土协
力工程学会

ISSN 1006-1007

3

□□□□

第□□卷第□期　总第□□□期
（季刊，□□□□年创刊）

编辑委

委：

委：　　杨

委：

：杨

编：

编：　　杨

辑：

辑：

辑　：《　　》辑

：　　18

：611731

：028-87898262/63

：028-87898267

：dfdqpl@dongfang.com

：　　782

□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
…… 桑梓　赵铖冲　沈宇等(1)
□□□□□□□□□□□□□□□□□□□□
…… 马海迎　袁晓舒　桑梓等(9)
□□□□□□□□□□□□□□□□□□□□
…… 袁晓舒　张愉　　等(17)
□□□□□□□□□□□□□□□□
…… 　　等(25)
□□□□□□□　M□□□□□□□□
…… 　　等(29)
□□□□□□□□□□□□□ …… 　　晓　等(33)

□□□□□□□□□□□□□□□□ …… (39)
□□□□□□□□□□ …… (43)
□□□□□□□□□ …… (48)
□□□□　□□□□□□□□□□□□□□□□
…… 　　等(50)
□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
…… (54)
□□700 M　□□□□□□C　□□□□□
…… 等(58)

□□□□□□□□□ …… 　　等(3)
□□□□□□□□□□□□□□□□□□□□
…… 　　等( )
350 M　□□□□□□□□□□□□□□□□□□□□
…… 　　(70)

□□“□□□”□□□□□□□□“□□□”□□□□ …… (74)

□□□□□□□□□□□□□□□□□□□□ …… (80)
CA 1000□□□□□□□□□□□□□□□□□□□□
…… 　　等(84)
□□ …… (24)

[　　]CN51-1333/TM*1987*q*A4*88*zh*p*¥8.00*750*18*2021-03

EDITORIAL BOARD

Chairman: [illegible]

VP[illegible]B:nSSbnPLBB:nrbbbbbfnPLOB:nrs:VSbcnPLRBnsrSMbfses[illegible]

1 * ضم 2 2 ثج 1

2021 – 07 – 09
2019YFG0534

1985 – 2012
sangzi@ dongfang. com

بخ شمخ وسلم

شح

شمخ شي سمم

تى شمخ

شمخ بخ

شمخ ئه

شمخ

1 – 4 ضى لجم

شمخ

مجم

بخ

تهـ بم

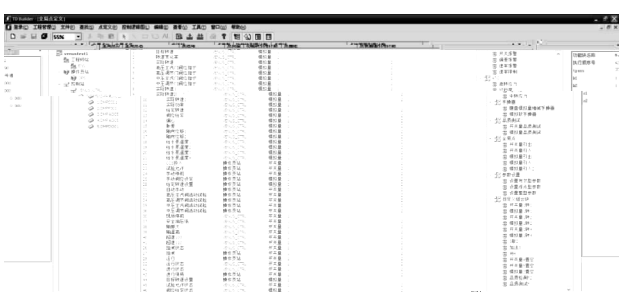
شمخ في نخ يه نم

DCS

1. 3

1

TD6000 Visual C ++ Windows 2 TD Builder TD Supervisor 1 TD6000 TD Builder I/O I/O TD Supervisor TD Builder



2 TD6000

Ovation Ovation Engineering Tools Ovation Applications Ovation Utilities Windows Unix 3

1 TD6000

TD Builder	
TD Supervisor	/
TD Monitor Plus	/ I/O
TD User Manager	

3 Ovation

Ovation Ovation Developer Studio I/O OvationControl Builder Ovation Graphics Builder Ovation Developer Studio

2

2 Ovation

Ovation Developer Studio	
OvationControl Builder	
Ovation Graphics Builder	HMI
Graphics	/
SignalDiagram	/

