CHAPTER II

THEORY AND LITERATURE SURVEYS

This chapter represents the theory background used to developing the improved system in Deflection Yoke Process. Not only the concerned theories are described, the related literatures that were researched by many authors have been summarized. Firstly, work measurement technique is studied so as to use to set standard time of DY process. The assembly line balancing techniques are studied, moreover, assembly line balancing steps are described so as to use to balance the new assembly lines effectively. Finally, classical types of layouts and approach to evaluate their effectiveness are studied so as to help to design and evaluate new proposed layouts. All details are explained as follows:

Work measurement and standard

Introduction

Work measurement is the application of technique to determine the standard time necessary for a qualified operator to perform a particular task. The standard time states the time a qualified operator, working at a normal rate of speed, is useful for several purposes.

- Establish work force and capacity requirement
- Determine the cost of production operations, provide the variance of the quotation and actual performance.
- Schedule production
- Monitor operator performance and provide an objective basis for motivating the workforce.

Work measurement techniques

There are four basic techniques for measuring work; (stopwatch) time study, element standard time data, predetermined motion time data, and work sampling. The choice of techniques depends on the level of detail desired and nature of the work itself. Because the nature of cycle time of each work element in DY process is likely to be short, the time study is considered to set DY standard time in this thesis. The method is explained in the following section

Time study method

Adam and Ebert (1995) stated that Time study is the development of a time standard by observing the task and analyzing it with the use of a stopwatch. The general approach can be explained as follows:

1. **Divide the work content into smaller work element.**

   Each work element should be defined to be short in during, but long enough so it can be timed with a stopwatch. There are some benefits for this practice as follow:

   - The list of elements and their time helps to describe the work method and show how the time for performing the task is distributed among the element.
   - Element can be collected and cataloged into standard data that can be used to apply to determine other standards of some jobs without the need for stopwatch time study
   - The performance can be rated independently on each element

- If the operator works with equipment that run independently, the actions of the operators and of the equipment should be separated into different elements.

- Time for similar work elements from several jobs may be compared to help keep standard uniform.

2. Measure the time needed to perform each element over a number of cycles.

In this step, the numbers of cycles (10- 15 cycles) are firstly timed and some preliminary calculations have been made to determine the total number of cycles should be timed. Such numbers of cycles are normally calculated based on the degree of accuracy desired for the standard and the variability of the observed time by using the formula,

$$N = (Zs / Ax)^2$$

Where

N	=	Total number of observations that should be taken to provide desired accuracy
x	=	Means of the time already collected
A	=	Accuracy desired expressed as decimal fraction of the true value
Z	=	Standardized normal deviate that has ½(1-confidence) as the area remaining in the tail of the distribution beyond the value of Z
s	=	Estimated standard deviation of distribution of element times, based on the observations already made

3. **Rate the performance of each work element.**

Because the objective of a time study is to arrive at a standard that is suitable for a normal employee, a performance rating must be included to adjust the observed time to the time require by someone working at "normal" pace (which is

considered as 100 percent). However, there is no universal criterion for what is normal, each company may need to have the own concept to rate their worker's performance. In general, a normal work pace should be one at which qualified workers can work all working days without undue fatigue.

4. **Use the performance rating to determine the normal element time.**

By using formula,

Normal time = Observed performance time/unit * performance rating

5. **Determine allowances for personal time, fatigue, and unavoidable delays.**

Finally, the time needs to include some allowances as follows

- Personal allowance such as time for going to restroom
- Fatigue allowance such as time needed for rest as a result of the physical activity of the job.
- Delay allowances incorporate only time for unavoidable delays, which occur on the job with no fault of the operator.

As same as the performance rating, the allowance may be determined by historical data of the company

6. **Determine the standard time.**

By using formula,

Standard time = Normal time + (Allowance * Normal time)

Where the allowances are expressed as a decimal fraction of a normal time

Assembly Line Balancing

Introduction

The general problems associated with assembly line balancing are to allocate work elements to work station in such a way to minimize the production cost of the product.

