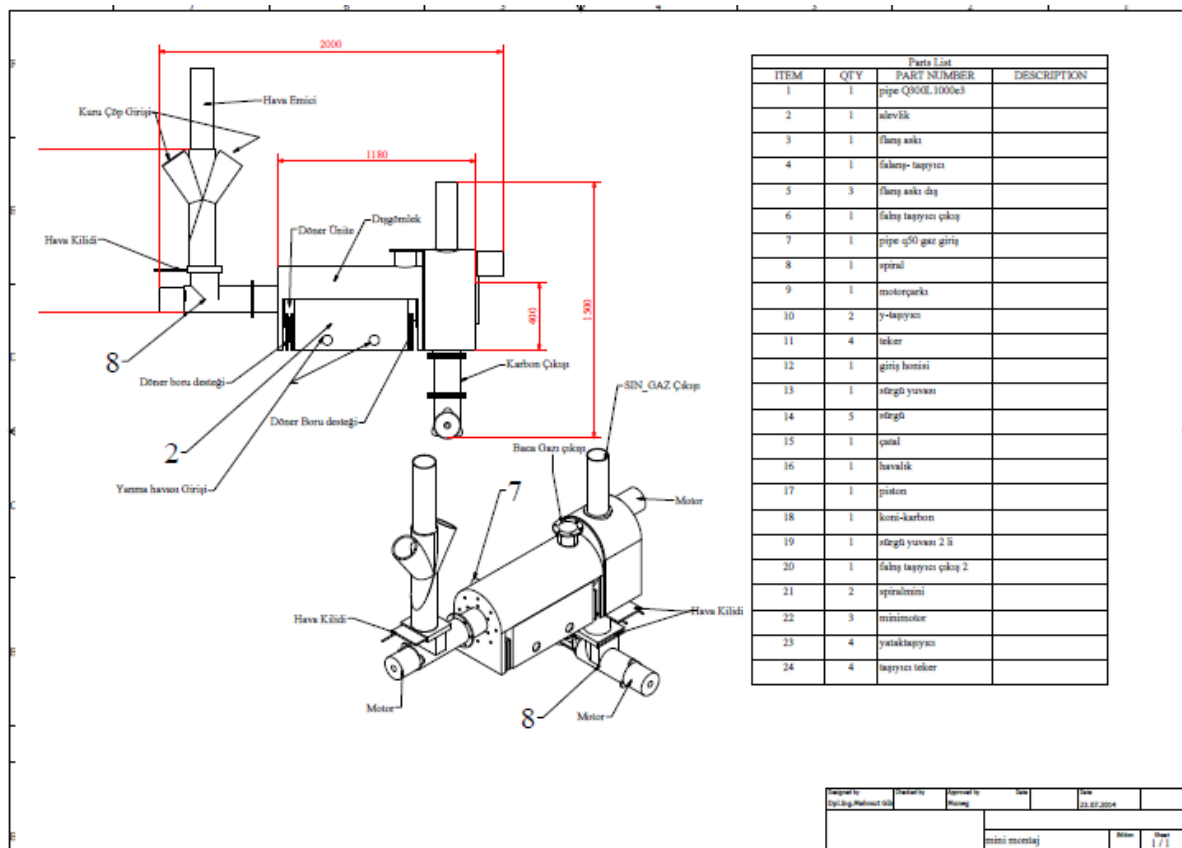


Figure 1. Perspective view of a pyrolysis reactor

## 2. Material and Methods

According to the literature, it's seen that pyrolysis of many materials such as hazelnut, birch, pine wood, cellulose, lignin and polyethylene is conducted, but there is hardly any place in the pyrolysis of urban waste[11-15]. Because solid waste content area varies according to country and even from even the province. In this study, thermodynamic analysis of the pyrolysis reactor for the grinding of raw solid waste, drying and pyrolysis process will be

made. 3-dimensional drawn pyrolysis reactor, after being transferred to the ANSYS-CFX software, system identification was performed. As an entry requirement, 50, 55 and 60 kg / h flow rate and temperature of 25 ° C were introduced. The reactor is heated by an external heater and a surface temperature of 500 ° C is also kept constant. The output of the reactor was assumed to 5 atm pressure. These values analyzes were carried out after introduction into the

system.

