Promoting Novel Approaches of MMS for Sustainable Energy Applications

Ion Visa

Abstract Sustainable product design and development has gone global by involving teams from all over the world, developing new/innovative, high-tech products, aiming to implement sustainability in our knowledge-based society. RT&D and education in product design must comply with these requirements. Mechanical Systems (MS), as product components must also comply, thus general methods for MS modelling and design are compulsory. The paper discusses the involvement of MMS in promoting sustainable energy systems; mechanical and mechatronic systems in renewables are presented along with energy efficient applications in automotives. A proposal to establish a new IFToMM Technical Committee for Sustainable Energy systems is also presented and justified.

Introduction

Energy represents one of the most powerful tools for our present and future development and one of the major problems of humankind. Energy promotes global industrial development and personal comfort but, the present pattern for energy production, use and end-of-life disposal is responsible for a large share of environmental pollution and for worldwide (in)security – to mention just two of the humankind problems. Today, our common energy sources are fossil and nuclear fuels, raising significant problems due to their limited amount and the wastes that result during energy production; today's energy consumers, both in residential and industrial applications, are wasting plenty of energy in non- or average efficient processes, equipment or buildings. Therefore, sustainable solutions for the future must be related to three aspects: (1) new energy sources, clean, and if possible inexhaustible - renewable energy sources; (2) energy efficient processes and (3) energy

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saving applications. *Sustainable Energy* represents the concept joining these three conceptual lines, developed in the 1990s, as an answer to the need for a concrete path of sustainable development. Seven major areas were identified as relevant to sustainable energy development, including: energy resources and development; efficiency assessment; clean air technologies; information technologies; new and renewable energy resources; environment capacity; mitigation of nuclear power threat to the environment, [1]. Implementing a sustainable energy concept and requirements needs an inter- and trans-disciplinary approach and engineering plays a key role. It is not only energy and electrical engineering that must be involved, but there are strong and concrete issues that need to be solved by mechanical, mechatronic, materials and civil engineering, along with IT or robotics. And, to unify the emerging concepts in new, optimized and efficient products there is needed a new product design concept, the *Integrated Sustainable Product Design*.

Changing energy production and use models must be done by providing affordable, marketable solutions, accepted by both industrial companies and by end-users, therefore the already existing experience in product design and development represents an asset. The science of machines and mechanisms plays a key role in this quest for sustainability.

Sustainable Energy and MMS

Large-scale hydropower and biomass combustion systems are dominating the search for renewable energy production. In addition to these systems, wind turbines, photovoltaic and solar thermal systems have grown rapidly in the past decade and together are expected to be 20% of total energy production in the EU, by 2020.

The MMS contribution to reaching this target is substantial and is related to key mechanisms in the systems' functioning (as for wind turbines and hydropower station) or to advanced solutions for increasing the conversion efficiency, as these are the tracking mechanisms for PV and PV-concentrator systems and for solar-thermal collectors, either flat or concentrating.

Plenty of studies have been devoted during the past 5 years to solar energy conversion, especially for photovoltaic convertors, because of a complex of concurrent factors: (1) while wind, hydropower or tides are unevenly distributed, solar energy is quite equally available, thus representing a path for global (energy) security; (2) the state of the art of photovoltaics, based on silicon, have a limited conversion efficiency, due to the material's physics (up to about 32%), thus research focuses on increasing the amount of solar radiation on the PV module, by using tracking systems and/or radiation concentrators. The tracking systems can be mono- or bi-axial, according to the accuracy targeted in following the sun's path. In choosing a tracking solution, besides this accuracy, other factors must also be considered: the energy gain versus the energy consumed during tracking, the construction limitations, the price. Solar thermal collectors are usually equipped with mono-axial systems, both for flat and for concentrating collectors. The PV trackers are usually bi-axial

