International Journal of Intelligent Information and Management Science
ISSN: 2307-0692, Volume 6, Issue 5, October, 2017

Reliability Modeling and Analysis of CNC Machine Tools Hydraulic System based on GSPN Model

Zhiyao Li[1], Tiantian Xu[1*], Jie Yu[2]
[1]Mechanical Manufacturing and Automation, Changchun University, Changchun, 130000, China
[2]Mechanical and Electrical Engineering, Changchun University, Changchun, 130000, China

Abstract: Traditional reliability modeling method cannot describe the system state in the process of dynamic change. The paper puts forward a modeling method that based on Generalized Stochastic Petri Net (Generalized Stochastic Petri Net, GSPN) on the basis of the thorough analysis. This paper introduces generalized stochastic Petri nets to dynamic reliability modeling of CNC machine tools. In this paper, on the basis of the based on the GSPN model of CNC machine tools hydraulic system reliability modeling, makes the simulation experiment, the effectiveness of the proposed method is verified by simulation experiment, providing theoretical reference for numerical control machine reliability analysis and design.

Keywords: Generalized stochastic Petri nets; CNC machine tools; Hydraulic system; Reliability; Availability

1. Introduction

With the progress of world science and technology and the development of machine tool industry, CNC machine tools as the mainstream of the machine tool industry products, has become the equipment manufacturing industry key equipment to realize modernization, it is the key of the equipment manufacturing industry development [1].From the Angle of qualitative CNC machine tool reliability analysis has made certain achievements, but from the perspective of quantitative analysis the reliability of CNC machine tool is still in its infancy. Therefore, choosing a suitable theoretical tool from the perspective of quantitative assessment of the numerical control machine tool is a particularly urgent theory and reliability engineering problems [2].

Generalized Stochastic Petri Net based on Stochastic Petri Net, the transition can be divided into two time transition and the instantaneous transition, It can reduce the number of state space when analyzing the same problem, and effectively alleviate the problem of state space explosion [3], It is a kind of advanced Petri nets, which has been researched and applied in many fields such as aviation, armored vehicle, software and so on. The purpose of this paper is to introduce GSPN technology to establish the reliability analysis model of CNC machine tools, and take the hydraulic system of NC machine tools as an example to analyze the dynamic process of its failure [2].

In this paper based on "Reliability Modeling of CNC Machine Tools Hydraulic System Based on GSPN Model", through the analysis of the hydraulic system failure model of CNC machine tools, the GSPN model of hydraulic system oil leakage S1 and hydraulic actuator fault S3 and the GSPN model of hydraulic system loop fault S2 are established, this article is based on "Reliability Modeling of CNC Machine Tools Hydraulic System Based on GSPN Model", Simulation experiments are carried out.

2. Simulation Experiment

2.1. Experimental environment and simulation configuration

TimeNET4.0 software is a suite developed by the research team led by Zimmermann A of the German Industrial University, which supports GSPN modeling and analysis tools.

In this software environment, the GSPN model of CNC machine tool hydraulic system is realized. We define that the availability of the CNC machines hydraulic system (T) is P_t=1-P$\{\#P_{tf}>0\}$; the availability of oil spills in hydraulic systems is P_{s1}=1-$P\{\#P_{s1f}>0\}$; The availability of hydraulic circuit faults is P_{s2}=1-$P\{\#P_{s2f}>0\}$; The availability of hydraulic actuators is P_{s3}=1-$P\{\#P_{s3f}>0\}$; Overflow valve failure availability is P_{s4}=1-$P\{\#P_{s4f}>0\}$; The availability of insufficient fuel supply is P_{s5}=1-$P\{\#P_{s5f}>0\}$; The availability of insufficient fuel pressure is P_{s6}=1-$P\{\#P_{s6f}>0\}$; The availability of pipe joints is P_{x1}=1-$P\{\#P_{x1f}>0\}$; The availability of the valve string cavity is P_{x2}=1-$P\{\#P_{x2f}>0\}$; The availability of end cap

