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Optimization of Machine Cycle Time Using Data Analytics (Python Programming) & Quality Management

Ritesh Radhakrishnan[1], Adithya Venkatesh[2], Priyanka. B[3]

1(Department of Mechanical Engineering, Meenakshi Sundararajan Engineering College, Chennai
Email: ritesh.radhu2010@gmail.com)

2 (Department of Mechanical Engineering, Meenakshi Sundararajan Engineering College, Chennai
Email:adi97_blue@yahoo.com)

3 (Department of Mechanical Engineering, MeenakshiSundararajan Engineering College, Chennai
Email : priyankabala1999@gmail.com)

Abstract:

This paper is aimed at bringing industrial engineering concepts such as plant layouts and cycle time along with data science and analytics together. A sample layout for an imaginary product has been designed and a suitable code has been created to analyse the machines that cause more delay. By use of this code, we will be able to know about the error prone machine(s) and stock up the spare parts and also arrange our production schedule accordingly. Python programming language has been used along with Microsoft Excel to work upon the collected data. Suitable causes of error are predicted for this product and solutions have been provided to make manufacturing process smooth. Our aim is to provide a package which comprises of a code which people or firms facing similar issues can use.

Keywords — **Data Analytics, Python, Machine Cycle Time, Assembly Layout.**

I. INTRODUCTION

Machine layouts are something very common and those are optimised to avoid bottlenecks. In a complex assembly which has many parts and whose parts are already mini subassemblies, it is very difficult to determine the region of error. Every production line has a pre-set cycle time and if that cycle time is exceeded, accumulation of jobs occurs. Hence, it is necessary to find a mechanism to identify the error prone machines and also collect sample data for documentation purpose.

We intend to use data analytics and generate a code which will help in identifying the machine where the delay occurs. Also, by identifying the machines that cause delay, we would like to analyse the problems due to which this delay occurs and we intend to provide some mitigative measures which would help in preventing delays in the long run.Our aim is to provide a package which comprises of a code which people or firms facing similar issues can use.

II. LAYOUT DEFINITION

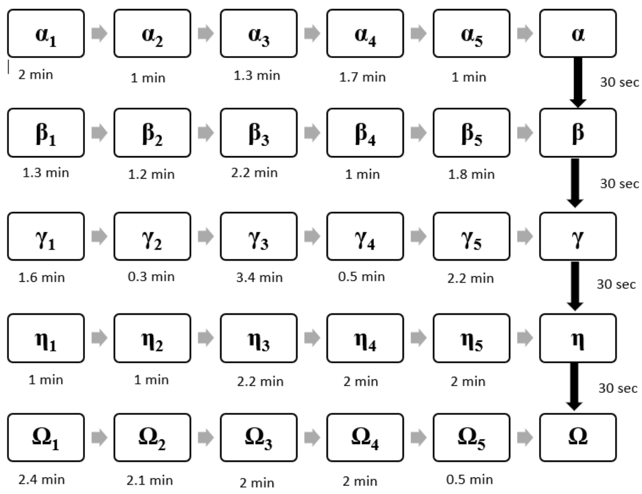

Fig. 1: Layout of the Machines

The imaginary component we have chosen has 5 parts and these 5 parts have 5 subparts each. The net cycle time of each product completely is 9 minutes. The 5 parts have been named Alpha, Beta, Gamma, Nu and Ohm and the respective 5 subparts have been named One, Two, Three, Four Five. For example, Alpha One, Alpha Two and so on.

The production of these parts take place simultaneously. Alpha gets completed in 7 minutes and takes 30 seconds to reach the Beta bay. By this time, Beta is designed to be completed and (Alpha + Beta) assembly is created. This (Alpha + Beta) assembly takes 30 seconds to reach Gamma bay which is designed to be completed by then and so on. Finally, at the end of 9 minutes, (Alpha + Beta + Gamma + Nu + Ohm) assembly will be done.

III. PROBLEM STATEMENT

In reality, the cycle time differs. The cycle time of most parts is greater than the pre-set time. The magnitude of deviation varies on the error prone machines and the causes in those machines as well.

IV. ASSUMPTIONS

There are a few assumptions made for this imaginary component.

1. The ideal cycle time per piece is set as 9 minutes (Pre-set Time).
2. There is no tolerance provided with respect to the ideal cycle time.
3. Irrespective of whether the cycle time matches with the pre-set time or not, the data gets stored.
4. The number of pieces produced per day is taken into account when viewed on a daily basis and if this package is used for a monthly basis, the data collected would be monthly data.
5. Ideal cycle time is the shortest cycle time.

