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LCA OF AN ULTRA-CLEAN MICRONIZED COAL SLURRY FUEL USED IN DIESEL ENGINES

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The present paper describes the activities developed by the Laboratory of Coal Slurry Fuel Preparation and Combustion of Beijing China University of Mining and Technology and by Politecnico di Torino, Dipartimento di Scienza e Tecnologia dei Materiali in a project powered by ICSC World Laboratory[1] aimed to the evaluation, on a Life Cycle Assessment (LCA) basis, of a diesel engine using an Ultra Clean Micronized Coal Oil Water Slurry Fuel (hereafter "UCMCOWS").

The main aim of developing UCMCOWS is to use this fluid on coal based fuel as an alternative to diesel oil for usage in diesel engine. From the environmental and energetic point of view, this is a very complex system, which includes the mining of raw coal, the preparation of conventional clean coal, the preparation of ultra-clean coal, the preparation of UCMCOWS, the application of UCMCOWS in the diesel engine and the combustion of by-products in boiler.

In order to achieve this target, a comparison between the two systems (production and use of UCMCOWS, production and use of diesel oil) was performed using the Life Cycle Approach following the ISO 14040 requirements. Main results of this approach show that the UCMCOWS system is characterised by high global environmental impact, but its local impacts are low if compared with the use of traditional coal.

THE COAL SLURRY TECHNOLOGY IN CHINA

Since coal is the main energy resource available in China, the application of the Coal Slurry Technology in China started in 1986 and was completed in 1998 in co-operation with Chinese institutes in Beijing and supported by World Laboratory. This coal water slurry (hereafter 'conventional CWS') is made of conventional clean coal from coal preparation plant (Figure 1)[2].

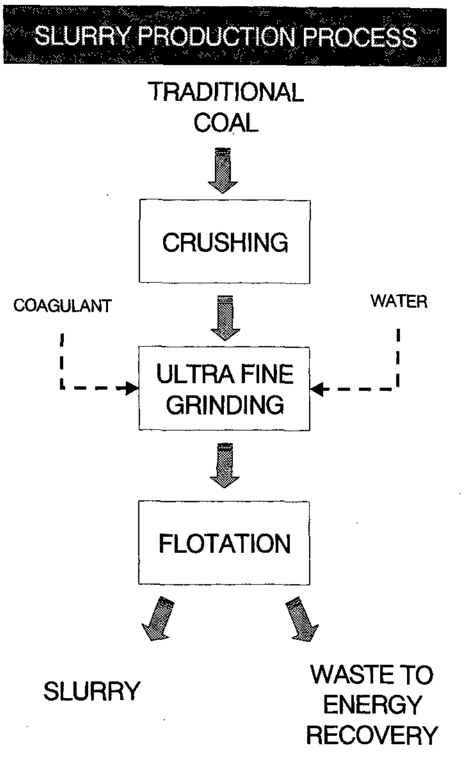

Figure 1 – Slurry coal production process

[1] World Laboratory is an international organization chaired by Professor Zichichi which supports many research projects and Centres all over the world (among them the World Laboratory Research Centre for Coal Slurrying Technology in Beijing).

[2] For further details about the production process see references.

The UCMCOWS has good flow ability and stability and can be conveniently pumped, atomised and stored for a long time; therefore it is a good coal-based alternative to diesel oil. The technology of UCMCOWS represents a follow-up of conventional CWS. Chinese researchers prepared the UCMCOWS fuel in a pilot plant and they carried out rheological measurements and stability tests. The main characteristics of the UCMCOWS are:

- the composition of UCMCOWS: 28.7% of coal, 53.8% of oil, 17.5% of water
- Viscosity: 300-500 mPa.s at a shear rate of 100 s^{-1}
- High heat value: 7000 - 7500 Kcal/kg (29.26 -31.35 MJ/kg)
- Stable storage time: 1 month

The domestic market price of such UCMCOWS is expected to be 60% that of diesel oil on base of equivalent heat content. Technology development on combustion of coal slurry fuel in diesel engine is therefore urgent.

This UCMCOWS diesel engine has been designed and rig tests of diesel engine at different loading with this UCMCOWS was performed at China University of Mining and Technology and assessed, but little indication were available concerning with potential environmental "hot-spots" during its life-cycle.

THE LCA APPROACH

Life Cycle Assessment, LCA, is a tool to quantify and to assess the potential environmental impacts of a process, product or service over its whole life. Issues such as energy use, resource depletion and waste management can be measured and their significance evaluated using LCA techniques. Through LCA the traditional economic/technical design approach is completed by an environmental and energetic quantification of the analysed system.

