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Production Effectiveness-based System Reliability Calculation of Serial Manufacturing with Checking Machine

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Abstract. The discrepancy between input and output in a typical serial manufacturing system is always exists, due to workstation reliability and stochastic factors. The novel system reliability concept that takes customer needs into account has been redefined. On the basis of description of serial manufacturing system with checking machine (SMSCM), system reliability evaluation method has been put forward based on production effectiveness. The proposed method framework applying to a cylinder production line case has been proved to be efficient and effective to the system reliability problem of serial manufacturing system under OTD lot production. The interactive relationship between system reliability and time unit or order lot-sizing is remarked as well, which provide some guidance.

Keywords: efficient rate of production, equivalent workstation, production effectiveness, serial manufacturing system with checking machine, system reliability,

1 Introduction

With improvement of productivity, multi-kinds with small lot-size production mode based on orders pulling has played an increasing role in manufacturing industry. The specific production mode is called order-to-delivery (OTD) system, which would be widely used in manufacturing industry in China. OTD manufacturing system requires the more accurate delivery date, higher quality product, more attention on the customer and its order etc. The discrepancy between input and output of manufacturing system is always exists for degradation of machines and stochastic elements occurred which absolutely cause defective [1]. The issue to recognize input and capability of production line to meet the order requirement is of great significance. As a crucial measured index of manufacturing performance, system reliability has been considered to determine the minimum input of raw material or work in process (WIP) for the specific orders' accomplishment. Conventional system reliability is a probability that denotes the ability that a system performs its demanded function under service conditions during a required period of specific mission time.

To evaluate system reliability considering comprehensive factors is of great significance, which could assist managers to determine the necessary input of production system. Reliability evaluation of component or workstation and systematic integration are the main points in system reliability evaluation [2]. In order to evaluate performance of the manufacturing system, reliability modeling and performance analysis of manufacturing system are crucial problems that should be resolved. Many authors have researched system reliability for past decades. The system structure format has an important influence on system reliability, such as serial, parallel, serial-parallel, which results in different formula when make integration on system reliability [3]. To the best of our knowledge, many techniques are triumphantly utilized

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for description and reliability integration of the complex systems, like fault tree analysis (FTA), reliability diagram block (RBD), petri net description, GO flow model, and Markov chain etc [2, 4-7]. Recently a novel stochastic-flow net theory has been applied into system reliability evaluation for stochastic factors during manufacturing processes [8]. While all of these research is focused on description and calculation of complex system itself, but not customers' order oriented, and quality of WIP.

System reliability analysis and modeling have proven to be a complex work, and many researchers contribute the system reliability measurement issue. Shu [9, 10] has evaluated availability and reliability indexes by applying Markov chain to describe the repaired manufacturing system with buffer. And stable probability has been calculated based on formulation of chart and equation of state transformation in multi-state, which focused on the relationship between buffer and workstation. Savsar [11] analyzed system reliability on the basis of manufacturing unit modeling, and made a conclusion that performance of workstation has a deep influence on system output. Jin and Chen [12] thought that the workstation performance had an interaction with product quality, who built a comprehensive evaluation model by making integration of reliability model and product quality. After that, Chen and Jin [13] resolved system reliability that produced qualified product under no failures considering relationship between workstations with manufacturing process flow, and reliability chain model was proposed based on QR-Co-Effect description. Meerkov [14] recognized serial manufacturing system as Bernoulli production line and make conclusions that system efficiency appears a monotone increasing when machine reliability improves with bottleneck analysis. Chiang [15] has researched productivity of serial manufacturing system with buffer and checking machine, which illustrated the application area of Markov reliability model and Bernoulli model.

Even if Lin and Shu [8-9] give a practical evaluation on manufacturing system, other factors like product quality is not considered comprehensively. While Chen et al. have an opposite value due to its comprehensive research and less practical application in production for its micro-view. The system reliability analysis for the specific order is not only to be affected by machine's performance and system structure, but also influenced by other stochastic factors. So a comprehensive practical method needs to be put forward for reliability analysis of OTD system.