V. WORKING

The program is coded that it accepts the allocated cycle times for each machine and the actual cycle time of each product as inputs and compares the data of 'n' number of products in each of the 5 assembly lines (Alpha, Beta, Gamma, Nu & Ohm) and their 5 subassembly lines.

If there is found to be any delay in the cycle times of the product, then the assembly line name and its subassembly will be displayed as output so that the machine that is causing the delay can be pinpointed and suitable measures for its optimization can be done.

I. CASE I: DELAY IN MACHINE BETA FOUR

If a delay is caused in the BETA FOUR machine, then the BETA bay gets delayed by the time of delay caused in BETA FOUR and thus, the subsequent bays also are delayed by the same time. Finally, this results in the overall delay of the assembly process.

Machine Name/ Machine Number	One	Two	Three	Four	Five	Main
Alpha	2	1	1.3	1.7	1	7
Beta	1.3	1.2	2.2	1	1.8	7.5
Gamma	1.6	0.3	3.4	0.5	2.2	8
Nu	1	1	2.5	2	2	8.5
Ohm	2.4	2.1	2	2	0.5	9

Fig. 2: Ideal Cycle Time of Machines

Machine Name/ Machine Number	One	Two	Three	Four	Five	Main
Alpha	2	1	1.3	1.7	1	7
Beta	1.3	1.2	2.2	1	1.8	7.5
Gamma	1.6	0.3	3.8	0.5	2.2	8.4
Nu	1	1	2.5	2	2	8.9
Ohm	2.4	2.1	2	2	0.5	9.4

Fig. 3: Case 1 – Delay in Beta Four Machine

```python
import pandas as pd
#to read the files and make the column without header as row names
#input is the input file
ip=pd.read_csv('main cycle.csv',index_col=0)
#test is the file we compare with
test=pd.read_csv('case1.csv',index_col=0)

#assign the column and row names
col_names = list(ip)
row_names=list(ip.index)

i=0;j=0
#traverse cell by cell and compare the values
#and print the corresponding row and column name
#wherever the values arent equal
while i<ip.shape[0]:
    j=0
    while j<ip.shape[1]:
        if(ip.iloc[i,j]!=test.iloc[i,j]):
            print(row_names[i],col_names[j])
        j=j+1
    i=i+1

```

Fig.4: Source Code for Case 1

```
Gamma Three
Gamma Main
Nu Main
Ohm Main
```

Fig. 5: Output for Case 1

As we can see from figures 1 and 2, the delay is caused in Gamma Three by 0.4 minutes and thus, the overall output is delayed by 0.4 minutes. This can be seen in the output (Fig. 4) indicating where the delay occurs and the which outputs are affected by the delay.

II. CASE II: IDEAL CASE (NO DELAYS)

If there is no delay in the machines, then the product coming out of each bay will have no delay and thus, the overall time taken for the assembly of the entire product will be the same as the allotted time. Thus, no delay occurs.

Machine Name/ Machine Number	One	Two	Three	Four	Five	Main
Alpha	2	1	1.3	1.7	1	7
Beta	1.3	1.2	2.2	1	1.8	7.5
Gamma	1.6	0.3	3.4	0.5	2.2	8
Nu	1	1	2.5	2	2	8.5
Ohm	2.4	2.1	2	2	0.5	9

Fig. 6: Ideal Cycle Times of Machines

Machine Name/ Machine Number	One	Two	Three	Four	Five	Main
Alpha	2	1	1.3	1.7	1	7
Beta	1.3	1.2	2.2	1	1.8	7.5
Gamma	1.6	0.3	3.4	0.5	2.2	8
Nu	1	1	2.5	2	2	8.5
Ohm	2.4	2.1	2	2	0.5	9

Fig. 7: Case 2 – No Delay in Machines

```python
import pandas as pd
#to read the files and make the column without header as row names
#input is the input file
ip=pd.read_csv('main cycle.csv',index_col=0)
#test is the file we compare with
test=pd.read_csv('case2.csv',index_col=0)

#assign the column and row names
col_names = list(ip)
row_names=list(ip.index)

i=0;j=0
#traverse cell by cell and compare the values
#and print the corresponding row and column name
#wherever the values arent equal
while i<ip.shape[0]:
    j=0
    while j<ip.shape[1]:
        if(ip.iloc[i,j]!=test.iloc[i,j]):
            print(row_names[i],col_names[j])
        j=j+1
    i=i+1

```

Fig. 8: Source Code for Case 2

Since there is no delay in any of the machines, the output will be blank. Only when there are any delays, the name of the bay and the number of the machine will be displayed.

