Investigations on Reliability Growth for High-Speed Punch Based on Whole Life Cycle

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Abstract. This paper presents a study on the reliability growth analysis of high-speed punch. The main contribution of the paper is the development of an efficient approach to analyze the reliability growth and to make reliability growth management of high-speed punch. The reliability growth methods for high-speed punch in different stages are presented. The approach is applied to improve the reliability growth of high-speed punch in whole life cycle, and in the meantime to provide some useful information for the improvement of the design, manufacturing and using of high-speed punch.

1. Introduction
High-speed punch is an efficient, high-precision and high-automation punching machine. It has been widely used in aeronautics and astronautics, automobile, traffic and transportation, metallurgical chemical industries and so on [1].

Weiss [2] proposed the first reliability growth model in 1956 when he studied the guided missile system. And the model is considered to be the prototype of reliability growth technology. Duane [3] proposed a model, which is called “Duane Model”, in 1964 and it has extensive applications in many fields. Department of defense in USA firstly took reliability growth technology into reliability working plan in national military standard [4]. Crow [5] gave an explanation of probability theory to Duane Model and proposed an Army materiel system analysis activity model based on Non-homogeneous Poisson process. In 1981, USA awarded a military handbook that included 17 reliability growth models and it was firstly used in military, then extended to civilian product [6]. And it was also used by many countries. The international electrotechnical commission set an international standard in 1989, which stipulates the requirements and rules of making the reliability growth plan [7]. Then, reliability growth problem has been paid attentions widespreadly in the world and then came so many papers, reports, standards and handbooks [8-16].

As stated previously, there is few study on reliability growth of high-speed punch. This work proposed a reliability growth method based on whole life cycle for high-speed punch.

2. Analysis of Reliability Growth
There will be a gradual process for a new product from design to manufacturing. The process usually can be broadly divided into three phases, as shown in Figure 1.

Reliability growth of the development process: the new product has a low reliability in the development process. The engineer uses design experience of traditional similar products for the design of new product development. The reliability comprehensive experiment is used to find the
failure of new product. Then, analyze the reason of failures to correct the design and to eliminate the weak link. Finally, the reliability of new product will grow to prescribed level.

![Diagram](Image)

**Figure 1.** The reliability growth

Reliability of the trial production: in the beginning of this stage, the reliability will be influenced by the equipment, the technology and the worker's proficiency. With the corrected design and worker’s training, the reliability would grow.

Reliability of the full-scale production: the product has been in the full-scale production process. There will be some problems in design and manufacturing and it will still influence the reliability. The reliability finally will grow after some corrective actions.

### 3. Reliability Growth Management of High-Speed Punch

The high-speed punch is a complex system that involves numerous fields, like mechanical structure design, manufacturing and assembly technology, electric and electronic technology, hydraulic and pneumatic transmission technology, computer automatic control technology and sensing technology. If any of the components goes bad, the punch will fail. Whether the main punch can work normally will mainly depend on the coordination and cooperation of all components.

The reliability growth management of high-speed punch is as follows:

- **Rules and regulations of reliability growth management.** To keep an efficacious management on reliability growth, the policy, regulation, rule of the management need to be made for institutionalization, normalization and standardization of information management.
- **Reliability information analysis.** There need to analyze practical requirements of information unions and users at all levels and to investigate the accuracy of collected information. The information collecting should be organized orderly to improve the actual benefit of information management.
- **The closed-loop reliability information management.** In the reliability growth process, resources need to be allocated properly by informational needs and then supply feedback information. The information management will be carried out according to this principle to form closed-loop management system.
- **The fault report, analysis and correcting system.** All failure information in reliability growth test will be collected by the fault report, analysis and correcting system. The failure information will be analyzed timely and the corrective action will also be recorded.

### 4. Reliability Growth Analysis of High-Speed Punch

#### 4.1. Reliability Growth Programming of High-Speed Punch
According to the characteristics of high-speed punch, the reliability growth programming of high-speed punch is as shown in Figure 2.

