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Energy management for servo presses

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Press manufacturers and press operators have been actively engaged in the topic of energy management, at the latest, since Siemens equipped the first servo presses back in 2008: Is energy management for servo presses necessary – or does it make sense? How does it impact the investment costs, for example, the unit costs? Is it even possible to reduce the amount of energy that servo presses consume? The starting point when clarifying these questions is always the metal forming process itself with its specific requirements.

Requirements of the metal forming process

The impact of the various energy management approaches is considered using a typical metal forming process. This involves a 2000 ton servo press with a 10 mm force stroke before bottom dead center (BDC). The end user specifies a minimum stroke of 650 mm, work capacity of approx. 550 kJ per stroke as well as a maximum forming velocity of 0.14 m/s. Based on this data, the power required for the actual forming process can be calculated, in this case it is approximately 2750 kW. 30 strokes per minute must be able to be achieved.

Typical servo press

Based on these specifications, the machine builder designs an excentric press with the following main mechanical data:

- Stroke: 650 mm
- Connecting rod: 2.650 mm
- Ram weight: 100 t
- Gearbox: 26
- Moment of inertia: 60.000 kgm²
- Mech. efficiency: ~ 92 %

For a mechanical efficiency of 92 %, for 2750 kW forming power, servos with a minimum drive power of 3000 kW are required.

Maximizing productivity through motion control

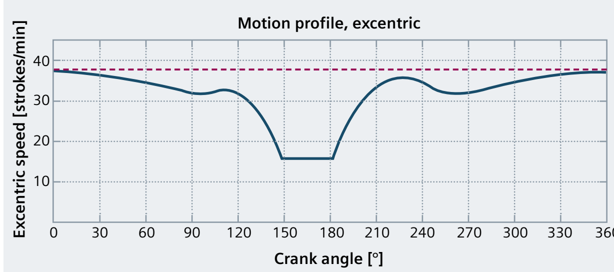
When using servo presses, the degrees of freedom for the motion control of the ram are decisive. They allow the forming quality, throughput and process reliability to be optimized. The two most important challenges placed on the motion control are as follows ...

1.) The system power determined from the static forming conditions, which must also be dynamically applied: Only then is the electrical system effectively utilized, and the maximum possible productivity achieved.

2.) All of the constraints of the overall system must be maintained, even at the specified 30 strokes per minute:

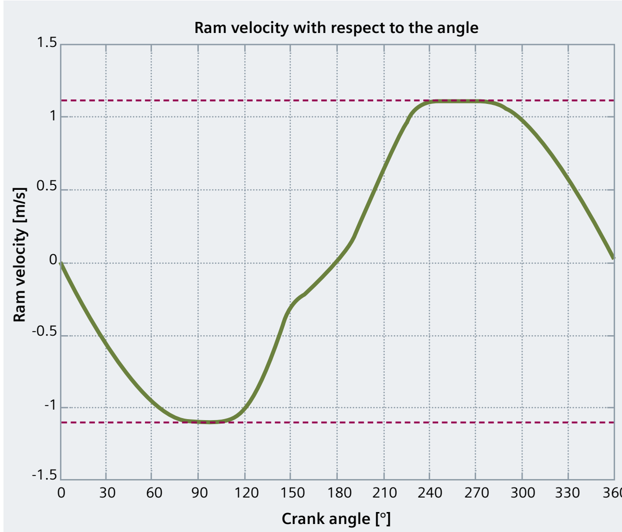
- Forming conditions
- Maximum motor speed
- Permissible ram velocity
- The installed motor power and available torque must never be exceeded
- There must be a minimum of 1.0 seconds for the part transfer between excentric positions 250 ° and 100 °.

For conventional methods, these types of motion tasks are solved using cams and higher order polynomial functions, and little or no emphasis is placed on the energy related aspects. As a consequence, the maximum possible productivity is not utilized. For this reason Siemens has developed a new technique for calculating the motion profiles of servo presses. A motion profile is calculated, with optimum energy utilization – but still taking into account all technological, drive-related and mechanical constraints – so that the specified productivity is guaranteed. The motion characteristic for a typical press, determined using this technique, is shown in the following diagram. Even at 30 parts per minute, all of the necessary restraints are complied with:

