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Towards greener machine tools – A review on energy saving strategies and technologies

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ABSTRACT

The imbalance between energy supply and demand is expected to keep increasing, with the manufacturing sector being responsible for about one-third of world energy consumption. Hence, concerns about energy-efficient and environmentally benign manufacturing process have become an emerging issue. This paper suggests a novel hierarchy of energy saving technologies for machine tools, mainly for machining. Cutting is a widely used traditional process, and accounts for a large portion of energy consumption in machine tool sectors. A novel hierarchy is suggested, from the perspective of a single device manager, in accordance with the level of application. Technologies and strategies were compiled from research project reports, journal and conference articles, energy policies, *etc.* They were then rearranged in respective levels in the suggested hierarchy. Theories and technologies in the assessment and modeling of energy characteristics were reviewed, and general strategies on micro process planning were discussed at the software-based optimization level. Then, technologies for control and cutting improvement, such as novel lubrication and assisted machining systems, were introduced, and their effects were presented. Finally, improvement of hardware components and design rules for the environment were reviewed. Future market demands have clearly drawn more attention to energy efficiency, and the energy consumption of machine tools should be more accurately modeled and controlled. Loss and unnecessary operation of partial components should be minimized. From the perspective of energy efficiency, machine tools are expected to become more compact and lightweight. Operators and manufacturers need to understand both the process and hardware for greener machine tools.

Contents

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1. Introduction

Due to the explosive growth in population during the last century, human beings are facing global problems in the supply of food, water, and energy. In particular, in the case of energy supply, the depletion of fossil fuels has become an emerging issue. Fossil fuels have been driving forces of explosive globalization and industrialization, but the world's interests are now focusing on the improvement of energy efficiency, and the development of alternative energy sources due to environmental pollution caused by carbon emission. Since 1990, the world's energy consumption has increased by more than 30%, as shown in Fig. 1, and the U.S. Department of Energy has predicted this trend has in particular increased with the growth of developing countries [1].

Due to this energy imbalance problem, developed countries, mainly in Europe, have shown increasing trends of power generation capacity by renewable energy, while regulating and reducing carbon emission. The power capacity of renewable energy sources, such as wind turbines, solar PV, and biomass, has hugely increased, as shown in Fig. 2, with increases in investment in renewable power capacity.

However, renewable energy sources have disadvantages in terms of economic costs, and the portion of renewable power generation capacity is under 10% worldwide. From this perspective, using less energy with higher efficiency in energy demand problems is still a very important intermediate strategy. Moreover, reduction in auxiliary energy consumption and improvement of energy efficiency at the use end will always be a valid strategy. Hence, numerous researches have been conducted.

Among the various sectors, the industrial sector is responsible for 37% of total energy consumption, and 17% of total carbon dioxide emissions [3]. In particular, emerging countries generally have a higher proportion of energy-intensive industries. Therefore, the acceleration trends in the depletion of energy sources will be connected to loss of the growth momentum of industries.

Fig. 3 shows the energy consumption ratio of manufacturing industries. The United States and the United Kingdom each account for about 20% of the total, and Canada for about 30%. In Europe, manufacturing industries occupy about 32% of the total energy consumption [4]. In the case of South Korea in particular, the industrial sector makes a large contribution to overall energy consumption, of over 50% of the total. In particular, China is a major energy consuming country in addition to the USA, and industrial sector occupies about 70% of total energy consumption and 72% of carbon dioxide emission [1].

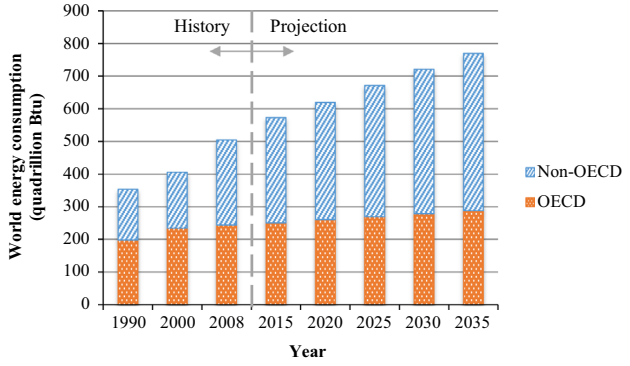

Fig. 1. History and prediction of the world's energy consumption for OECD and Non-OECD countries (redrawn with data from the U.S. EIA International Energy Outlook [1], with kind permission from the U.S. Energy Information Administration (EIA)).

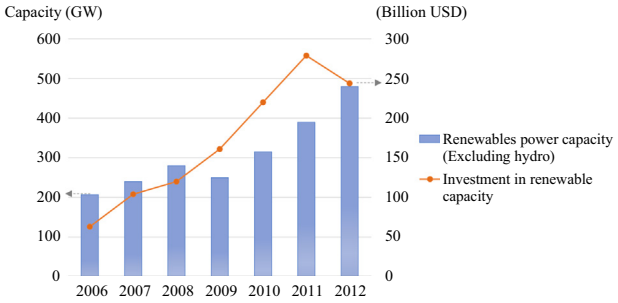

Fig. 2. Renewable power capacity trends and annual investment in renewable capacity (redrawn with data from the REN21 Global Status Reports [2], with kind permission from the Renewable Energy Policy Network for the 21st Century (REN21)).

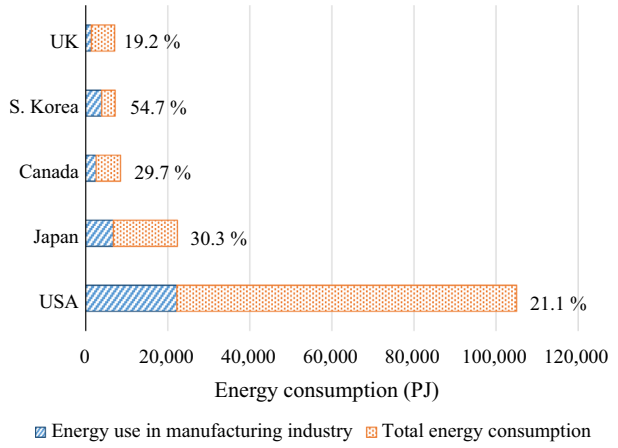

Fig. 3. Comparison of the energy use ratio of manufacturing industries to the total (redrawn with data from Park et al. [3], with kind permission from the Korean Society of Precision Engineering).