VI. IDENTIFICATION OF POSSIBLE CAUSES OF DELAY IN MACHINING

The manufacturing process is a complex one that can be impacted by many factors like supplies, equipment, factory overhead, the people working at all points in the process etc.Delays occurs in the day to day process during manufacturing. But in process terms, delays are one of the biggest causes of ineffectiveness, inefficiencies, and poor performance.

One such problem is delay due to the plant layout. The combination layout is followed in our case, as the name suggests it is a combination of process layout and product layout. In process layout or functional layout all machines performing similar functions are grouped together. Alpha, Beta, Gamma, Nu & Ohm are manufactured by this method. The final assembly is then carried out in a product type layout, wherein all the machines are arranged in sequence and the product is assembled.

Another reason for time delay in manufacturing is the machining vibrations, also called chatter. It is the relative movement between the workpiece and the cutting tool which results in an uneven surface finish and reduced tool life. This is avoided by reducing the cutting velocity, thereby increasing machining time.

A common cause of delay in machining time is due to toolfailure. Variables like spindle speed, feed, coolant, depth of cut, work hardening affect the tool life. Tools fail due to various reasons like flank wear, crater wear, thermal cracking, deformation, chipping, mechanical breaking, built up edge etc. It is false economy to slow down a job to get more parts per tool.

Other factors affecting the machining time are delays in order processing, inefficient capacity management by suppliers, delays at the receiving port and much more.

VII. MITIGATION OF POSSIBLE CAUSES OF DELAY

There are various methods by which the delay in the machining process can be mitigated in order to improve the productivity of the manufacturing systems. Few of the recent trends that are followed to overcome the delay in machining have been summarised below.

Lean Six Sigma [1] is a tool that can reduce muda (waste) during the manufacturing process. Lean six sigma plays a major role in the reduction of non-value-added activities and delay in the manufacturing process that leads to the inefficiency. Lean Six Sigma is a combination of Lean which eliminates wastes and Six Sigma which reduces variation. The focus is to use the knowledge of the workers with the proper tools to design, improve, and control the key processes of the product manufactured. Lean approaches focus on reducing cost through process optimization. Six Sigma is about meeting customer requirements and stakeholder expectations, and improving quality by measuring and eliminating defects. The Lean Six Sigma approach draws on the philosophies, principles and tools of both.

Optimization of buffer storage [2]: A production line is a series of workstations that are linked together by the handling systems that transfer parts from one station to the other. Stochastic flow lines are typically subjected to disruptions due to the variations in the processing times and failure of the workstations. These disruptions cause the production line to be idle and result in decreased throughput. In order to reduce or eliminate the effect of these disruptions, buffers are placed in between the machines. The buffer storage enhances the throughput of the production line by reducing the blocking and starving time of the workstations, thereby improving the flow line efficiency. Increasing the size of the buffer space between machines results in increasing the throughput of a stochastic production line.

Various optimization algorithms [5] like genetic algorithms, particle swarm optimization (PSO), simulated annealing, ant colony optimization,conjugate gradient method, Broyden–Fletcher–Goldfarb–Shanno algorithm, Powell method, penalty function, augmented Lagrange multiplier method, sequential quadratic programming etc are applied in optimization of machining time. However, Differential evolution[3] method is well suited to solve chatter related problems as it is less time consuming, locally optimal and more robust than other conventional algorithms.

Quality management tools like Just in time, seven wastes, 5S, Kaizen, Kanban etc can also be implemented in plant layout optimization [4]. The plant design is often directly related with production control and product quality. Well-organized machine or department arrangements and suitable transportation paths create an efficient plant. Plant layout analysis generally incorporates a study of the production line process flow charts, material flow diagrams, product routings, processing times, development of from-to charts, relationship diagrams between different departments in the facility and the cost of material movement.

VIII. INFERENCE

The program is thus designed to compare the ideal cycle time and the given sample time of the assembly layout. The same program can be used for any type of product that is produced using this layout. Thus, this method is universal.

IX. RESULT

Optimization of machine cycle time using data analytics (python programming) and quality management package has been provided and has been done successfully. The code used can be altered according to the number of machines used.

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