Electro mechanical alternatives to increase the efficiency of industrial systems

Saving energy by using electro mechanical actuators

Christoph Pohl, Jens Hesselbach, Universität Kassel, Germany
Christian Becker, Exlar Europe GmbH

Authors

Dipl.-Wirtsch.-Ing., Dipl. Oec. Christoph Pohl is scientific member at the University of Kassel in the area of environmentally sound products and processes (Fachgebiet Umweltgerechte Produkte und Prozesse).

Dipl.-Ing. Christian Becker is sales manager at the Exlar Europe GmbH and responsible for the sales channel in Europe, Middle East and Africa

Prof. Dr.-Ing. Jens Hesselbach chairman of the chair of environmentally sound products and processes (Umweltgerechte Produkte und Prozesse, upp) at the university of Kassel in Germany.

Contact

University of Kassel
Institute for Industrial Engineering and Logistic
(Institut für Produktionstechnik und Logistik)
Area of environmentally sound products and processes
(Fachgebiet Umweltgerechte Produkte und Prozesse)

34125 Kassel
Tel.: +49 561 / 804 3460
Fax : +49 561 / 804 3995
E-Mail: pohl@upp-kassel.de
URL: http://www.upp-kassel.de

Fluid power, including hydraulic and pneumatic technologies are the backbone of the world wide machine building industry. Hydraulic and/or pneumatic manufacturing lines are an integral component of today's industry. However, the air driven systems as well as oil driven systems are afflicted with inefficiencies. In these cases electro mechanical alternatives need to be seriously considered compared to traditional actuation. Due to the large efficiency differences, the choice of actuators might be made with energetic considerations. The efficiencies of hydraulic, pneumatic and electro mechanical system's is the content of this publication.

In the long-term, global trends have more and more influence on the entire electrical supply of states and countries. Especially countries like China and India that push for further development of industrialization to reach a standard of living as it is in western industrial

nations. Those facts accompany the global need of resources, energy, and finally lead to higher demand, higher prices, and a shortage of fossil feuls. „the safe keeping of a reasonable, economic and ecological electrical supply is one of the biggest challenges of the 21. Century.“ [1].
To keep the ability to compete in a the long term, governments of European countries, i.e. Germany, have called out a challenging goal according to the „Future Energy Concept„: With competing costs of energy and the high standard of living, Germany should become one of the most energy efficient economies in the world.“ [1].
This concept stipulates that the main part of the „Future Energy Concept” will be covered through regenerative energies like wind or bio energy. As this activity by its own is not enough to cover all the energy needs, the focus must also be to increase energy efficiency. Therefore, all possible energy savings in residential, but mainly in industrial uses have to be taken in consideration. Studies talk about a potential of savings of 10Billion€ per year in the German industry. [1].

Important Efficiency Potentials in the Area of Fluid Power.

A big part of what needs to be done to increase the efficiency is in the usage of industrial air. For the production of pressurized air, in Europe alone, about 80 Billion kWh, (Germany 14 Billion kWh) are needed [2]. The production of air is afflicted with very high losses. In average, 10 percent of the needed electrical energy can be finally used as effective energy. [3]

Beside the subgroup of pneumatics, hydraulics also belongs to the field of fluid power. “Fluid power technology, either with air or oil transmits force and power to drive, control, or move applications“[4]
At this time hydraulic applications have effectiveness of about 70% and enough room for possible savings. (An example application listed below is 200bars of pressure, a flow rate of $0.57 m^3/h$ and a power consumption of 4626Watts) Hydraulic systems use similar components to pneumatic systems, such as generators (pumps) and infrastructure (tubes, hoses, valves, filters).

20 years ago the slogan was: „Hydraulics and pneumatics are the most important technologies to move machines […] and are a substantial alternative to electric actuators[…].“[5]. Today that is not valid. These days, economies are forced to save energy and protect the word climate. Given this, it is mandatory to use energy in a more sufficient way. Legislation, the media, and consortiums are advising on the huge potential of energy efficient behavior.[6].
This especially affects industry and business. Energy efficient technologies should be used more often and processes should be improved.[7].

Hydraulic and pneumatic systems did not completely lose their importance, but electro mechanical actuation offers many industrial areas a better alternative from the economic point of view and from an energy stand point.

In reality advantages and disadvantages of each technology have to be taken under consideration. In addition to costs, the level of required controllability, speed, force and safety need to be thought of.

Studies give a general relationship between the cost of pneumatic, hydraulic and electro mechanical actuation as follows:

Pneumatic : Electric	=	10..12	: 1
Pneumatic : Hydraulic	=	1.25	: 1[8]

Experimental Analysis

To show how big the savings potential is in different ranges of fluid power the University of Kassel did an experimental analysis in the context of the „HIER!" project "Production without Air". This project was done by the chair of environmentally sound products and processes at the University of Kassel in Germany.
By using experimental set-ups, energy comparisons were done to show the possible savings by making the right choice of actuators. Not only is the technical aspect taken under consideration but also the economical point of view in terms of the costs to implement or retrofit an existing system.

A direct comparison of different actuators should show the differences in cost, use of energy, and CO2 usage. Therefore a specific duty cycle was chosen in the experimental set-up. Parameters have been chosen in that a real application is simulated to get a realistic picture of each actuator.

Picture 1: Energy comparison of a pneumatic, hydraulic and electro mechanical actuator (from Exlar).

All actuators (hydraulic, pneumatic und electro mechanical) were mounted inline so the required duty cycle is exactly the same.

A choice of cylinders has been done where the technical specifications are similar. Cylinders have a stroke of 50cm and a max load of 1000N. The set up was done so that different loads can be chosen. Different weights can be used to simulate different loads. For this test the max load of 100kg was used.

