NRGWaste
A safe small scale thermal treatment for unsorted solid waste with recovery of energy

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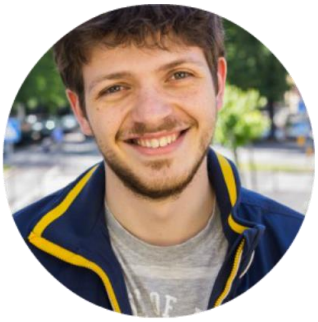

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PROJECT DESCRIPTION

NRGWaste is a micro scale, turnkey, self-contained system for the treatment of unrecoverable waste at the point of arising, based on high temperature plasma pyrolysis and on downsized waste pre-treatment technology (metal extraction, shredding, pelletisation). The core of the micro treatment prototype is based on the downsizing of the technology used in large waste to energy plants using components already largely used for industrial applications (i.e. TIG welding torches as a basis for a new way of generating plasma at low cost) coupled with a novel, self-adaptive control system to reach the highest levels of efficiency. The system includes a fully-automated control of the electric arc generating the plasma and a gas recirculation system to ensure safe generation of syngas (i.e. no furans and dioxins) ready to be exploited for energy generation.

The prototype was fully studied from the modelling side as well as from the experimental campaign performed at IRIS Srl facilities. Some improvements on the present technology arose from this project and were proposed to the company in order to fit different market applications ranging from stationary to non-stationary waste treatment as a result of the different skills present in the team, hereafter described, and to IRIS Srl company, always involved during the whole duration of the project.

Team Description

Energy Engineering
Cecilia Vicinanza

She was the team leader. She mainly worked on the energy engineering aspects of the project, performing the thermo-economic analysis together with her colleague Nicola. She also had a supervisory role, interacting with team members, tutors and stakeholders, taking care of the bureaucratic aspects of the ASP project.

Nicola Frascella

Together with Cecilia, he evaluated the interactions with energy world, from assessing the exergetic balance of the system to evaluating the market feasibility for the component.

Chemical Engineering

Manuel Innocenti

He worked on the system chemical modelling, focusing on the code assembly and the computational simulation. Moreover, he performed the sensitivity analysis for the same system through the computational model he had built.

Ahmed Mohamed Sadek Elgendy

He worked on the litter characterization and street sweeping waste, identifying the chemical reactions involved in the pyrolysis/gasification process and the related kinetic and thermodynamic calculations.

Eddy Christopher Batok Embanglian

He focused on the initial marine waste characterization, based on composition. Further, he separated the waste based on the various compositions for the rest of the experiment.

Electrical Engineering

Davide del Giudice

He focused on developing an improved version of the mechatronic control module in order to achieve a higher arc stability and thus a more efficient waste thermal treatment.

Mechanical Engineering

Donato Sportelli

He put his attention on developing a rotational system to achieve a better-treated waste processing by increasing its exposure to the plasma arc, improving the prototype efficiency.

ABSTRACT

NRGWaste is a prototype, owned and patented by IRIS Srl, that consists of a small scale system for the thermal treatment of unsorted solid waste using plasma technology, allowing energy recovery through thermal and electrical power generation with no harmful emissions. The system is constituted by a reactor, inside which there are two electrodes connected to a power generation unit. During operation, an electric arc is ignited to obtain plasma, capable of conducting electricity and characterised by a high temperature. The electric power generated in the arc is converted into thermal power, exploited for the treatment of the waste.

The main challenges that were faced were: the stabilisation of the arc, the evaluation of the syngas composition with respect to the waste composition, the introduction of a new

mechanical rotating system, the performing of thermo-economic analysis of the component.
In order to ensure a proper arc voltage, the MCM (mechatronic control module) continuously regulates the distance between the electrodes during operation. The team proposed different versions of the MCM code, which have been tested on the real prototype to assess which code could ensure the best performance of the MCM.
Laboratory experiments have been performed on the plasma generator model using three waste typologies: household, street sweeping and marine waste. A simulation model has been developed to describe the gasification process and a sensitivity analysis was performed to study the temperature impact.
A mechanical solution was developed to obtain a suitable rotational system able to mix up the waste inside the reactor and to expose it more uniformly to the heating source.
In order to verify the feasibility of the machine, an input-output thermo-economic analysis was performed for three different applications, which gave as a result the percent value of which the price of the NRGWaste component should decrease in order to make its sale profitable for the user.

