

RESEARCH ON INHERENT TESTABILITY DESIGN TO CHASSIS SYSTEM OF SELF-PROPELLED GUN

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ABSTRACT

Testability is one of the important contents of modern equipment design. The test performance and fault diagnosis capacity of system can be effectively improved by testability designing. Simultaneously, equipment effectiveness, technical support levels, and economic benefits also can be raised substantially. In this paper, testability theory is applied to chassis system of track-type self-propelled guns. Its structure characteristics and failure modes have been analyzed. Based on the FTA and FMECA of chassis, the inherent testability design criteria and the inherent testability assessment methodology are presented. In addition, this paper offers an example of the inherent testability evaluation to typical chassis in service, and its inherent testability value is figured out.

INTRODUCTION

Testability engineering is a new subject that is established in 80's. It separated from maintainability with the development of high and new technology. Its aim is that the requirements of testability must be thought over as early as possible in developing and designing of a weapon system. It includes that a design to a system should assure that failures of equipment could be checked out in time and with the least costs as system working. The testability of equipment has consanguineous relations with reliability and maintainability, and it is an absolutely necessarily link and bridge between reliability and maintainability. When testability, including build-in test (BIT), is synthesized into a design, system failures can be detected and diagnosed rapidly and easily, and they can be located and removed rapidly[1]. Therefore, testability becomes one of the contents that must be considered when designing large and complex equipment this day.

Track-type self-propelled gun is one of the important equipment in our army. Its structure is complicated; its subsystems are covered by armor, and its technical support is very difficult. Soldiers cannot learn about its state in time. The fighting efficiency of SP Gun is

reduced, and support costs are high [2]. Therefore, it is an important way to advance equipment support levels by considering the testability of SP Gun adequately in design.

ANALYSIS TO STRUCTURE OF SP GUN CHASSIS

Most of the chassis of SP Gun are medium track-type armored chassis; it is composed of body, engine system, transmission system, traction system, electric system, and hydraulic system [3]. Mechanical system has many disadvantageous factors in testability design, as summarized below [4]:

- (1) Detection signal of mechanical equipment must be translate into electric signal first, then, it can be analyzed and disposed.
- (2) There are many high temperature, strong noise, and strong vibration environments in mechanical equipment; they have serious effects to sensors or BITE.
- (3) The choosing and fixing of sensors, the setting of test interface is more difficult than electric equipment.
- (4) It is not suitable to adopt many complex and expensive BITEs.

Therefore, external test (ET) is the cardinal way in test of SP Gun chassis. Enough test points, test interfaces or sockets are mounted in chassis, so performance measurement, fault diagnosis and isolation can be conducted rapidly and accurately by using external test equipment (ETE). BITEs are only designed in critical assemblies to realized real-time monitoring.

FAULT TREE ANALYSIS AND FAILURE MODE, EFFECTS AND CRITICALITY ANALYSIS OF SP GUN CHASSIS

Testability design is based on fault tree analysis (FTA) and failure mode, effects, and criticality analysis (FMECA). All the failure modes that cause top events

taking place can be identified by FTA, simultaneously, some indexes, such as incidence rate, importance grade of top events, could be figured out, Fault rate (FR), fault detection rate (FDR) and fault isolation rate (FIR) also can be achieved. The result of FTA shows in table 1 (Process of FTA omitted):

Table 1 Subsystem data of chassis

Item Subsystem	FR (%)	FDR(%)	FIR(%)
Engine	28.12	69.7	59.2
Transmission	23.29	44.1	26.5
Traction	19.74	56.1	46.3
Electric	15.74	69.2	48.1
Hydraulic	9.76	42.3	34.6

FMECA is one kind of systematized reliability analysis procedure, its aim is to find out all the potential failure modes; determine every fault's effect influence to system; locate single point faults and confirm harmfulness according to failure modes' incidence rates and stern grades. FMECA is conducted in two steps, viz. failure mode and effects analysis and criticality analysis. The critical assemblies of chassis that affect system function significantly are found out, show as follows (Process of FMECA omitted):

- Water radiator
- Oil-box
- Air cleaner
- Fuel injector
- Warmer glow plug
- Big brake strap
- Front housing body
- Behind housing body
- Torsion shaft
- Balance elbow shaft
- High-pressure gas container
- Hydraulic oil pipe

INHERENT TESTABILITY DESIGN AND ASSESSMENT OF SP GUN CHASSIS

Inherent testability design criteria of SP Gun chassis is presented according to the requirements of Testability program for equipment ” based on FTA and FMECA. The criteria is showed as follows [5][6]:

(1) Mechanical design

- Is enough spacing provided between Components to allow for test sensor?
- Are all components oriented in order?