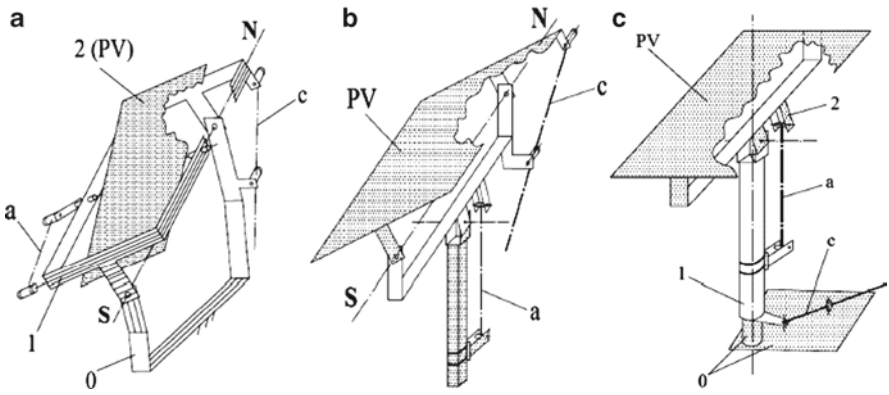

Fig. 1 Trackers: (**a**) equatorial; (**b**) pseudo-equatorial; (**c**) azimuthal

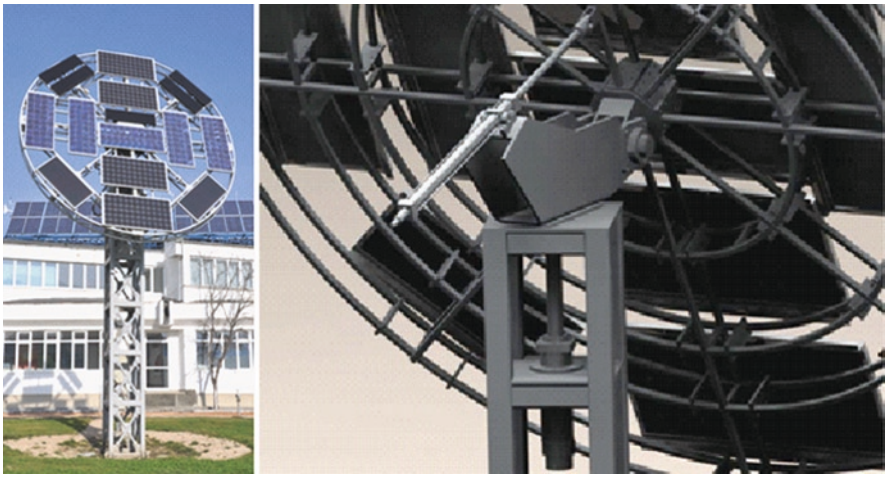

Fig. 2 PV tracked platform installed in the Transilvania University of Brasov

providing a daily motion and a seasonal motion. According to their order, the bi-axial trackers can be equatorial, pseudo-equatorial or azimuthal, Fig. 1.

Tracking can be insured by linkages mechanisms, [2–5], gear mechanisms, cam-follower mechanisms, [6, 7], by hydraulic systems – especially for big loads in large PV platforms. One example is the tracking system developed by the Transilvania University of Brasov, [8, 9], in the project PV Twin Laboratory, consisting of a tracked PV platform with bi-axial, pseudo-equatorial tracking system having an actuator and a hydraulic motor, Fig. 2. The platform acts as an out-door testing stand for four different types of PV modules and functions beginning in 2008.

Many renewable energy systems require transmissions to modify the input speed. The solar systems drive trains include a speed reducer, while the wind turbines

and hydro units usually contain a gearbox to increase the speed of the input shaft to the generator.

Hydropower convertors represent thus another application field for MMS; large plants, of thousands of MW are developed but the main unexploited potential lies in small rivers; developing small hydros (with installed power lower than 5 MW), using the potential of variable water sources, with minimal/null investment in dams or water storage systems (run-of-river design) represents the target of many studies and requires novel solutions for efficient mechanical transmissions and for rotor blade design, aiming for efficient running of the turbine all through the year, [10].

Wind turbines registered the most dynamic development in the past 5 years, mainly because their development gives maximal use of the existent experience in mechanical, mechatronic and electric systems, [11]. Due to the large wind turbine development (up to 5 MW), electricity cost is comparable to the production costs of power based on fossil fuels, and – in the other limit of magnitude – small or micro-wind turbines were developed, starting at very low wind speed (<2 m/s), thus being implemented in various rural or urban areas. For this last application, highly efficient speed increasers are required, with low weight and volume, along with novel rotor design solutions, involving composites with specific properties.