As the customer requirement and order quantity are crucial terms under OTD environment, system reliability analysis considering orders' situation is inevitable. Lin and Chiang proposed a new concept of reliability for manufacturing system from the standpoint of orders and customers, who recognized probability that the manufacturing system satisfies a specified level of order as the system reliability, which absolutely provided guidance for our research [16]. He has researched different systems based on workstation modeling and stochastic flow theory, while fails to consider WIP quality affected by stochastic elements during processing flow. Thus a novel system reliability concept considering WIP quality, workstation reliability and customer needs have been defined. It denotes the probability that a manufacturing system accomplishes specific order considering comprehensive factors under OTD environment.

This paper described the serial manufacturing system with checking machines (SMSCM) production line by considering product quality and reliability of workstations represented by qualified rate and efficiency. System reliability evaluation method has been put forward based on production effectiveness. The contributions of this paper are illustrated as follows: To the best of our knowledge, this paper puts forward the concept of production effectiveness for the first time, which represented by equivalent workstation considering combination of WIP quality characterized by virtual checking machine and workstation reliability. The novel definition of manufacturing system reliability has been successfully applied to this research to reflect the relationship between reliability and order quantity, processing cycle time of a part etc. Manufacturing system reliability evaluation calculation proposed in this paper from two dimensions considering product quality and order quantity is a kind of absolute reliability which reflects directly customers' requirement.

After abovementioned presentation of references reviews, this paper is organized as follows. In section 2, SMSCM conceptual model with equivalent workstation and some rational assumption has been formulated. Research framework based on production effectiveness with effective productivity calculation has devised in section 3. A Cylinder production line example is given to illustrate proposed method in section 4. We close the paper with certain conclusions and remarks on the issue of system reliability based on production effectiveness, some future studies need to be researched in depth is proposed as well.

2 Description of SMSCM and assumptions

Manufacturing systems usually have four kinds of structural model, namely serial, parallel, series-parallel and cycles that systems with rework actions [3, 17]. Those different structures can be modeled by production lines or networks analysis etc. This paper discusses the most common serial system structure, that is, SMSCM which is a representative structure to research the system reliability based on production effectiveness.

There are various of ingredients to affect the manufacturing systems' performance, such as technological level, buffer capacity, the workstation lifespan, check machine reliability and other stochastic disturbance etc. However, most of previous studies focused on reliability and performance of workstations or machines, with ignorance of other stochastic factor or the other representative index. Shu [9] has researched the system relaibility by taking buffer's state into account, and has succeedly proposed the equivalent workstation considering the relationship of states between machine and buffers, which provided guidance for comprehensive consideration of this paper. The equivalent workstation with checking machine has been put forward and studied for serial manufacturing system based on the previous research.

In order to know more about the effectiveness of each operation with qualification rate g_i , supposed there is a virtual checking machine S_i represented by rectangle after a workstation M_i represented by circle. In practice, not all production process contains a checking test after manufacturing operation. If there is no checking operation in real manufacturing, the value of g_i can be recognized as 1, which means all of the work-in-process (WIP) are qualified and the checking machine is virtual. Manufacturing procedure of SMSCM is constructed by serially various kinds of units illustrated by Fig.1a, which depicted as Fig.2 manifests. The every unit of procedure including workstation and checking machine can be recognized as an equivalent workstation illustrated by Fig.1b.