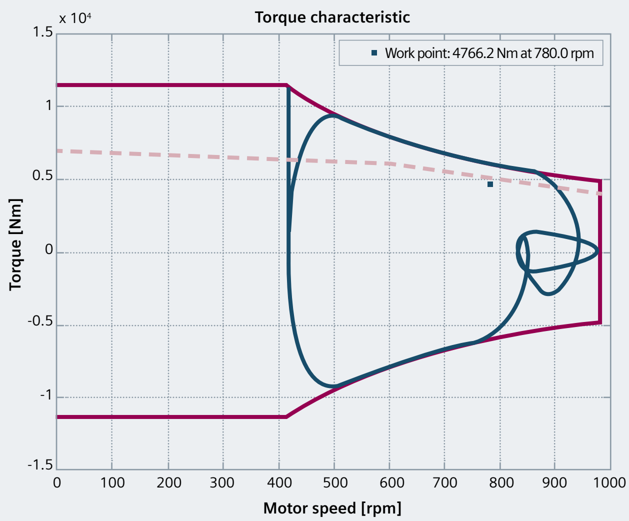


- Maximum motor speed and transfer time of 1.0 seconds are maintained

This particular press achieves a productivity of 30 strokes/minute with a press force of 2000 tons at 10 mm before BDC and 550 kJ forming work per stroke.



- Maximum ram velocity is maintained

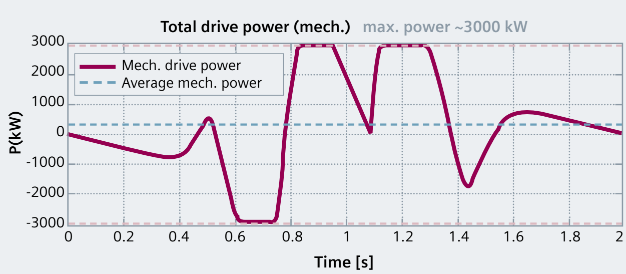


- Maximum motor power is maintained

Siemens has integrated the new calculation technique into its SIMOTION motion control system: The OACAMGEN block automatically generates motion curves, which for the specified stroke rate, comply with all of the mechanical and electrical constraints of the overall system. As a consequence, the company operating the press has the maximum degree of flexibility. He can very simply adapt press motion to the die, material and part to be produced.

Energy-related considerations

The motion profile shown above for the maximum utilization of the servo press results in the following power characteristic at the motor shaft:



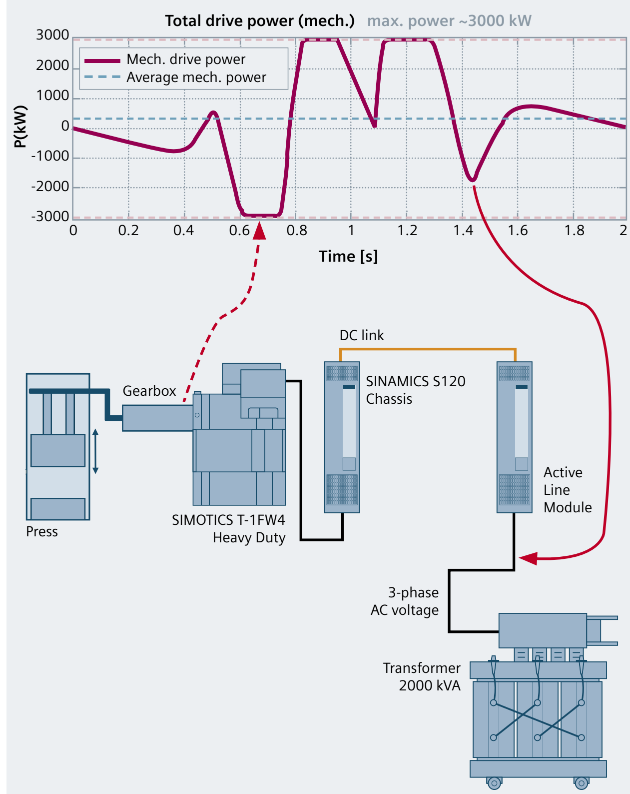
Average power (P̄)	299 kW
RMS power (P̃)	1.630 kW
Max. power (P̂)	3.000 kW
Min. power (P̌)	-3.000 kW
Power fluctuation (ΔP)	6.000 kW

Electrical power losses have still not been taken into account.

The large difference between the useful and rms power indicates that the motion control optimally utilizes the overall system. The use of torque motors extends the degree of flexibility. As a result of their dynamic performance they allow the highest possible productivity to be achieved for the specified stroke rate.