Conversion possibilities of a planetary chain-set from speed reducer into a speed increaser, by inverting the energy flow were analyzed [12]. The transmission can be integrated in small wind turbines and hydropower stations. By inverting the energy flow, the reducer can become a speed increaser only if its efficiency is positive. Comparative analyses of the structural, kinematical and dynamic specific features of the different types of planetary speed increasers were formulated and solutions were recommended for micro-hydro systems, [13].

Implementing the sustainable energy requirements by using the knowledge developed in MMS is not limited to renewables. The automotive industry represents another field where energy recuperation (e.g., from brakes), efficient and novel transmissions or mechanical parts are expected for the “automobile of the future”. Either electric or hybrid, using conventional fuel, biofuel or hydrogen, this represents a major research topic set at national or European levels, as an answer to the real threat represented by the need for raw materials and pollution mitigation.

Actually, the future development of mechanisms and machines must consider advanced functionalities but also driving energy efficiency and the cut of losses, thus, the future of MMS is intrinsically linked to sustainable energy.

Multybody System Method for Mechanisms in Renewable Energy Systems

The mechanical systems are key components in many renewable energy systems and their development, according to the *Integrated Sustainable Product Design* concept, requires new approaches and the use of dedicated software, integrated in virtual prototyping platforms, as presented in Fig. 3.

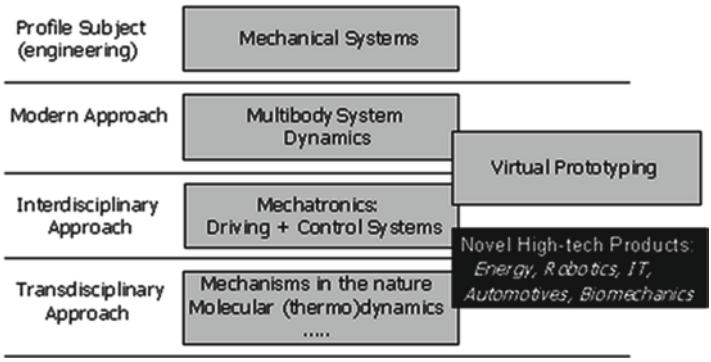

Fig. 3 Integrated sustainable product design of mechanical systems

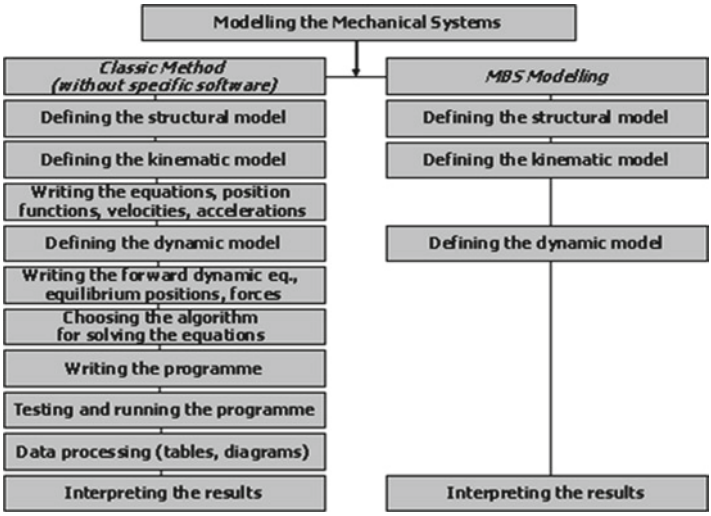

Fig. 4 Classical methods for modelling mechanical systems versus MBS

Modelling mechanical systems can be done either by following the traditional path or by using new methods as it is the Multibody System Method, MBS, [14–21], that provides a unitary model that can be applied to all mechanisms, regardless of their type (linkages type, cams, gear mechanisms, etc.), allowing the study and optimization of the dynamic behaviour for the entire product.

