TECHNICAL AND ETHICAL IMPACT OF UNCONVENTIONAL PROPULSION SYSTEMS ON SUSTAINABLE AGRICULTURE

ТЕХНИЧЕСКО И ЕТИЧЕСКО ВЛИЯНИЕ НА НЕТРАДИЦИОННИ ТЯГОВИ СИСТЕМИ ВЪРХУ УСТОЙЧИВОТО СЕЛСКО СТОПАНСТВО

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Abstract. *The paper makes a review the technical and ethical problems arising in the front of modern agriculture, focusing on emerging technologies of unconventional propulsion together with their appliances in the agricultural vehicles. The problems of balancing the needs of a growing World population with the requirements of sustainability and of not overloading the carrying capacity of Earth's environment are discussed. Also the link between agriculture and energy is emphasized. The new propulsion methods such us: more efficient internal combustion engines, new bio-fuels, as substitutes for fossil fuel, and new unconventional propulsion systems as replacements of the internal combustion engines are presented and their impact on agriculture is presented.*

KEY WORDS: Sustainable AGRICULTURE, ENERGY, PROPULSION, INTERNAL COMBUSTION ENGINES, BIO-FUELS, ELECTRIC VEHICLES, FUEL CELLS.

1.- Introduction

Agriculture is a key human occupation and is considered to be the base activity that led to the rising of civilization. It produces food and goods for the growing population of the world through farming and forestry. In 2007, about one third of the world's workers were employed in agriculture. According to the International Programs Center_U.S. Census Bureau, the total population of the World, projected to 9.08.2009 at 14:03 GMT was 6,778,625,348. The World population is projected to reach 7 billion early in 2012, up from the current 6.8 billion, and surpass 9 billion people by 2050, reveals the United Nations Department of Economic and Social Affairs [1]. Most of the additional 2.3 billion people will enlarge the population of developing countries, which is projected to rise from 5.6 billion in 2009 to 7.9 billion in 2050. This grow rate was made possible because of the Green Revolution that take place in agriculture in developing countries such as Mexico, India, China and, we must say, Romania, after 1945. The Green Revolution spread technologies that had already existed, but had not been widely used outside industrialized nations. These technologies include mechanization, pesticides, irrigation, synthetic fertilizers and improved crop varieties developed through conventional biotechnologies or genetic engineering methods. Many analysts state that the Green Revolution has allowed food production to keep pace with world population growth while others state that it caused the great population increases seen today and would lead to overpopulation and will overload the sustainable carrying capacity of Earth. The concept of carrying capacity [3] in the modern context refers to the number of humans who can be supported without degrading the natural, cultural and social environment. Exceeding the human carrying capacity implies impairing the environment's ability to sustain the desired quality of life over the long term.

The concept of carrying capacity is widely discounted, in part because it is fluid and virtually unquantifiable. Past discoveries and technological breakthroughs have, many times, raised carrying capacity, and much western science encourages the belief that technology's potential is unlimited. Technological optimists typically reject scientific warnings that no substitutes exist for topsoil, fresh water, clean air, and the "free services" of many species, or that technology and its deployment to replace existing uses of petrochemical energy will take 20 years to bring on line, minimum. The standard answer to evidence that a non-renewable resource is being depleted, or a renewable one degraded, is that, if a resource becomes "scarce" or pollution too detrimental, prices will rise sufficiently to call forth either substitutes or innovative technology that overcomes the problem. Technology and market mechanisms, it is said, will always enable humans to overcome putative natural limits.

Critics of this theory [4] argue that serious shortages of natural resources, such as land, water, soil, and biota, prevent their use as substitutes for technology. For instance, technology cannot double the world arable land, double the flow of rivers or replace bees for pollination.

Sustainability, in a broad sense, is the capacity to endure. In ecology, the word describes how biological systems remain diverse and productive over time. For humans it is the potential for long-term maintenance of wellbeing, which in turn depends on the wellbeing of the natural world and the responsible use of natural resources. Sustainable agriculture refers to the ability for long term producing food, without causing severe or irreversible damage to the ecosystem. Two key issues are biophysical (the long-term effects of various practices on soil properties and processes essential for crop productivity) and socio-economic (the long-term ability of farmers to obtain inputs and manage resources such as labor). Sustainable agriculture was addressed by the U.S. Congress in the 1990 Farm Bill [2]. Under that law the term sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fiber needs;
- enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- sustain the economic viability of farm operations;

enhance the quality of life for farmers and society as a whole.

