Improvement of Awamu Gasifier Stove

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Why Awamu Gasifier Stove

- Students from the Technical University of Graz started a case study with the goal to improve the CO-Emissions of a household biomass cook stove in spring 2018.
- They found the Awamu Gasifier Stove from Uganda in the “Clean Cooking Catalog” http://catalog.cleancookstoves.org/
- After e-mail correspondence with Nolbert Muhumuza, two Awamu Gasifier Stove’s were fast and easily provided in May 2018.

The case study project

- The goal is to measure the CO-Emissions and the efficiency of the Awamu Gasifier Stove and of one improved version of the Awamu Gasifier Stove.
- Measurements of the efficiency are conducted with the water boiling test (WTB, Version 4)
- In order to conduct the CO-Emission tests, the stove is placed inside the combustion chamber of a 30 kW boiler, so that the flue gas is collected and the CO emissions are measured.

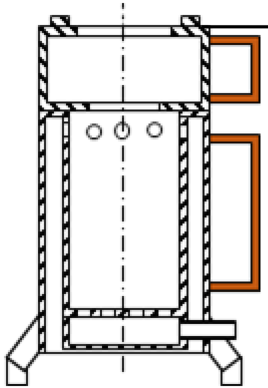
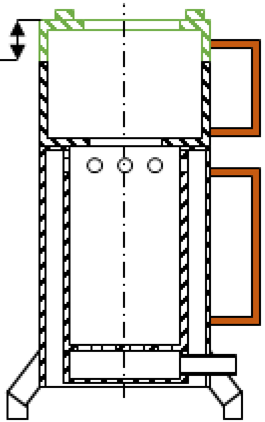
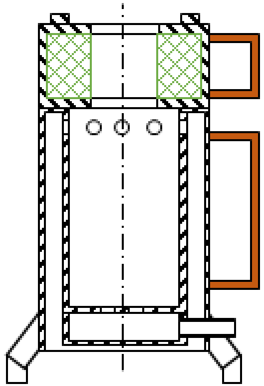
Inside the 30 kW boiler

Closed 30 kW boiler

Optimization concept - Theory

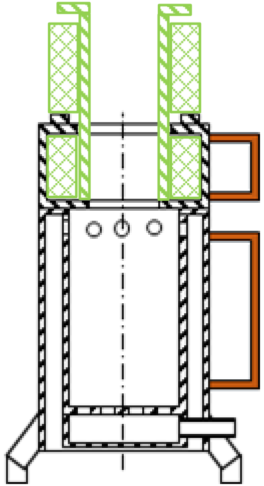
Goal: Modification in combustor, with currently a low gas residence time, to decrease the CO-Emissions

Theory: If the residence time and gas temperature inside the combustor are increased, the CO-Emissions decrease.

The original Awamu Gasifier Stove	Theoretical variant 1: Increased height of combustor	Theoretical Variant 2: Insulate the surface of combustor
	 • Residence time↑ • natural draft↑	 • Temperature↑ • Heat losses↓

Realization of the improved combustor

- Build an extra combustor with a surface insulated with rock wool and place it on top of the original combustor.
- Choose the outer diameter of the extra combustor in a way that it can be easily connected to the original combustor.
- Insulate the external surface of the extra combustor, including the gap between the original and extra combustor.



Realization of the improved combustor

- Connect the original and extra combustor.
- The height of the improved combustor is approximately 26 cm (+ 11 cm more than original).
- The total height of the improved Awamu Gasifier Stove, plus a 5 litre stainless cooking pot, is approximately 72 cm.

Experimental tests

The following experimental tests were conducted:

- Water content test of the fuel
- Ash content test of the fuel
- Fuel elemental analysis
- Ignition mass loss test
- Water boiling test (WBT)
- CO-Emissions test

Used biomass fuel for the experiments

- It was not possible to get eucalyptus wood logs for the measurement tests. Therefore spruce wood chips were used for all measurement tests.
- The spruce wood chips had a water content of 11 % mass (wet basis) and an ash content of 0.74 % mass (dry basis).
- All CO-Emission test and WBT used a initial wood chip amount of 0.5 kg (wet basis).

Ignition mass loss test

The ignition mass loss test were conducted to define the actual used amount of fuel in the WBT and CO-emission tests. Every ignition of the Awamu Gasifier Stove was realised in the same way and lasted 5 minutes.

The result of the ignition mass loss test was that all CO-Emission tests and WBT started actually with 0.42 kg of fuel instead of 0.50 kg.

