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

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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. Express to delay change failure and maintenance of CNC machine tools. Based on the CNC hydraulic system as an example, analyzed the change of dynamic hydraulic system failure process.

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

1. Introduction

Generalized stochastic Petri net based on stochastic Petri net, the change can be divided into the time vicissitude and the instantaneous change, it can decrease number of state space when analysis of the same problem and relieve the state space explosion problem effectively[1].

2. CNC Machine Tool Hydraulic System Failure Mode Analysis

According to the function and the connection relationship of the system, taking a top-down principle, establishing dynamic fault tree of CNC machine tool hydraulic system, as shown in Figure 1 [2]. Top events T : CNC machine tool hydraulic system; Intermediate event S: S1 - hydraulic system leak, S2 - hydraulic circuit failure, S3 - hydraulic actuator faults, S4 - overflow valve failure, S5 - oil shortage, S6 - insufficient oil pressure; Bottom event X: X1 - pipe joint loosing, X2 - string in the valve cavity, X3 - end cover leakage, X4 - spring adjustment loose, X5 - spring too soft, X6 - hydraulic pump suction empty, X7 - motor power is not enough, X8 - hydraulic pump wear and tear, X9 - piston clearance is too large, X10 - piston seal is poor, X11- each valve failure[3].

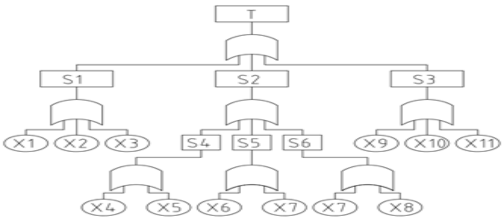

Figure 1. CNC Machine Tool Hydraulic System Fault Tree

3. Reliability Modeling of CNC Machine Tools Hydraulic System Based on GSPN Model

3.1. The basic assumptions

Usually in order to guarantee the GSPN model exactly and effectively and easily application, we need to do some limit and assume the following conditions:
Hypothesis 1: system units with just two states are: fault and normal.
Hypothesis 2: the unit of the system fault are independent of each other, and do not have two or more units at the same time down [3].
Hypothesis 3: assuming adequate maintenance equipment, unit failure after timely maintenance, and repair, such as new [4]

3.2. The usage GSPN model elements

In the GSPN modeling of CNC machine tool hydraulic system, a variety of specific usage of model elements is shown in table 1.

Table 1. GSPN Model Elements

Element	Symbol	Usage
Place	○	Describe the CNC machine tool hydraulic system of normal and fault condition
Time transition	□	Description of CNC machine tool hydraulic system failure, maintenance and other events
Instantaneous transition	▮	Description of CNC machine tool hydraulic system logic control and so on
Directed arc	↖	Causality in the description of CNC machine tool hydraulic system
Inhibitor arc	o—	The state of the control of CNC machine tool

		hydraulic system
Sign	●	Describe the dynamic behavior of the process of CNC machine tool hydraulic system

3.3. GSPN model of CNC machine tool hydraulic system reliability analysis

Based on the module, first of all, establishing a GSPN model of the hydraulic system leak S1, hydraulic circuit fault GSPN model of S2 and hydraulic actuator fault GSPN model of S3, and then synthesize to get the global GSPN model of CNC machine tool hydraulic system T [2].

3.4. GSPN model of the hydraulic system leak S1 and the hydraulic actuator fault S3

GSPN model of the hydraulic system leak S1 and the hydraulic actuator fault S3 is shown in Figure 2.