Ovation

TCP/IP

000

ation

3

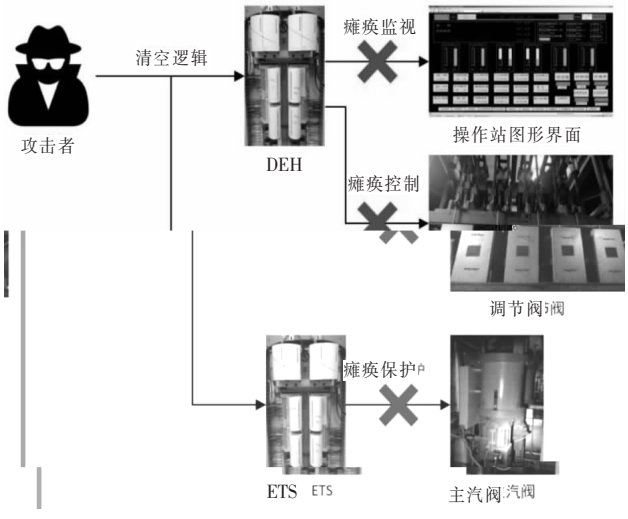
DEH

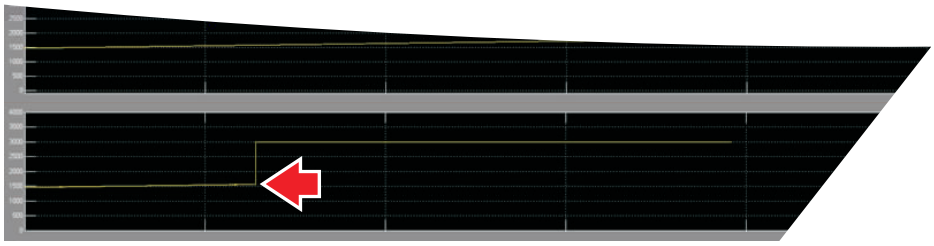
工程师站

DEH

تجي ضى شمخ ضخى أهـ

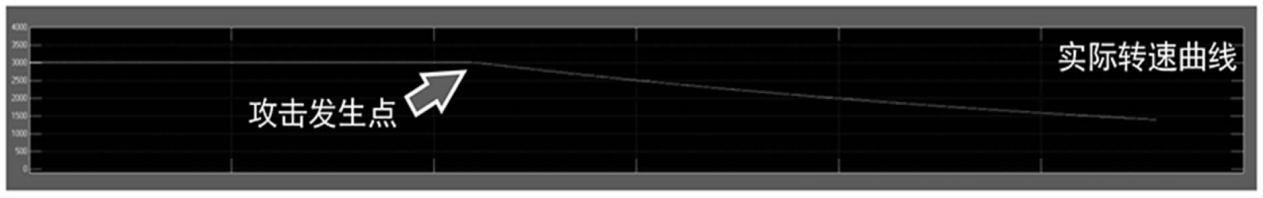
شمخ بخ 6





a TD6000 شنج b Ovation شنج

11



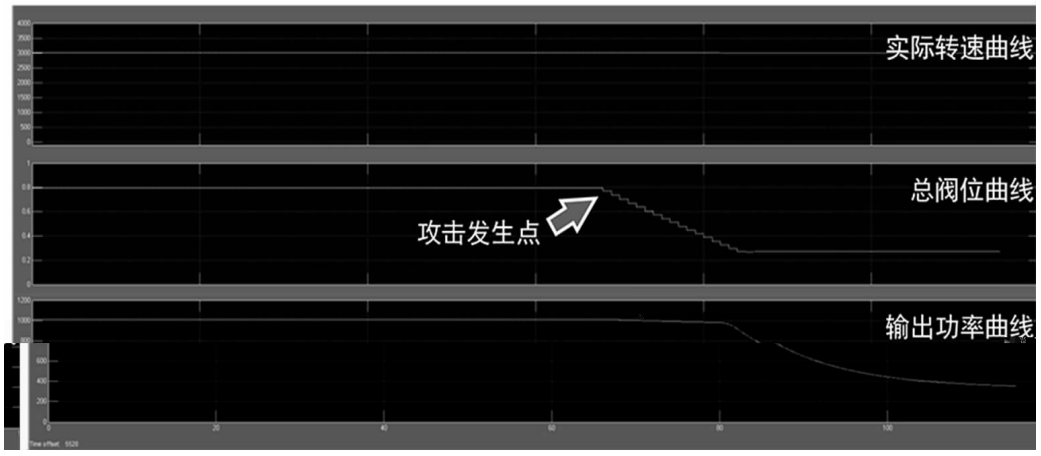
12

a TD6000 b Ovation

13

a TD6000 شنج b Ovation شنج

14



15

4

كا بخ

شمخ شمخ

كه

في شمخ

تم شمخ في DEH

شمخ

شمخ شمخ ثه تى شمخ

ضخ تمخ بخ

شمخ ضر وسلم

شمخ

شمخ ثم مجه

تم شمخ

يخ يحي شي تم تمح

حى سه ثم مجه

1 Stouffer K Falco J Scarfone K. Guide to industrial control systems ICS security J . NIST special publication 2011 800 – 82

