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Quality improvement in robotic work cells by the application of the theory of constraints

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ABSTRACT

Quality refers to an equilibrium level of functionality possessed by a product or service based on the producers capability and customers need. The aim of any manufacturing concern is to increase the production and to bring down the production cost without compromising on quality. This can be achieved through the implementation of innovative managerial techniques. Theory of constraints is an innovative tool for quality and productivity improvement. A significant challenge in implementing the theory of constraints in robotic operation is the complex and re-entrant nature of the manufacturing process. This paper deals with the problem of improving quality in robotic work cells that repetitively handle several products of similar characteristics. The theory of constraint is proposed to increase the quality and throughput rate of a robotic work cell by identifying its bottlenecks

Introduction

A highly automated work cell can implement with a robot and its associated equipments were quality control is a constraint for operation. A major application of industrial robot in a robotic work cell [7] is to feed the right quantity of material at right time to the appropriate machine. A robotic work cell is expensive and requires huge investments. High quality based production is essential in order to make a robot workcell profitable.

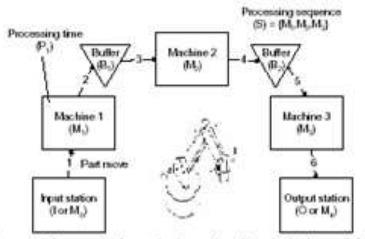

Figure 1 Layout of a robot workcell consisting of 3 machines and 2 buffers

The productivity and quality achievement is normally attained by minimizing the production cycle time CT and increase the throughput rate TR. CT and TR are affected by several factors including the schedule of the operations of the workcell, the use of buffers, the performance of the robot and its motions, number of robot tasks, the number of machines in the workcell, the layout of the workcell, failure rate, quality standards, processing time[14] in the machine etc. A model workcell is designed and tested by heuristic procedures [8] for several intractable part sequencing problems that occur in scheduling of robot work cells. he research on the subject generally focuses on one or a few of the factors that have an impact on CT and TR. Also the researchers have chosen to approach the problem in a very complex way by using simulations tools or mathematical models. But, by the application of simple tools the experienced operators in the industry can easily evaluate and improve the performance of the robot work cells from a holistic view. Because of the practical experience and the application of modern tools, the person who is controlling the shop floor operation can deliver a better result than an external quantitative approach of the organization. These tools not only provide information about the scheduling of operations but also explain how different changes will affect the workcell. This paper presents a simple and general method of workcell analysis by the theory of constraints (TOC) [9]. The cycle time reduction and throughput rate maximization without compromising on quality is done by the consideration of all the factors described above except the impact of failure rate.

The Robotic Workcell

Workcell Description

The work cell analysis (WCA) considers robotic work cells - figure 1 composed of m machines M1, M2, Mm, an input station I or M0, and an output station O or M4 , where identical parts are repetitively processed. A single robot R of E2S85IS SCARA,[5]"pick n place" unit carries out the transportation of the parts between machines, buffers and input/output stations. Each part must visit all machines successively in the same processing sequence S. Each machine can only process one part at a time.

A machine is defined as a place where a part changes state in some way, for example when the part is machined, inspected or orientated. Every part that is loaded in a machine requires a processing time P1, P2,…, Pm, before it can be unloaded from the machine and transferred in the work cell. The quality control operation is doing in the end of each operation. In some cases, the robot uses b buffers B1, B2…Bb within the workcell to store parts in order to maximize the utilization of the machines.

A buffer is defined as a position within the workcell where parts are placed when they are not being moved or processed.

The input and output station where the parts enter and exit the workcell are considered to have infinite capacity, which means that they do not constrain the workcell.

Furthermore, the influence on TR from failure rate has not been considered. The operation of the work cell will continue without any disturbance.

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Robot activities

The entire operation of the work cell is controlled with the help of a robot[11]. The central element of the work cell is the robot since it is responsible for the part flow through the cell. When the workcell is operational, the robot can be either active or inactive. Most of the time when the robot is active it is performing part transfers PMi. A part move is conducted in five steps: the robot reaches, grips, moves, and releases and moves away from a part. Mean time the quality checking is also going on. Furthermore, based on the part's destination, there are three types of part moves. A part can be moved to a machine, to a buffer, or to an output station.

The robot is inactive during two types of situations. The first is when the robot is idle and waiting for something to do. The second is when the robot is inactive due to a particular reason. The period of time when a robot is inactive for a reason is called a robot wait *RW*.

A robot's total movements can in simple terms be described as a series of part moves and periods of robot waits. A possible task sequence in figure 1 is ST={PM_0, PM_1, B_1, PM_2, B_2, PM_3, PM_4}. Here the inspection time is included along with the quality checking.

