S2.1: List of identified process parameters for the centerless grinding process

Parameter	**Parameter name**
$P_{grinding}$	Grinding power consumption
$P_{hydraulic}$	Power consumption of the hydraulic system
$P_{cooling\_pump}$	Power consumption of the cooling pump
$P_g^{spindle}$	Power consumption of the grinding wheel spindle motor
$P_r^{spindle}$	Power consumption of the regulating wheel spindle motor
P_{el_wp}	Power consumption of the electronic system and waste pump
$t_{loading}$	Loading time
$t_{unloading}$	Unloading time
t_{app}	Approaching time of the regulating wheel
t_{rt}	Retracting time of the regulating wheel
t_{sp}	Spark-out time
$t_{grinding}$	Grinding time
t_{setup}	Setup time
$t_{dressing}$	Dressing time
N	Size of the batch

S2.2: Power consumption and process characteristics of the studied in-feed centerless grinding process

The sequence of operations for the graph for the studied centerless grinding process is as follows.

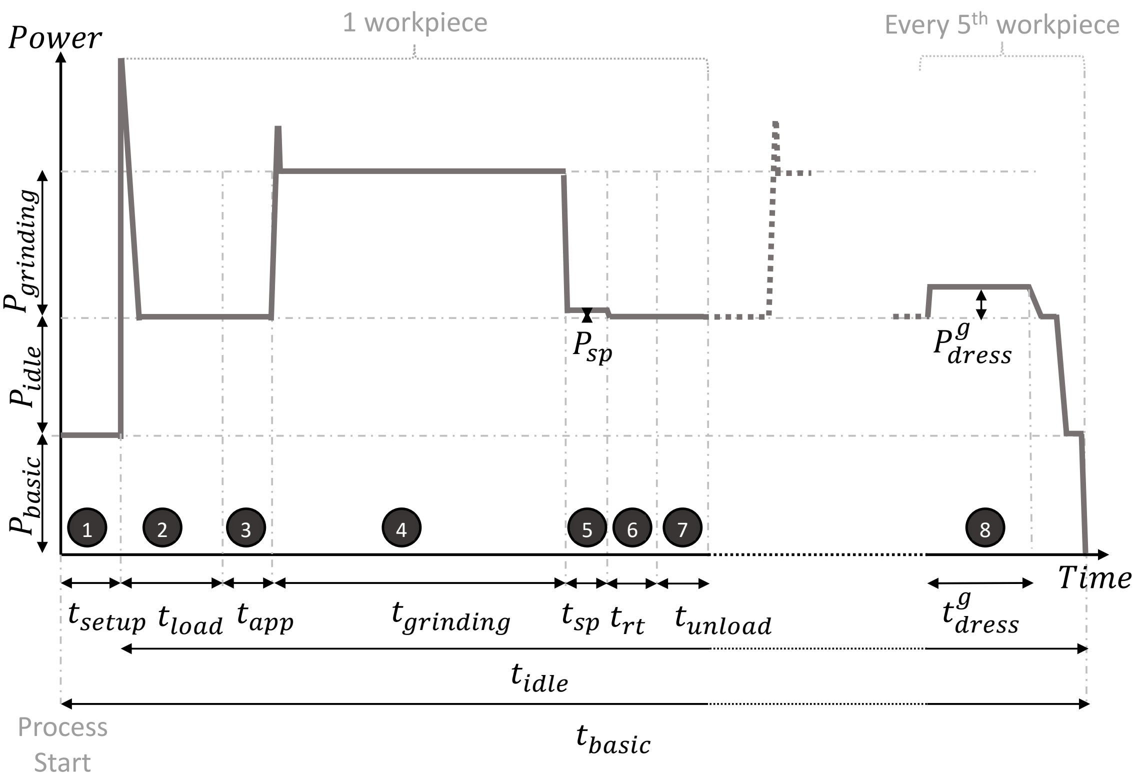
1. A process sequence starts with the operator setting up the machine and inputting process parameters at the beginning of a new batch. During this period peripheral systems of the machine are in function and draw a specific amount of power.
2. The grinding and regulating wheels are started after the machine is set, and workpieces are fed one-at-a-time.
3. The regulating wheel rapidly approaches the workpiece immediately after the loading process.
4. The grinding process starts once the workpiece contacts the grinding wheel, and it continues until the workpiece reaches the specified diameter.
5. The finishing process for the workpiece includes a sparkout stage.
6. The regulating wheel rapidly retracts from the workpiece after the sparkout stage.
7. The workpieces are unloaded from the machine while the grinding and regulating wheels continue to run at no load.