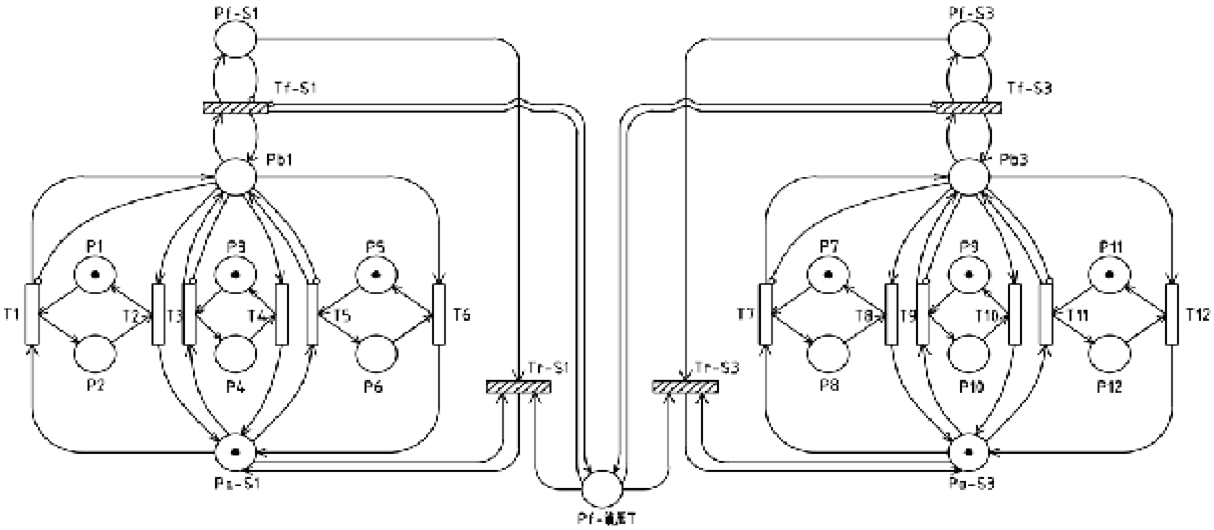

Figure 2. GSPN model of the hydraulic system leak S1 and the hydraulic actuator fault S3

Working Principle of the Model Analysis:
Place of P1, P3, P5, P7 ,P9 and P11 respectively show the failure in a normal state of pipe joint loosing, string in the valve cavity, end cover leakage, piston clearance large, piston sealing difference, each valve;
Place of P2, P4, P6, P8, P10 and P12 respectively show the failure in the fault state of pipe joint loosing, string in the valve cavity, end cover leakage, piston clearance large, piston sealing difference, each valve;
Place of Pb1 and Pb3 respectively show the failure unit number of oil hydraulic system, hydraulic actuator;
Place of Pa-S1 and Pa-S3 respectively show the normal unit number of oil hydraulic system, hydraulic actuators;
Place of Pf - S1 and Pf - S3 respectively show the failure of oil hydraulic system, hydraulic actuators;
Place of Pf -T show the failure of hydraulic system.
Transition of T1, T3, T5, T7, T9 and T11 respectively show the time transition and caused each units state change "failure" event;
Transition of T2, T4, T6, T8, T10 and T12 respectively show the time transition and caused each units state change "fix" event;
Tf-S1 and Tr-S1 as the instantaneous transition respectively show the hydraulic system leak failure and repair,
Tf-S3 and Tr-S3 respectively show the hydraulic actuator fault and repair.
Model identification as shown in figure 2, at this point, the model in the initialization state, hydraulic system does not leak, normal work, after a random time, pipe joint loose and the T1 is stimulated, at the same time Tf-S1 is stimulated, Pa–S1 token disappear, Pf-S1 obtain a token, this suggests that the malfunction of the hydraulic system leak, hydraulic system failure. Because of the existence of inhibitor arc, at this time, the valve cavity and end cover leakage will stop working, the failure will not occur in the process of repairing pipe joint loosing. After a certain time delay, T1 is stimulated, pipe joint return to work, Pa-S1 appear a token, at the same time , the transition Tr-S1 is stimulated, the token disappear in the Pf1 the, hydraulic system leak repair, hydraulic system is normal

3.5. GSPN model of Hydraulic system circuit fault S2

The GSPN model of hydraulic circuit fault is shown in Figure 3.

