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Lean Production Planning for 5 Axes CNC Driven Milling Machine

Sandor Bodzas[1], Bela Krakko[2]

[1]Department of Mechanical Engineering, University of Debrecen, Debrecen, Hungary
[2]Diehl Aircabin Hungary Ltd., Nyirbator, Hungary

Email address:
bodzassandor@eng.unideb.hu (S. Bodzás), bela.krakko@diehl.com (B. Krakkó)
[*]Corresponding author

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Abstract: The aim of this publication is to determine the OEE (Overall Equipment Efficiency) indicator for a 5 axes milling machine found at Diehl Aircabin Hungary Ltd. for the present and future state. Based on this value, the utilization of the machine for the given production amount can be calculated. With the optimal choice of the right production parameters (the number of cuts, feeding, depth of cut, etc.) greater productivity can be achieved i.e the machine main time (time of cutting) will be less. The possibilities of the reduction of the machine time will be analyzed and calculated.

Keywords: OEE Value, Production Planning, Lean, Milling Machine

1. Introduction

Lean is a company organizational, company conducting system of which aim is to produce its products and services by the most economical way. A lean company shapes its activities primarily based on the customers' needs, and what they take as valuable. Those things which do not create value for the customer, and for which the customer does not pay, Lean system takes as loss, and increases the efficiency of the processes by ceasing these losses or making them as less as possible [4, 5].

Diehl Aircabin Hungary Ltd. (9. Ipari street, Nyírbátor) is the first and only subsidiary of Deihl Aircabin GMbh located in Laupheim, and through its parent company, this company is a member of the Deihl Aerosystem. In Nyírbátor, there are more than 400 labourers working for the company. The aim is to have 550 labourers till 2018.

At Deihl Aircabin Hungary Ltd. doors – doorframes, side elements, climatic tubes for Single Aisle (short-term travel) and Long Range (long-term travel) airplane types are produced (Figure 1). Other products are isolation packages for Airbus aircrafts.

a) Airbus A320 type Single Aisle

b) A330/340 type Long Range

Figure 1. *Aircraft types.*

2. Maka Type Cnc Driven Milling Machine Having 5 Axes

At Diehl Aircabin Hungary Ltd. there is a MAKA M7t type CNC driven milling machine having 5 axes (Figure 2). The overall dimension of the machine: 5.2 m x 9.2 m x 6.2 m. Year of its production: 2015.

Figure 2. *MAKA M7t type CNC driven milling machine [1].*

The milling machine has 2 work tables. Because of this, manufacturing activity and the fixing of the workpiece can be paralleled (Figure 2) [1]. If we would like to use more than one tool, the automatic tool change system can change tool and it is possible to fix 12 tools in the tool storage system. (Figure 3) [1, 2].

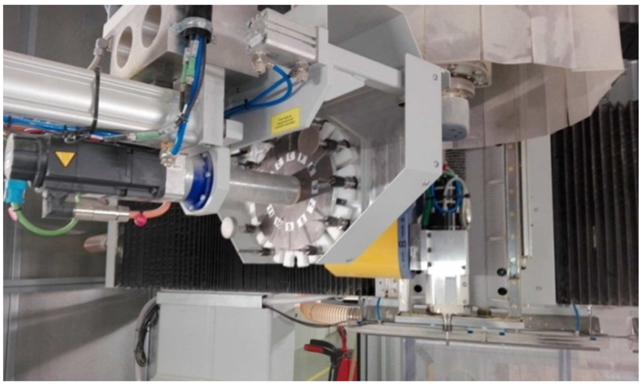

Figure 3. *Main spindle and the tool storage with 12 tool places.*

3. The Calculation of Oee Indicator

The OEE (Overall Equipment Efficiency) value shows how many percentage of the amount of the products are produced, of which the machine is being capable under optimal circumstances [4, 5] (Figure 4). OEE indicator is formed by 3 factors [5]:

- The indicator of availablility (A) refers to those time losses when the equipment could produce but due to some reasons it is stopped. The losses that influence this factor: malfunction, change over time, and the time of tool change.
- Performance indicator (P) includes those losses when the machine is running but it is not producing at all or not producing with the appropriate amount. The sources of losses, which influence this factor: micro shut downs, loss of speed.
- Quality indicator (Q): the equipment is running, producing but the product cannot be used because its quality is not appropriate. The sources of losses, which influence this factor: quality loss, start up loss.