Case 1:
Servo press without energy management

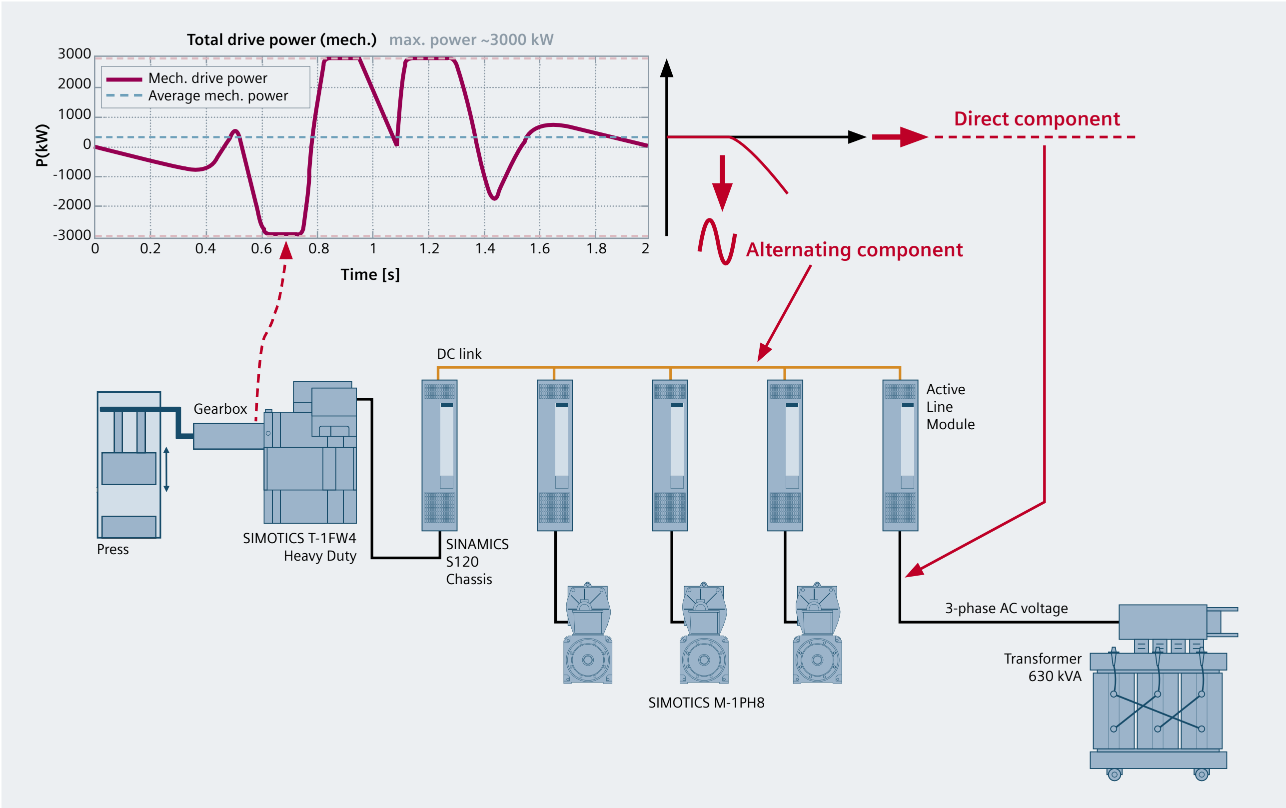
For a servo press without energy management, the mechanical power to be output by the motor – as well as the power loss of the electric system – must always be completely covered by the infeed and the line supply.



In this case, the infeed unit must cover a peak power of over 3000 kW, the upstream transformer must be able to handle these load peaks, and the significant load fluctuations directly impact the line supply. A transformer with a minimum rated power of 2000 kVA is required.

Case 2: Servo press with
"Full Size" energy management

For a complete energy management, the drive system of the press example is expanded to include three kinematic energy storage devices with a maximum power of 1000 kW. As a consequence, it is possible to keep the alternating component of the power in the servo press drive system. For this reason, the infeed sees an almost constant load – and regenerative feedback into the line supply is not required. Only the direct component is drawn from the line supply, which comprises the forming work per stroke and the mechanical and electrical system losses. This means that the infeed and transformer rated powers are reduced to a minimum.



For the “full-size” energy management system, energy storage devices buffer the energy that is otherwise fed back into the line supply. As a consequence, the rms value of the infeed power is the same as the average value, thus preventing energy from being fed back into the line supply.