Aim of the use of LCA in this Project N-V/NET-5 is to support the assessment of the environmental impact of the emissions deriving from the above mentioned innovative fuel in terms of either gaseous or particulate emissions. LCA analysis of the environmental performances of this innovative coal slurry engine will highlight impacts in terms of relevant parameters during the whole life-cycle such as the contribution of gas emissions in term of CO_2 equivalent (Global Warming Potential) or the ozone layer depleting agents and compared with a traditional diesel engine.

DATA QUALITY AND SOURCES

The data and the information used to perform the LCA come both from specific measures (primary data) and from performed studies.

For the specific measures, a pilot-plant with capacity of 200 kg per hour for preparing the UCMCOWS was created by the Chinese Partner in China University of Mining and Technology. The slurry coal was tested in a boiler and in an engine.

Table 1 shows the sources detail of the used information. The collected information have been completed and elaborated by using the Boustead Model 4.4[3].

Table 1 - Details of data sources

	PHASE	DATA SOURCES
UCMCSF system	Raw coal extraction	Boustead Model data base Version 4.4
	Traditional coal production	INCO project[4]
	UCMCSF production	Specific measures[5]
	UCMCSF engine use	Specific measures
Diesel system	Crude oil extraction	Boustead Model data base Version 4.4
	Diesel production	INCO project
	Diesel engine use	Specific measures

[3] www.boustead-consulting.co.uk

[4] INCO project (Eco-compatibility of Industrial Process, powered by EU) has been conducted in 1997-1999 by 7 partners (2 Italians, 2 German, 1 Danish, 2 Chinese) and co-ordinated by Politecnico di Torino (Prof. De Benedetti). This project was aimed to transfer the LCA know-how to Chinese researcher and an assessment of a car production and use was performed. During this project the Chinese energy mix was deeply studied and the results have been used in the present research.

[5] Data about CO_2 emission from boiler have been estimated on stoichiometric bases

ENVIRONMENTAL RESULTS

The output of a life cycle inventory is a set of parameters, each of which describes a certain aspect of the behaviour of the system under examination. Inventory results are usually organised in terms of energy requirements and environmental consequences of the considered processes in order to identify precisely the environmental burden origin associated with the analysed system. In this report, the results will be presented used simplified indicator as following is shown:

- **crude oil**: this indicator shows the gross crude oil consumption of the system;
- **natural gas**: this indicator shows the gross natural gas consumption of the system;
- **coal**: this indicator shows the gross coal consumption of the system;
- **Acidification Potential (AP)**: this indicator shown the gross contribute to the acidification of the system;
- **Photochemical Ozone Creation Potential (POCP)**: this indicator shown the gross contribute to the ozone creation acidification of the system;
- **Eutrophication Potential (EP)**; this indicator shown the gross contribute to the eutrophication of the system;
- **Global Warming Potential (GWP)**: this indicator shown the gross contribute to the global warming of the system;
- **Heat recovery**: this figure show the heat recovery generated by the system.

Table 2 shows the data for the *fuel production phase* for diesel and for UCMCSF (50% of water). The Figure 2 shown as the indicators change with the oil content in the slurry.

Table 2 - Fuel production phase data are referred to the production of 1 MJ of fuel

Fuel production: Environmental impact indicator	Diesel oil production	Coal water slurry[6]	Coal water oil slurry[7]
Crude oil [g/MJ]	23,8	1,0	13,2
Natural gas [g/MJ]	0,6	0,2	0,4
Coal [g/MJ]	< 0,1	103,2	43,6
Acidification Potential [g SO_2/MJ]	0,148	1,0	0,502
Photochemical Ozone Creation Potential [g C_2H_4/MJ]	0,016	0,012	0,014
Eutrophication Potential [g PO_4^{3-}/MJ]	0,011	0,021	0,015
Global Warming Potential [g CO_2/MJ]	11,3	150	69,4
Heat recovery [MJ/MJ]	0	0,571	0,241