Elsayed & Thomas (1994) mentioned two main problems in assembly lines:

- Balancing the workstations
- Keeping the assembly line in continuous production

And also noted that Perfect Balance of the lines means to combine the work elements of work to be done in such a manner that at each workstation just equal the Cycle Time (C)

In single model assembly line, classified simple assembly-line balancing problems into two types:

Simple assembly line balancing Type I, whose objective is to determine the minimum number of workstations necessary to maintain the production rate (1/ Cycle Time) while observing the precedence constraints

Simple assembly line balancing Type II, whose objective is to assign tasks to a fixed number of workstations to maximize the production rate while observing the precedence constraints

In mixed model assembly line balancing problem, the same objective is also applicable. It is evident from the literature review that the most proposed assembly - line balancing models are designed to solved the problem type I i.e. to find the of work station nearly minimum. It is also suitable to apply them to problem type II by varying a given cycle time and searching for nearing minimum cycle time subject to a given number of workstation.

Terminology

1. **Assembled product**

   Assembled product is a product that passes through a sequence of workstations where tasks are performed on the product until it is completed at the final workstation. The throughput of the assembly line is measured by the numbers of assembled products per unit time.

2. **Work element**

   Work element is a part of the total work content in an assembly process. If n *represents* the total numbers of work elements required to completed the assembly, and i *represents* the work element number i in the process, noted that $1 \leq i \leq n$

3. **Workstation**

Workstation is a location on the assembly line where a work element or elements are performed on the product. The minimum numbers of workstation, Nt, is greater than or equal to 1.

4. **Cycle time**

The cycle time (C) is the time between the completions of two successive assemblies. The minimum value of cycle time must be greater than or equal to the longest station time.

5. **Station time**

Station time (St) is the sum of the time of work elements that are performed at the same workstation. The station time should not exceed the cycle time (C).

6. **Delay time of a station**

The delay time of a station (or idle time) is the different time between the cycle time and the station time. Much the delay (or idle) time implies unbalance assembly line and result in low line efficiency.

7. **Precedence diagram**

Precedence diagram is a diagram that described the ordering in which work elements should be performed. Because the diagram shows sequential relationship which some jobs that cannot be performed unless their predecessors are completed, then it is the useful diagram that helps to assign appropriate work element to the workstation and the layout of workstations along the assembly line also depends on the precedence diagram.

Assembly line balancing techniques

To make perfect line balance, there is a lot of research proposed assembly line balancing techniques through several decades and some effective guidance is to be followed.

Kilbridge & Wester (1961) proposed a procedure that firstly assigns the operations with the **lowest predecessor number of the workstations**. The step procedure is summarized as follows:

1. Construct the precedence diagram for the work elements and list them vertically in columns. The work elements that need not follows others are firstly listed in column I and the following elements are continuously listed in other columns in the same way.

2. Determine feasible cycle time and the permissible number of station that is

$$K = \sum Ti / CT$$

Where

K = Permissible number of station

$\sum Ti$ = The total elemental times

3. Assign work elements to the workstations in order of column number such that the sum of the elemental time does not exceed cycle time.

Helgeson & Birnie (1961) proposed the **"Rank Positional Weight"** method to solve the assembly line balancing problems. After developing the precedence network, the steps to balance line are as follows:

1. Determine the positional weight of each work element. A position weight of an operation corresponds to the time of the longest path from the beginning of the operation through the reminder of the diagram.

2. Rank the work elements based on the positional weight that the highest positional weight work element is ranked first.

3. Assign the work elements to the workstations, where elements of the highest positional weight are assigned first, as long as the operation does not violate the precedence constraints and the station time does not exceed the cycle time.

4. Repeat steps 2 and 3 until all elements are assigned to the workstations.

Moreover, because assembly line balances frequently result in unequal workstation time, there are other practical ways considered to solve assembly line balancing problems as follows:

- **Split the task** so that the complete units are processed in two workstations. It is normally used when task time of the workstation is more than cycle time.

- **Share the task.** The operator in the adjacent station will help to do some parts of the work. This differs from split the task because the adjacent station acts to assist, not to do some units containing the entire task.

- **Improve operation.** The task, especially exceeds the cycle time, will be analyzed to reduce non value added operation such as excessive movement, or inspection so that total task time will be reduced to meet cycle time successfully.

- **Use a more skilled worker** so that the task will be performed with the higher speed. This option may be used to apply with the task that exceeds cycle time, and require high skill.