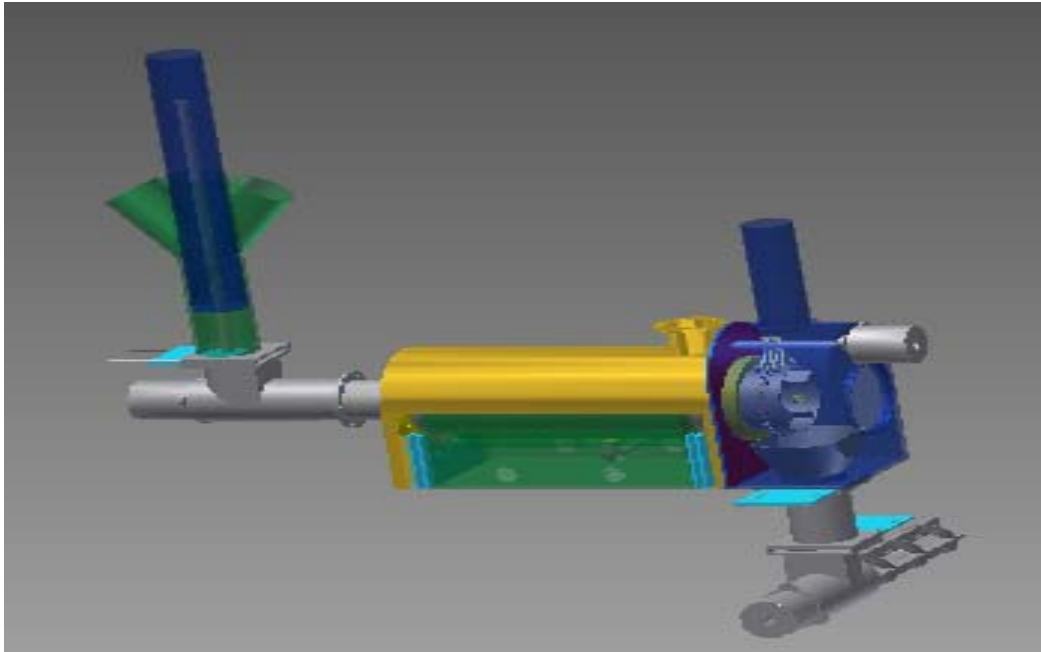


Figure 2 Mini pyrolysis reactor

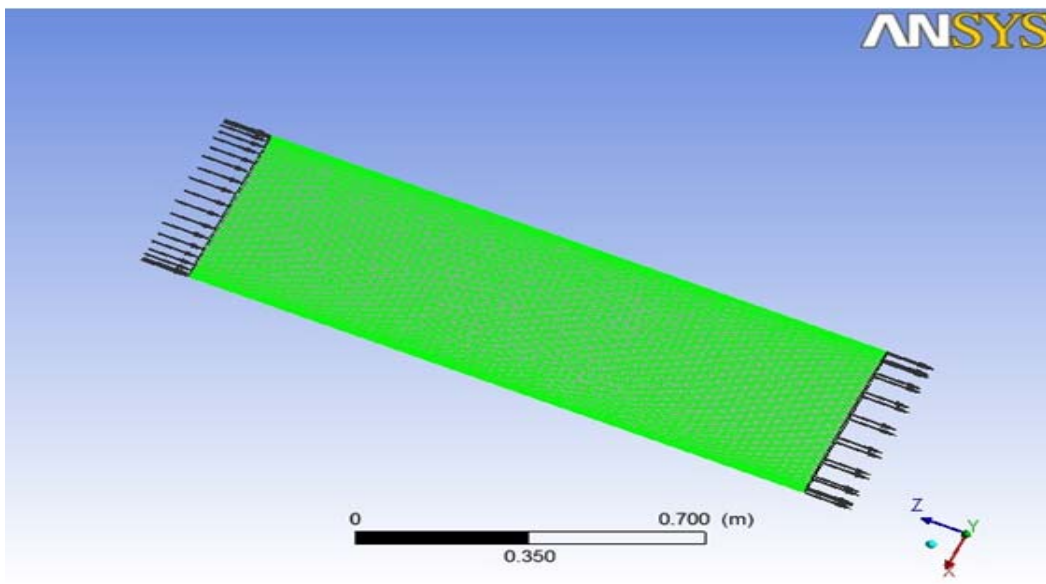


Figure 3. Pyrolysis reactor modeling

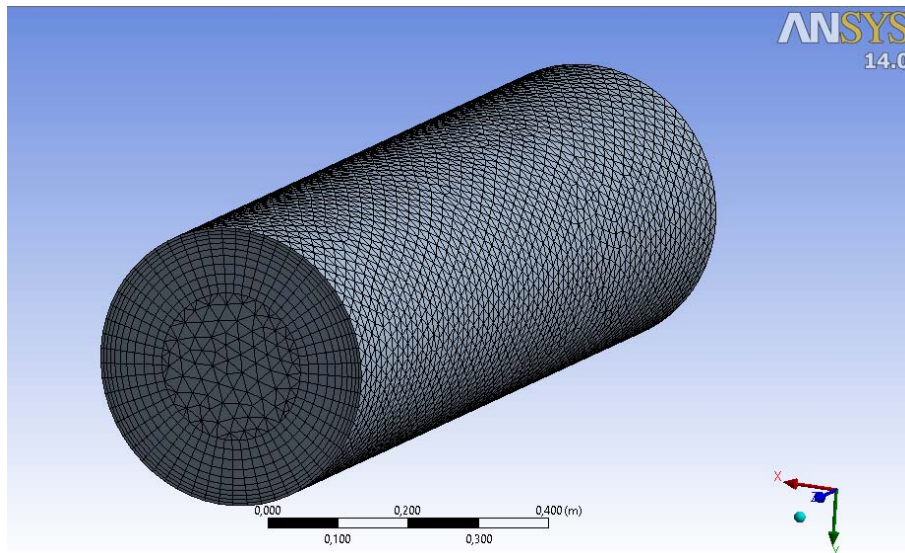


Figure 4 Mesh modeling of reactor

### 3. Results

This study has investigated the processing of municipal solid waste by pyrolysis method, system identification are performed energy analysis and fluid analysis performed at various temperatures of the pyrolysis reactor, which was built in ANSYS-FLUENT 3D drawing program. Disposal of municipal solid waste by pyrolysis

