European Plastics and Rubber Machinery

EUROMAP 46.1	**Extrusion Blow Moulding Machines Determination of Machine Related Energy Efficiency Class**

Version 1.0, January 2014
13 pages

This recommendation was prepared by the Technical Commission of EUROMAP.

EUROMAP Technical Commission
c/o VDMA • FV KuG
Lyoner Str. 18
DE 60528 Frankfurt am Main
Phone + 49 (69) 6603-1833
Fax + 49 (69) 6603-2833
E-Mail:euromap@vdma.org

Contents Page

1 Introduction

1.1 Scope and application

This recommendation specifies the procedure for measuring and calculating the absolute/specific energy consumption of Extrusion Blow Moulding (EBM) machines. The goal is to establish a comparison method among machines in order to provide a classification based on the energy efficiency regardless of tools or customer/product related factors, which may influence the energy consumption.

This recommendation deals with EBM machines[1]:

- for the processing of thermoplastics;
- with one or more extruders
- with electrical barrel and head heating;
- with one or more shuttles;
- which are able to process Polyethylene (PE) (see test material);
- for continuous or intermittent extrusion (see accumulator head).

For the determination of the absolute/specific energy consumption of complex installations as well as for measuring the energy consumptions according to customer/product specification, EUROMAP 46.2 requirements shall also be used.

This recommendation enables the evaluation of the energy consumption of basic machines regardless of ancillary movements, ancillary equipment or auxiliary units, so that the energy efficiency of the main units should be ascertainable.

All the energy/power values defined and used further on are "machine related".

The procedure to measure the specific energy consumption of machines with liquid cooling systems (barrel, motor and drive, oil) is described in Appendix A.

The procedure to measure the specific energy consumption of machines with accumulator head is described in Appendix B.

1.2 References

Short name	Title	Version
EUROMAP 46.2	Extrusion Blow Moulding Machines – Determination of Product Related Energy Consumption	2013-12
IEC 62053-22	Electricity metering equipment (a.c.) – Particular requirements – Part 22: Static meters for active energy (classes 0,2 S and 0,5 S)	2003-01

[1] Machines with pneumatic driven shuttles are excluded by this recommendation

2 Definitions

2.1 Total energy consumption

Consider the power diagram of Fig. 1, representing the power consumption of a machine obtained by using a measuring method/instrument as specified in Sect. 4.

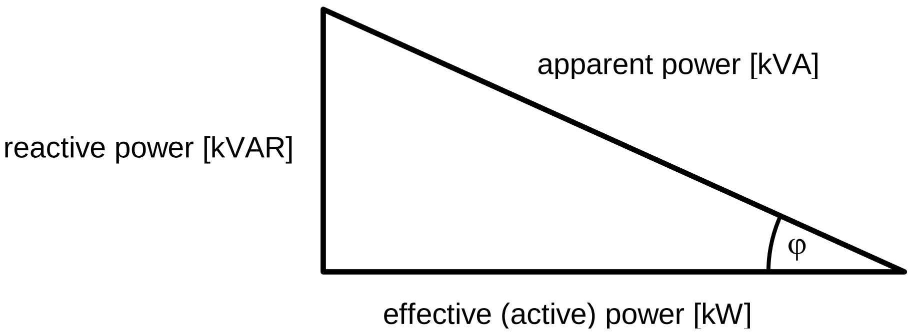

Figure 1: Power diagram

The **machine total energy consumption E_{tot} [kWh]** in a given time interval ΔT is defined as:

$$E_{tot} = P\Delta T \qquad [kWh]$$

where P is the mean active power supplied to the machine in the time interval ΔT.

2.2 Total specific energy consumption

The **machine specific energy consumption E_{sp} [kWh/kg]** is defined as the energy consumption E_{tot} in a given time interval ΔT divided by the extruded mass m in the same time interval ΔT:

$$E_{sp} = \frac{E_{tot}}{m} \qquad \left[\frac{kWh}{kg}\right]$$

2.3 Subsystems energy consumption (optional)

Similarly to the previous definitions, the following energy consumption values can also be measured.

2.3.1 Extruder motor and drive energy and specific energy consumption

The **extruder motor and drive energy consumption E_m [kWh]** in a given time interval ΔT is defined as:

$$E_m = P_m\Delta T \qquad [kWh]$$

where P_m is the mean active power supplied to the motors in the time interval ΔT.

