GA no 282826

Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction

Deliverable No. D4.3

Scientific paper on fundamental densification characteristics of torrefied materials

Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Nature		
R	Report	
O	Other	x

Deliverable Details		
Due date:	30.06.2014	
Submission date:	13.08.2014	
Authors:	Magnus Rudolfsson, Torbjörn Lestander, Wolfgang Stelte	
Involved participants:	DTI	Wolfgang Stelte
	SLU	Magnus Rudolfsson
	SLU	Torbjörn Lestander
WP no. and title:	WP4 Densification	
WP leader:	DTI	
Task no. and title:		
Task leader:		
Draft/Final:	13 August 2014	
Keywords:	Parametric study, densification, torrefaction, pelletization	

Table of Contents

1 Summary

The present study investigates the mutual correlation of the key processing parameters – torrefaction temperature, particle size, moisture content, pelletizing temperature. The parameters were adjusted to a five level fractional factorial design. Torrefaction of biomass following the factorial design were made in a batch torrefaction reactor at the Swedish University of Agriculture in Umeå. The torrefied materials were ground and sieved in the according particle size fractions and adjusted to distinct moisture contents. The pelletizing properties were tested in a single pellet press tool at the Danish Technological Institute allowing the control of pressure and temperature and an exact monitoring of the forces during the pelletization and a determination of the pellet mechanical properties.

The results have shown that all tested parameters as expected have an influence on the friction generated during pelletization and the pellet quality. In general it was found that the energy consumption required for pelletization is least and the pellet mechanical properties are best when the degree of torrefaction is low, while the moisture content and the pelletizing temperature are increased.

The detailed experimental set-up and results are under publication in a scientific journal and results will be made available on the SECTOR homepage when the scientific paper has been published by the journal.

The following report is a short version of the study and serves as deliverable 4.3 for the SECTOR project. It will be supplemented with the full paper once it has been published in a scientific journal. Both documents will be available through the SECTOR homepage.

2 Introduction

Torrefaction of biomass has been developed to a mature technology during the past decade and usually torrefied biomass is compressed into pellets or briquettes to improve its handling properties and to reduce dust emission. The pelletization and briquetting of torrefied biomass has been shown to be challenging and has been underestimated by technology developers. Main issues when compacting torrefied biomass are the high energy consumption and heat development due to high friction generated when passing torrefied biomass through a pellet mill, and poor product quality expressed by low durability and crackled pellet surfaces and dust formation. Extensive process development during the past years has resulted in solutions to these issues, mainly by “trial and error” experiences rather than by fundamental understanding of the physics and chemistry behind the process. Key parameters affecting the pelletizing properties of torrefied biomass have been identified as raw material type, torrefaction degree, moisture and temperature. Processes development during the past years has resulted in acceptable pellet quality and processing costs however the SECTOR project consortium identified the need to investigate processing parameter of torrefaction and densification more closely with respect to mutual influence and correlation with the aim to find the optimum processing conditions or at least a more clear understanding of the dependency between the processing conditions.

3 Materials and methods

3.1 Materials

Norway spruce grown in Sweden (Värmland province) harvested in fall 2011 was cut and dried in a wood kiln. The material was chopped into pieces 4-8 mm and stored dry for 12 month before usage.

3.2 Methods

Experimental design

Parameters to be modified during this study were: torrefaction degree, particle size, moisture content and pelletizing temperature. A D-optimal fractional factorial design was chosen. The parameters were varied within defined intervals:

Torrefaction degree: Mass yield 71.1 – 90.5 % (d.b.)

Particle size (x): x < 0.5 mm and 0.5 < x > 2 mm

Water content of the material dry to 10 % (d.b.)

Pelletizing temperature: 125 – 180 C

The factorial design resulted in a set of 29 experiments as illustrated in Figure 1.