method, an issue that has recently focused on the international scientific community and users. Pyrolysis of urban solid waste according to the speed at the inlet of the reactor, pressure, temperature and viscosity distribution are shown in latest figures. Figures from 5 to 8 show the values of 50 kg/s flow rate.

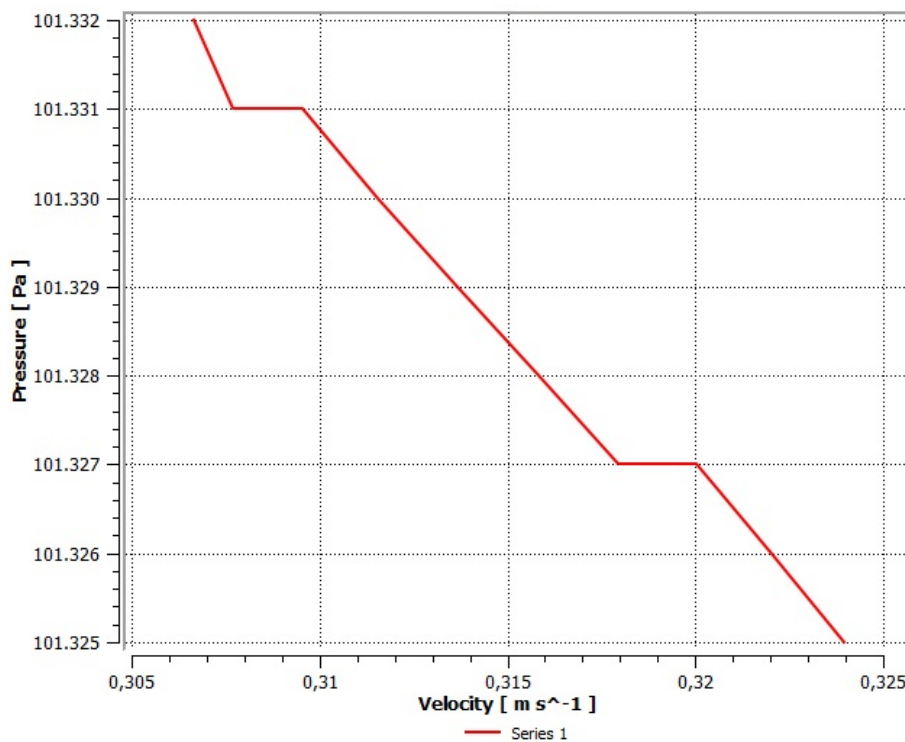


Figure 5. Speed-dependent pressure

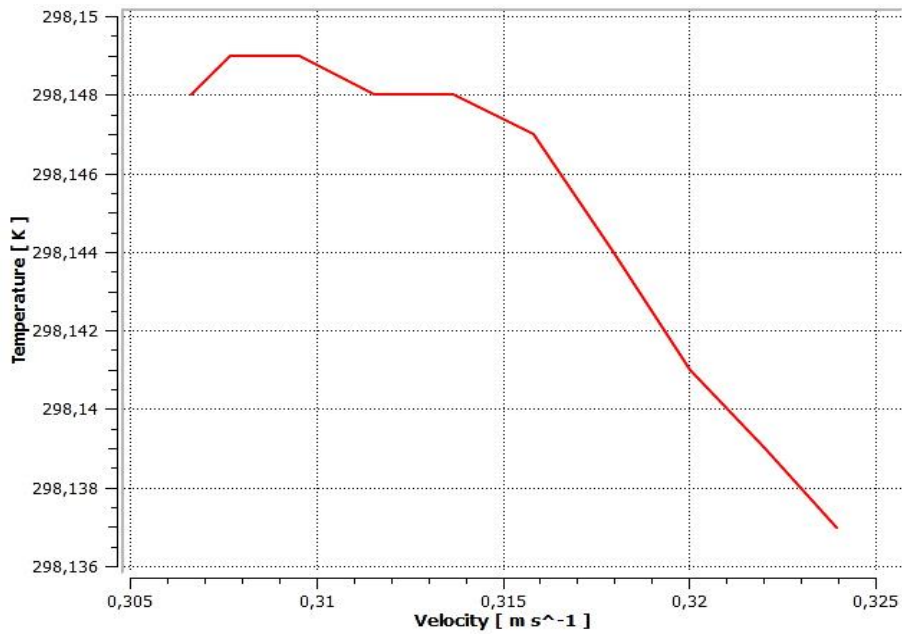


Figure 6. Speed-dependent temperature