Ignition with barbecue lighter

Initial fuel amount of 0.5 kg

Water boiling test (WTB)

- WBT realized in open space and only with natural draft
- Employed a 5 litre stainless cooking pot
- Weight measurement of the empty 5 litre cooking pot
- Filled the stainless cooking pot with 4 litre of water
- Measured the weight of the filled cooking pot before and after the WBT
- Choice of the right amount of fuel (0.5 kg before ignition) to boil 4 litre of water inside the 5 litre cooking pot
- Used a 5 minutes ignition time before starting with the WBT
- Measured the water temperature during the WBT
- Measured the needed time for the WBT
- Measured the weight of the produced amount of dry biochar after the WBT
- The Awamu Gasifier Stove was always operated in a full load position
- Every WBT was repeated three times

Water boiling test

5 litre stainless steel cooking pot

Thermocouple type K

CO-Emission test

- The Awamu Gasifier Stove (and improved version) were ignited outdoors and after the 5 minutes of ignition time the Awamu Gasifier Stove together with a pot full of water were placed inside the 30 kW boiler (see slide 3)
- The use of the 30 kW boiler (designed for wood chips) as a testing facility gave the opportunity to measure the mass flow of air and flue gas and log the data with a Labview software
- The under-pressure in the 30 kW boiler was always 16 Pa for each CO emission test
- The water temperature in the pot was measured with a thermocouple type K during the CO emission tests
- The CO emissions were measured with a Testo 350 XL exhaust gas analysis system
- The Awamu Gasifier Stove always operated in a full load position

CO-Emission test

- The CO-Emission tests were conducted once with the original Awamu Gasifier Stove and once with the improved Awamu Gasifier Stove.
- Repetitions could not be conducted because the filter of the Testo 350 XL exhaust gas analysis system was blocked after one and a half CO-Emission tests and there was a shortage of filters at the time of the measurements.
- The calculation of CO-Emissions is presented in grams per MJ delivered to the pot. The test results for the WBT are used for these calculations (it was checked that similar efficiencies are obtained placing the stove inside the 30 kW boiler).

CO-Emission test

Thermocouple type K

Open 30 kW boiler with stove inside

Closed 30 kW boiler with stove inside

Results of the WBT

- The obtained thermal efficiency is of 26 – 29 %. It is similar for the original and improved Awamu Gasifier Stove and there is a good reproducibility.
- The obtained thermal efficiency is lower than the one reported for the Mwoto and Quad TLUD stoves (41% and 33%, respectively) and similar to the one of the Troika gasifier stove (30.9%) (Homepage Awamu). Three main reasons for these differences could be: different type and size of fuel, the fuel loss in the ignition time and the small amount of used fuel.
- The average time to boil the water was shorter with the improved Awamu Gasifier Stove because of the higher firepower. The reason of this effect was a higher natural draft caused by the new total height of the improved Awamu Gasifier Stove
- The obtained char at the end of the experiments is around 50 g.

Comparison of the original and improved stove

Original Awamu Gasifier Stove

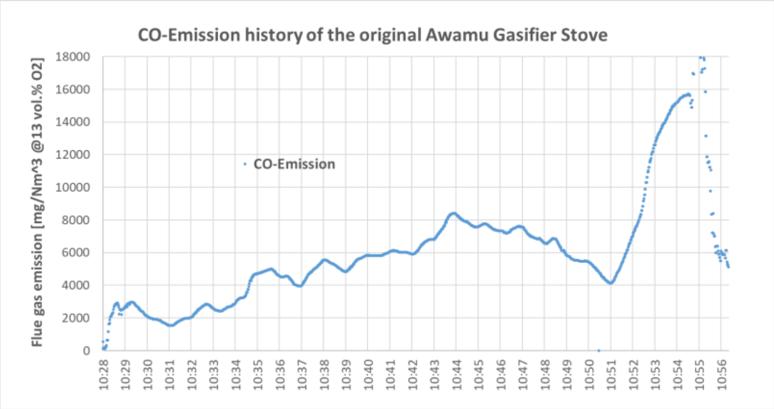
1. HIGH POWER TEST (COLD START)	units	Test 1	Test 2	Test 3	**Average**	St Dev	COV
Time to boil Pot # 1	min	20	24	23	22.3	2.1	9%
Temp-corrected time to boil Pot # 1	min	21	24	23	22.7	2.0	9%
Burning rate	g/min	14	11	12	12.4	1.1	9%
Thermal efficiency	**%**	27%	28%	28%	**28%**	1%	3%
Specific fuel consumption	g/liter	79	81	83	80.8	2.2	3%
Temp-corrected specific consumption	g/liter	81	82	84	82.2	1.8	2%
Firepower	watts	4 328	3 607	3 885	3940	363.8	9%