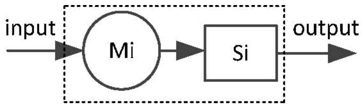

Fig. 1a. Unit of SMSCM

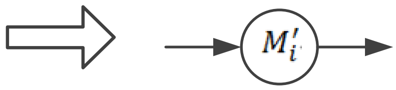

Fig. 1b. Equivalent workstation/unit

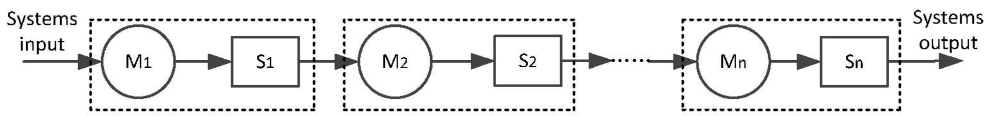

Fig. 2. SMSCM with n working procedure

The state of the workstation is usually recognized to be a binary variable, namely functioning state and failure state. With similar to workstation, the state of checking machine is also a binary variable, namely good product state and defective product state. The state of checking machine is utilized to represent whether the product after this process is qualified. Qualified rate is an index for measuring product quality after workstation's operation, which is represented the probability of the WIP's good state disposed by the checking machine. Workstations can be usually recognized as Bernoulli machine when comes to their reliability model [3]. As structure model in above figures shows, the WIPs are checked by previous checking machine, which means the WIPs flowing into next unit are always good products.

Savsar, Meerkov and Zhang [11, 14] has studied system reliability by modeling serial production system with buffer and check machine, as well perfomance indexes have been analyzed. The basic assumption in SMSCM analysis is based on the previous researches.

There are some assumption should be taken into consideration for SMSCM as follows:

(1) The input of system (same with the input of workstation M_1) are always qualifications;

(2) All the checking machines, no matter virtual or practical are reliable with no failures, which means the checking procedures are effective all the time;

(3) There are no capacity constraints and limitations for checking machines, that is, the incoming WIP is always checked by the checking machine, which means there will be no defective products flow into

the next workstation.

Workstations are independent each other, and SMSCM has Markov characters for isolation of checking machine.

3 Reliability modeling and analysis of manufacturing system

3.1 Production effectiveness of procedure unit

As description of the serial manufacturing system abovementioned, which is constructed by a series of equivalent workstations including machine and virtual checking apparatus, modeling analysis and calculation for the reliability of serial manufacturing system have been implemented considering machine efficiency and WIP quality.

3.1.1 Efficiency evaluation of workstation

Workstation efficiency is determined by its working time or downtime, which is represented by reliability analysis. Reliability modeling of numerical control machines was researched mutually based on observed data [18], which laid solid foundation on the efficiency evaluation of workstation. In practice, several elements do impose influence on reliability of workstation, such as accuracy and quality of tools, fixing devices, operation loading, material quality and some stochastic disturbance. Sun, Xi, Du and Ju [19] has argued it is owed to three kinds of factors, that is, stochastic failure of workstation, quality of work-in-process, and degeneration of key components of the workstation.

Efficiency denotes the average performance of the workstation within the cycle time T and is represented as e_i. Efficiency of the workstation is reflected via average working time and failure time. Uptime and downtime are general variables in workstation reliability model, which is defined as a random variable whose probability distribution function (PDF) is estimated according to observed data. General reliability models for workstations have proven to be rational and authentic, that is, Exponential reliability model, Rayleigh reliability model, Weibull reliability model, and Gamma reliability model etc. [3]. Functioning time is the mean time between failures and represented as T_{up}. Failure time here is the time period represented as T_{down} that make machine functional after its breakdown related to closely with maintenance parameters. Both of T_{up} and T_{down} can be calculated by machine reliability model.