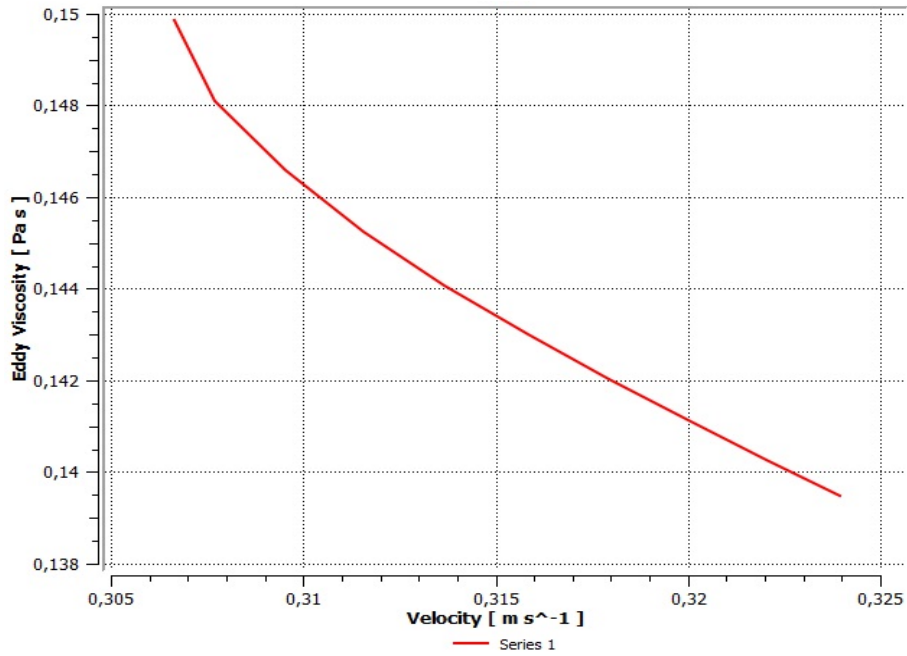


Figure 7. Speed-dependent dynamic viscosity

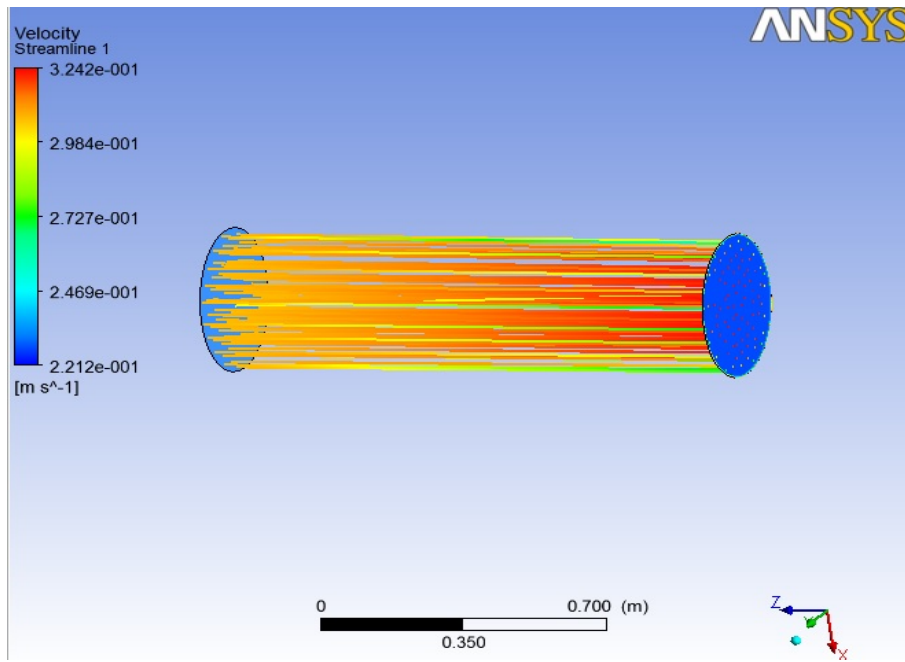


Figure 8. 3D Temperature distribution of the pyrolysis reactor

Figures from 9 to 12 show the values of 55 kg/s flow rate. When figures analyzed, compared to the other distributions in this flow has been

observed that a more uniform linear structure. But looking at the red area, it is seen that the increase in flow is more critical.