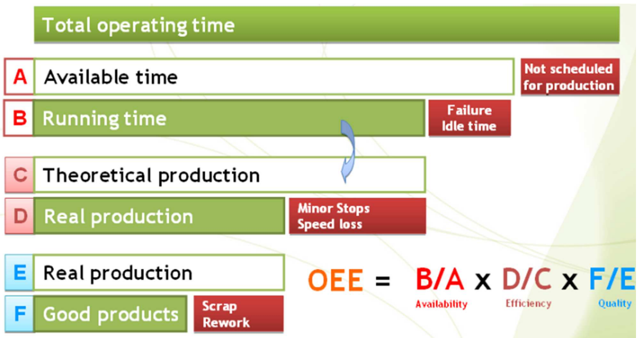

Figure 4. *The background principle of the calculation of the OEE.*

At Diehl Aircabin Hungary Ltd. OEE indicator is calculated annually for MAKA type CNC milling machine. Sidewalls, doors and doorframes are the products produced on this machine. [1]. For the calculation the following data are needed:

- number of produced pieces;
- time schedule;
- number of reworked workpieces;
- number of scraps;
- production time;
- unplanned shutdowns.

The total amount is the number of the total produced pieces in the examined period.

The steps of calculation of OEE indicator are the following [4, 5]:

Total amount = number of produced pieces + number of reworked pieces+ number of scraps (1)

Indicator of availability (A) = (Production time – Unplanned shutdowns) / Production time (2)

Performance indicator (P) = (Total amount x Time schedule) / Production time (3)

Quality indicator (Q) = Number of produced pieces / Total amount (4)

$$OEE = A \cdot P \cdot Q \quad (5)$$

For 2015 (recent state) based on the data available and using the formulas in (1) – (5) the value of OEE indicator has been calculated, which is 47%. So i.e. MAKA type CNC milling machine produces 47% of its amount of products, of which it would be capable in optimal case [1].

For 2016 (future state) at Deihl Aircabin Hungary Ltd., the customer needs, number of produced products and their complexity are continuously growing. Based on the data available and using the formulas in (1) – (5) the value of OEE indicator has been calculated, which is 159.3%. The calculated OEE indicator is above 100%, which means if there is that high production volume, one MAKA type CNC milling machine will not be enough for production. Thus for this reason 2 machines will be needed.

4. Making a Computer Program for Oee Indicator Calculation

For the fast calculation of OEE indicator, we have made a computer program. The aim was to ease the work of the company because with the help of the program OEE indicators can be calculated annually as well as for monthly periods. The input data of the program are the following [1], which you should give:

1. How many months or years I would like to make the calculation
2. Which month or years I would like to make the calculation
3. The number of produced items
4. Time schedule expressed in minutes
5. Number of reworked products
6. Number of scraps
7. Production time expressed in minutes
8. Unplanned shutdowns expressed in minutes

After all, the program calculates the following values below, shows them on the screen and it saves them in a different file [1]:

- Total quantity;
- Availability indicator;
- Performance indicator;
- Quality indicator;
- OEE indicator;
- OEE indicator in %;
- Number of machines needed for production.