2. Propulsion in agriculture

As we can see in the previous section propulsion is implied in diverse agricultural activities such as carrying out the various works on soil or on agric cultures and also for transportation of crops or various useful materials and tools, being one of the key production cost of crops.

The main propulsion system used, up to date, for agricultural machines remains the internal combustion engine using liquid fossil fuel, especially the compression ignition engine or Diesel engine (around 90%). This aspect isn't due to it's thermodynamic efficiency which is rather low (35% at usual Diesel engines) but, especially, to the great capacity of energy storing of liquid fossil fuels like Diesel fuel as compared with other energy storing sources. The mass energy density of Diesel fuel is around 11600 Wh/Kg, comparatively, e.g., with a classical lead-acid battery of electric accumulators having a mass energy storing density of around 30 Wh/Kg. Taking in account the low effective efficiency of the internal combustion engine, gearbox and transmission system assembly (around 20%) as compared with the relatively high efficiency of electric motors (around 90%), the effective mass specific energy is 2320 Wh/Kg at internal combustion engines machines and of 27 Wh/Kg at those with electric motors. This means that a 100 litters Diesel fuel tank stores the same effective energy amount as 8.5 tons of current lead-acid batteries of electric accumulators.

Another advantage is the compactness and the flexibility of propulsion groups with internal combustion engines in comparison with other propulsion systems at the same power. These two aspects leaded to the generalization of internal combustion using at agricultural machines within the past century. Together with that generalization started to become visible the drawbacks of internal combustion engine using:

- The global resources of liquid fossil fuels are fading and are randomly distributed. The first signal of this problem was the rise of oil price during the oil crisis from 1973. According to the „Peak Oil" theory [5] emitted by Marion King Hubbert in 1956, the peak of oil extraction was reached in the main producing countries, following that in the next decades the decline and vanishing of these resources to occur. E.g. we present the oil producing countries past peak established by the Energy Watch Group [7] (see fig. 1).
- The internal combustion engine is also the main responsible for the chemical pollution of the atmosphere producing [8]: 18% of solid carbon suspension particulate, 27% of volatile unburned hydro-carbonates, 28% of lead, 32% of nitrogen oxides (NO_x) and 62% of carbon monoxide (CO). They also generate 25% of carbon dioxide (CO_2) considered the main responsible for the green house effect. This pollution adds to the environmental negative impact of agriculture.

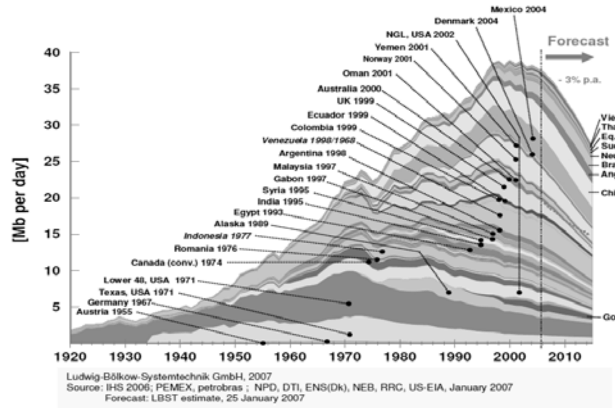

Figure 1. - Oil producing countries past peak.

There are three ways that should be followed for fossil fuel resources economy and reduction of pollution and green house effect:

- Research of new internal combustion engines with higher efficiency leading to reduction of fuel consumption and diminishing of pollution;
- Developement of new fuels for the internal combustion engines from other sources then crude oil;
- Total or partial replacing of internal combustion engines with other propulsion systems.

It can be noticed that the three directions are not divergent, combinations being possible, leading to the development of unconventional propulsion systems applicable in the agricultural machines' domain. We present in the following sections some of the state of the art realizations in the field, from all around the world.

3. *Internal combustion engines with higher efficiency*

The increasing of the internal combustion engines' efficiency was attempted through various methods, from which we may consider[8][9]:

Supercharging of the internal combustion engines by introducing of the air under pressure in the inlet of cylinder, leading to the rising of the inlet cycle efficiency. Nowadays the supercharging is done with a radial air compressor power-driven by turbine turned by the exhaust gases from the cylinder (turbo-charger group). For counterbalancing the loss of air density due to the heating produced by compression, on the inlet manifold is placed an air cooling device (intercooler). A further rising of the turbocharged engines efficiency is done by the so called turbo-compound engines (fig. 2) that have on the exhaust manifold a supplementary gas turbine which conveys the rotation movement to the propulsion group. E.g., the New Holland CRC9090 [10] combine has a turbo-compound engine with a power of 544 HP (400 KW) at normal working speeds and a maximum power of 591 HP (435 KW)(see fig. 3), having a 61 CV (45kW) power rise than its predecessor.