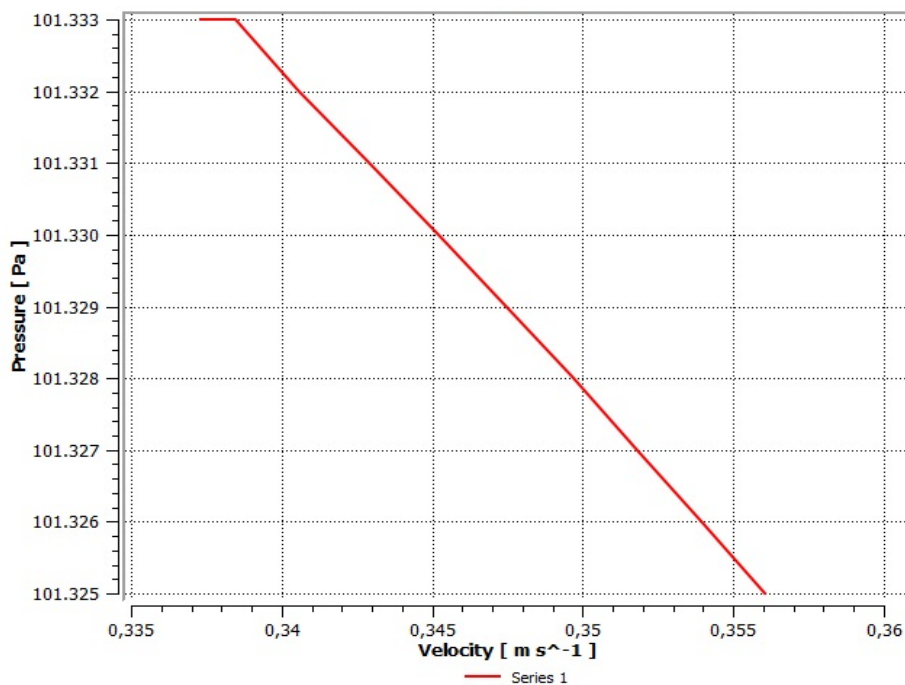


Figure 9. Speed-dependent pressure

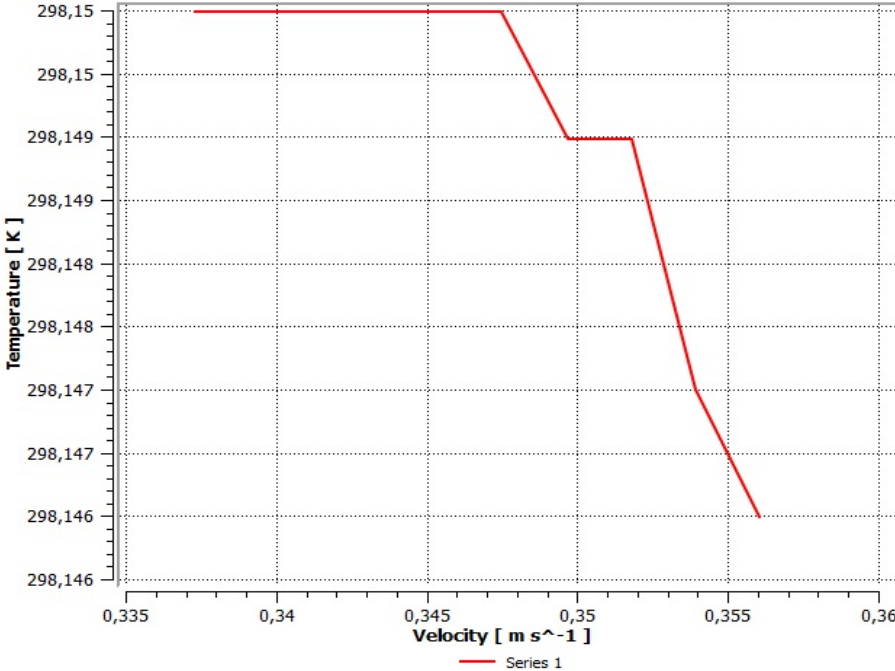


Figure 10. Speed-dependent temperature

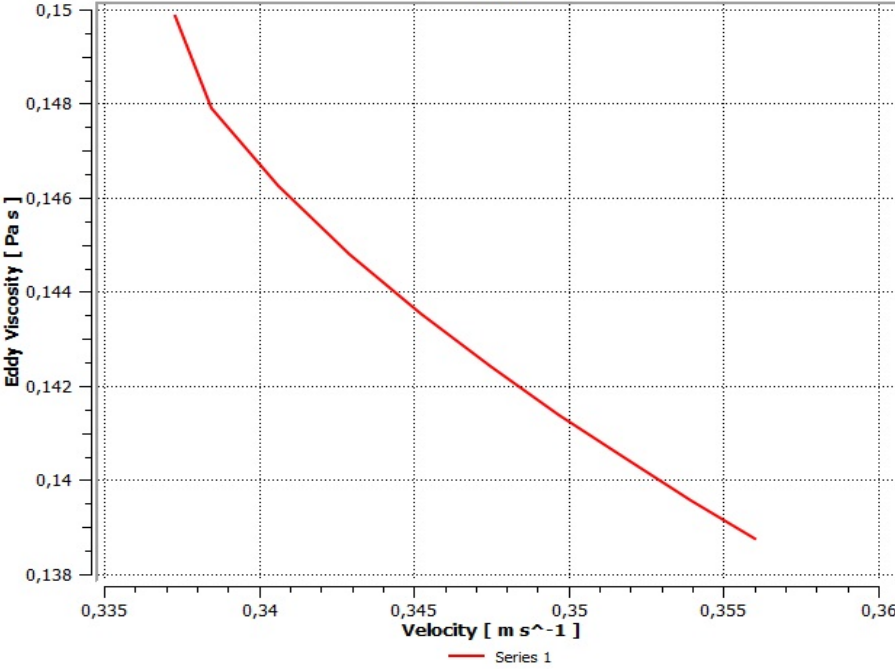


Figure 11. Speed-dependent dynamic viscosity

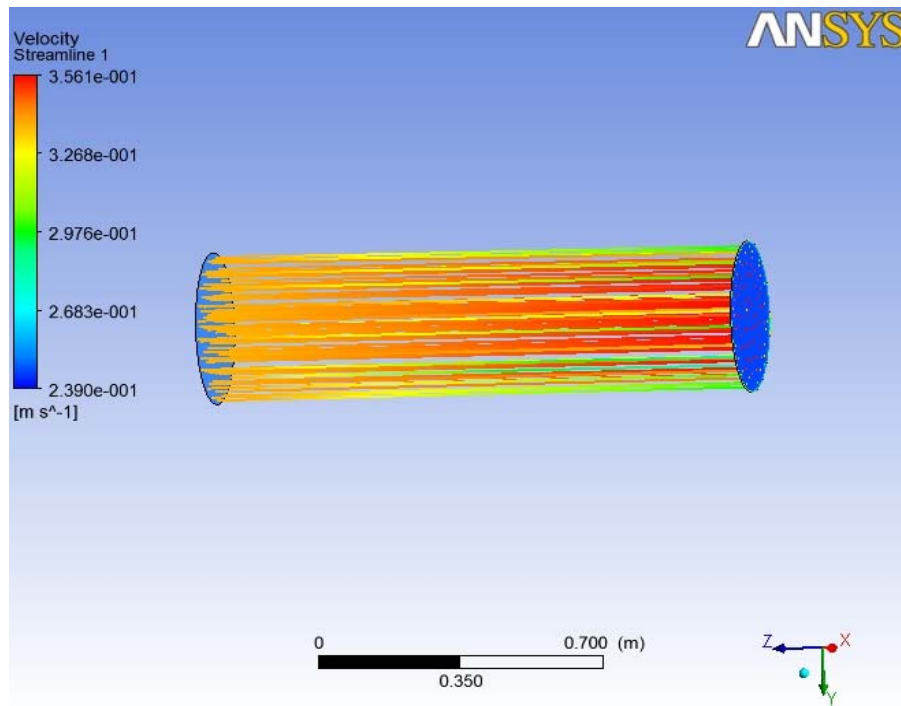


Figure 12. 3D Temperature distribution of the pyrolysis reactor

Figures from 13 to 16 show the values of 60 kg/s flow rate. When analyzing the figure 16, compared to the other distributions, amount of red area is more bigger than the others. As a

result of this analysis, it can be say that increasing the flow rate of municipal solid waste is not very logical.