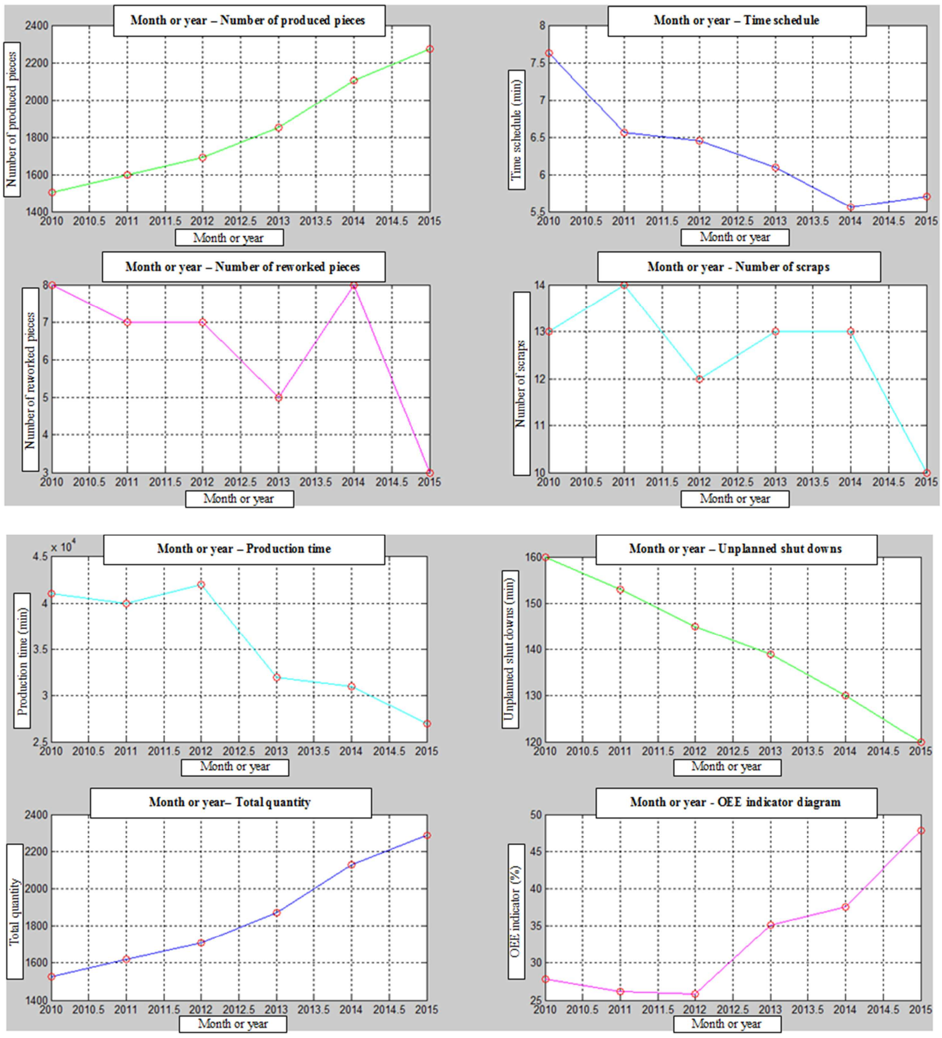

Figure 5. *Output functions of the computer program.*

The program draws 8 functions, which are the following (Figure 5) [1]:

- Month or year – Number of produced pieces;
- Month or year – Time schedule;
- Month or year – Number of reworked pieces;
- Month or year - Number of scraps;
- Month or year – Production time;
- Month or year – Unplanned shut downs;
- Month or year– Total quantity;
- Month or year - OEE indicator diagram.

5. Defining Production Main Time

Possible main production operations are defined on the machine (drilling, milling) and their main machine time in general in relation to the technological parameters. Figure 6 shows the structure of norm time of total production series.