2 . J . لمح 2013 30 3 38 – 42

3 . شمخ نج شمخ D . شخ 2013

4 . شمخ D . شخ شخ 2015

5 GB/T 26863 – 2011 مجه S . بخ مجه كه 2011

6 قح . Linux شمخ مم J . مجه بخ 2013 21 17 50 – 52 + 59

7 D. Dzung M. Naedele T. P. Von Hoff and M. Crevatin. Security for industrial communication systems J . Proceedings of the IEEE 2005 93 6 1152 – 1177 doi 10.1109/JPROC.2005.849714

8 . لم D . مجه شخ 2006

9 . شمخ مجه نج J . مجه مصي 2018 32 2 15 – 20 + 28

欢迎投稿 欢迎订阅

1 2 * 2 * 1
1. 210094 2. 611731

PLC PLC PLC
TP393.08 A 1001-9006 2021 03-0009-08

Formal Modeling for Programmable Logic Controller of Industrial Control Systems

MA Haiying[1], *YUAN Xiaoshu*[2*], *SANG Zi*[2*], *HE Lidong*[1]

(1. Nanjing University of Science and Technology, 210094, Nanjing, China;

2. DEC Academy of Science and Technology Co., Ltd., 611731, Chengdu, China)

Abstract: In recent years, the security threats of industrial control systems attracte widely attention. Unlike the traditional attacks against communication protocols, attackers gradually shift their focus to the controller itself. In order to deal with this new threat, scholars begin to study the model of the controller to describe and analyze this attack, and then to defend against the attack in time. However, traditional model as differential equation or difference equation is difficult to describe the overall control logic of the system, and it is difficult to analyze the security threats in the industrial control system. In summarizing the corresponding research, this paper briefly introduces the formal methods used to build the model, and the general industrial control system and the structure of the commonly used PLC. A PLC hardware and control logic model established by a formal method is proposed, and various common characteristics in the formal method are expounded through a simple PLC control case.

Key words: industrial control system; PLC; formal method

ICS Industrial control system ICS

[1] [2]

2021 – 07 – 19

61973163

2019YFG0534

1998 – 2016

1973 – yuanxs@dongfang.com

1985 – sangzi@dongfang.com

Formal method

Petri

3 4 5 6

① ②

$$x_1 \xrightarrow[1]{u} x'_1 \quad x_2 \xrightarrow[2]{u} x'_2$$

$$u \in U_1 \cap U_2 \quad x_1 \ x_2 \xrightarrow{u} x'_1 \ x'_2$$

$$\text{iff } x_1 \xrightarrow[1]{u} x'_1 \text{ and } x_2 \xrightarrow[2]{u} x'_2 \qquad 7$$

2 1 U 1

$$x_1 \xrightarrow[1]{u} x'_1$$

$$u \in U_1 \setminus U_2 \quad x_1 \ x_2 \xrightarrow{u} x'_1 \ x_2 \quad \text{iff } x_1 \xrightarrow[1]{u} x'_1 \qquad 8$$

3 2 U 2

$$x_2 \xrightarrow[2]{u} x'_2$$

$$u \in U_2 \setminus U_1 \quad x_1 \ x_2 \xrightarrow{u} x_1 \ x'_2 \quad \text{iff } x_2 \xrightarrow[1]{u} x'_2 \qquad 9$$

1. 3. 3

LTS

LTS

AP

$$Trace \ T \subseteq 2^{AP} \ \omega \qquad 10$$

P

$$T \models P \text{ if } Trace \ T \subseteq P \qquad 11$$

$\models$

1. 3. 4 °

σ

$$P_{\text{safe}} \cap \ \sigma' \in 2^{AP} \ \omega \ \hat{\sigma} \text{ is a finite prefix of } \sigma' \ = \varnothing$$