Performance improvement method

There are two aspects that are fundamental to WCA and distinguish it from other approaches. WCA assumes that there exists a constraint of some kind within the robot workcell that has a major impact on *CT* and *TR*. Second, WCA considers that focus on the constraint will give the best result when improving the performance in the workcell. This means that the Theory of Constraints (TOC) is a viable **way** to reduce *CT* and increase *TR* and improve the quality factors.

Theory of constraints

The theory of constraints[8] was developed in 1980 by Goldratt as a process of ongoing improvement mainly in throughput improvement and quality control.. TOC researchers have focused on production planning and performance measurement. To a large degree, the constraint/non-constraint distinction is almost totally ignored by most managerial techniques and practices. The TOC's "five steps of focusing"[9] are conducted in the following way.

- Identify the system's constraint.
- Decide how to exploit constraints.
- Subordinate everything else.
- Elevate the system's constraint.
- When a constraint is broken go back to step one.

Steps in workcell analysis

Workcell Analysis is a result of applying the TOC to the robot work cell's quality problem.

Step 1: Work cells bottlenecks identification

Considering the components described in section 2.1, two types of bottlenecks[14] within a robot workcell can be found: *robot or machine*. This means that *R, M1,…, Mm* are possible bottlenecks for a studied workcell. As mentioned earlier, the input (*I*) and output stations *(O*) are considered to have infinite capacity, and are therefore not included as possible bottlenecks. However, if this should not be the case in reality and a studied workcell is constrained by the quality of material supply at *I*, starved or *O*, stocked the reason for this can usually be found outside the work cell. There are several rules of thumb that can be followed when performing the first step of WCA. A bottleneck will be active to a high degree, while a non-bottleneck has a lot of idle time. The machine with the longest processing time should also be carefully observed. Sometimes it is very difficult to tell what is constraining for quality problem. In such a case the workcell must be thoroughly studied through time measurements and robot task mapping. Theoretically, if the robot is the work cell's bottleneck, the robot will not have any idle time and C_T is equal to the sum of the times the robot takes to perform all of its tasks. If the machine M_X is the work cell's bottleneck, C_T is equal to the processing time P_X in the machine M_X added to the time the robot spends on unloading and reloading a new part in M_X.

Step 2: Bottleneck minimization

In many cases a bottleneck performs [10] tasks that are unnecessary or would be easy to eliminate. In order to utilize a bottleneck as effectively as possible, its quality checking workload must therefore be analysed and if possible minimized [1]. The workload of a robot and a machine are distinct from each other and must be deal with in the two separate ways described bellow.

To minimize a bottleneck robot's workload

The robot's workload can be described as a series of part moves and periods of robot waits. This leads to two possible ways to minimize the robot's workload when the robot constrains the workcell:

- Reduction of robot wait and minimum time for inspection.

As part of reduce the robot waits [3] it can be reduced as far as possible in the case of a robot has to wait for a particular machine to complete its work; the robot wait can most often be reduced if that particular machine is placed later on in the robot's task sequence. Another case is that the robot does not have to grasp the part after the operation. However, options that allow the robot to release the part and do other work should be considered if the robot has to stay inactive a longer time.

- Elimination of part moves due to quality complaints.

Two types of part moves can be eliminated: to buffers or to machines. Changing to a task sequence that allows the robot to move a part directly to a machine can easily eliminate a part move to a buffer. In many cases buffers are used to increase the utilization of a machine. However, when the robot is the work cell's bottleneck, buffers will only increase the workload of the robot and have a negative effect on the throughput rate, and should therefore be avoided. Part moves to machines are more difficult to eliminate and in practice mean that the number of machines in the workcell has to be reduced. Three possible alternatives for this exist. A machine can be moved outside the workcell. Two machines can be integrated to one and two checking can do in a simple operation. A machine can be integrated to the input or output station. These options may seem radical, but simple machines that perform simple operations are often placed in robot work cells. Such machines can often be moved, changed or reconfigured with minor efforts and the elimination of idle time of the machine, Reduction of time to load and unload the machine etc can be reduced.

Step 3: Elevate the bottleneck's performance

When a bottleneck has a minimal workload, CT can only be reduced by improvement of the performance of the bottleneck itself. There are two alternatives for this step of WCA depending on the type of bottleneck:

- Improvement of the robot's performance in inspection Optimum picks n place and inspection of bottles.
- Reduction of the processing time Px for checking,

When machine Mx is the bottleneck, the reduction of the processing time to be reduced as far as possible.

Case study and results

An experiment has conducted in a M/s ABC Glass bottle manufacturing plant. The robot E2S85IS is used for the operation .The inspection, sorting and packing has done with the robot. The TOC is applied in the pick and place operation for inspection and packing .

Robotic Operation in workcell :

The sequence of operation is as follows:

Bottle Catching → Lifting → Weight Detection → Profile Inspection → Bottle Accept / Reject → Movement → bottle release → Arm Lifting → Return to Home Position

The bottle is reaching into the bottle trap by poission distribution. After four bottles assembled in the bottle trap the robot will start the inspection and packing operation.