According to Fig. 4, classical modelling without the use of specific software requires sequential steps for developing a structural model, the kinematic and dynamic models and the kinematic – dynamic study of the mechanical systems. Moreover, for each configuration of mechanical systems, the analytical equations of the positions, velocities, and accelerations must be developed, based on the specific computational programs that have been formulated.

A modelling study without using dedicated software has a set of drawbacks:

- a long time dedicated to the design of the mechanical systems;
- the functions in the model depend on the mechanism's type and configuration;
- lack of unitary modelling for various types of mechanical systems (linkages, cams, gears), resulting in limited possibilities for integrated product design;
- strong difficulties in the dynamic modelling of the mechanical system, due to the complexity of the dynamic equations;
- when considering the elements and joints as deformable/flexible entities, complex models result, raising high difficulties in developing the explicit form;
- the need of comprehensive knowledge on the detailed analytical developments, for all the designers involved in product development;
- in the conception phase of a new complex mechanical system, specific knowledge on the conceptual design for each mechanism type is required;
- limited or no possibility for real time simulation of the dynamic behaviour of the newly developed products (automotives, aircrafts, aerospace installations, etc.);
- difficulties in integrating the control systems in the product design;
- limited use of advanced knowledge in the research for developing new products.

Formulating the teaching content and methodology of the Mechanism Science without adapting them for eliminating the above mentioned drawbacks will result in a limited use of knowledge in the integrated design of new products, which may have negative effects in this subject evolution.

Thus, there is a strong need to use methods based on dedicated software for promoting advances in mechanism conceptual design and in their kinematic-dynamic study. In this case, according to Fig. 4, the designer's work implies the unitary description of the structural, kinematic and dynamic models (regardless the mechanism type) and the results' interpretation obtained when using the adequate software followed by the mechanism optimization (if necessary) for insuring the targeted dynamic behavior of the product.

This approach is particularly valid for developing novel, efficient, performant solutions embedded in renewable energy systems, [4–6, 22, 23].

A New IFToMM TC on Sustainable Energy

During the large international events dedicated to renewable energy systems it became obvious that the MMS must become strongly involved in research and in providing answers for the many unsolved problems. Combining energy efficient solutions with energy saving results, the design and development of renewable energy systems involving new mechanisms and mechatronic systems represents a trend followed by research groups all over the world. Recognizing this need, the IFToMM board considered the idea of launching a new Technical Committee on

Sustainable Energy Systems and, during the SYROM 2009 conference, Transilvania University of Brasov took the charge to prepare this proposal.

The new Sustainable Energy Systems Technical Committee will promote the strategy and values that govern IFToMM and is dedicated to advances in machines and mechanisms science, developed by respecting the sustainable energy concepts, implemented in a broad range of applications: automotives, robotics, solar energy conversion systems, wind turbines, hydro-systems, etc. Emerging applications of the mechanical systems theories are expected in new frontier research such as the Multibody System Theory applied to molecular systems.

Besides research, the new TC aims to support a re-shaping of the education and training programmes, at university level, largely involving project based and problem based learning, by developing gradually complex products, using the integrated product design for sustainability with subjects focusing particularly on renewable energy systems and components.

The promoter, Transilvania University of Brasov, runs a complex of diploma programs, involving *Sustainable Product Design, Industrial Design and Engineering of Renewable Energy Systems*, offering tailored knowledge and expertise in the field of MMS and sustainable energy systems. These courses are followed by an M.Sc. course *Product Design and Environment for Sustainable Development*, with a flexible curricula, opening a training path for research in doctoral programs. The doctoral and post-doc programs are run in research departments that have been restructured over the past 6 years. The entire high level research developed in the university is concentrated in 22 departments, 14 for product development and 8 for support activities, Fig. 5.

Further, international cooperation represents the tool offered by this frame for a harmonized development of sustainable energy systems, and the new TC intends to develop as a forum opened for discussions and joint work.