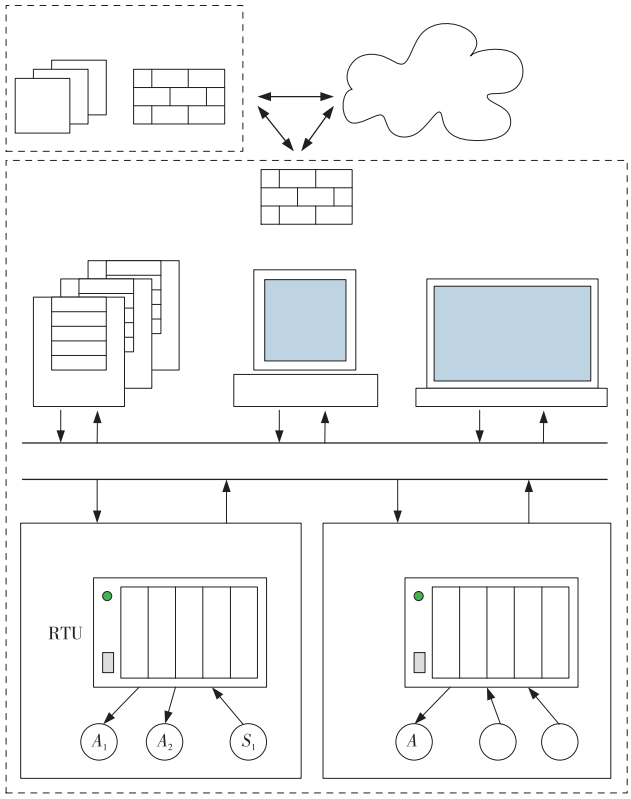
12

1. 3. 5

2 PLC

2. 1

3



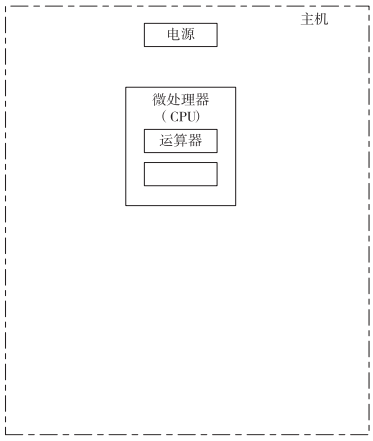
2.3 PLC

PLC

PLC

CPU RAM ROM

[12] 4



نح يخ شمخ PLC شمخ

PLC نح ضض شمخ كم

شمخ بخ شمخ نه بخ

نح شمخ PLC بخ بخ

شمخ سمم شمخ نح

startCyc finCyc أه

3. 1. 2 PLC شمخ

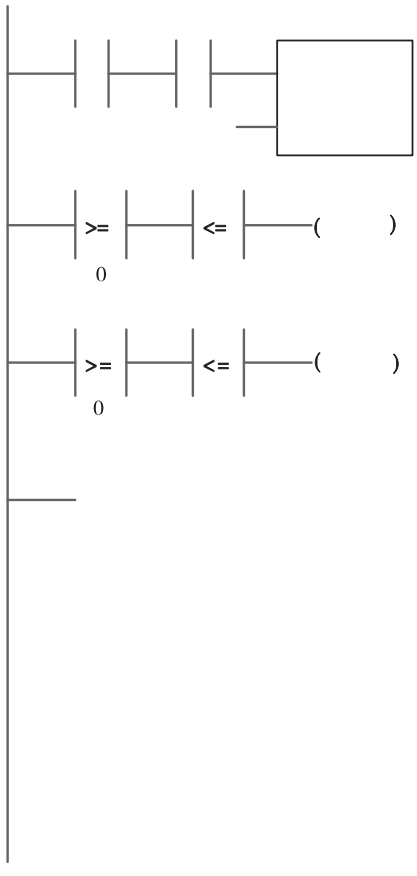
PLC شمخ “