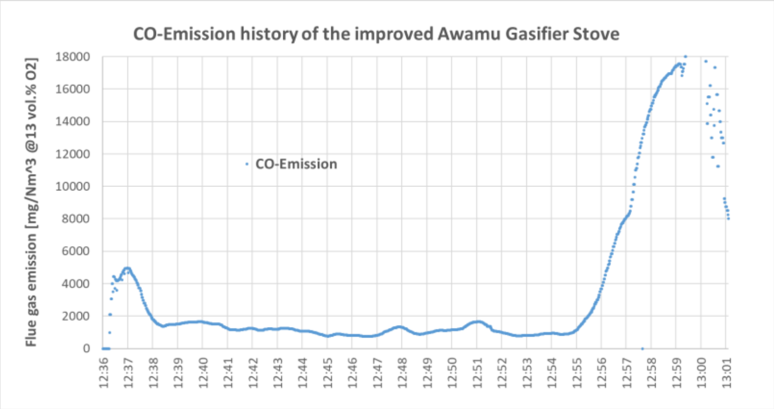
Improved Awamu Gasifier Stove

1. HIGH POWER TEST (COLD START)	units	Test 1	Test 2	Test 3	**Average**	St Dev	COV
Time to boil Pot # 1	min	22	19	18	19.7	2.1	11%
Temp-corrected time to boil Pot # 1	min	22	19	18	19.8	2.1	11%
Burning rate	g/min	13	16	16	14.7	1.6	11%
Thermal efficiency	**%**	26%	26%	29%	**27%**	2%	7%
Specific fuel consumption	g/liter	81	84	76	80.5	4.3	5%
Temp-corrected specific consumption	g/liter	82	85	77	81.0	4.0	5%
Firepower	watts	4 062	4 939	4 964	4655	513.9	11%

Results of the CO-Emission test

- The CO-Emissions of the original Awamu Gasifier Stove were high while the flame was strong. After 10:51 the flame was decreasing and the CO-Emission were increasing strongly
- The CO-Emissions of the improved Awamu Gasifier Stove were much lower during the main combustion phase. When the flame was strong there were low CO-Emissions, but the CO-Emissions also increased strongly when the flame was decreasing





Results of the CO-Emission test

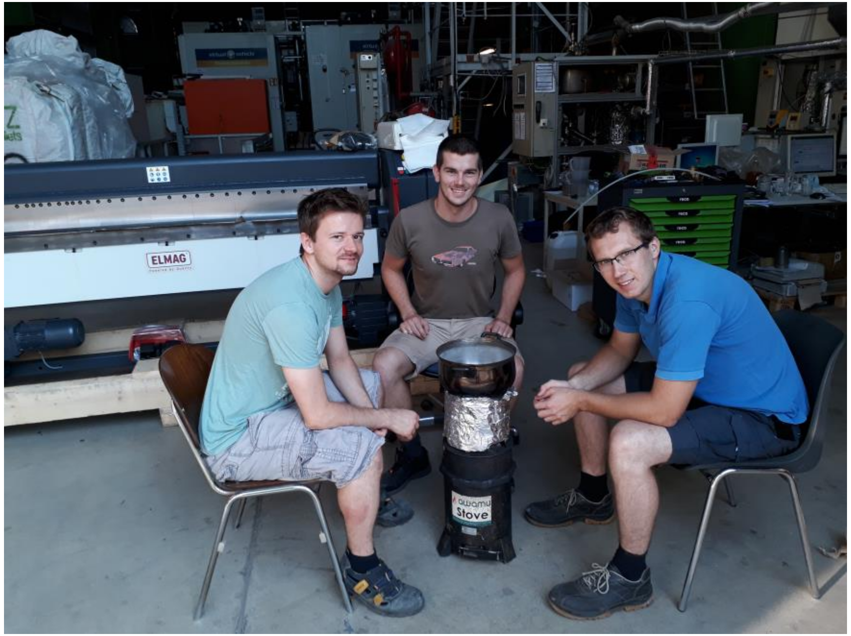
- The Original Awamu Gasifier Stove had average CO emissions similar to the Troika results from CREEC (9.5 g CO /MJ_{del}) (Homepage Awamu)
- The improved Awamu Gasifier Stove showed an average CO-Emission reduction of approximately 65% in comparison to the original Awamu Gasifier Stove

CO-Emission Test High power	mg_{CO} / Nm^3 @ 13% O_2	mg_{CO} / MJ_{del}
Original	5464	8637
Improved	1875	3012

Summary

- The Original Awamu Gasifier Stove had average CO emissions similar to the Troika results from CREEC
- The thermal efficiency is lower than for the Mwoto and Quad TLUD stoves
- The improved Awamu Gasifier Stove decreased the CO-Emissions around 65% in comparison with the original Awamu Gasifier Stove
- Do not use the Awamu Gasifier Stove after the flame is decreasing because the CO-Emissions increase dramatically

The improvements of the combustion chamber showed a good performance for reduction in CO-Emissions



Best regards from Austria