- Are standard or universal instruments used for testing conveniently?
- Is method of in situ detection adopted in subsystems and independent devices test?
- Are enough test points provided and no excrescent ones?
- Are standard connector plugs and socks used in interface?
- Do test interfaces and test points have obvious symbol and matching mark?
- Does the arrangement of connector plugs avoid the dangerous?
- Are preventive maintenance monitoring Functions (oil analysis, gear box cracks) in place?
- Has preventive maintenance been analyzed?

(2) Partitioning

- Are line replaceable units modular structure and easy to replace?
- Do assemblies in one ambiguity group belong to same device?
- Does function detection make fault detection and isolation cost less?
- Does LRU level reach in fault detection and isolation?

(3) Test control [7]

- Is the input of UUT and signal being test easy to be identified and analyzed?
- Can connections of sensors, cable, test interfaces connect and disconnect rapidly?
- Is the distribution of test points convenient for detection? Is their accessibility all right?
- Is test operation simple and result easy to be read?
- Is equipment required in test less and provided to every support level?
- Can all the dynamic and static tests be done with external test equipment?
- Has it compatibility between traditional technical inspection?
- Have MSCM and battle damage monitoring functions been integrated with other performance monitoring function?

(4) Built-in test [8]

- Can BIT in each item be exercised under control of the test equipment?
- Can BIT interface ports be utilized by ETE?
- Are BIT indicators on UUT used for important functions? Are BIT indicators designed such that a BIT failure will give a “fail” indication?
- Does BIT include a method of saving on-line test data for the analysis of intermittent failures and operational failures that are non-repeatable in the maintenance environment?

- Is the predicted failure rate of BIT within stated constraints?
 - Is the additional weight and volume attributed to BIT within stated constraints?
 - Is the predicted failure rate of BIT within stated constraints?
 - Are the data provided by BIT tailored to the differing needs of the system operator and the system maintainer?
 - Does the data provided by BIT satisfied the differing needs of the system operator and the system maintainer?
 - Is fault detection time associated with the criticality of the function being monitored?
- (5) Performance monitoring
- Have critical functions been identified which require monitoring for the system operation and users?
 - Has the displayed output of the monitoring system received a human engineering analysis to ensure that the user is supplied with the required information in the best usable form?
- (6) Sensor
- Have positions been planed for fixing sensors?
 - Do sensors have the best locations for test?
 - Has the selection of sensors taken into account the environmental conditions under which they will operate?
- (7) Diagnostic capability integration
- Have test compatibility concepts been established, employed, and documented?
 - Have a means been established to ensure compatibility of testing resources with other diagnostic resources at each level of maintenance (technical information, personnel, and training)?
 - Has the diagnostic strategy (dependency charts, logic diagrams) been documented?
- (8) Test requirements
- Have a “level of repair analysis” been accomplished?
 - For each maintenance level, has a decision been made for each item on how built-in test, automatic test equipment, and general-purpose test equipment will support fault detection and isolation?
 - Is the planned degree of test automation consistent with the capabilities of the maintenance technician?
- (9) Test data
- Are testability features included by the system designer documented in the test requirement documents in terms of purpose and rationale for the benefit of the test designer?
 - Are test diagrams included for each major test? Is the diagram limited to a small number of sheets? Are inter-sheet connections clearly marked?

Inherent testability assessment of SP Gun chassis is accomplished according to criteria listed above based on the means prescribed in appendix A of “Testability program for equipment”. Inherent testability checklist table must be used (Table 2). This assessment is conducted in eight steps, as summarized below [5][6]:

- (a) Determine testability criteria.
- (b) Assign weighting factors (WT) to each item base on its relative importance in achieving a testable product. (1 WT 10).
The relative importance of each checklist element is established through the assignment of a weight in the range of 1 to 10. Any design criteria that are critical to meeting testability requirements should be assigned a weighting factor of 10. A weighting factor of 5 shall be assigned to design criteria that are important, but not critical, to meeting testability requirements.
- (c) Any criteria that contribute to good testability design practices, but are not critical to meeting testability requirements, shall be assigned a weighting factor of 1. This keeps the requirement visible but will not significantly affect the final calculated testability figure of merit.
- (d) Count the design attributes that are relevant to each testability item, and fill it in relevant column.
- (e) Count the design attributes that meet the testability criteria for each item and fill it in relevant column.
- (f) Calculate the score S_i for each criterion, and fill it in column “score”.

$$S_i = N_0 \times 100 / N_t$$

S_i -- Score for No. i criterion

N_0 -- Number of design attributes that are relevant to No. i item.