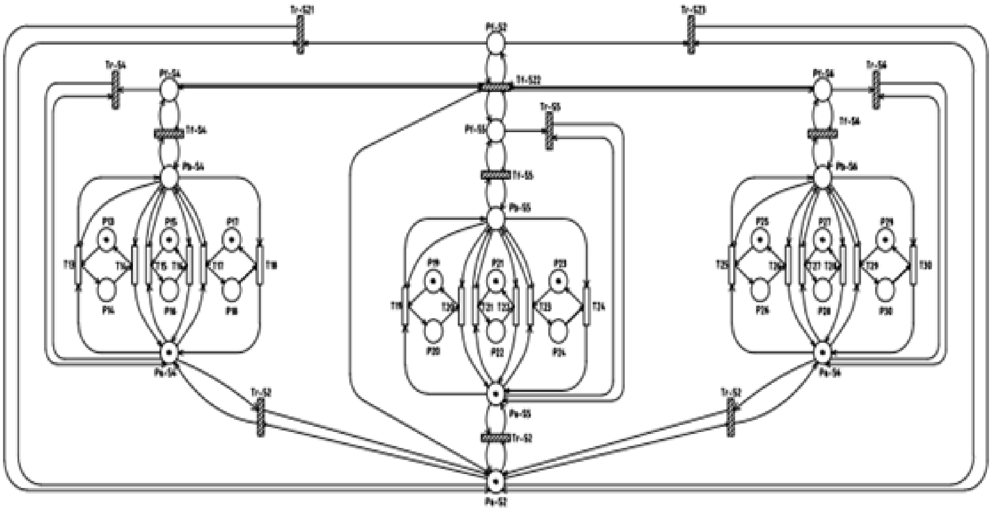

Figure 3. GSPN Model of Hydraulic System Circuit Fault S2

Working principle of the model analysis:

Place of P13, P15, P17, P19, P21 and P23 respectively show the failure in a normal state of spring adjustment loosing, spring soft ineffectively , hydraulic pump suction empty, insufficient power of the motor, motor power, hydraulic pump ;

Place of P14, P16, P18, P20, P22 and P24 respectively show the failure in the fault state of spring adjustment loosing, spring soft ineffectively , hydraulic pump suction empty, insufficient power of the motor, motor power, hydraulic pump ;

Place of Pb4, Pb5 and Pb6respectively show the failure unit number of the overflow valve failure, insufficient oil, and oil pressure;

Place of Pa-S2, Pa-S4, Pa-S5 and Pa-S6 respectively show the normal unit number of hydraulic circuit failure, overflow valve failure, normal insufficient oil and oil pressure;

Place of Pf-S2, Pf-S4, Pf- S5 and Pf-S6 respectively show the failure unit number of hydraulic circuit failure, overflow valve failure, insufficient oil, oil pressure ;

Transition of T13, T15, T17, T19, T21 and T23 respectively show the time transition and caused each units state change "failure" event;

Transition of T14, T16, T18, T20, T22 and T24 respectively show the time transition and caused each units state change "fix" event;

Tf-S22, Tr-S21 / Tr-S23, Tf-S4, Tr-S4, Tf-S5, Tr-S5, Tf-S6 and Tr-S6 as the instantaneous transition respectively show hydraulic circuit failure, overflow valve failure, insufficient oil and oil pressure system failure and repair;

Model initialization, as shown in figure 3, at this point, the hydraulic circuit system works normally, after a random time, assuming that spring adjustment is too loose from the state work condition P13 into fault P14, (Place of Pa - S4 sign number is one, in order to prohibit other units of work in the failure in the overflow value failure), so the overflow valve change the state from the working state of Pa - S4 into fault state Pf - S4. if the oil is insufficient also failure and working state by Pa-S5 into fault state Pf-S5, instantaneous transition Tf-S22 activate, hydraulic circuit system change the state from the work of Pa - S2 into fault state and Pf - S2.Again after a random time, assuming that the spring adjustment is too loose to get maintenance, the failure state P14 into working state P13 (at this point, the mark in the place of P14 and Pb4 disappear), the overflow valve also change the state from fault state Pf-S4 into work state,Pb-S4, then instantaneous transition Tr-S21 activate, place of Pf-S4 marker disappear, and the place of Pa-S2 obtain a sign, the overflow valve recover working condition.