The main parameter of machine is failure rate λ and maintenance rate μ in reliability model. The probability distribution function of functioning time and failure time both can be recognized as exponential distribution as Equation (1-2) illustrated:

$$f_{t_{up}}(t) = \lambda e^{-\lambda t}, t \geq 0 \quad \textbf{(1)}$$

$$f_{t_{down}}(t) = \mu e^{-\mu t}, t \geq 0 \quad \textbf{(2)}$$

According to reliability model abovementioned, the average functioning time and average failure time can be obtained by the following formula (3-4):

$$T_{up} = \int_0^\infty t f_{t_{up}}(t)dt = \int_0^\infty R(t)dt \quad \textbf{(3)}$$

$$T_{down} = \int_0^\infty t f_{t_{down}}(t)dt = \int_0^\infty B(t)dt \quad \textbf{(4)}$$

Li [3] thought that no matter what the PDFs of working time and failure time are, as long as there is an explicit value for T_{up} and T_{down},the workstation efficiency e_i is always calculated by the following formula (5):

$$e_i = \frac{T_{upi}}{T_{upi} + T_{downi}} \quad \textbf{(5)}$$

3.1.2 Production effectiveness evaluation of workstation with ERP index

The connotation of production effectiveness is proposed to describe the system performance oriented order requirements, which denotes accomplishing the specific order to produce the qualified products with no failures. To evaluate the production effectiveness of equivalent workstation, effective productivity (PE) index represented as P_1 is put forward. It denotes the efficiency of equivalent workstation operating under the specific standardization and systematic requirements within its cycle T. The ERP index of a procedure unit can be determined by the performance of workstation and WIP quality, which can be calculated by the following equation (6).

$$P_i = e_i \times g_i \tag{6}$$

3.2 System reliability calculation of SMSCM based on production effectiveness

Researchers have a discrepant definition on manufacturing system reliability. Manufacturing system reliability in this manuscript denotes the probability that the specific system successfully finish a task without systems failure, and the task is that the quantity of a qualified products produced by this manufacturing system in the cycle time T is not less than order requirement under OTD environment. There are three kinds of data need to be known in advance, that is, observed data of workstation historically, qualified rate of WIP which is the state probability of checking machine, and the requirement or orders quantity. The overall framework and the calculation procedure of SMSCM to derive system reliability illustrated in Fig.3, and the production effectiveness (*ERP* index) represented by P_1 is described at the former section.

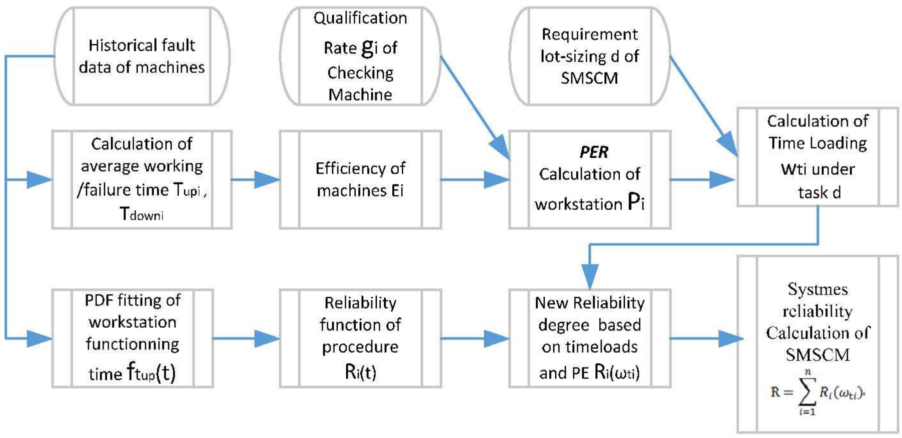

Fig. 3. Reliability calculation procedure of SMSCM

3.2.1 Load calculation of equivalent workstation

According to the transformation of equivalent workstation, the manufacturing system is constituted by a series of units, with homogeneous structure of manufacturing processes. The order quantity of SMSCM is d. The input and output of this system are illustrated in Fig.4 below. The input of i-th equivalent workstation $M_i^{'}$ is I_i , and the input of the system $I_1 = I$.

