ENERGY EFFICIENCY IN MACHINE TOOLS FOR PLASTIC DEFORMATION

INTEREST IN THE THEMES OF ENERGY EFFICIENCY AND ENVIRONMENTAL IMPACT OF PRODUCTION PROCESSES AND MACHINE TOOLS IS INCREASING. THEY HAVE BECOME THE FOCUS OF KEEN ANALYSES PERFORMED TO OBTAIN AN EXHAUSTIVE UNDERSTANDING OF THE PROBLEM, AND TO DEFINE TECHNOLOGICAL AND/OR MANAGEMENT SOLUTIONS THAT MARK AN IMPROVEMENT. FOR THE BENEFIT OF OPERATORS, WE SHALL DISCUSS THE ENERGY CONSUMPTION ASPECTS OF PLASTIC DEFORMATION MACHINES, REPORTING ANALYSES, EXPERIMENTAL FINDINGS AND PROPOSALS FOR IMPROVEMENTS.

The paradigm of sustainable production can also be pursued in the deformation industry by adjusting the specifications of the product to be manufactured, defining the technological process to be implemented and designing the machine/system that will carry out the production. Nowadays, plastic deformation machines constitute a type of machine tool that is widely available on the market, and which is constructed in few countries, namely USA, China, Japan, Germany and Italy. Examples of machines for the deformation of metals include presses for drawing, for bending and for forging and die-casting machines, while machines for thermoforming and injection moulding are typical applications for plastic and rubber processing. Current statistics seem to indicate a future increase in the demand for new presses with a subsequent rise in the environmental impact resulting from their production/use. It is no mere chance that plastic deformation machines are included in the list of machines governed by EuP/ErP directives, and with their related work (preparatory study by Fraunhofer, self-regulation initiative of Cecimo, etc.). In terms of regulations, the Technical Committee appointed to define standard ISO 14955 on the evaluation of the environmental impact of machine tools has dedicated a special section–section 4 [3], currently DIS– to test specifications and procedures to be implemented when conducting energy surveys on plastic deformation machines. Hence, it would be useful to provide indications on how to pursue energy efficiency in the “press” segment.

PLASTIC DEFORMATION MACHINES

In a broad sense, presses are differentiated by type of function and material processed. There are several types of presses available on the market, and the main ones can be classified based on implementation:
- hydraulic presses;
- mechanical presses;
- electric presses (evolution of mechanical presses, presence of brushless motors for the generation of motion).
- hydroforming presses

The decision to use one type of press rather than another depends on several factors: product specifications or expected output, machine performance required, desired system and process. Energy consumption and environmental impact have a certain importance among the various drives that guide the choice, though bonds and technical specification are decisive, at times. However, the criterion of increased energy efficiency can play an important role in the design and construction process of the press, even after implementation-related decisions, and in terms of operation when the press is being used (parameters and process strategies, status management). It must be said that the application field of hydraulic presses on the one hand and of electric/mechanical presses on the other hand have always been identical. The former offer extension options for adjustments, while the latter guarantee a wide choice of pressing speeds. It is obvious that in certain application frameworks, which require large lots, the design of the pieces has been changed to make them manageable, for instance, by pressing with electric-mechanical presses, thus exploiting their faster speeds. In any case, none of the solutions always prevails on the others. In many «special» moulding sectors, e.g., the aerospace framework or deep drawing processes, the hydraulic drive is still the best solution, and often the one required.

ENERGY CONSUMPTION IN PRESSES

Studies and analyses of energy efficiency problems for plastic deformation machines are published in technical/scientific literature. The University of Porto conducted an LCA analysis on hydraulic presses for metal sheet bending, observing significant energy contributions both in terms of power required during use (55%), and during the machine construction/assembly phases (45%). For other deformation processes, particularly for massive ones and/or those involving thermal processes, energy consumption prevails during use. The same study reports that, daily monitoring of the absorption power of a hydraulic press (max force 170 tons, rated power 15kW) used for standard metal sheet bending cycles revealed the division of energy consumption between the various machine statuses: working 52%, standby 43%, off (with only the electric cabinet operating as required) 5%. But a power control system is installed on the machine that is analysed to automatically switch off the machine if a standby period of 10 mins. is exceeded. The incidence of the standby status on consumptions can even be higher in applications generally used in companies. Measurements taken by MUSP on electric servo presses for pressing (320 tons) by Mossini indicate mean power absorption during standby of ca. 8kW, 34% of which is absorbed by the chiller, 40% by basic power supply, and 26% by drives. Hence, a considerable amount of the total energy demanded by the plastic deformation machine (electric) is related to machine maintenance in an idle state, without performing any work cycle. In the case of a medium/low quality hydraulic press, standby consumptions are often caused by continuous function of the hydraulic power unit that operates at maximum power even when the mechanisms are not moving. In electric presses, instead, these "baseline" consumptions are related to the function of auxiliary systems for cooling/temperature regulation of machine parts. Hence, crucial aspects include the duration of the single cycle (in the first place by reducing to a minimum both waiting and set-up times) and the possible use of operative/management technologies to reduce energy consumption during stand-by. A comparison between energy surveys performed by the University of Port on two presses with different types of drives, hydraulic and electric, respectively, during performance of the bending cycle of a metal sheet, revealed that the mean power absorbed by the electric press (max pressing force 100 tons, main motor power 11kW) and the one required by the hydraulic press (max pressing force 110 tons, installed power 11kW) have a 1:2 ratio. Generally, the hydraulic drive is in itself more inefficient than the electric one in terms of energy, especially when there are forces in the range of 10-100 tons (e.g., bending tubes or sheet metal), due to the power required for hydraulic system function at operating regime. Electric presses also offer the option of installing regeneration devices for energy recovery when the closure system brakes. This energy is restored to the system as electricity. Regardless of the type of press, especially when performing heavy processing (with forces in excess of 1,000 tons, e.g., heavy processing for forging and hydroforming), the gravitational effect of the masses of machine elements and friction gain importance from an energy-related standpoint. The indication is to carry on operations by making the most of the runs to avoid empty machine cycles as far as possible. In terms of construction, the advice is to adopt an approach focused on light-weight design, however evaluating the trade-off with the need to ensure adequate structural stiffness in order to limit elastic deformations of the structure.