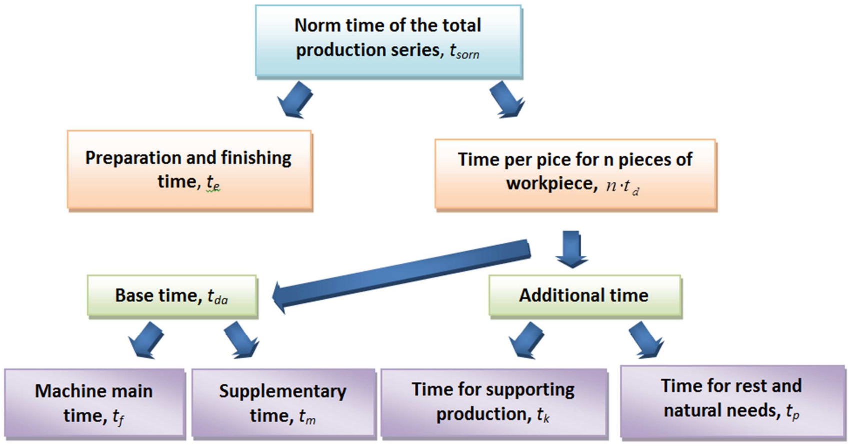

Figure 6. *The structure of norm time of the total production series.*

The most general equation for the time of producing one item [3, 7, 8, 9, 10, 11]:

$$t_d = t_f + t_m + t_k + t_p \tag{6}$$

Defining the duration of the operation elements [3, 7, 8, 9, 10, 11]:

$$t_{fg} = i_f \cdot \frac{L}{n \cdot f} = i_f \cdot \frac{L}{v_f} \tag{7}$$

5.1. Determination of the Machine Main Time in Case of Turning

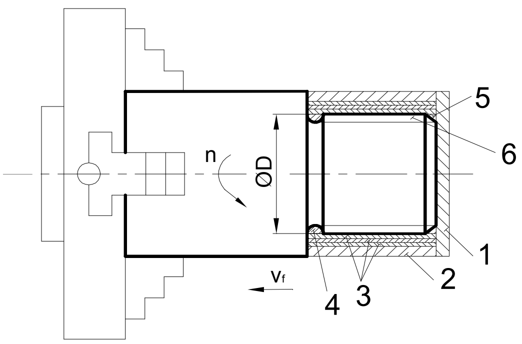

Figure 7. *Determination of the machine time in case of thread cutting.*

On Figure 7 a thread cutting manufacturing process could be seen. The numbers (1 -6) are nominated the manufacturing steps. The aim is the total machine time has to be calculated. The machine times of every manufacturing steps has to be added.

The total machine time is

$$t_{fg} = \frac{L_1}{n_1 \cdot f_1} + \frac{L_2}{n_2 \cdot f_2} + 3 \cdot \frac{L_3}{n_3 \cdot f_3} + \frac{L_4}{n_4 \cdot f_4} + \frac{L_5}{n_5 \cdot f_5} + 2 \cdot \frac{L_6}{n_6 \cdot f_6} \tag{8}$$

5.2. Calculation of the Machine Main Time for Drilling

Based on Figure 8, drilling length is:

$$L_f = L_r + L + L_t + \frac{d}{2 \cdot tg\kappa_r} \tag{9}$$

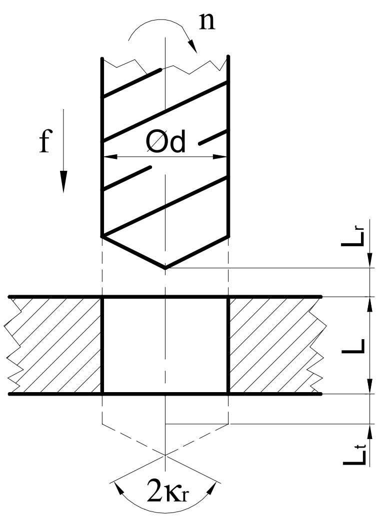

Figure 8. *Defining drilling length.*

Machine main time based on (7) and (9):

$$T_f = \frac{L_r + L + L_t + \dfrac{d}{2 \cdot tg\kappa_r}}{n \cdot f} \quad (10)$$

5.3. Calculation of Machine Main Time for the Technology of Plain Milling

Based on Figure 9, the length of milling is:

$$L_m = L_t + L + L_r \quad (11)$$

Based on (7) and (11) the machine main time is:

$$T_f = i_f \cdot \frac{L_m}{v_f} = i_f \cdot \frac{L_t + L + L_r}{n \cdot f} \quad (12)$$