According to the IFToMM Statute, the TC Sustainable Energy will act for fulfilling the following objectives:

- Promote research and development in the field of Machines and Mechanisms considering the Sustainable Energy action lines.
- Broaden contacts among persons and organizations of different countries engaged in scientific or engineering work in the field of Machines and Mechanisms, designed for energy efficiency, energy saving and applied in renewable energy systems.
- Promote the exchange of scientific and engineering information and experts in the field of advanced machines and mechanisms for sustainable energy.
- Promote the Sustainable Energy concept in IFToMM conferences and events, in scientific journals and other special publications.
- Encourage the visits of experts and students between countries, either as individuals or as teams.
- Establish the necessary relationships with other international organizations and unions whose activities are of interest to the TC Sustainable Energy.

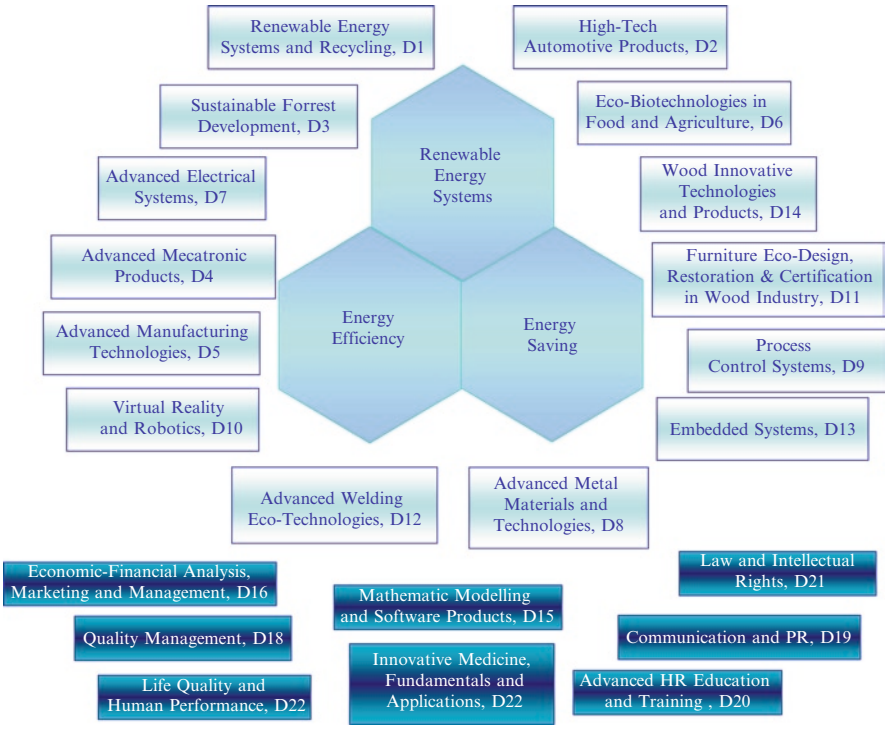

Fig. 5 Research departments in the Transilvania University of Brasov

The activities that are part of the working plan for the proposed committee can be synthesized as:

- Developing a collaborative frame of working groups, active in the field of mechanical systems for sustainable energy. Networking among the research, education and industry groups is a pre-requisite for successful activities, with real impact in the economic area.
- Joint development of complex projects, strengthening the resources, experience and expertise of the groups.
- Joint development of education and training guidelines and courses, preparing graduates for the real needs identified in the labor market.
- Organizing of thematic scientific events as part of IFToMM events and/or developing specific events in the frame of IFToMM.
- Developing instruments for dissemination of the TC activities: web-site, specific publications (monographs, journal).

Relevant personalities, active in the MMS field with strong links to sustainable energy, have confirmed the viability and the need for this new structure and have declared their support for its development.

Conclusions

Implementing sustainable development requires concrete actions and engineering is one key provider for new/innovative solutions able to change our present and future. Energy production, consumption and waste disposal are part of this action complex; the past decade formulated a strategy for increasing energy efficiency, cutting losses for energy saving and adopting renewable energy systems as major energy providers, known as *Sustainable Energy*. The MMS is deeply involved in developing sustainable energy systems, in the concepts of Sustainable Integrated Product Design. For advances in this direction, new methods and tools must be used, such as the Multibody System Method coupled with dedicated software, which can be included in virtual prototyping platforms. Sustainable Energy Systems represent now a complex topic, and IFToMM decided to tackle the idea of a new Technical Committee, with the same name. A real consensus on this new TC was registered, and the proposal is under development.

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