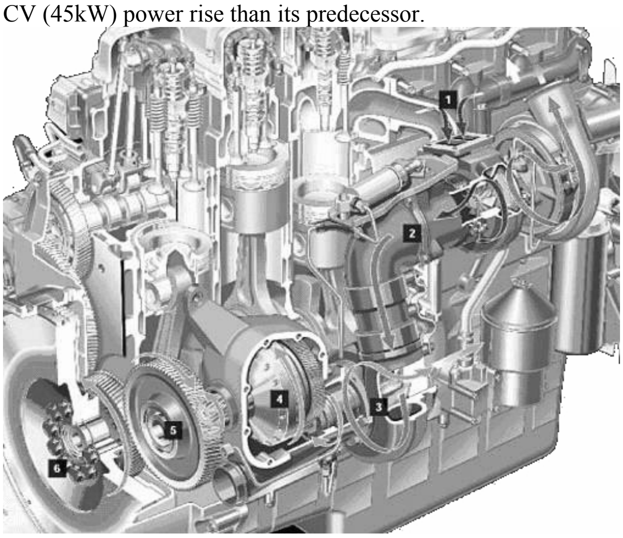

Figure 2. – Scania Turbo-Compound System

Another supercharging method is that using the pressure waves from the exhaust manifolds through the Comprex system (fig. 4).

- Developing of the so called adiabatic engine [11][12], by insulating of the thermally stressed engine's components, such us: combustion chamber, cylinders' internal surfaces, piston head and valves, using ceramic materials such as carbides alumina, zirconia, etc. Thus the working temperature of the engine could be raised and the heat losses through the engine's cooling systems could be eliminated which would lead to a raise of the thermodynamic efficiency of the diesel engine up to 68%.
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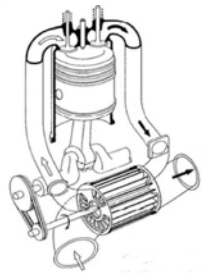
Figure 3. – New Holland CRC9090 combine

- Stratification of the fuel-air mixture, allowing the burning of lean mixtures, whith subunitar fuel-air ratios, or using of two different fuels at hte same engines, leading to consumption reduction.



- Figure 4. – Comprex System

4. *Alteranive propulsion systems*

There are two directions for the total or partial replacing of the internal combustion engine in the propulsion of agriculural machines:

- The electric motor;
- The external combustion engine (Stirling engine) which is fit for burning of any fuels including those caming from biomass.

- Electric motor. The first electric car came into sight in the year 1830. In 1899 Camille Jenatzy goes beyond the speed of 100 Km/h, for the first time, with its electric car „Jamais Contente". However, after 1910 the production of electric cars recorded a decline because of the internal combustion engines improvements.

Together with the occurrence of the oil crisis and of the problems linked of the environment pollution, the electric propulsion systems tend to become opportune because of their lack of chemical and noise pollution. We must notice however that in fact the pollution is extrapolated to the electric energy producers, which makes necessary the development of renewable, non carbon energy sources. Nowadays, there exist the following types of electric propulsion systems:

Accumulator batteries systems. The galvanic (electrochemical) cell is a convertor directly transforming the chemical energy in electric energy. Galvanic cells can be primary cells (without the regeneration of electro-active species from the poles), secondary cells (named as accumulators, with the regeneration of electro-active species from the poles by electrolysis). Currently are used the following types of accumulators: lead-acid; nickel-metallic hydride; nickel-cadmium; etc. The most improved accumulators nowadays are the Lithium-Ion ones, having a stored specific energy of 115 Wh/Kg.

The main disadvantages of these systems are: The big weight of the accumulators, the reduced autonomy and the reduced life cycle. A sample of electrical mini-tractor is the Elec-Trak model developed by General-Electric (see fig. 5).

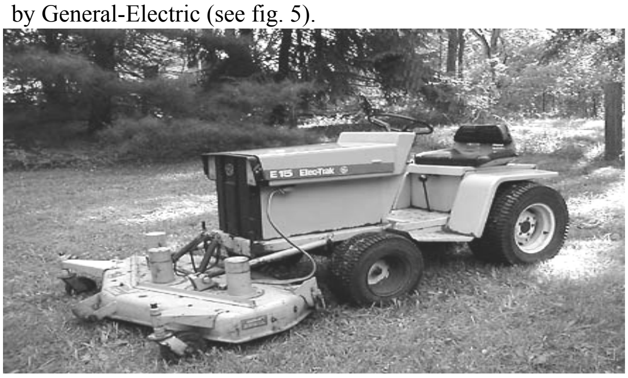


Figure 5. –Electric mini-tractor Elec-Trak

- Electric systems using fuel cells.