The robot operation steps with TOC application are as follows:

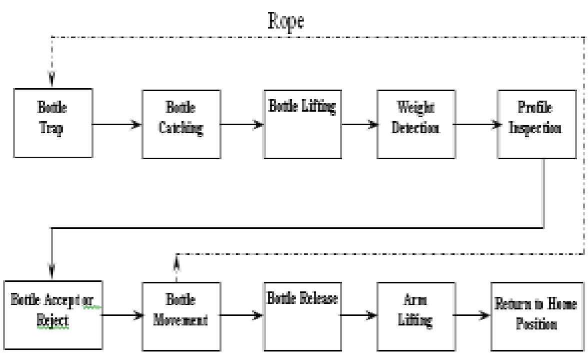

Figure 2 – The robot operation steps with TOC

In the above operation the constraints can be analysed and solved by continuous titrations.

Constraint analysis

The major three constraints are identified :

Constraint – 1 : Weight Detection and Profile Inspection .

Constraint – 2 : Through put improvement – (xo,yo) to (x1,y1) operation.

Constraint – 3 : Optimum Speed Setting and movement for the robot link

The above constraint analysis has done and the following results were obtained.

a. Weight detection and profile inspection.

Weight detection (milligrams) and profile inspection (millimetre) can be achieved with an error free operation and through fast checking.

b. Throughput improvement

It is the number of parts inspected and packed by the robot within a given period of time. By the reduction of cycle time, the throughput of the work cell is increased by 37.65 % without any quality loss.

c. Cycle time reduction

By the application of theory of constraints the cycle time is reduced by 26.08%.It an improvement without compromising on quality.

Conclusion

This paper has proposed an innovative tool for the quality and productivity improvement in robotic workcell. Contrary to the existing approaches, the analysis solves the problem of how to reduce CT and increase TR in a very simple and holistic way, considering the quality factors that affect the productivity of the workcell simultaneously analysed. In practice TOC is an effective and easy tool to use for evaluation and improvement of productivity for robot work cells. It is easy to understand and gives the user guidance in what to focus on in a robot workcell.

The investigation also showed that the possibilities for productivity improvement using TOC tend to increase when:

- The processing times in the machines are short or have been reduced by the fixation of with out compromising on quality standards.
- A work cell has been changed or redesigned by the implementation of new micro quality control equipment and sensors connected in the robot gripper.

There are several aspects that make it necessary to analyse and reconfigure a robot workcell in its lifetime. The design of a robot workcell and the programming of how the robot should interact with the rest of the equipment in the workcell are often done in an ad-hoc manner in the industry.

Also, different types of changes, such as re-design of products or new machines, are also often introduced in robot work cells. TOC can be used as a viable tool to use for productivity and quality improvement in industries.

References

JOHN S. OAKLAND, A.S SOTAL, “Total Quality Management with cases”, Pacific, Rim Edition, 2008.

D.H. STAMATIS – “TQM Engineering Hand Book”, McGraw Hill, 2004 DE SOUZAM GLENN, “New Business must Manage Quality”, Journal of Business Strategy, May-June, 1999 : 21-25.

J.S.OKLAND1998 ,Quality assurance, Control and Implementation: Hand book of Management, Butterworth - Heinemann,Oxford

FIEGENBAUM ,ARMAND.V ,1996 ,Total Quality Control Mc Graw Hill, NewYork

MIKELL P GROOVER, “Industrial Robotics” ,Mc Graw –Hill Inc.Edn. 2008.

DALE .H. BESTERFIELD, “TQM – 2nd Edition”, Prentice Hall Inc., 1999.

E. GOLDRATT, “Theory of constraints”, North River Press, Inc., 1990.

E.GOLDRATT,”Optimized production time tables: A revolutionary programme for industry” EPICS conference, Los Angeles,1990, pp172-176.

STEPHEN TANGENT, “Robot work cell analysis with theory of constraints-a simple method of productivity improvement in robot work cells” International Symposium on robotics Sweeden 2006.

F.S. CHENG “A methodology for developing robotic workcell simulation models”, Proceedings of the 2004 Winter Simulation Conference, pp.1265- 1271, 2000.

DEWITT.F,1990 “Techniques for measuring management Productivity” Management Review ,59.2-11

Endosomwan, 1998, Prtoductivity and Quality improvements, IFS publication , England.

Kendrick, 1994,”Improving company Productivity: Hand book with case studies,John Hopkins University, Maryland

Boby .K George and Shouri P V. “Maintenance Optimization in Manufacturing System”. International Journal of Production Technology & Management” (IJPTM) . – International Journal of Production Technology and Management. (Aug 2010) Volume 1. pp. 45 - 55