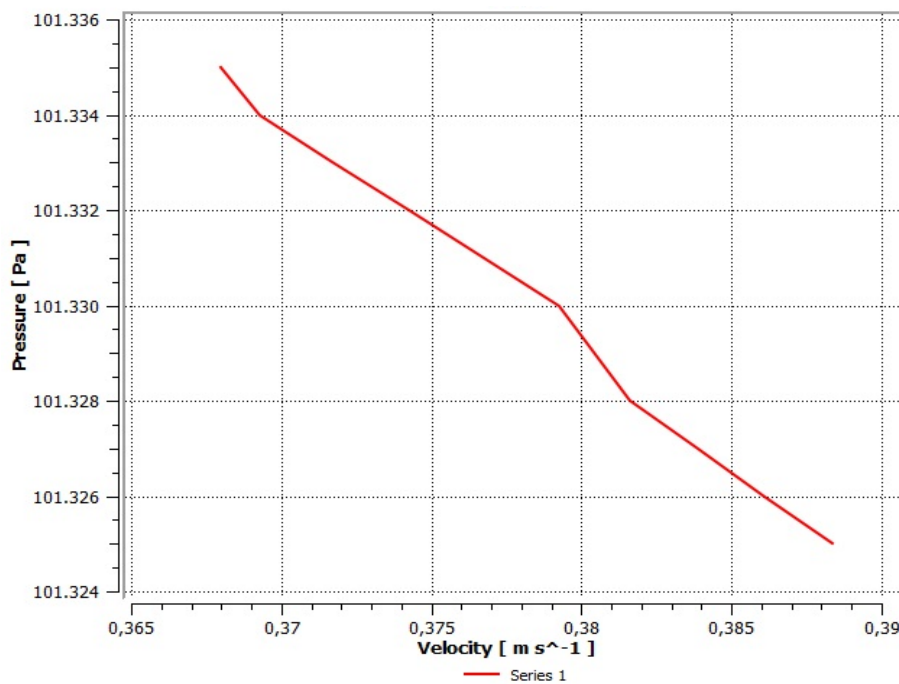


Figure 13. Speed-dependent pressure

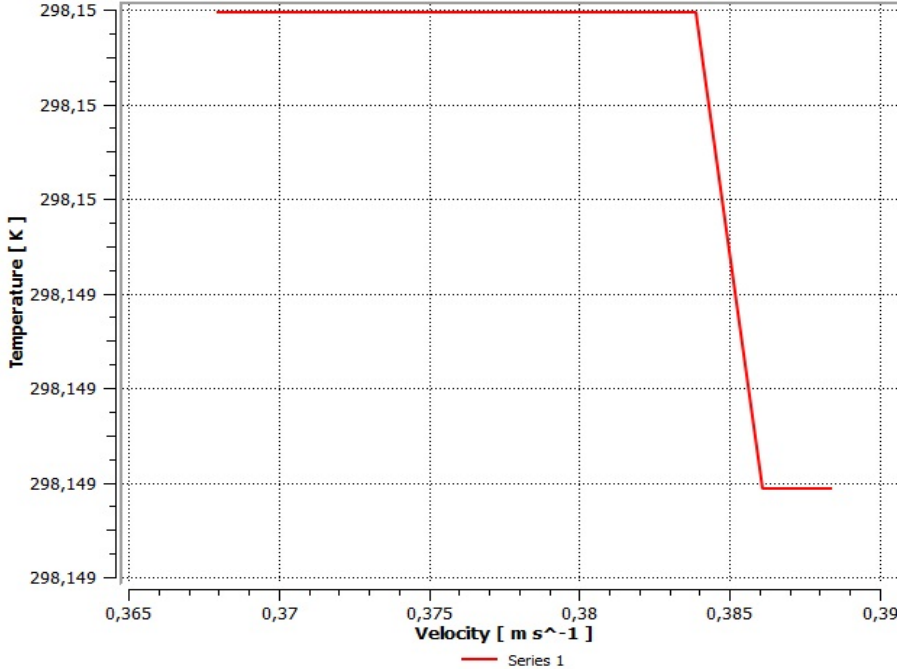


Figure 14. Speed-dependent temperature

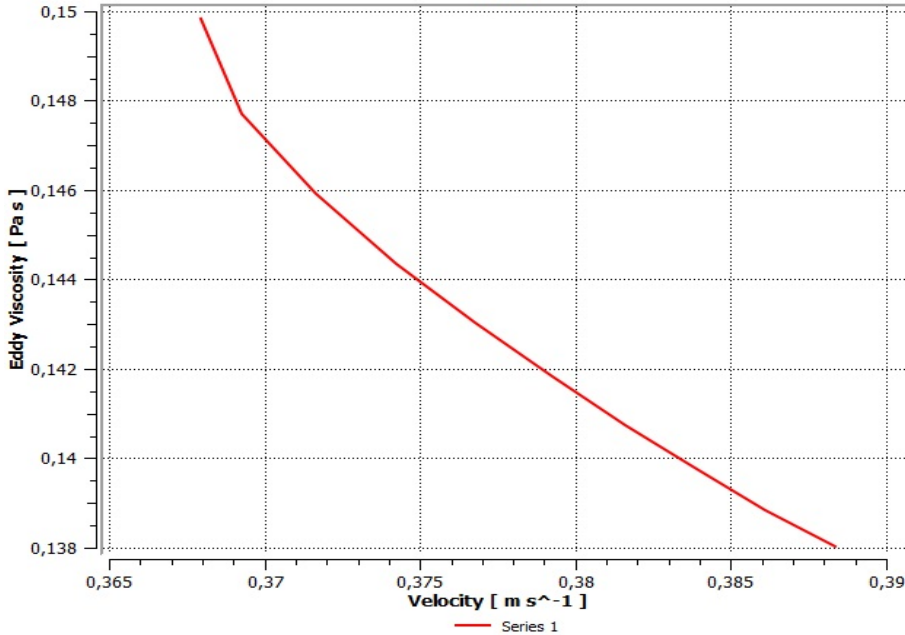


Figure 15. Speed-dependent dynamic viscosity

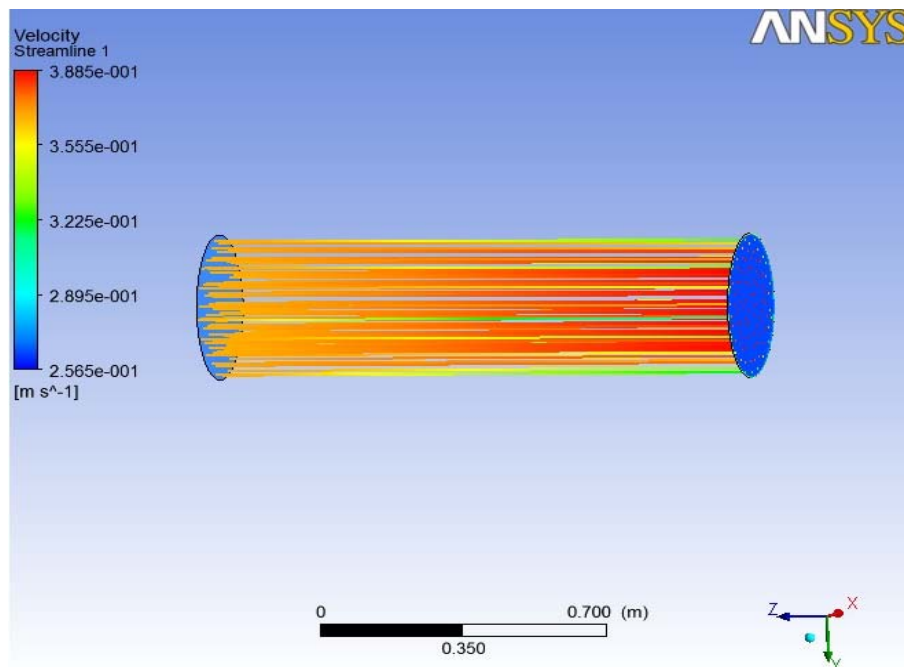


Figure 16. 3D Temperature distribution of the pyrolysis reactor

#### 4. Conclusion and outlook

In this study, the processing of municipal solid waste by pyrolysis method has investigated, system identification are performed, energy analysis and fluid analysis of the pyrolysis reactor at various temperatures performed with ANSYS-FLUENT program. Municipal solid waste is no longer seen as a source of problem

seems to be removed before this as an energy source. As long as pyrolysis method used, municipal solid waste will be converted into raw materials out of the waste class. There will be no need to landfill and these fields can be used for agricultural or other purposes. This research was supported by Duzce University BAP Project.

#### References

- [1] Baggio P., Baratieri M., Gasparella A., and Longo G. A., "Energy and environmental analysis of an innovative system based on municipal solid waste (MSW) pyrolysis and combined cycle," *Appl. Therm. Eng.*, vol. 28, no. 2–3, pp. 136–144, Feb. 2008.
- [2] Zarghami M., Experimental investigation of the effects of fuel aging on combustion performance and emissions of biomass fast pyrolysis liquid-ethanol blends in a swirl burner, University of Toronto, 2012.
- [3] Kawaguchi K., Miyakoshi K., and Momonoi K., Studies on the pyrolysis behavior of gasification and melting systems for municipal solid waste," *J. Mater. Cycles*, pp. 102–110, 2002.
- [4] Zaman A. U., Life cycle assessment of pyrolysis–gasification as an emerging municipal solid waste treatment technology, *Int. J. Environ. Sci. Technol.*, vol. 10, no. 5, pp. 1029–1038, Mar. 2013.