leaks is P_{x3}=1-$P\{\#P_{x3f}>0\}$; The availability of loose spring adjustment is P_{x4}=1-$P\{\#P_{x4f}>0\}$; The spring is too soft and the invalid availability is P_{x5}=1-$P\{\#P_{x5f}>0\}$; The availability of suction for hydraulic pumps is P_{x6}=1-$P\{\#P_{x6f}>0\}$; The availability of an insufficient motor power is P_{x7}=1-$P\{\#P_{x7f}>0\}$; The availability of hydraulic pump wear is P_{x8}=1-$P\{\#P_{x8f}>0\}$; The availability of the Piston clearance widely is P_{x9}=1-$P\{\#P_{x9f}>0\}$; the availability of poor sealing of the piston is P_{x10}=1-$P\{\#P_{x10f}>0\}$. The system parameter settings are shown in Table 2; the software parameters in the simulation are as follows: the simulation confidence period is 95%, the maximum relative error is 10%, the sampling point is 20000, and the simulation times are 200 times.

Table 2. System Parameter Setting

Name	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
failure rate	0.852	0.839	0.863	0.883	0.862	0.875	0.881	0.869	0.871	0.853	0.838
Maintenance rate	0.8	0.7	0.8	0.7	0.7	0.6	0.7	0.6	0.8	0.8	0.8

2.2. Simulation results and analysis

The global availability curve of CNC machine's hydraulic system gradually decreased with the increase in working hours, the change range of [0.762,1], the range of variation in available oil leakage of hydraulic system is [0.832, 1], the range of variation in available hydraulic actuator fault is [0.824, 1], the availability curve of the hydraulic circuit fault is the same as that of the hydraulic system of the CNC machine tool, and it decreases gradually with the increase of working time, the range of change is [0.776,1], the range of variation in available of the overflow valve failure is [0.841,1], the range of variation in available of the insufficient fuel is [0.851, 1], the range of variation in available of insufficient supply pressure is [0.848,1], they are larger than the hydraulic loop fault availability values. Because the hydraulic circuit fault is the logic of the OR gate fault, the number of failures is the superposition of the number of failures of each subsystem unit, so that the system work time is reduced accordingly. In addition, the hydraulic circuit fault is basically consistent with the change trend of the hydraulic system availability curve of the CNC machine tool. It is known that the hydraulic circuit fault has the greatest impact on the availability of the hydraulic system of the CNC machine tools. Therefore, in order to improve the availability of hydraulic system of CNC machine tool, the reliability design and analysis of hydraulic circuit should be increased.