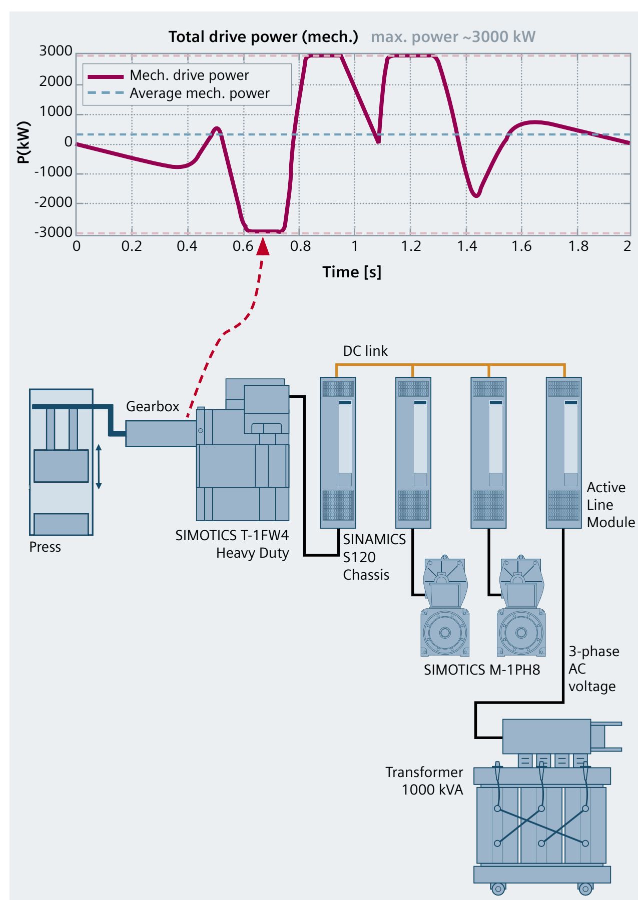
For this type of energy management, the electrical energy storage device corresponds to the mechanical flywheel of a conventional press; Both of these “devices” ensure that pulsetype power is not drawn from the line supply. However, the drive system must be expanded, which also increases the electrical losses.

This disadvantage is essentially compensated as a result of the significantly lower infeed rating (ALM/AIM) and the far smaller transformer: Instead of a ± 3000 kW infeed rating, now with 516 kW – a significantly smaller 630 kVA transformer is adequate with the associated lower costs!

Case 3: Servo press with “semi” energy management

When only part of the kinetic energy is recuperated, the power of the energy storage motors is reduced. This means that instead of three, only two are used, for example. This reduces the machine price – at least at a first glance.

This is because the power of the energy-storage motor that is eliminated must now be covered by the infeed (ALM/AIM), which means that a higher rating infeed unit is required. As the kinetic energy is only partially buffered, the power drawn from the line supply can no longer be completely smoothed.

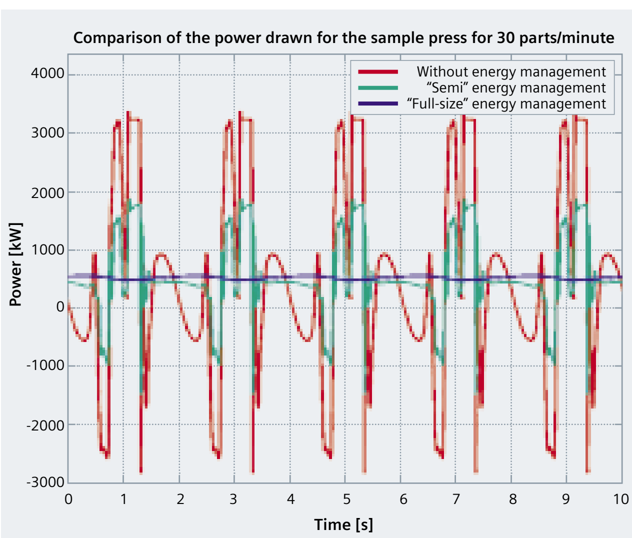


This means that the peak load is significantly higher than for the “full-size” energy management – and it fluctuates between a positive and negative load, between infeed and regenerative feedback. The supply transformer must also be correspondingly larger; and in this particular case, it must have a minimum 1000 kVA rating.