Accordingly, the **extruder motor and drive specific energy consumption E_{spm} [kWh/kg]** is defined as the extruder motor energy consumption E_m in a given time interval ΔT divided by the extruded mass m in the same time interval ΔT:

$$E_{spm} = \frac{E_m}{m} \qquad \left[\frac{kWh}{kg}\right]$$

In machines with multiple extruders, the contributions of all motors and drive shall be added.

2.3.2 Barrel and head thermoregulation system energy and specific energy consumption

The **barrel and head thermoregulation system energy consumption E_{th} [kWh]** in a given time interval ΔT is defined as:

$$E_{th} = P_{th}\Delta T \qquad [kWh]$$

where P_m is the mean active power supplied to the thermoregulation system in the time interval ΔT.

The **barrel and head thermoregulation system specific energy consumption E_{spth} [kWh/kg]** is defined as the extruder thermoregulation energy consumption E_{th} in a given time interval ΔT divided by the extruded mass *m* in the same time interval ΔT:

$$E_{spth} = \frac{E_{th}}{m} \qquad \left[\frac{kWh}{kg}\right]$$

In machines with multiple extruders, the contributions of all extruders shall be added.

2.3.3 Extruder energy and specific energy consumption

The **extruder energy consumption E_{ex} [kWh]** in a given time interval ΔT is defined as:

$$E_{ex} = P_{ex}\Delta T \qquad [kWh]$$

where P_{ex} is the mean active power supplied to the extruder in the time interval ΔT.

If E_{th} and E_m are measured over the same time interval ΔT, E_{ex} *can be calculated as:*

$$E_{ex} = E_{th} + E_m \qquad [kWh]$$

.

The **extruder specific energy consumption E_{spex} [kWh/kg]** is defined as the extruder energy consumption E_{ex} in a given time interval ΔT divided by the extruded mass *m* in the same time interval ΔT:

$$E_{spex} = \frac{E_{ex}}{m} \qquad \left[\frac{kWh}{kg}\right]$$

E_{spex} can be calculated by:

$$E_{spex} = E_{spth} + E_{spm} \qquad \left[\frac{kWh}{kg}\right]$$

In machines with multiple extruders, the contributions of all extruders shall be added.

2.3.4 Forming system energy and specific energy consumption

The **forming system energy consumption E_f [kWh]** in a given time interval ΔT is defined as:

$$E_f = P_f\Delta T \qquad [kWh]$$

The **forming system specific energy consumption E_{spf} [kWh/kg]** is defined as the forming energy consumption E_f in a given time interval ΔT divided by the extruded mass *m* in the same time interval ΔT:

$$E_{spf} = \frac{E_f}{m} \qquad \left[\frac{kWh}{kg}\right]$$

In machines with multiple shuttles, the contributions of all shuttles shall be added.

In the case of machines with moving parisons, the forming system energy consumption refers to the energy consumption to move the parison (and, possibly, the shuttle).

2.3.5 Relation between the total energy consumption and the subsystems energy consumption

-

The total (specific) energy consumption can be calculated by:

$$E_{tot} = E_{th} + E_m + E_f \qquad [kWh]$$

$$E_{sp} = E_{spth} + E_{spm} + E_{spf} \qquad \left[\frac{kWh}{kg}\right]$$

For Machines using liquid cooling systems the related energy consumption shall be determined according to Appendix A. The resulting **cooling energy consumption** (i.e. E_{barr}, E_{oil}, etc…**[kWh]**) and **cooling specific energy consumption** (i.e. E_{spbarr}, E_{spoil}, etc…**[kWh/kg]**) shall be added to the total energy consumption E_{tot} respectively to the total specific energy consumption E_{sp} defined in Sect. 2.1-2.2.

For Machines using extruders with accumulator head the related energy consumption shall be determined according to Appendix B. The resulting **accumulator head energy consumption** E_{acc} **[kWh]** and **accumulator head specific energy consumption** E_{spacc} **[kWh/kg]** shall be added to the total energy consumption E_{tot} respectively to the total specific energy consumption E_{sp} defined in Sect. 2.1-2.2.