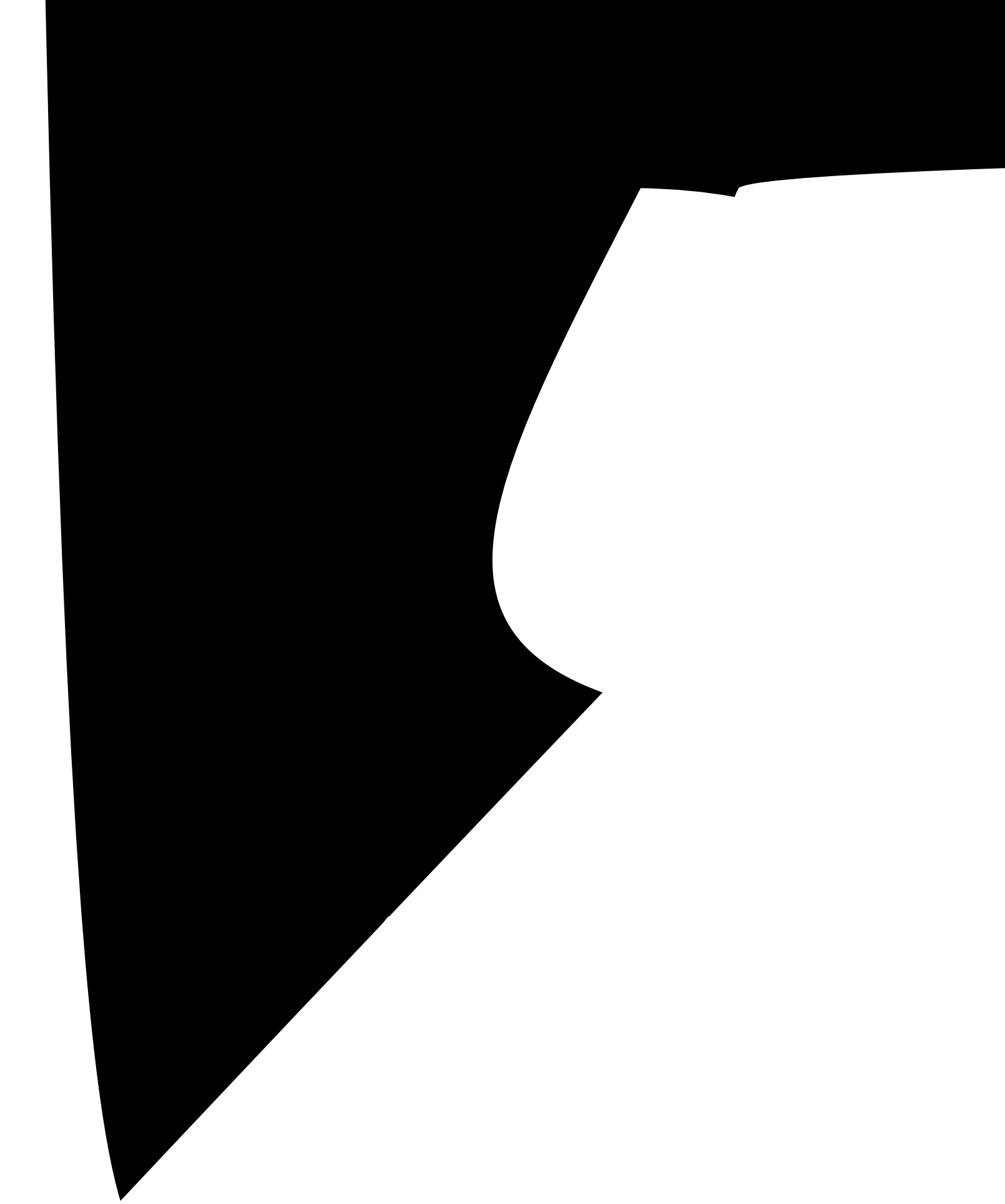
نجـ شي أه بخ ” كم

سمم شي نجي

شمخ شي كم شي كم شي كم

كم 7


>=
<=
0
>=
<=
0



1 * 1 1 1 2

1. 611731 2. 210094

TM73 TP393.08 A 1001-9006 2021 03-0017-08

Research on False Data Injection Attack of Power Plant Steam Turbine

YUAN Xiaoshu[1*], *ZHANG Yufei*[1], *YANG Bo*[1], *SANG Zi*[1], *XIE Yunyun*[2]