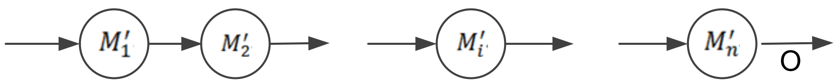

Fig. 4. SMSCM with n-order equivalent workstations

According to the structural model and assumption, all products flowing out of each equivalent workstation are qualified and there is no damage during the transmission between equivalent workstations. In addition, the output of equivalent workstation $M_i^{'}$ is the same as input of next unit, that is, the following formula (7) is correct.

$$I_i = O_{i-1} \quad (7)$$

Then the effective output of SMSCM is formulated as Equation (8) shows.

$$O = O_n = I_n \times P_n = I \times \prod_{i=1}^{n} P_i \quad (8)$$

In order to meet the requirement, the effective output of the system needs to satisfy the following constraint, which means there is a lower bound for system input.

$$O = I \times \prod_{i=1}^{n} P_i \geq d, I_{\min} = d / \prod_{i=1}^{n} P_i \quad (9)$$

After the abovementioned analysis of SMSCM, the minimum operation load of each equivalent workstation can be obtained as follows:

$$W = (w_1, w_2, ..., w_i, ..., w_n) = (I_{\min}, I_{\min} \times P_1, ..., I_{\min} \times \prod_{j=1}^{i-1} P_j, ..., / \prod_{j=1}^{n-1} P_j) \quad (10)$$

3.2.2 Reliability calculation of SMSCM with equivalent workstation

The time load of each unit for one part τ_i can be obtained from the standard operation procedure. As for SMSCM oriented orders, reliability focused on the probability that succeeds in performing the order task. We can obtain the time load of each unit for one lot $w_{\tau i}$, due to τ_i and quantity of one lot represented by w_i. Thus time load can be calculated as shown $W_t = \{w_{\tau i} | w_{\tau i} = w_i \cdot \tau_i, i = 1, 2, ..., n\}$.

Reliability model parameterized of each workstation can be derived from historical failure data through logic regression analysis. According to the reliability model of each unit above and its time load, system reliability of SMSCM can be calculated as follows.

$$R_s = \prod_{i=1}^{n} R_i(t) = \prod_{i=1}^{n} P_i(t \geq w_{\tau i}) = \prod_{i=1}^{n} P_i(w_{\tau i}) \quad (11)$$

4 Case calculation and parameter discussion

4.1 Case calculation for cylinder core manufacturing system

This paper takes the cylinder core component, the key part of hoisting reducer as an example, which is a core subassembly of lorry-mounted crane to achieve lifting function. The main construction of hoisting reducer includes five parts, that is, pistons, cylinder core and cylindrical shell, sun wheel, planet wheel, and plate. Cylinder core component as the link between gear and cylinder shell, had played an important role for hoisting reducer's function, whose orders' satisfaction is vital to enterprises.

We choose the production of QS122C cylinder core component as an example, to analyze the reliability of its manufacturing system. The production processes are shown in Fig.5, and its basic parameter is illustrated as Table 1 manifests. Suppose the production line is on stable equilibrium, thus its processing cycle of a part for each workstation is equal, which recognized as exponential machine.

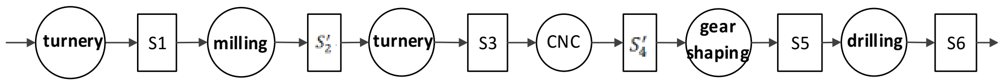

Fig. 5. Process procedure of cylinder manufacturing with SMSCM

Table 1. Basic parameters of each workstation of SMSCM

Items	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6
τ_i	6.4min	6.4min	6.4min	6.4min	6.4min	6.4min
$T_{up,i}$	450.37	1515.5	504.15	1493.20	356.02	572.27
$T_{down,i}$	3.632	1.157	1.157	9.031	2.149	16.485
λ	0.0022	0.0007	0.0020	0.0007	0.0028	0.0017

Scenario 1:

As previous studies like Shu and Lin [8-10], the efficiency of workstation is taken into account, with ignorance of WIP quality affected by stochastic factors, which mean the reliable workstation absolutely produces qualified products. The reliability performance for each workstation can be calculated based on reliability model is as following vector shows:

$$P = e = (e_i)_{1\times 6} = (0.992,\ 0.999,\ 0.997,\ 0.994,\ 0.994,\ 0.972)$$

The operation load w_i and time load $w_{\tau i}$ can be obtained respectively (*d*=100):

$$W = (w_i)_{1\times 6} = (105.38,\ 104.54,\ 104.44,\ 104.13,\ 103.50,\ 102.88)$$

$$W_t = (w_{ti})_{1\times 6} = (11.24, 11.15, 11.14, 11.11, 11.04, 10.97)$$

System reliability of SMSCM for Cylinder manufacturing can be obtained $Rs = \Pi_{i=1}^{n} R_i(w_{ti}) = 0.8940$.

Scenario 2:

In practical manufacturing, the system reliability has been affected by various factors, such as the state of workstation, where this paper takes WIP quality into consideration instead. This means that even if the workstation is reliable and healthy, the defectives may occur. The manufacturing system constituted by equivalent workstation with checking machine has been put forward for analysis under the OTD environment. As for scenario 1, the system reliability analysis fails to consider the WIP quality. The second scenario applies the systems reliability formula proposed in this paper into SMSCM for cylinder manufacturing. The probability of the good state for checking machine, namely WIP quality parameter can be obtained statistically as the following g_i illustrated in Table 2.

Table 2. Basic parameters of each workstation of SMSCM

Items	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6
g_i	0.960	1.000	0.975	1.000	0.950	0.985

According to the basic parameters and the aforementioned calculation steps, we can obtain some in-process results items as following.

The qualified rate and PE of each equivalent workstation is calculated respectively:

$$e = (e_i)_{1\times 6} = (0.992,\ 0.999,\ 0.997,\ 0.994,\ 0.994,\ 0.972)$$
$$P = (p_i)_{1\times 6} = (0.952,\ 0.999,\ 0.972,\ 0.994,\ 0.944,\ 0.957)$$

If the demand quantity of order d is 100, then the operation load w_i and time load $w_{\tau i}$ can be obtained respectively as follows.

$$W = (w_i)_{1\times 6} = (120.32,\ 114.59,\ 114.47,\ 111.28,\ 110.61,\ 104.45)$$
$$W_t = (w_{ti})_{1\times 6} = (12.83, 12.22, 12.21, 11.87, 11.80, 11.14)$$

Then, as for Cylinder manufacturing, which can be recognized as SMSCM, system reliability can be obtained $Rs = \Pi_{i=1}^{n} R_i(t) = \Pi_{i=1}^{n} R_i(w_{ti}) = 0.8857$.

The two scenarios for system reliability calculations and input quantity have been illustrated in Table 3.

Table 3. The comparison of two scenarios

Items	Scenario 1		Scenario 2	
d	R_s	Input *NO.*	R_s	Input *NO.*
100	0.8940	112	0.8857	113

From the results of the above two scenarios, we can figure out that R_s value by previous consideration has been overestimated comparing to the proposed system reliability calculation formula. The new system reliability concept is linked with order requirement, and the OTD environment requires time effectiveness, which means the risk for failing to manufacturing is absolutely higher. The reliability calculation in scenario 2 is inferior to the former, which means the proposed reliability formula has a more stable solution, as well as high risk-resisting, especially in OTD environment for the significance of order requirement and comprehensive time control. In practical, multi-criteria should be considered when make a decision on the input of the manufacturing system. The reliability and input determination may be inaccurate when it takes only the production efficiency of the single workstation with reliability model into consideration, which may put the production in a high risk environment. The results argue that there should be more input for manufacturing system with a lower reliability evaluation, in case of stochastic factors. The lower system reliability means there should be more input for the production line, which caters to the practical situation.