2.4 Ready-to-operate machine

All units (i.e. possibly required ancillary units, inverters, electronic control system and their cooling devices,…) required for the main machine movements (mould closing/opening, mould backward and forward movements, bobbing, metering, screw motors and drives, etc.) are ready-to-operate. The hydraulic system, if any, shall be always switched on and at the operating pressure. The barrel heating is switched off.

2.5 Idle power

The **idle power** P_i **[kW]** is the mean power consumption of the ready-to-operate machine measured in the conditions specified in Sect. 2.4.

3 Energy consumers

The following shall be included:

- electric motors and drives of the extruders (included motor and drive liquid cooling, if any);
- electric heating of barrels and heads (including barrel (liquid or air) cooling system, if any);
- electric motor and drives for all axis movements in the forming process (shuttle or parison);
- accumulator head for the production of discontinuous parisons (if any);
- pump and drive for the hydraulic power generation (if any);
- oil cooling system (if any);
- control system electronics;
- internal maintenance devices (supplied by the machine manufacturer), e.g. cooling of electrical components, grease systems, cooling of the hydraulic oil.

The following shall be excluded:

- ancillary equipment, e.g. conveyors, metering equipment, pick and place devices;
- external supply of fluids related to mould cooling or blowing system;
- gearbox cooling, if any;
- pump and drive of the barrel, motor etc… cooling systems, if any;
- material transport/improvement of the material properties (e.g. dryers)

4 Measuring method

4.1 Measuring equipment

The power measurements shall be performed using instrumentation compliant to the IEC 62053 family of international standards. More specifically, the instrumentation shall be certified accordingly to IEC 62053-22:2003 (Static meters for active energy - classes 0,2 S and 0,5 S). The measurement devices should be positioned at the main power supply input.

4.2 Test material

The tests shall be carried out with virgin PE-HD with density 0.950 +/- 0.005 MFR (accordance to ISO 1133) = 8-10 g/10 minutes (at 21,6 kg and 190 °C), not dried and not preheated, at an ambient temperature below 30°C.

4.3 Melt quality

The melt shall show no visual inhomogeneity or degradation.

4.4 Measurement operating conditions

The barrel temperature of all zones (except the cooled ones) shall be within ±10°C of the set-point value.

The machine is in a stable condition, i. e.:

- stable automatic operation without the necessity of manual intervention for at least 15 min;
- the barrel has been at set-point temperature for at least 15 min;
- stable oil temperature (for hydraulic machines) has been reached and maintained for at least 15 min.

The tests are intended to be performed without any mould. It is therefore necessary to guarantee the target clamping force (see Table 1) during the mould closure.

The tests shall be performed at the conditions reported in Table 1.

Table 1 - Machine parameters during tests

Parameter	Value
Mould clamping force	≥ 90% of maximum value
Bobbing speed	≥ 90% of maximum value
Shuttle and mould closing / opening speed	≥ 90% of maximum value
Shuttle and mould movement speed	≥ 90% of maximum value
Shuttle and mould acceleration / deceleration	≥ 90% of maximum value
Shuttle and mould displacements	≥ 90% of maximum value
Blowing time(1)	$T_b = \begin{cases} 0.155\frac{s}{kN} \cdot F_{cmax} + 7.2\ s & when\ F_{cmax} < 200\ kN \\ 0.051\frac{s}{kN} \cdot F_{cmax} + 28\ s & when\ F_{cmax} \geq 200\ kN \end{cases}$
Extruder(s) total throughput	≥ 90% of maximum value(2)
Barrel set-point temperatures (all zones except the cooled ones)	190 °C

(1) The blowing time is defined as a function of the nominal maximum mould clamping force F_{cmax} [kN]

(2) The total throughput must be 90% and the different components must be in the correct compound proportion.

4.5 Tests for energy consumption measurement

The following tests shall be performed in order to measure the energy values defined in Sect. 2.1-2.2 and in Sect. 2.5.

Test 0 - measurement of E_{tot}, E_{sp}

The goal of this test is to measure the total and specific energy consumption of the machine. Since the forming part is not equipped with any mould, the extruded melt shall be separately collected for weighing.