UNDERSTANDING THE PROBLEM

Waste disposal is an issue which deeply permeates the modern society, from the largest point of view (cities, countries) to the smallest one (isolated mountain villages, ships). Particularly addressing this last area, the available solutions to deal with waste disposal are not so performing, and generally require high costs and lead to resources wastage. Therefore, the IRIS Srl Green Plasma project, which NRGWaste has prosecuted, specifically considered that application field and proposed a small prototype for those small, isolated entities, in order to heavily reduce the waste disposal problem and to treat waste on place, through the thermal plasma technology and the pyrolysis process. Consequently, the principal involved stakeholders have been the potential customers (big/small ships, isolated mountain villages) and IRIS Srl (NRGWaste external partner and owner of the prototype), both of them interested in the prototype economical and developing aspects. However, also research institutes and governmental authorities have been identified as concerned by the project outcomes, particularly considering its researching, innovative and environmental aspects.
All those stakeholders have then allowed to identify and define the different requirements and tasks, which affected all the expertise areas of each group member and leaded to carry on the project work. The different considered aspects started from the need to find a way to move the reactor, in order to ensure a temperature homogeneity and to let the entire waste amount being reached by the plasma, and then involved the necessity to provide a chemical model of the system, to set it on a software and to use the software to perform a sensitivity analysis, necessary to study the system behaviour. Moreover, experiments on the real prototype were required, in order not only to validate the chemical model, but also to test the different Arduino codes; in fact, improving and modifying the Arduino code represented another fulfilled activity, aimed to make the plasma arc stabler and therefore increase the overall process efficiency. Lastly, a thermo-economical analysis was proposed, in order to evaluate the prototype feasibility for those potential application areas.

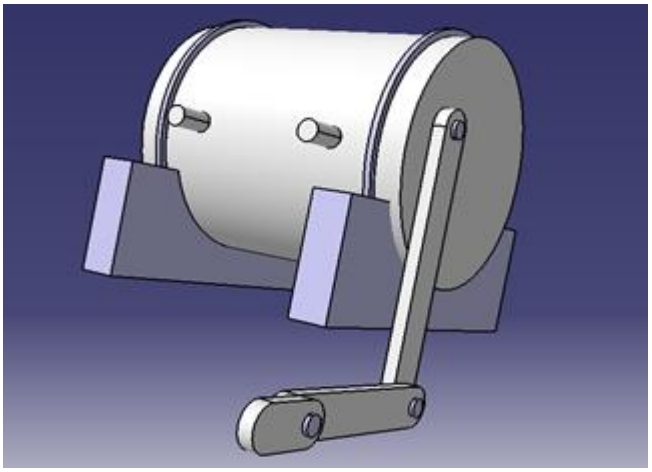
EXPLORING THE OPPORTUNITIES

The main concern with small-scale devices, is that of making a safe and clean environment also profitable, without the possibility of scaling up taking advantage of scale factors. On the other hand, once obtained an effective prototype and identified the potential stakeholders, the market share available is weakly limited, entering a sort of “Blue Ocean”.
To evaluate correctly the potential of such innovation, an input-output analysis was carried on from a thermo-economic point of view, in order to clearly understand the energy fluxes interesting the process, the value created in it and where the inefficiencies compromising the result came from. Indeed, any activity producing waste and disposing it in an expensive way would be interested in getting rid of such cost, obtaining synthesis gas in exchange. As the team understood in international conferences, syngas exploitation is gaining interest in the energy field, since it could lead to clean carbon fueled technologies; this trend is leading to an increasing number of bottoming machines, such as microturbines or internal combustion engines, able to use such fuel to cogenerate electricity and heat. However, since the flexibility of such devices depends mainly on the composition of the syngas and consequently of the waste, experiments were made in order to evaluate the chemical compounds most likely produced during the process. Further requirements came from the continuity of the process, mined by the extinction of the electric arc, and the maximization of the energy output, compromised on one side by a portion of waste not affected by the reaction, and on the other side by a portion of water cooling down the reactor and sent to a chiller. To overcome the former problem, the team had to understand the code regulating the electrodes responsible for the plasma stability, while to tackle the second problem two different paths were considered: regenerating the value of the hot water as thermal power, and making the whole system rotate.