When compared to a servo press without any type of energy management, partial buffering of the kinetic energy reduces the load peaks that impact the line supply. However, the undesirable features of a machine without energy management still apply: In addition to the energy feed that is productively used by the press, the infeed, transformer and feeder cables must also handle the alternating load of the cyclic processes. As a consequence, they must be appropriately over dimensioned. An analysis must be made on a case-for-case basis as to which version is the most favorably priced and offers the most advantages.

Comparison: Power drawn

For the three energy management versions considered, the diagram shows the power to be covered by the press transformer for 30 parts per minute and a forming energy of 550 kJ per part:



An almost constant infeed power and exclusively a positive power demand are only achieved with the “Full-size” energy management system. For the other versions, the power drawn fluctuates significantly – and the regenerative feedback of electric power into the line supply, with all of its associated disadvantages.

Additional comparison of key data:

Energy management	Transformer rating	Induction motors	$\bar{P}$ [kW]	$\tilde{P}$ [kW]	$\hat{P}$ [kW]	ΔP [kW]
Without	2000 kVA	–	481	1687	3211	6000
“Semi”	1000 kVA	2	501	812	1853	3316
“Full-size”	630 kVA	3	516	516	551	75

Values refer to the infeed input

Energy costs versus energy usage

An increased amount of energy is used with lower energy drawn from the power utility company, as energy is kept within the press system. To estimate the most favorable energy management version, the energy usage required for the machine motion and forming work – as well as the costs to achieve this – are compared. The usage measured at the transformer output is decisive in this case. Main calculation data:

Operating hours	Approx. 7000 h/a
monthly price for power (provision):	10 €/kW
Active power tariff for industrial customers (consumption):	12 ct/kWh

Energy fed back into the line supply is not credited. The energy consumption of die cushions – that might possibly be used – has not been taken into account

	Energy costs per year for 12.6 million parts	Energy cost per part	Energy usage per part	
	[€/a]	[ct/part]	[kWh/part]	[kJ/part]
“Full-size” infeed	859,060.–	6.8	0.277	996
“Semi” E. mgt.	561,330.–	4.5	0.283	1020
“Full-size” E. mgt.	501,900.–	4.0	0.290	1046

The comparison indicates: Under the specified constraints, the servo press equipped with the “full-size” energy management has the lowest energy costs. This is the case, although the energy usage per part is somewhat higher than that with “semi” energy management or without energy management.

The transformer price must be taken into account when analyzing the investment costs. It is by far the lowest for “Full-size” energy management. Already with this cost saving, a large percentage of the additional cost for the energy management system can be compensated. This means that the breakeven point for this investment is frequently reached very quickly.

Comparison with a mechanical flywheel press

A comparison with a mechanical press with comparable requirements in continuous operation shows that here, a connection power of 216 kW is adequate (including all of the mechanical and electrical losses); however, a productivity of only 16 parts/minute is achieved.

As a result of the “flywheel mass” energy storage system inherent to mechanical presses, the average value of the power drawn is equal to the rms value; this means that there is no regenerative energy. To achieve the specified unit quantity of 12.6 million parts, not one, but two flywheel presses are required.

	Energy costs per year for 12.6 million parts	**Energy cost per part**	**Energy usage per part**	
	[€/a]	[ct/part]	[kWh/part]	[kJ/part]
With 2 mechanical presses	378,000.–	3.0	0.219	788

In order to achieve the productivity of a servo press, two machines are required. In turn, this means twice the surface area, twice the number of personnel and for each product, also two dies. This relativizes the lower energy costs of a mechanical press.

Summary

The end user requirements regarding the forming process define the drive power of a servo press. An intelligent motion control utilizes this drive power with maximum productivity, assuming that all system-related constraints are fully utilized, also under dynamic performance perspectives. This means that the power required by an efficiently utilized servo press is high. Servo presses without an energy management system have no buffer for the kinetic energy in the system. As a consequence, for the power they draw from the line supply, there is a significant difference between the average and rms values. The power drawn can be effectively smoothed by installing a “full-size” energy management system. When directly comparing the hardware costs of various energy management versions, the costs of a supply transformer must also be taken into account. Depending on the size of the kinetic buffering integrated in the drive system, the costs vary widely.

The difference between the higher energy costs of servo presses when compared to a mechanical press is minimized when using an energy management system adapted to the particular application. This means that the technological advantages of servo presses – their far higher flexibility and production quality as well as their significantly higher productivity of the footprint used – can be utilized to achieve the most cost effective solution.

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