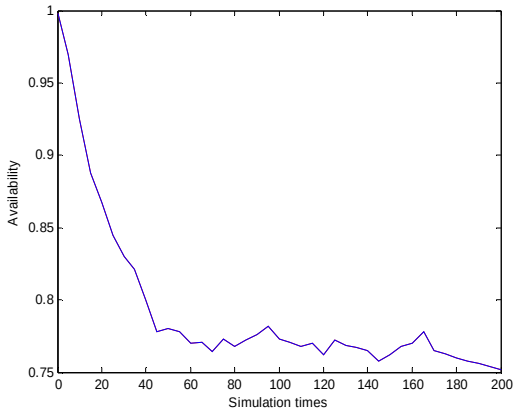

Figure 1. Hydraulic System Availability Curve

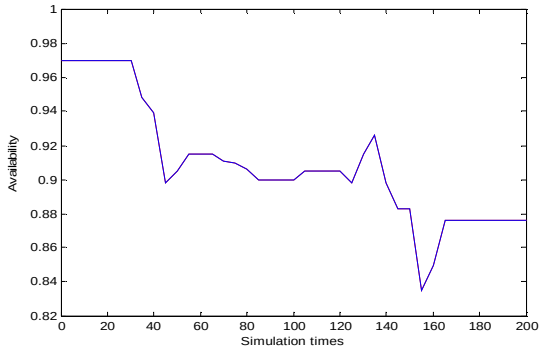

Figure 2. Hydraulic System Oil Spill Availability Curve

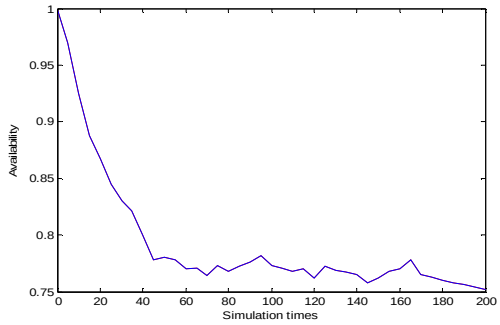

Figure 3. Hydraulic Circuit Fault Availability Curve

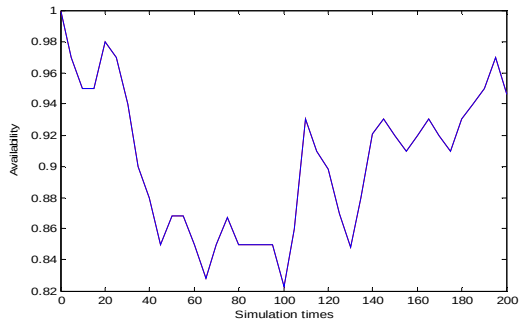

Figure 4. Hydraulic Actuator Failure Availability Curve

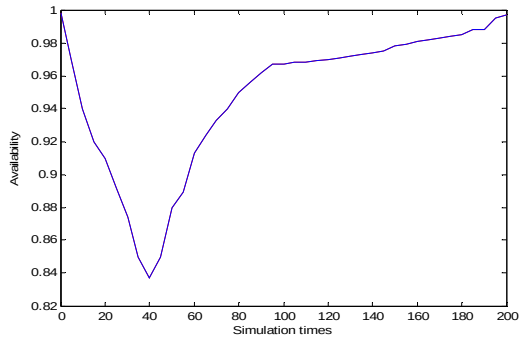

Figure 5. Overflow Valve Failure Availability Curv

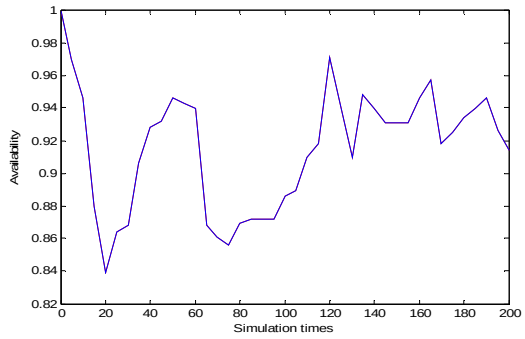

Figure 6. Insufficient Fuel Availability Curve;

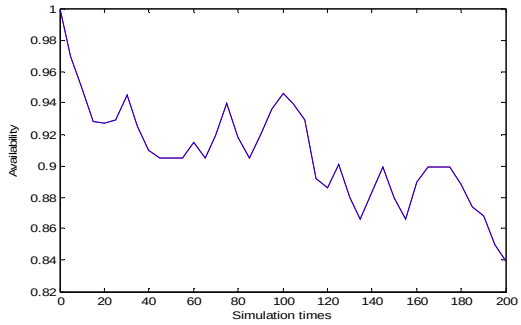

Figure 7. Insufficient Availability Curve of Fuel Supply

3 . Conclusions

In this paper, the hydraulic system of CNC machine tools is taken as the object of study. Based on the theory of generalized stochastic Petri nets, a dynamic fault behavior of CNC machine tool hydraulic system based on GSPN is proposed, On the basis of the model, the dynamic curve of availability index is obtained by simulation experiment, and the influence of each function subsystem on the overall availability of CNC machine tool hydraulic system is analyzed. The model can be used as a theoretical support tool for the analysis, design and optimization of CNC machine tools. The GSPN model and simulation experiment of other systems of NC machine tools will be built and analyzed in the later stage.

Acknowledgement

Jilin province education department project, project number: 2015 LY501l05.

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