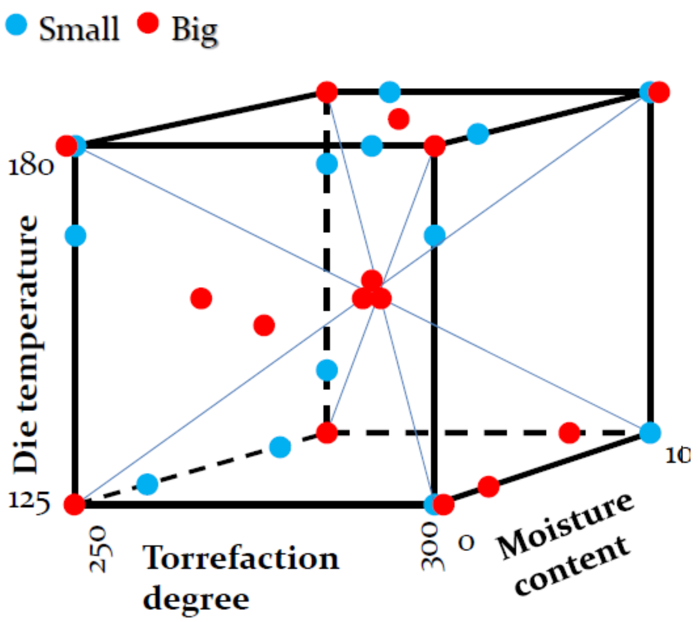

Figure 1. Factorial design of torrefaction and densification parameters

Torrefaction

Torrefaction was made in a small scale batch reactor at SLU laboratories. The reactor consisted of a stainless steel metal container with a volume of approximately 1 liter with a gas inlet and outlet. It was filled with the wood chips and flushed with nitrogen at a rate of 0.5 l/h. The reactor was placed in an oven and heated to the temperature set point. Temperature was controlled by a thermocouple placed in the middle of the reactor. The set-point temperature was maintained for 60 minutes. The process was stopped after 60 minutes by cooling the reactor with water.

Adjustment of the torrefied biomass

The torrefied material was cut with a knife mill and sieved into two size fractions < 0.5 mm and 0.5 – 2 mm.

Water content was adjusted by using a spray bottle and spraying of water onto the wood particles and subsequent mixing. The required mass of water was calculated and the resulting water content was checked using a moisture analyzer and corrected if required. The samples were shipped to DTI in Denmark where a final moisture analysis / adjustment was made.

Pelletization

The biomass was pelletized using a single pellet press manufactured and designed at the Danish Technological Institute, Denmark. The units consisted of a cylindrical die made of hardened steel, lagged with heating elements and thermal insulation. The temperature was controllable using a thermocouple connected to a control unit. The end of the die could be closed using a backstop. Force is applied to the press using a universal testing system (AGX, Shimadzu, Japan) and detected using a 200 kN load cell connected to a detection software (Trapezium X, Shimadzu, Japan). Data recorded where the compression force and friction (force that is requited to extrude the pellet from the press.

The temperature of the press channel was adjusted according to the experimental design between 125 and 180 C. 750 mg sample material was compressed at a rate of 100 mm/min until a maximum pressure of 300 MPa was reached. The pressure was held for 10 seconds and released.

Subsequently to compression, the bottom piston was removed from the die, and the pellet was pressed out of the channel at a rate of 100 mm/min. A value for the static friction was determined from the force required to initiate the pellet motion. The average value of at least 5 measurements was determined and a 95% confidence interval was calculated

4 Selected Results and discussion

More than 86% of variation in compression work (W_{comp}), static friction (F_{max}) and dynamic friction (W_{fric}) are explained by temperature, moisture and mass yield. The higher temperature, moisture content and mass yield (lower degree of torrrefaction) the lower friction and less compression work needed (see Figure 2). Pellet strength seems to be more complex and only about 70% of the variation explained by the tested parameters. Smaller particles, higher temperature and higher mass yield resulted in higher pellet strength. Pellet density increased by higher temperature, moisture and mass yield.

A more detailed analysis will be published in a scientific paper that will be linked to from the SECTOR homepage.