For this analysis, standard hydraulic and pneumatic components have been used, the electro mechanical actuator was an integrated actuator (Tritex II from Exlar).

Picture 2: Energy comparison of pneumatic, hydraulic, and of electro mechanical linear actuators.

To get a real comparison, the hydraulic cylinder must be noted. In reality, industrial applications using a hydraulic cylinder operates with high pressures like 200-250 bar. With the simple physical equation: „Force is the result of pressure multiplied with surface of the cylinder“ it is obvious that even the smallest cylinder has higher capacity then the pneumatic and electro mechanical systems. At the same time the hydraulic pump needs much more energy to generate such a high pressure. In that case, a realistic comparison would not be shown.

To get the comparison for the described cases the energy consumption of the hydraulic cylinder is taken proportionally, exactly with that energy that would be necessary to move 100kg.

For the experimental example of the energy comparison, the setup is fitted with measurement device. The energy of electro mechanical cylinder, including the control unit, can be taken

direct through energy meter. To define the need of energy of the pneumatic cylinder a calorimetric flow device for air is installed. To get the volume needed for the hydraulic cylinder a counter was installed. Buy measuring the flow, the needed energy can be calculated. In the case of the pneumatic cylinder an efficient compressor is used, that needs 120Wh for the compression of one cubic meter of air. For the estimation of energy consumed in the case of the hydraulic cylinder a characteristic factor of 1,6kWh per cubic meter is taken.

Savings of up to 90% when using electro mechanical actuators

The measured consumption of energy will be multiplied with the number of operating hours and extrapolated to the real need during a year. In our calculation 6000 hours per year have been taken as a basis. The need of energy of an air cylinder is 8380kWh per year. A hydraulic cylinder uses 3602kWh per annum. The electro mechanical alternative has just 816kWh per year. The CO_2 consumption of the pneumatic system is 5,3tons per year and 2,3tons for the hydraulic actuator compared with 525kg for the electro mechanical one. That is a saving of 90 percent compared to the pneumatic cylinder and 77 percent compared to the hydraulic one.

The calculated energy consumption per year multiplied with the average industrial energy cost of 0,1€/ KWh defines the cost of each system. The evaluation of the CO_2 emission is based on the German carbon emission/ energy formula of 644gr(CO_2)/(kWh).

A comparison that is based on the energy consumption of the electro mechanical actuator brings us to the result that the hydraulic actuator needs for the same duty cycle 4,4 times more energy. The pneumatic cylinder needs even ten times more energy.

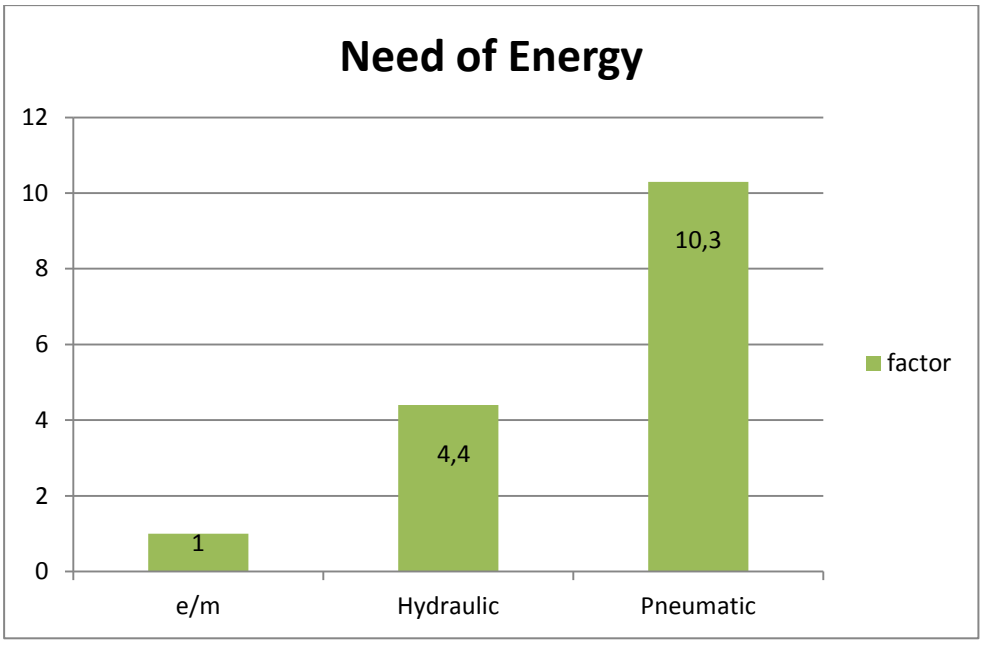

Bild 2: factorized comparison

Cost of investment of electro mechanical actuators are higher compare to the cost of pneumatic or hydraulic cylinders. All components that have been needed during the test, like control units, connectors, cables, valves, tubes and hoses have been taken in consideration.

Higher investment cost can be amortized due to the savings during operation in about 2,5 years. The higher investment is economically reasonable for the described application as the savings have effect within the life time of the actuators.

We have to take in account that only one specific case with specific test parameters and conditions has been taken in consideration. A generalization of the results of this comparison is not possible. Not every application might have the same high savings.

However, at this point we can refer to experimental analyses that have been already done and confirm the findings of this test.

Similar savings have been seen in a comparison of a more complex application in a handling machine. [9].

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C. Pohl/C. Becker/J. Hesselbach: Electro mechanical actuators as key for energy efficiency for linear movements

Schlüsselwörter:
Substitution von Druckluft, Hydraulik, Wirkungsgrad, energetischer Vergleich, elektrische Antriebe

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