- [5] Massaro M. M., Mechanical, pyrolysis, and combustion characterization of briquetted coal fines with municipal solid waste (MSW) plastic binders, Master Of Science Thesis, Purdue University, 2012.
- [6] Banks S. W., Nowakowski D. J., and

- Bridgwater A. V., Fast pyrolysis processing of surfactant washed miscanthus,” *Fuel Process. Technol.*, vol. 128, pp. 94–103, Dec. 2014.
- [7] Tetik E. and Göllü E., “Biofuel production using slow pyrolysis of the straw and stalk of the rapeseed plant,” pp. 1–12, 1999.
- [8] Şensöz S. and Kaynar İ., “Bio-oil production from soybean (*Glycine max* L.); fuel properties of Bio-oil,” *Ind. Crops Prod.*, vol. 23, no. 1, pp. 99–105, Jan. 2006.
- [9] Greenhalf C. E., Nowakowski D. J., Harms A. B., Titiloye J. O., and Bridgwater A. V., Sequential pyrolysis of willow SRC at low and high heating rates – Implications for selective pyrolysis, *Fuel*, vol. 93, pp. 692–702, Mar. 2012.
- [10] Sensöz S. and Angin D., Pyrolysis of safflower (*Charthamus tinctorius* L.) seed press cake in a fixed-bed reactor: part 2. Structural characterization of pyrolysis bio-oils., *Bioresour. Technol.*, vol. 99, no. 13, pp. 5498–504, Sep. 2008.
- [11] Ryu C. and Shin D., Combined heat and power from municipal solid waste: current status and issues in South Korea,” *Energies*, vol. 6, no. 1, pp. 45–57, Dec. 2012.
- [12] Li S. -Q., Ma L.-B., Wan W., and Yao Q., A mathematical model of heat transfer in a rotary kiln thermo-reactor,” *Chem. Eng. Technol.*, vol. 28, no. 12, pp. 1480–1489, Dec. 2005.
- [13] Saracoğlu N., The importance of bioenergy and energy forestry for Turkey. Tübitak– JRC Zero Emissions Workshop, Gebze, Turkiye, 2007.
- [14] Apaydın E., Pütün E.A., Rice straw as a bio-oil source via pyrolysis and steam pyrolysis, *Energy*, 29:2171-2180, 2004.
- [15] Apaydın E., Pütün E., Rice straw as a bio-oil source via pyrolysis and steam pyrolysis. *Energy*, 29:2171-2180. 2004.