TESTS AND POWER MEASUREMENTS ON NAVA HYDRAULIC PRESSES

Hydraulic presses are a type of plastic deformation machines that are widely used nowadays for various applications (rubber/plastic, sheet metal products and components, thermal compression, elastic forming for the aerospace industry) in the Italian industrial sector. Hence, they are the focus of detailed analyses to provide additional experimental data about energy consumption and indications about environmentally efficient solutions to improve them. The above machines, as all machine tools, generally, are instrumental assets that have a very long lifetime and high investment costs. Hence, Italian companies, especially small and medium size enterprises, currently use “outdated” and potentially inefficient machines. Hence the need to understand any gap present in terms of energy efficiency in plastic deformation machines, which constitute the current user segment, to then propose and encourage the replacement and/or reconditioning of these, in favour of solutions designed to reduce energy consumption, among other things. Particularly, the author, in partnership with the manufacturer F.lli Nava Srl of Monza (MB) and MUSP, conducted tests and measured the power on a Nava hydraulic press model 2MI 100/50 for cold deformation of sheet metal for drawing at the manufacturer’s facility. This machine is a small hydraulic press with hydraulic drive conceived in the late 1990s, before the technical improvements implemented by the manufacturer over the years. Considering standard ISO 14955 as general reference, a specially designed cycle was carried out on the press, comprising the phases specified below:

1. hammer approach to the sheet press on which the metal sheet to be processed is placed;
2. reaction of the sheet press;
3. stabilisation (maintaining the hammer under pressure with mould closed, a phase that is often either reduced or absent, and is inserted here to numerically assess the energy-related impact);
4. rise;
5. sheet press rise A load of 100 tons on the main (hammer) and of 30 tons on the sheet press was applied during the test phase.

The electricity required was acquired by using a power sensor produced by the Milan Polytechnic University (3 currents measured by circular LEMs with Hall effects and 3 voltages measured in parallel, compared to the network voltage), and installed to the general three-phase switch of the machine. The total power absorbed and measured is used:
- for the main motor (hammer drive +metal sheet press drive);
- for the auxiliary motor (exchange pump for oil conditioning + accumulator pump + valve control);
- to commute solenoid valves;
- to supply power to the PLC and to lights in the processing area (basic power supply) (oil cooling is not considered here as it is performed by cold water from the corporate water network, which is outside the “confines” of the system analysed).

Though the cycle performed cannot be considered significant in absolute terms as it depends on the processing, which determines the resistant hydraulic load, the measurements (Fig.1) indicate that baseline absorption of power during standby accounts for few percentage points, compared to the nominal power installed (sum of rated power of the main and auxiliary motors). The outcome, which apparently deviated from the results reported in technical literature, is, instead, the result of the environmentally efficient standby solution implemented by the manufacturer F.lli Nava Srl. The machine regulates the oil pump capacity to the mechanical minimum (minimal capacity required only for pump «washing»), while the functional control units commute the small remaining oil capacity of the pump directly to the tank’s outlet with zero pressure, determining almost no power. Moreover, absorption during standby includes the consumption of auxiliary systems, which is constant in time and minimum in terms proportion, compared to that of the main motor that drives press movements. Optimisation of the machine’s energy-related behaviour during processing is, in the first place, related to the extensive use of proportional pressure adjustments and to the use of electronics for press control/management. Unlike machines with a thermal compression cycle, correctly dimensioned presses for metal sheet drawing always need the utmost fluid capacity. during the moulding phase. to prevail on the load (to obtain maximum performance of piece moulding velocity. Hence, the system works efficiently at nominal power, underscoring the fact that the solution with regulated capacity drive and maximum constant power is the best in terms of energy for this type of presses.

The use, if any, of oil drives with pressure/capacity regulators on pumps for primary regulation does not determine evident differences in terms of performance (the absence of prolonged phases under pressure with minimum diminishing capacity to be managed).

Hence, oil drives are not useful to increase energy efficiency. Likewise, even start/stop with prolonged standby is not an improvement. Regarding the cooling/heat exchanged system, efficiency is given by the control circuit that works smartly “by thresholds”, thus minimising the consumption of energy required for cooling (cold water from the corporate network or from the dedicated local chiller for the press), and optimising the parameters of the working fluid, maintaining them within a narrow optimal range, thus achieving a better overall performance and performance that is as constant as possible during processing. Besides design, programming press operational parameters is of the utmost importance in terms of energy efficiency. Furthermore, the manufacturer has long insisted on the importance of energy-related aspects even when training the client’s personnel, building their awareness of the impact of work cycle definition and reg-

ulation on machine production costs (firstly direct consumption, duration and mould consumption).
All environmentally friendly solutions proposed by the manufacturer to reduce consumption–they must be limited to the actual need for production–are now used as standard in all hydraulic presses of the Nava range, such as models 2MI 1200/500 and 2MI 500/300 [9] (Fig. 2 and Fig.3), in the ad hoc design of new systems and for reconditioning/ retrofitting of existing machines. The adoption of these options, consistently with the specific application and the operational scene, can allow a considerable reduction in energy consumption, compared to the "baseline scenario" of power use of a common traditional plastic deformation machine of medium-low quality, and conceived with obsolete terms.