The total energy consumption E_{tot} as defined in Sect. 2.1 shall be measured at the conditions reported in Sect. 4.4, provided that the following constraint are all verified:

- $\Delta T \geq 10$ min;
- extruded mass $m \geq 5$ kg;
- at least 10 cycles are performed.

The collected extruded mass *m shall be weighed* and E_{sp} determined as defined in Sect. 2.2.

Test 1 - measurement of P_i

With the machine at the conditions described in Sect. 2.4, the mean supplied power P_i over a time interval $\Delta T_i \geq 5$ min shall be measured.

The following tests can be optionally performed in order to measure the energy values defined in Sect. 2.3.

Test A (optional) - measurement of extruder related energy consumptions

The goal of this test is to measure the energy consumption of the extruder. For this purpose, if it is not possible to measure it separately from the forming process, it shall be provided that the forming section shall be switched off (no mould movements). In hydraulic machines the pump shall be switched off. The extruded melt shall be separately collected for weighing.

The extruder energy consumption E_{ex} as defined in Sect. 2.3.3 shall be measured at the conditions reported in Sect. 4.4, provided that the following constraint are all verified:

- $\Delta T \geq 10$ min;
- extruded mass $M \geq 5$ kg

The collected extruded mass *m shall be weighed* and E_{spex} determined as defined in Sect. 2.3.3.

Other optional measurements

If the subsystems are equipped with separate power supplies, it is recommended to separately measure the electric motor energy consumptions E_m, E_{spm} and the thermoregulation energy consumptions E_{th}, E_{spth} with the same constraints as above: $\Delta T \geq 10$ min and $m \geq 5$ kg.

Test B (optional) - measurement of forming section related energy consumptions

The goal of this test is to measure the energy consumption related to the movements of the forming section. To this aim, if it is not possible to measure it separately from the extruder, it shall be provided that the extruder motor and thermoregulation system are switched off.

The forming system energy consumption E_f as defined in Sect. 2.3.4 shall be measured at the conditions reported in Sect. 4.4, provided that the following constraint are all verified:

- $\Delta T \geq 10$ min;
- at least 10 cycles are performed

The specific energy E_{spf} shall be calculated according to the following:

$$E_{spf} = \frac{E_f}{M}\frac{\Delta T_A}{\Delta T}$$

where m is the extruded mass collected in a time interval ΔT_A (for instance in the previous experiment - test A).

5 Energy classes

According to the determined specific energy consumption the machine shall be assigned to one of the following classes:

Table 2 - Efficiency classes

Class	Specific energy consumption E_{sp} [kWh/kg]
1	> 1.30
2	≤ 1.30
3	≤ 1.00
4	≤ 0.80
5	≤ 0.62
6	≤ 0.53
7	≤ 0.45
8	≤ 0.39
9	≤ 0.34
10	≤ 0.29

A plus ("+") shall be added to the class, if the determined idle power is less than 1 kW.

6 Reporting

Table 3presents the mandatory report for classification. If this report is not provided, the machine is considered in a worse energy efficiency class.

In Table 4, the report on optional measurements is presented. This table too could only be partially filled.

Notice that, if Test A and Test B are performed the information for Test 0 can be obtained from them.

Table 3 - Mandatory tests report form

Test 0,1 - Machine consumption, idle power		
Cycle time		[s]
Blow time		[s]
Cycle number		#
Measurement time ΔT		[min:s]
Extruded mass M		[kg]
Total energy consumption E_{tot}		[kWh]
Liquid cooling energy consumption (if applicable)		[kWh]
Specific energy consumption E_{sp}		**[kWh/kg]**
Idle Power P_i		**[kW]**
Idle measurement time ΔT_i		[min:s]
Efficiency class		

Table 4 - Optional tests report form

Test A - Extruder related consumption		
Measurement time ΔT		[min:s]
Extruded mass M		[kg]
Extruder energy consumption E_{ex}		[kWh]
Extruder specific energy consumption E_{spex}		[kWh/kg]
Extruder motor energy consumption E_m		[kWh]
Extruder motor specific energy consumption E_{spm}		[kWh/kg]
Extruder thermoregulation system energy consumption E_{th}		[kWh]
Extruder thermoregulation system specific energy consumption E_{spth}		[kWh/kg]
Barrel cooling specific energy consumption E_{spcool}		[kWh/kg]
Accumulator head specific energy consumption E_{spacc}		[kWh/kg]
Test B - Forming process related consumption		
Measurement time ΔT		[min:s]
Cycle number		#
Forming energy consumption E_f		[kWh]
Forming specific energy consumption E_{spf}		[kWh/kg]