- The fuel cells [20](with continuous feeding with electro-active species at the two electrodes) are direct conversion systems of chemical energy in electric energy. Although not a new ideea, beeing invented arround the years 1840, the fuel cells seems that would become in the next years a serious replacer of the internal combustion engine.

The fuel cells were first used in space applications such us the Gemini and Apollo programs. The fuels used in fuel cells are: hydrogen (H_2), methanol (CH_3-OH), carbon monoxide (CO), hydro-carbonates, hydrazine (NH_2- NH_2), sodium amalgam(Na, Hg), ammonia (NH_3), etc.. The fuell cells can be *direct*, if the fuel is used unmodified, *indirect*, if the fuel suffers first a catalytic conversion for generating hydrogen, and *regenerative*, if the fuel is regenerated from the reaction products and recycled, in an anci device coupled with the fuell cell or in the fuell cell itself. The fuel cells used today are: metal hydride; electro-galvanic; zinc-air cells; formic acid fuel cell; with direct methanol; with reformed methanol; with direct ethanol; with direct borohydride; with proton changing membrane; with phosphoric acid; with melted carbonate; with direct carbon; regenerative alkaline; tubular solid with oxide; protonic ceramic.

We must mention that biochemical or microbial fuel cells, using the fermentation process of biomass for direct generation of electric power (third generation bio-generators), are under developement.

Fuel cells have an efficiency of around 50% in electric energy generation, the rest being thermal energy, which can nevertheless be recovered by using heat pumps.

The prototype of the first tractor using a fuel cell, NH2, was developed by New Holland (fig. 7). The hydrogen-oxygen fuel cell generates 106 HP, acting two electric motors, one for the tractor propulsion and another for rotating the power plug and ancilary equipments.

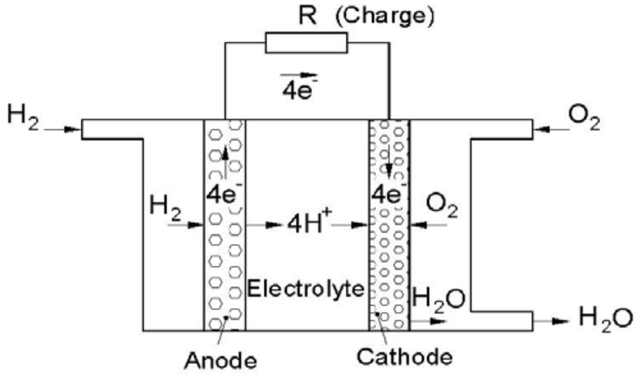


Figure 6 – The hydrogen-oxigene fuell cell principle

Figure 7. – Prototype tractor with hydrogen fuel cell, NewHolland NH2.

Systems using electric supercapacitors.

Double-layer electric capacitors, also named supercapacitors, are electrochemical capacitors with a energy density thousands times greater than the usual ones, but, usually, with a reduction of the working voltage. Batteries of double-layer capacitors could have capacities of 5000 farads. The greatest stoking specific energy, currently possible, is 30Wh/Kg. Supercapacitors tend to fill the gap between capacitors and accumulators. Supercapacitors are used as „smoothers" in energy supply and like momentum chargers. The first utilizations were at starting capacitors for great engines of tanks and submarines and, together with the lowering of the prices, started to be used at diesel engines of locomotives, trucks and tractors.

More recently they have become a source of interest in the green energy world because of their ability of rapid energy accumulation which makes them very suitable for regenerative braking applications, where the accumulators encounter difficulties because of their low speed of recharging. New technologies could develop supercapacitors with a specific energy sufficiently high to become an attractive replacement of the accumulator batteries at all electric and hybrid vehicles, because they charge rapidly and have a stable temperature.

4. *Conclusion.*

For facing the needs of a growing population agriculture must became sustainable by not overloading the of carrying capacity of Earth environment. One of the ways of doing so is the use of the unconventional propulsion systems. They offer the chance of reducing the costs of energy and have a benefic impact on the environment by reducing of pollution and of the green-house effect. Special care must be taken not to grow the culture of energetic plants in disadvantage of food. This can be done by conversion of the biomass wastes in bio-fuels. Thus agriculture can practically ensure its energetic autonomy, increasing its economic efficiency and leading to the growing of everyone of us' life quality.

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