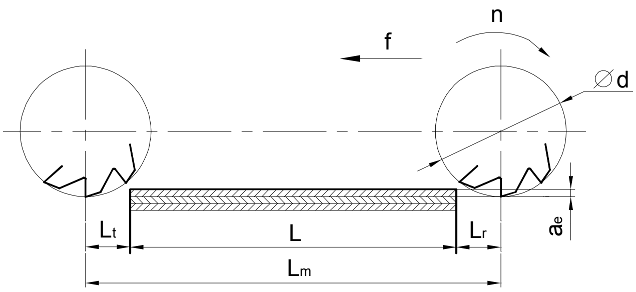

Figure 9. *Determining milling length for plain milling.*

5.4. Calculation of Machine Main Time for Face Milling

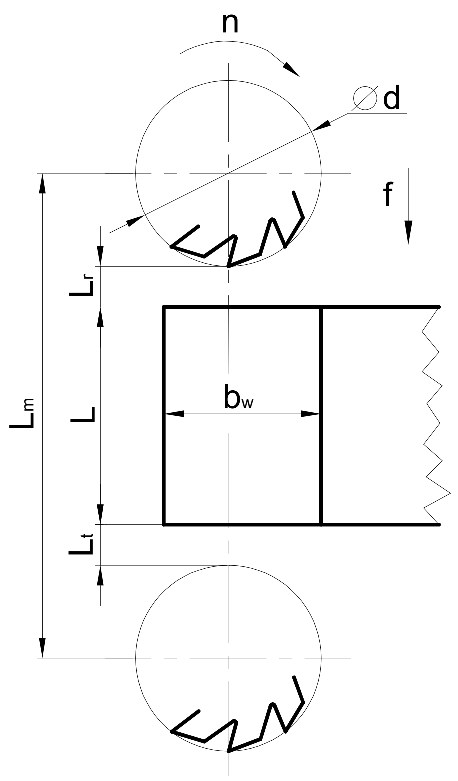

Figure 10. *Defining milling length for face milling.*

Based on Figure 9 the length of milling is:

$$L_m = L_t + L + L_r + d \quad (13)$$

Based on (7) and (13) the machine main time is:

$$T_f = i_f \cdot \frac{L_m}{v_f} = i_f \cdot \frac{L_t + L + L_r + d}{n \cdot f} \quad (14)$$

5.5. Calculation of Machine Main Time for Manufacturing Keyway

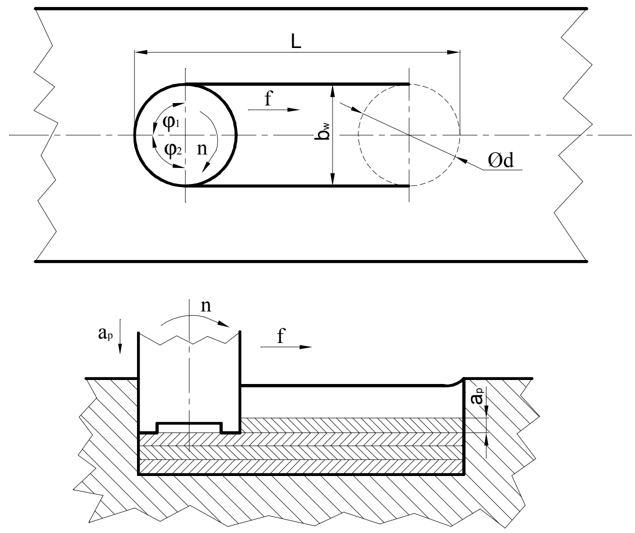

Figure 11. *Technological planning of keyway manufacturing.*

Figure 11 shows the technology of manufacturing a keyway. During manufacturing in case of every cut the tool goes into the depth of the keyway with a_p value (i.e. depth of cut), then the material is peeled along the length of the keyway. Because of these facts there are 2 components that make up the main time of the technology (the component towards the direction of the depth of the cut, the component towards the direction of feeding).