- **Keep buffer inventory**

Steps Assembly-Line Balancing

Chase and Aquilano (1995) proposed assembly line balancing procedure. The steps can be summarized as follows:

1. Specify the sequential relationship among tasks using precedence diagram.

2. Determine the required cycle time (C),

   Using the formula,

   $$C = \frac{\text{Production time per day}}{\text{Required output per day (in units)}}$$

3. Determine the theoretical minimum number of workstations (Nt) required to satisfy the cycle time constraint.

   Using the formula,

   $$Nt = \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}}$$

4. Select a primary rule by which tasks are to be assigned to workstations, and a secondary rule to break ties.

5. Assign tasks to the first workstation until the sum of the task times is equal to the cycle time, or no other tasks are feasible because of time or sequence restrictions. Repeat the process until all tasks are assigned.

6. Evaluate the line efficiency.

Using the formula,

$$\text{Line efficiency} = 1 - \frac{\text{Total idle time}}{\text{Total No. of workstation * cycle time}}$$

7. If efficiency is unsatisfactory, rebalance using a different decision rule.

Facility Layout

Classical types of layouts

Most plants are laid out using a combination of three classical types of layouts as follows:

1. Product layout

In this type of layout, only one product, or one type of product is produced in a given area. The product must be standardized and manufactured in large quantities in order to justify the product layout. The raw material arrives at one end of the line and goes from one operation to the next operation quite rapidly, with a minimum of work-in-process storage and material handling.

This type of layout is the most productive in term of man-hours invested per product; for mass production.

The relative advantage of product layout

1. Lower total materials handling cost.
2. Lower total production time
3. Less work-in-process
4. Greater simplicity of production control.

The suitable condition to use product layout

1. One or few standard products
2. Large volume of production of each product over a considerable period of time
3. Mostly use the same machine or work station for one operation (minimum number of setups required)
4. Possibility of good labor and equipment balance.
5. Minimum of inspection required during sequence of operations.

2. Process layout (or functional layout)

In this type of layout, all operations of the same type are grouped together in a department. For example, h-coil winding is done in the h-coil winding section, V-coil winding is done in the V-coil winding section, and assembly operation is done assembly area. Similar equipment and similar operations are grouped together in the process layout. This type of layout is particular useful where low volume is required and more desirable if the product is not standardized because it has greater flexibility than product layout.

The relative advantage of process layout

1. Greater flexibility of production.
2. Better and more efficient supervision possible through specialization
3. Less duplication of equipment, hence lower total investment in equipment
4. Easier to handle breakdowns of equipment by transferring work to another machine or station.

The suitable condition to use process layout

1. Many types of products, or emphasis on special orders.
2. Relatively low volume of production on individual items (but the total production may be high)
3. Difficult to achieve good labor and equipment balance.
4. Many inspections required during a sequence of operations.
5. Frequent necessary to use same machine or work station for two or more different operations.

3. Fixed-position layout

In this type of layout, the material or major component remains in a fixed location, and tools, machinery, and men as well as other pieces of material are brought to this location. In the present day, because the machinery has grown in size and complexity, it is easier to move the materials to the various pieces of equipment than to move the equipment. Then, the fixed-position layout is rarely found in today's manufacturing processes. The good example of the fixed-position layout is aerospace industry.

In practical, a good layout should optimize the chosen criteria in any given situation to achieve the best satisfies management objective. Then, it may need combination of three classical types of layouts

Objective of layout design

In general, an optimum plant layout provides minimum satisfaction to all party concerned; the employees, management, as well as the stakeholders. The major objectives of a good plant layout are as follows:

1. Provide overall simplification
2. Minimize cost of material handling
3. Provide effective space utilization
4. Avoid unnecessary capital investment
5. Stimulate effective labor utilization
6. Provide work-in-process turnover
7. Provide worker convenience, job satisfaction, and safety.

Evaluation of layouts

Moore (1962) proposed many systematically evaluated layout solutions as follows:

1. Cost comparison

Cost comparison is a quantitative approach to evaluate the alternative layouts. The solution is done by establishing the total factory cost of a product and the added investment and then compare the cost between the alternatives. In detail, factory cost includes materials and labor, as well as general cost such as floor space, power, fuel, and taxes. And investment cost includes the initial cost of the new equipment and also accessory cost such as jigs and fixtures, handling equipment, and installation.

2. Productivity evaluation

Productivity evaluation is another one of the quantitative approaches used to measure the effectiveness of alternative layouts. The productivity comparison may be measured in term of the man-hours required on a given quantity of the product or the products generated on a given manpower. Material handling distance may be calculated in this section to find the man-hours saving between the alternatives.