3.6. Global GSPN model of hydraulic system

GSPN model of hydraulic system is shown in Figure 4 below.

The working process of the model: hydraulic system leak fault occurs, the transition of Tf-S1 activate, the hydraulic system leak (Pf-S1)change into fault state, at the same time, hydraulic system (Pf-T)change into fault statue. After a random time, hydraulic system does not leak and returns to normal work, so the transition of Tr-S1 activate, the hydraulic system leak change the state from fault state Pf-S1 into working state Pa-S1, at the same time, place of Pf-T marker disappear, the hydraulic system return to normal work.

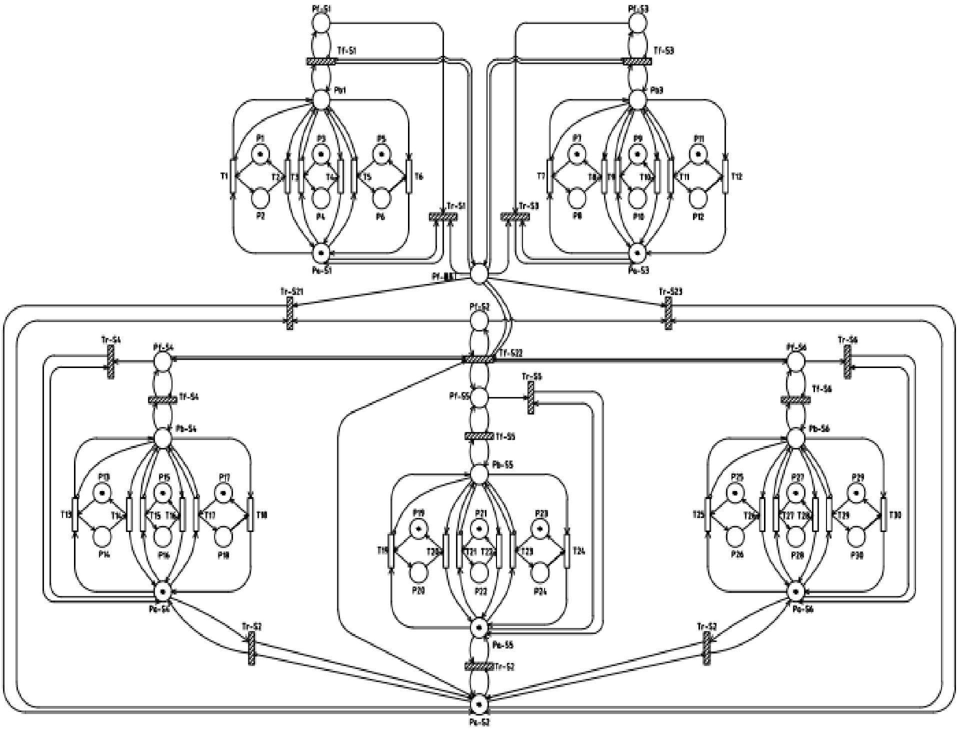

Figure 4. Global GSPN Model of CNC Machine Tool of Hydraulic System

4 . Conclusions

In this paper, the hydraulic system of CNC machine tools is taken as an example, according to the theory of generalized stochastic Petri network tools; this paper puts forward Reliability Modeling of CNC Machine Tools Hydraulic System Based on GSPN Model, this model effectively describe the dynamics of the CNC machine tool hydraulic system fault behavior. On the basis of this model, the simulation experiment will take place in the subsequent; the model could be used to the analysis, design and optimization of the CNC machine tool reliability.

Subject sources

Jilin province education department project (No. 2015 LY501l05).

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