4.2 Parameters analysis and discussion

As abovementioned description of SMSCM with equivalent workstation, production effectiveness and PE calculation have been researched which aims at calculation of system reliability. The performance of SMSCM, like system reliability is not only closed relation with parameters of workstations, it is affected by manufacturing parameters as well. As the case studied above, the influence that parameters of the workstation and system on performance of system reliability are discussed below.

(1) Interaction Between Production Order Quantity d and R_s

The interaction between these two factors is as Fig.6a manifests, when the processing cycle of a single part is a constant, which means production lines are in equilibrium state, R_s will decrease absolutely with the soaring of order quantity d, whose gradient is related with processing cycle per part. That means, the longer process cycle is, the more obviously performs the gradient influenced by order quantity d, and vise visa. The relationship curve between order quantity and system reliability approaches to steep variation within a short enough processing time cycle, while the curve tends to slow with a long enough processing time cycle. From the Fig.6a, we can deduce the less processing circle time will show the more excellent robustness for system reliability.

(2) Interaction Between processing cycle of a single part and R_s

Working time cycle as a parameter of the production system, it is not only affected by process complexity and technique level, but influenced with the whole system for line balance. As is shown in Fig.6b, R_s starts to down with the increasing of unit time of workstation under the specific demand, whose gradient is discrepant in different order quantity. The curve between processing time cycle and system reliability shows a uniform change with small order quantity, while it approaches to exponential connections with sufficiently large order quantity. From the Fig.6b, we can deduce the less order quantity will show the more excellent robustness for system reliability.

(3) Interaction between Qualified Rate of Checking Machine and R_s

The interaction between qualified rate and R_s in Fig.6c with g_i recognized as a qualified rate influenced by stochastic factors. As part of system reliability model, qualified rate definitely has a positive effect on R_s , while those workstations in the front of the SMSCM have been proved to be more sensitive to R_s . It confirms the reality in practice, which means with the improvement of workstation, can we make the system more reliable. It shows the significance of sequences, which caters to reality that the former workstation has more influence on the system performance.

(4) Interaction between Workstation Efficiency and R_s

In practice, the relation between efficiency and R_s has great similar to the above one, for it is calculated by qualified rate. As illustrated in Fig.6d, the front workstation has a deeper influence on system performance. As obviously depicted, R_s can be improved with enhancement of single workstation that absolutely conforms to realistic. On the other hand, the system is striving for achieving perfect reliable, which is hard to reach this perfect objective by only improve the workstation efficiency. Quality performance caused by stochastic elements needs to be taken into account as well.

As shows from the above two figures, the reality can be confirmed that it is not adequate to improve the efficiency or quality rate of equivalent unit respectively to make the whole system reliable. Only both of them are optimized simultaneously, could the system performance be satisfactory. Besides, the productive effectiveness reflected by ERP index can represent the performance of the manufacturing system or a single equivalent workstation.