3. Space utilization

Space utilization approach is used to evaluate how effectively a layout space is allocated. The quantitative comparison most frequently used is the area saving between the alternatives. Space saving benefits not only more area available, but also utility cost reduction. Nevertheless, only space criterion may not be adequate if other factor such as ceiling clearance is also the constraint.

4. Factor analysis

In many cases, the plant layout, which is designed to achieve the objective, cannot be measured the effectiveness by using only quantitative approach. For example, one layout is designed to meet a set of objectives " to minimize material handling, high flexibility, and safety". Obviously, the first objective can be measured the effectiveness of the design on the quantitative scale, whereas the rest, which are the intangible objectives, seem to be difficult to be measured in the same way. The factor analysis is then established to measure the effectiveness of the plant layout in qualitative term. This approach is used when qualitative objectives are involved than when only quantitative objectives are required.

This technique is a rating procedure with the various factors weighted according to their importance. In practical, these qualitative factors can be weighed by asking the board of director to ensure that they are best fit for the company's objective and direction. After all factors are weighed, the alternative layouts are evaluated by rating their effectiveness factor by factor. The rating is classified as A, E, I, O, U which values are 4, 3, 2, 1, 0 respectively. The rating values are multiplied by the factor weight and then repeat the process until all factors of all alternatives are rated and multiplied. Finally, all rating values of each alternative are totaled, the alternative with the highest totals is the best.

Literature surveys

Assembly Line Balancing

Hossain (1995) developed a method to redesign the mixed model assembly line for a motor cycle manufacturer by using the expected time concept so that single model line balancing techniques are applied to mixed model assembly line. To analyze, redesign, and evaluate performance measures, the COMSOAL (Computer Method of sequencing Operation for Assembly Lines) algorithm was applied to find the better solution. From this research study, it can be concluded that the expected time concept can be used in mixed model assembly line balancing, however, the solution is still needed investigation the positional constraint and other relevant factors in order to get the optimal one.

Given N models products, each with its own precedence constraints, assign the work elements to work stations so that

1. Each work element is assigned to exactly one workstation.
2. The number of stations is the same for all products.
3. The precedence constraints are satisfied.
4. The work content of any station does not exceed the available shift time i.e.,

$$\sum_{i=1}^{N} ni*Ski \leq \text{Available shift time} \qquad ; k = 1,2,\ldots, K$$

Where

Ski = Work content of station k for product i

K = No. of stations in line

ni = No. of units of product i

Total idle time $$I = \sum_{k=1}^{K} (\text{ available shift time} - \sum_{i=1}^{N} ni*Ski)$$

For fixed shift time, minimizing idle time is equivalent to minimizing the number of stations.

Minimum number of work stations (K)

$$K = (\sum_{i=1}^{N} \sum_{j=1}^{Ji} ni*Pij) / \text{Available shift time}$$

Where

Pij = Processing time of work element j for product i

K = No. of tasks in product I

Duong (1998) applied Tabu search algorithm, a heuristic method for solving combinatorial optimization problems, to two types of assembly line balancing problems for a motorcycle assembly plant. Solution methodologies have been developed and evaluated the results with the existing models.

Aruntheerapoj (1999) developed the new process design and inventory for a plastic part manufacturing plant by applying the methodology of Demand flow technology, developed from Just-In-Time technique. The study included designs the new process, workstation and resources. For inventory management, Kanban system is also applied to manage appropriate inventory. Under the assumption that the production operator have the standard workmanship skill and can perform multiple task, it can be concluded that new designed process can reduce non value added movement, labor cost, and also production lead-time.

Facility Layout

Huynh (1995) developed the alternative layouts to improve production capacity of the Battery plant in Vietnam. To achieve the optimal layout, the computer package program called FACTORY and simulation package called SIMPLE++ will be used to analyze, improve and evaluate the generated layouts base on the criteria; minimizing material handling cost, minimizing total distance travel, and providing a smooth flow of materials.

Indraningrum (1997) proposed the improved layout based on multi objective optimization. LINGO package software is used to find out the optimum solution. The comparison of the existing layout and the proposed layout shows the latter is better in term of improving the distance traveled.

Aruntheerapoj (1999) also generated the alternative process layouts, evaluated the results based on the qualitative criteria, and proposed the highest weight alternative as the optimal one.