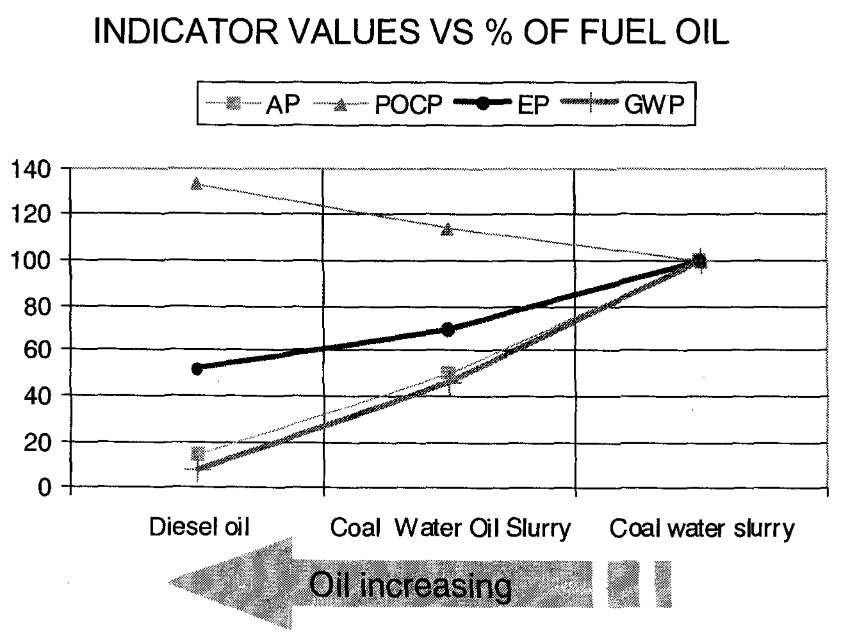

Fig. 2 - Impact indicator values for different content of fuel oil in the slurry. The figures are shown as index value: 100 correspond to the indicator value for a completely water based slurry (UCMCSF)

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[6] Coal 68%; water 32%

[7] Coal 28,7%; Water 17,5%, oil 53,8%

CONCLUSIONS

The technology of preparation and combustion of UCMOWS developed by China University of Mining and Technology (Beijing) uses the energy source in China easily available.

The production and application of UCMCOWS is a very complex process characterized by different environment impacts. The results assessed by LCA show the difference between the preparation of diesel oil and UCMCOWS under a life cycle point of view and it is quite clear that the worst environmental performances are obtained by the slurry coal system. The larger energy consumption during the preparation of the UCMCOWS would be the reason.

The rig test of application of UCMCOWS in diesel engine is just in first stage. Even if the information are still incomplete because the measuring apparatus for gas flow rate for flow rate didn't set up and the dual-functional fuel pump wasn't put in operation, from the data given in Table 3.1 it can be seen that at the same output of energy (2.236 kW) the emission of NO_x (54 ppm) from engine operation on UCMCOWS was obviously lower than that on diesel oil (133 ppm).

Generation of NO_x comes from combustion at high temperature. The temperature of flue gas from engine operation on diesel was always higher than that on coal slurry fuel at the whole range of loading. This must be the reason of higher NO_x emission.

The emission of SO_2 from engine operation on diesel oil was nil, implying the diesel oil used was a good fuel without sulphur content. Nevertheless the emission of SO_2 from engine operation on UCMCOWS was only 15 ppm, higher than that on oil, but environmentally acceptable.

This is due to low sulphur coal (0,265% total sulphur) used to prepare the coal slurry.

Even if the LCA assessed that under a life cycle perspective the slurry coal system has a higher environmental impact if compared with the diesel oil system, this result has to be considered together with other important parameters. In fact, LCA is a good methodology when used to assess GLOBAL effect, but it has to be integrated with other approaches if the goal is the improvement of LOCAL environment.

For this reasons, the lower emissions of NO_x and SO_X are very important for the air quality of the big cities and taking into account that the coal is a very important resource in the Chinese economy, the slurry coal could be a good way to use it reducing the local environmental impacts.

REFERENCES

- ICSC World Laboratory; *"Preliminary consideration on the work for environmentally friendly development of an ultra – clean micronized coal slurry fuel used in diesel engines"*; Lausanne; 2003
- Boustead I., Hancock G. (1979); *"Handbook of Industrial Energy Analysis"*; The Open University, West Sussex, England;
- De Benedetti, Baldo, Marino, Liu; *"Eco-profile of a small-size car produced in Europe and in China"*; The Third International Conference on EcoBalance, Tsukuba (Japan), November 1998;
- De Benedetti, Baldo, Marino; *"Final results of a co-operation between China and Europe"* - The 4th International Conference on EcoMaterials; Gifu (Japan); 9-12 of November 1999
- De Benedetti, G.L. Baldo, M. Marino; *"A Co-Operation between China and Europe in the field of sustainable development: main results and planned activities"*; First International Symposium on sustainable manufacturing; Shanghai Jiaotong University; 15-17 November 1999; Shanghai, China
- De Benedetti, J. Yang, M. Marino; *"LCA and transport systems in China"*; International Symposium on strengthening eco-environmental planning and management; 11-18 October 1999; Hainan Island, China
- EAI; European Energy Agency;
- Hauschild, Wenzel (1998); *"Environmental assessment of products"*; Chapman & Hall;
- ISO 14040 series
- PRC (People Republic of China); *"China Energy Annual Review 1997"*; Department of Resources Conservation and Comprehensive Utilisation; State Economic and Trade Commission
- SSB (State Statistic Bureau); *"China Statistic Yearbook 1995"*; Chinese Statistic press; Beijing 1996;
- WB (The World Bank); *"Clear water, blue skies: China's Environment in the New Century"*; China; 1997

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