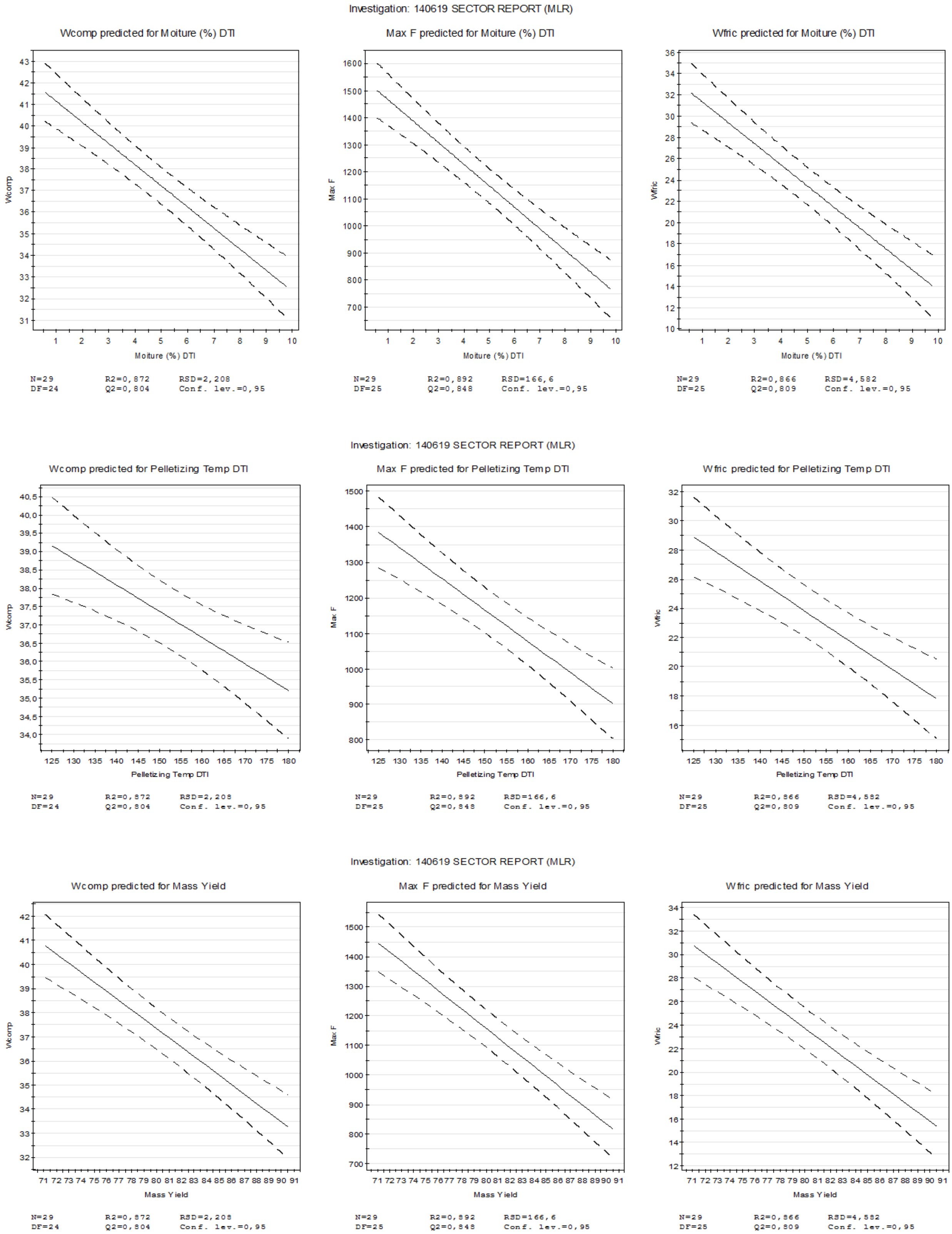

Figure 2. Predicted (W_{comp}), (F_{max}) and (W_{fric}) for moisture content, pelletizing temperature and mass yield.