N_t -- Number of design attributes that meet the No. i item.

- (g) Calculate the weighted score S_{wi} for each criterion, and fill it in column “Weighted score”.

$$S_{wi} = W_i \times S_i$$

S_{wi} -- Weighted Score for No. i criterion

W_i -- Weighted factor for No. i criterion

- (h) Calculate the testability figure of merit (TFOM).
Sum the weight (WT) and weighted score (WT Sore) columns and use the following equation:

$$TFOM = \sum_{i=1}^n S_{wi} / \sum_{i=1}^n W_i$$

n -- Total number of applicable criteria

Table 2 Inherent testability checklists

Testability design criteria	WT	Total number	Number meeting criteria	Score	WT score
Criterion 1	10	5	2	40	400
Criterion 2	1	5	2	40	40
Criterion 3	5	8	4	50	250
Criterion 4	10	8	4	50	500
Criterion 5	5	8	4	50	500
Criterion 6	1	5	0	0	0
Criterion 7	5	5	1	20	100
Criterion 8	5	5	1	20	100
Criterion 9	5	5	1	20	100
Criterion 10	1	5	2	40	40
Criterion 11	5	8	4	50	250
Criterion 12	5	20	12	60	600
Criterion 13	5	5	1	20	100
Criterion 14	10	8	4	50	250
Criterion 15	5	8	4	50	500
Criterion 16	1	5	1	20	20
Criterion 17	1	5	1	20	20
Criterion 18	5	5	1	20	100
Criterion 19	5	8	4	50	250
Criterion 20	5	5	1	20	100
Criterion 21	1	5	1	20	20
Criterion 22	5	5	0	0	0
Criterion 23	1	5	1	20	20
Criterion 24	1	5	1	20	20
Criterion 25	5	5	1	20	200
Criterion 26	1	7	4	57	57
Criterion 27	5	4	4	100	500
Criterion 28	1	4	4	100	100
Criterion 29	1	4	2	50	50
Criterion 30	5	4	4	100	500
Criterion 31	5	7	0	0	0
Criterion 32	1	8	4	50	50
Criterion 33	5	8	4	50	500
Criterion 34	5	8	4	50	250
Criterion 35	5	5	1	20	100
Criterion 36	5	5	2	40	200
Criterion 37	1	8	4	50	50
Criterion 38	5	5	4	80	400
Criterion 39	5	5	5	100	500
Criterion 40	5	5	5	100	500
Criterion 41	1	5	5	100	100
Criterion 42	1	5	5	100	100
Criterion 43	5	5	2	40	200
Total	170				8637

So, the inherent testability value of SP gun chassis is achieved.

$$TFOM = \sum_{i=1}^n S_{wi} / \sum_{i=1}^n W_i = 8637 / 170 \approx 51$$

“Testability program for equipment” demands that inherent testability threshold value of a weapon system should be between 85 and 95 [6]. However, that value of SP Gun chassis in service is 51. It indicates that the testability of SP Gun should be improved urgently, especially, to solve this problem in design of new type SP Guns.

REFERENCES

- [1] Gan maozhi, “Maintainability designing and certification,” Beijing, national defence industry press, 1995 (in Chinese).
- [2] Zheng haiqi, “Report for SP Gun integrated detection compartment,” Shijiazhuang, Ordnance engineering college, 1998 (in Chinese).
- [3] Kong qingchun, “SP howitzer construction and maintenance,” Shijiazhuang, Ordnance engineering college, 1992 (in Chinese).
- [4] Wei youmin, “Research on testability of SP Gun,” Shijiazhuang, Ordnance engineering college, 2000 (in Chinese)
- [5] GJB2547: Testability program for Equipment, 1995 (in Chinese).
- [6] MIL-STD-2165: Testability program for system & equipment, 1993
- [7] Jeffrey A.Schutt; “A commonsense approach to good testing,” Test Engineering & Management, Aug./Sep. 1998
- [8] Colin Maunder, “A universal framework for managed built-in test,” International test conference, 1993, pp.21-29