Appendix A

When considering machines with liquid cooling systems, the **cooling power *P_{cool}* [kW]** shall be calculated using the machine nominal values, according to the following equation

$$P_{cool} = 10^{-3}\rho w c_v (T_{out} - T_{in}) \quad [kW] \tag{1}$$

where:

T_{in} $[K]$ is the cooling liquid input temperature (can possibly be measured - see Sect. 4.4);

T_{out} $[K]$ is the cooling liquid output temperature (can possibly be measured - see Sect. 4.4);

ρ $[\frac{kg}{m^3}]$ is the cooling liquid density;

c_v $[\frac{J}{kg\ K}]$ is the cooling liquid specific heat;

w $[\frac{m^3}{s}]$ is the cooling liquid volumetric flow (can possibly be measured - see Sect. 4.4).

Equation1 can be used for the calculation of the energy consumption of a cooling system. The **barrel cooling energy consumption *E_{barr}* [kWh]** in a given time interval *ΔT* is defined as:

$$E_{barr} = P_{barr}\Delta T \quad [kWh]$$

where P_{barr} is computed according to Eq. 1.

The **barrel cooling specific energy consumption *E_{spbarr}* [kWh/kg]** is defined as the barrel cooling energy consumption E_{cool} in a given time interval *ΔT* divided by the extruded mass *m* in the same time interval *ΔT*:

$$E_{spcool} = \frac{E_{cool}}{m} \quad \left[\frac{kWh}{kg}\right]$$

The **oil cooling energy consumption *E_{oil}* [kWh]** in a given time interval *ΔT* is defined as:

$$E_{oil} = P_{oil}\Delta T \quad [kWh]$$

where P_{oil} is computed according to equation 1.

The **oil cooling specific energy consumption *E_{spoil}* [kWh/kg]** is defined as the oil cooling energy consumption E_{oil} in a given time interval *ΔT* divided by the extruded mass *m* in the same time interval *ΔT*:

$$E_{spoil} = \frac{E_{oil}}{m} \quad \left[\frac{kWh}{kg}\right]$$

This procedure can be extended to motor and drives cooling systems.

The energy consumption of liquid cooling pump drives, if any, can be neglected.

Appendix B

When considering machines with accumulator head, additional tests shall be performed at the following conditions:

1) The extruder shall be at the operating conditions specified in Sect. 4.4.
2) The polymer mass for each cycle shall correspond to at least 70% of the head nominal volume value.
3) The ejection speed shall be at the value necessary to extrude at least 70% of the head nominal volume value in 10 s.
4) The hydraulic circuit pressure shall be:
   - at the nominal value at the normal machine operating conditions, when the head does not have an independent hydraulic plant.
   - at the minimum value to satisfy the previous constraint 3, when the head has an independent hydraulic plant.
5) The polymer temperature shall not be greater than the extruder temperature specified in Sect. 4.4.
6) The die's opening shall not be larger than 10 mm.
7) At least 10 cycles are performed.

The **accumulator head energy consumption *E_{acc}* [kWh],** in a given time interval *ΔT,* is defined as:

$$E_{acc} = P_{acc}\Delta T \qquad [kWh]$$

being ***P_{acc}* [kW]** the mean power consumption over the considered time interval.

The **accumulator head specific energy consumption *E_{spacc}* [kWh/kg]** is defined as the accumulator head energy consumption E_{acc} in a given time interval ΔT divided by the extruded mass m in the same time interval ΔT:

$$E_{spacc} = \frac{E_{acc}}{m} \qquad \left[\frac{kWh}{kg}\right]$$

EUROMAP

Europäisches Komitee der Hersteller von Kunststoff- und Gummimaschinen

European Committee of Machinery Manufacturers for the Plastics and Rubber Industries

Comité Européen des Constructeurs de Machines pour Plastiques et Caoutchouc

Comitato Europeo Costruttori Macchine per Materie Plastiche e Gomma

See you again

http://www.euromap.org