Step 1 is repeated at the beginning of a new batch, while **steps 2-7** are repeated for each workpiece.

8. The dressing of the grinding wheel is performed after grinding every fifth workpiece. The dressing of the regulating wheel is not considered in this study as it is not performed during production.

S2.3: Analytical model for process GWP and total energy consumption

The process sequence from S2.2 was encoded in the form of a power vs. time graph, to model the total energy consumption of the machine (see Figure below).



The global warming potential (GWP) of producing a batch of N parts on the centerless grinding machine was estimated using the equation below.

$$GWP_{total} = E_{total} \times e_{intensity}$$

Here, E_{total} is the total energy consumption of the centerless grinding process for producing a batch of N parts. $e_{intensity}$ represents the CO_2 intensity of electricity consumption and was assumed to be 0.207 kg. eq. CO_2 / kWh based on the Danish electricity grid https://ens.dk/en/our-services/statistics-data-key-figures-and-energy-maps/key-figures.

To estimate the total process energy consumption per cycle, basic, idle and grinding energy are calculated as the product of corresponding time and power consumption, as shown below.

$$E_{total} = E_{grinding} + E_{idle} + E_{basic} + E_{dressing}$$

$$E_{total} = P_{grinding} \times t_{grinding} + P_{idle} \times t_{idle} + P_{basic} \times t_{basic} + P_{dress} \times t_{dress}$$

P_{idle} is calculated as:

$$P_{idle} = \left(P_r^{spindle} + P_g^{spindle}\right) + P_{coolant\_pump}$$

$P_r^{spindle}$ & $P_g^{spindle}$ are the power consumed by the spindle motors for the regulating and the grinding wheel ,respectively. After both spindles are activated, the coolant pump $P_{coolant\_pump}$ is activated automatically.

Idle time t_{idle} is calculated as follows:

$$t_{idle} = t_{loading} + t_{app} + t_{grinding} + t_{sp} + t_{rt} + t_{unloading}$$

The basic energy consumption of in-feed grinding represents the energy consumed by auxiliary systems throughout the operational stage of the process.

P_{basic} is estimated using:

$$P_{basic} = \left(P_{electronic} + P_{waste\_pump}\right) + P_{hydraulic}$$

t_{basic} is calculated as follows:

$$t_{basic} = \frac{t_{setup}}{N} + t_{idle}$$

Here, t_{setup} represents the time needed to set up the process parameters for grinding the workpieces.

S2.4: Nominal operating conditions for the centerless grinding process

Experimentally measured process parameters for the infeed centerless grinding setup

	$\boldsymbol{t_{loading}}$	1.5 s
Process parameters	t_{setup}	119.0 s
	$t_{loading}$	1.5 s
	t_{app}	0.5 s
	t_{rt}	0.5 s
	t_{sp}	2.0 s
	$t_{grinding}$	8.0 s
	N	9240
Power measurements for the Danobat Estarta 318 MV-DC	$P_{coolant\_pump}$	2.01 kW
	$P_{grinding}$	8.30 kW
	$P_{hydraulic}$	0.15 kW
	$P_r^{spindle} + P_g^{spindle}$	2.63 kW
	$P_{electronic} + P_{waste\_pump}$	0.22 kW

In the Danobat Estarta 318 MV-DC process setup, dressing of the grinding wheel occurs during the grinding process. However, due to the low power consumption of the dressing operation, it was not possible to extract the data. As a result, in the equation for total energy consumption, we took the average value of the grinding power consumption over time, which also includes dressing operation.

Calculated parameters calculated for the infeed centerless grinding process based on experimentally measured process parameters and Equations is S2.3

$\boldsymbol{P_{idle}}$	4.64 kW
$\boldsymbol{P_{basic}}$	0.37 kW
$\boldsymbol{t_{idle}}$	14 s
$\boldsymbol{t_{basic}}$	14.01 s
$\boldsymbol{E_{total}}$	136.54 kJ
$\boldsymbol{GWP_{total}}$	0.00785 kg. eq. CO_2