Based on (7) the main machine time for one cut is (Figure 11):

$$t_f = \frac{L - d}{f_z \cdot z \cdot n} + \frac{a_p}{f_z \cdot z \cdot n} \quad (15)$$

If i_f is the number of cuts then machine main time of milling of the total keyway is:

$$T_f = t_f \cdot i_f \quad (16)$$

5.6. The Reduction of the Machine Time

The are many methods of the reducing of the machine time. This time could be reduced by using of vintage tool, more favourable cooling and lubrication conditions or reduction of tool life.

High reduction of the machine time could be reached by the contraction of manufacturing steps (Figure 12 and 13).

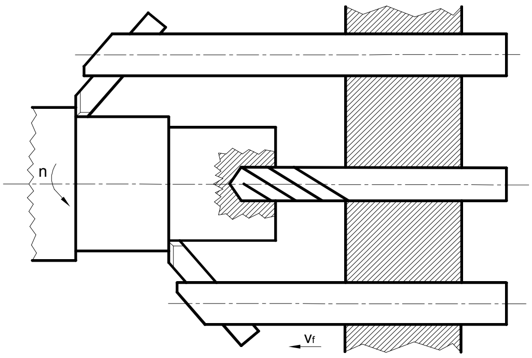

Figure 12. *Contraction of turning and drilling manufacturing steps.*

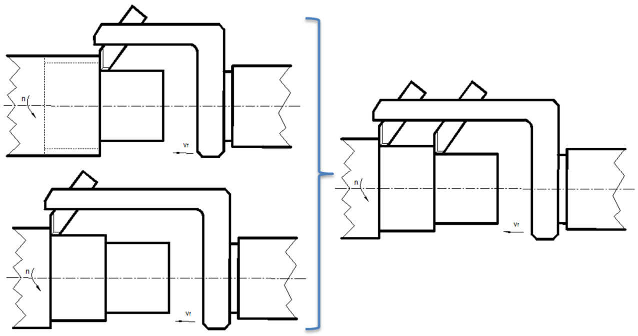

Figure 13. *Contraction of turning manufacturing steps.*

6. Conclusion

We have determined the OEE indicator values for MAKA type CNC driven milling machine having 5 axes found at Diehl Aircabin Hungary Ltd. for the period of 2015 and 2016.

The results have shown that the utilization of the machine is 47% in 2015. Although for making the calculation for 2016, we have got the result that 2 CNC milling machines will be needed for producing the planned number of products.

We have developed a computer program for the analysis and calculation of the OEE indicator. With the help of our computer program, OEE indicator values for any types of machine can be calculated easily and fast. It helps a lot in the activity of the company.

Machine main time for the main technological operations on the milling machine have been determined. During production to optimize the machine main times, you need to choose the right technological parameters (feeding, depth of cut, rotational speed etc.).

Due to these, you can have higher number of produced items during a given period. Based on machine main times, norm time of the total production series can be planned.

List of Signs

A		Availability indicator
P		Performance indicator
Q		Quality indicator
OEE		Overall Equipment Efficiency
t_{sorn}	[min]	norm time of the total production series
t_e	[min]	preparation and finishing time
t_{da}	[min]	base time
t_f	[min]	machine main time
t_m	[min]	supplementary time
t_k	[min]	time for supporting production
t_p	[min]	time for rest and natural needs
n	[1/min]	rotational speed
f	[mm]	feeding
f_z	[mm]	feeding for one edge
d	[mm]	diameter of the tool
L_r	[mm]	pre travel
L_t	[mm]	over travel
L	[mm]	length of the workpiece
L_m	[mm]	length of manufacturing
i_f	number of cut	
κ_r	[°]	tool cutting edge angle
b_w	[mm]	width of the workpiece
φ_1, φ_2	[°]	angles of wrap
a	[mm]	depth of cut
T_f	[min]	machine main time for the total manufacturing

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