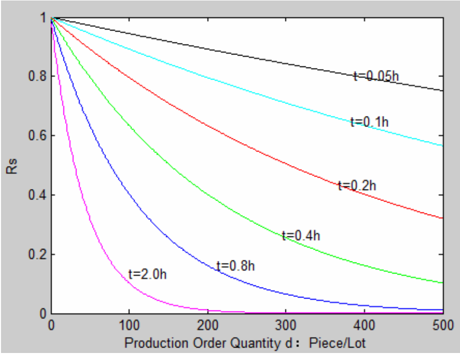

Fig. 6a. Correlation between d and R_s

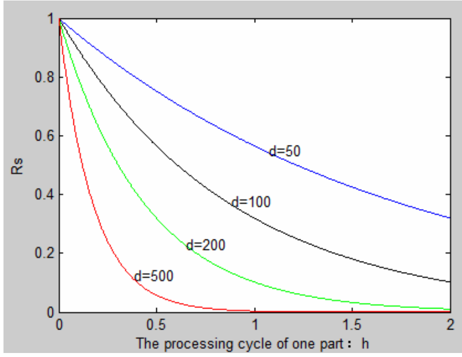

Fig.6b. Correlation between τ_i and R_s

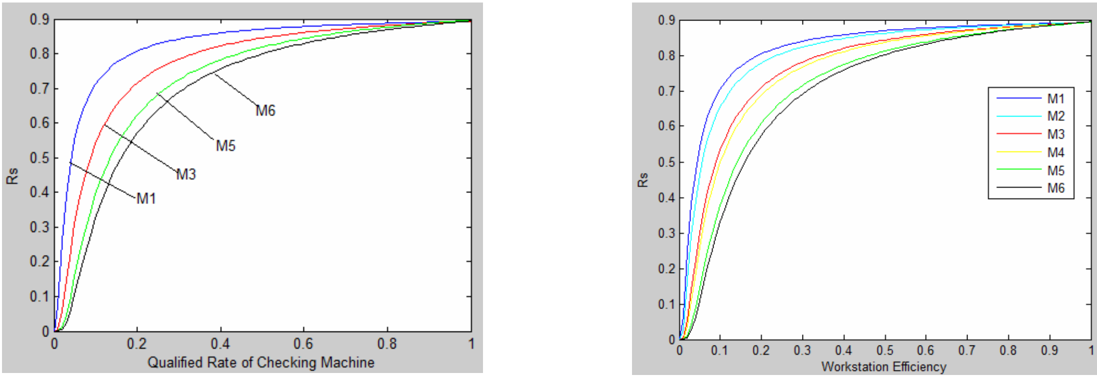

Fig. 6c./6d. Correlations between qualified rate/ p_i and R_s , respectively

5 Concluding remarks & future direction

As for the discrepancy of input and output for the manufacturing system, the state-of-art system reliability of SMSCM has been defined from the perspective of customer requirement. This paper proposed a system reliability analysis method of SMSCM based on production effectiveness, which calculated on the basis of observed data and rational assumptions. System reliability of SMSCM is defined as the probability of satisfying specific order quantity with no unqualified product and no failures of workstation, and calculation steps has been put forward with a case study. The calculation of effective productivity makes a great contribution to the system reliability analysis with calculation on working load and time load of each equivalent unit. Some parameters discussion is researched as well. Conclusions have been made after this research as follows.

(1) System reliability based production effectiveness has been studied, and the framework and algorithm steps have been successfully applied into its calculation. The result calculated by the proposed formula manifests its priority and reality compared previous consideration.

(2) The system reliability of SMSCM has a close relationship with system parameters and indexes of workstation, which got conclusions as follows:

A. System reliability of SMSCM Rs would decrease with the increasing of unit time and order quantity respectively.

B. System reliability of SMSCM Rs is influenced by qualified rate and efficiency of each workstation and checking machine, where the front unit of system performs greater influence.

Proposed research framework and method on SMSCM in this paper have proven to be great advantages. Firstly, it is enough comprehensive, that is, the evaluation method for SMSCM is a three-dimensional framework which takes WIP quality, order quantity, unit reliability into consideration. Absolute reliability to meet the requirements can be obtained. Secondly, it can be implemented easily, namely, data required can be observed and obtained from the production line, which makes the problem and the method practical. Last, it can make a contribution for enterprises to understand their own production capacity, which will make an excellent guidance for providing better product or service.

This paper analyzes system reliability of SMSCM and makes some conclusions under rational assumptions, which are based on previous researches. While, there are some assumption like the no failures of checking machine and practical atmosphere need to be taken into account. Reliability model of equivalent workstation has to be expanded due to various uncertainty factors, and multi-order requirement situation needs to be considered. Besides, as we know from the parameters discussion, the multi-criteria in SMSCM show their paradoxical effect on system reliability, and to make an accurate decision on the input quantity and reliability robustness optimization from an integration optimization model is of great significance in the future.

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