Planning approaches and procedures are shown as follows:

- (1) The planning procedure of the new type high-speed punch should firstly be made after the theoretical analysis, computer simulation analysis and reliability design.
- (2) To make prototype design of new type high-speed punch with reference to product data, expertise and computer simulation results of similar product in the same category.
- (3) To product the prototype punch based on reliability manufacturing and management.
- (4) To make comprehensive experimental scheme, which includes the experiment objective, content, standard, method and evaluation, for reliability growth for the new type prototype punch.
- (5) To carry out sample performance test, which includes geometric accuracy test, static accuracy test and dynamic accuracy test.
- (6) To make early fault test scheme according to the relevant norms and standards for high-speed punch and then carry out the test.
- (7) To find the prototype fault and to make reliability growth plan.
- (8) To make failure settle scheme: take timely corrective action to failures which can be corrected timely and take delay corrective action for others.
- (9) To make design amendment in accordance with the corrective action and then carry out more test.
- (10) To make evaluation of reliability growth based on a small sampling of Bayes method for new type high-speed punch.
- (11) To analyze the evaluation result: if the result achieves the target, then go to next step, otherwise go back to last step.

**Figure 2.** Planning procedure of reliability growth for high-speed punch
(12) To count the failure of reliability appraisal test into fault database. The analysis and fault diagnosis will be made and then draw the relevant improvement measures.

(13) To make design typification if the reliability appraisal test pass and type it into Press Model database, otherwise go back to step (7).

(14) To make mass production with reliability manufacture and reliability qualities management.

(15) To carry out reliability acceptance test: if it passes the test, to deliver into users, or go back to step (14) for more improvement measures.

(16) To take relevant improvement measures for reliability growth in accordance with the failure in using stage.

By the steps, to achieve the significant reliability growth.

4.2. Reliability Growth Analysis of High-Speed Punch

Based on the foregoing analysis, the reliability growth of high-speed punch is divided into 3 stages: reliability growth of design phase, reliability growth of manufacturing phase and reliability growth of using phase.

4.2.1. Reliability Growth of Design Phase. The reliability design requires of high-speed punch are made firstly based on planning requirements. Then, make reliability distribution of components and make reliability analysis and reliability optimization of components with high failure frequency. Finally, make reliability prediction of high-speed punch and if the result does not meet the requirement, modify the design. The process of reliability growth in design phase of high-speed punch is shown in Figure 3.

![Figure 3. The process of reliability growth in design phase of high-speed punch](image-url)

4.2.2. Reliability Growth of Manufacturing Phase. The manufacturing process and quality control during manufacturing greatly affect system reliability. The reliability will grow by removing systematic defects in manufacturing. The reliability of complex system usually decreases from design
and development to production and the quality control technology is more and more important for reliability growth.

To improve the reliability, the early malfunction and weak links of high-speed punch should be found and improved design should be made. The test of early malfunction of high-speed punch is as shown in Figure 4.

The early malfunction test is to find potential early malfunction of high-speed punch, to check the stability of the punch. So the weak links can be found and some relevant maintenances and corrections can be made for accumulating design experience. The reliability growth process of high-speed punch is as shown in Figure 5. While the testing is under way, the systematic failure should be analyzed as soon as possible and some relevant corrections should be made to the prototype punch.

![Test of early malfunction of high-speed punch](image)

*Figure 4. The test of early malfunction of high-speed punch*
4.2.3. Reliability Growth of Using Phase. The performance and reliability of any product is far away from perfect from design, to manufacturing, to using primitives. There is always quality feedback and quality improving in the manufacturing and using phase and the reliability is growing all the time. In fact, it is the reliability growth.

The process of reliability growth in using phase of high-speed punch is as shown in Figure 6.

- To make record of utilization information of high-speed punch, such as on-off time, operating conditions, failure situations and maintenance status.
- To make fault information consolidation of high-speed punch.
- To make statistical analysis of fault information and to find weak links of high-speed punch.
- To make reliability growth plan based on fault analysis.
- To verify the validity of reliability growth plan: if it works, to implement improvements; or to make reliability growth plan again.
- To examine whether the punch could satisfy the requirement: if it works, it is the end; or to make reliability growth plan again.

5. Summary
The reliability growth analysis was analyzed based on the process from design to manufacturing. The reliability growth management of high-speed punch was carried out by 4 ways. The reliability growth programming of high-speed punch was made by 16 steps. The reliability growth of high-speed punch was divided into 3 stages: design phase, manufacturing phase and using phase, laid the foundation for the reliability growth of high-speed punch.

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