GENERATING A SOLUTION

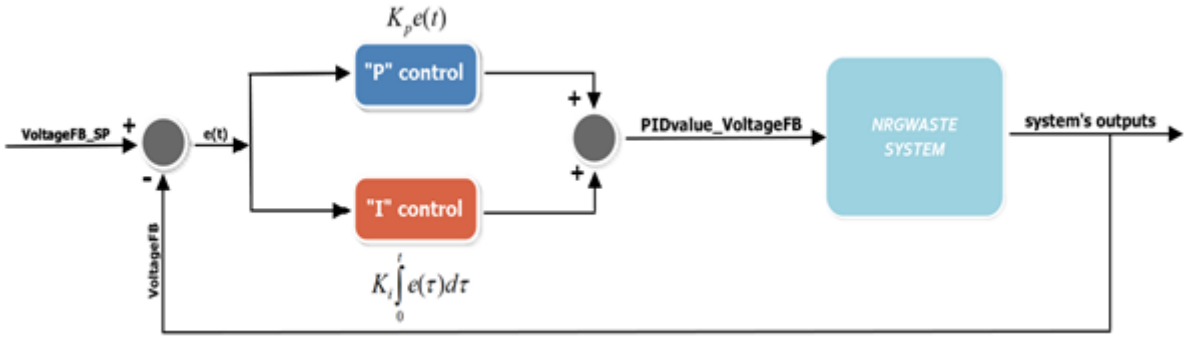
The solution proposed by the team is aimed at increasing the energy efficiency of the prototype, as well as its attractiveness from the potential customer viewpoint in the light of a commercial roll-out.

The team designed a rotational system for the reactor that could allow the waste inside it to be thermally treated in a uniform manner. The team analysed two solutions: a fluid dynamic model and a mechanical model. In the former solution, the water inlet coming from the heat recirculation module of the system is exploited to rotate the reactor. In the latter solution, instead, an electric motor connected to the reactor by means a four-linkage mechanism (constituted by a crank, a rod and a rocker) is used. After a comparative analysis of the two solutions, the team deems the mechanical model to be the best fit due to its much lower costs of implementation.



The mechanical model solution for the rotation of the system.

Another focus of the project was to develop an improved version of the script used in the mechatronic control module. In particular, the parameters of the PI filter used for the electrodes position control have been changed and tuned to ensure a better system operation. The new script, which has been tested and validated on the real prototype during the experimental campaign organised by IRIS Srl at its lab, proved to make the mechatronic control module less susceptible to the peaks and dips in arc voltage, enabling the system to maintain a constant arc voltage and temperatures inside the reactor, resulting in an overall more efficient waste thermal treatment.



Block scheme representation of the PI filter used for the electrodes position control in the MCM.

The previously mentioned experimental campaign also allowed to validate the chemical model used to describe the chemical reactions occurring inside the reactor during operation and to understand how the syngas composition changes based on the waste input characteristics and on specific process parameters. On one hand these findings can be a noteworthy contribution to the efforts of research centres and universities devoted to analyse the plasma pyrolysis process. On the other hand, such results provide a good starting point from which the potentialities of the NRGWaste system can be assessed not only for waste disposal, but also for cogeneration purposes.

In order to evaluate the attractiveness of the proposed solution in case of its commercial roll-out, a thermo-economic analysis has been performed by simulating the adoption of the prototype in different scenarios, such as isolated mountain villages, small boats for marine litter disposal and cruise ships. Despite its investment cost, it has been observed that the adoption of the prototype is particularly beneficial in touristic islands. In fact, the prototype would allow an easy disposal of waste around the shores and the syngas produced from the thermal treatment could be used later on for electricity production in an energy storage system connected to the island's main grid.

TAGS
Waste to energy, sustainability, micro cogeneration, plasma.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