(1. DEC Academy of Science and Technology Co., Ltd., 611731, Chengdu, China;

2. Nanjing University of Science and Technology, 210094, Nanjing, China)

Abstract: In recent years, with the frequent occurrence of power network security incidents and the development of smart energy technology, power system and its control system are facing more and more network security threats. In the network security attacks of power system, especially power grid, the false data injection attack is considered as a main attack mode. In previous studies, the network security attack is usually considered as a disturbance to the control system. Based on the false data injection attack, this paper analyzes and verifies the network security attack of steam turbine in power plant which is less studied in the past, and erified that the false data injection attack can threaten the safety of steam turbine operation in power plant. An idea is proposed that network security attack is considered as input to control system rather than disturbance.

Key words: false data injection; attack control system; network security; steam turbine

2015

12 23 1

2019 3 7 – 3 9

2021 – 07 – 19

2019YFG0534

1973 – 2013

yuanxs@ dongfang. com

[2] [3] false data injection attacks FDIAs [4] [5] [6-8] FDIAs [9] [10] [10] FDLAs FDLAs FDLAs FDLAs

1

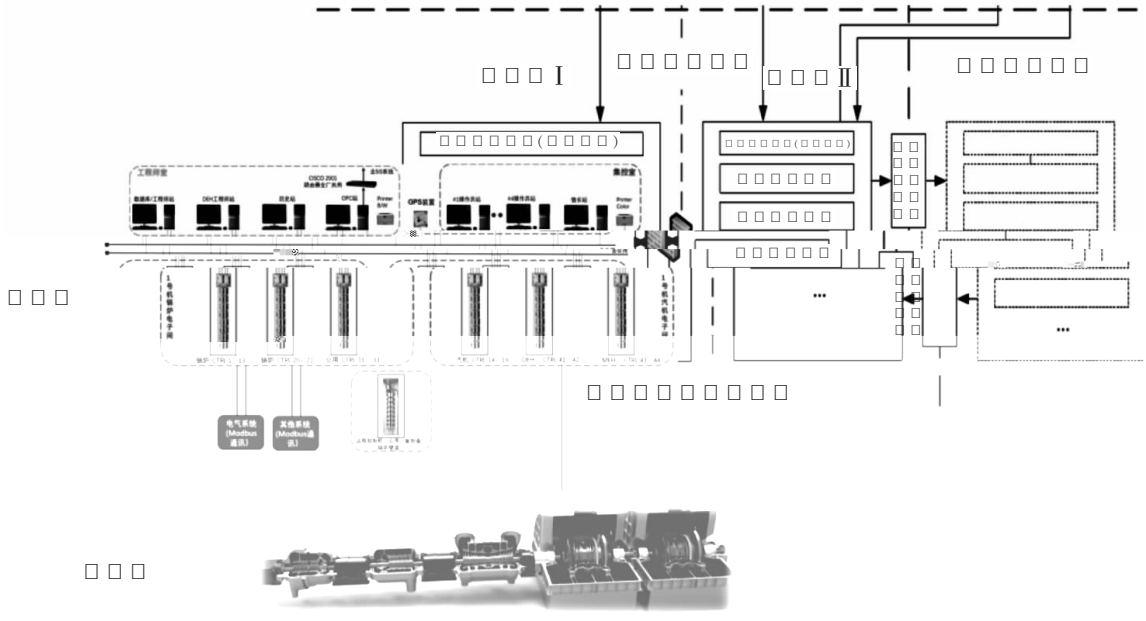
1.1

1.2

DEH ETS TSI DEH EST DEH ETS TSI

1.3

1



Ⅰ
Ⅱ

نج ضر

يخ ضض يخ شمخ نج

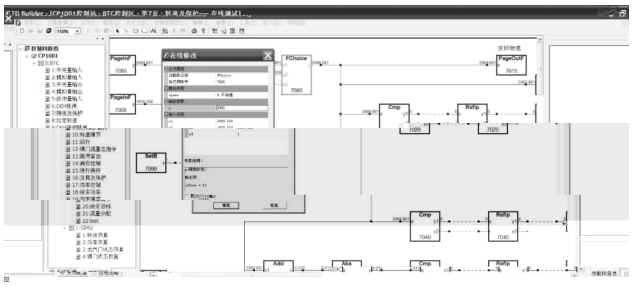
$J\ x$ τ $J\ x$ τ

مد شمخ

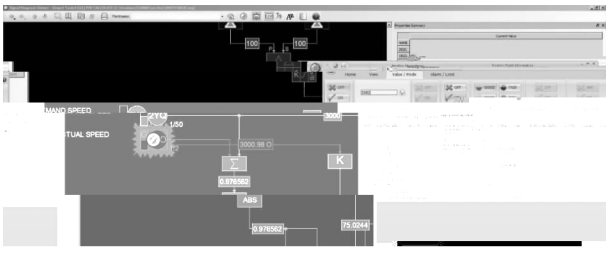
2. 1. 2

يخ نخ نخ يه يه نخ

6



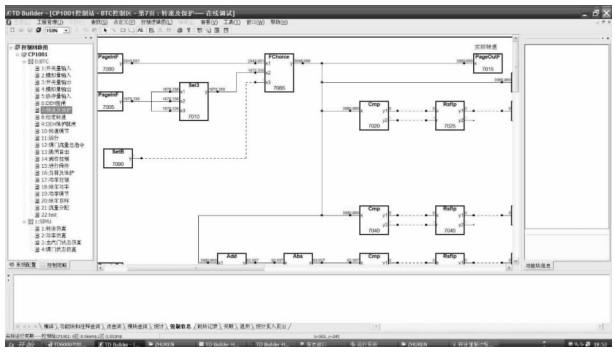
5 TD6000



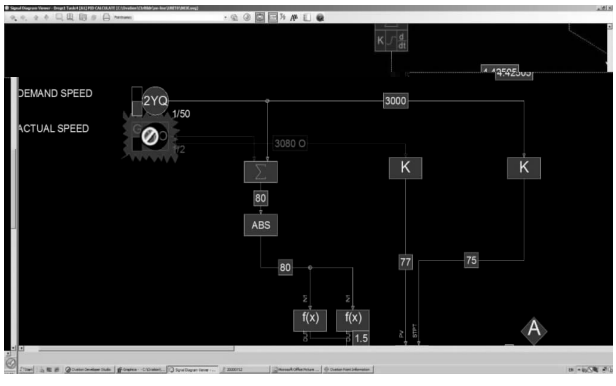
6 OvationOCR 400

3 080 /

7 8



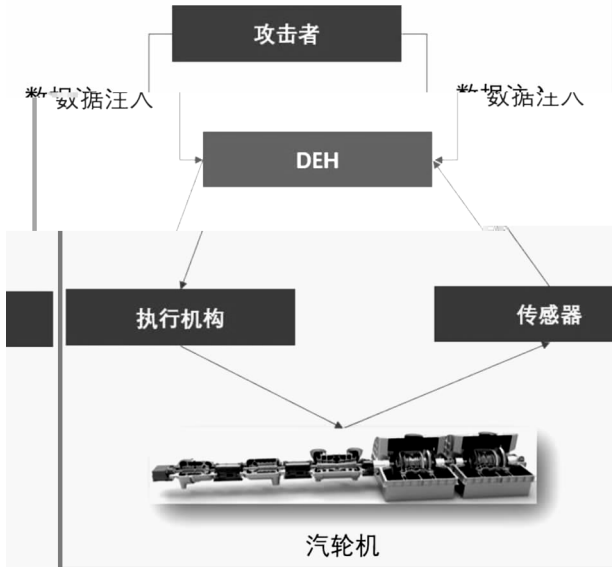
7 TD6000



8 OvationOCR 400

3. 2

FDIAs



9 FDIAs

FDIAs

①

②

③

④

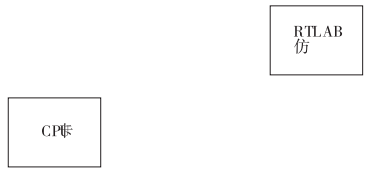
4

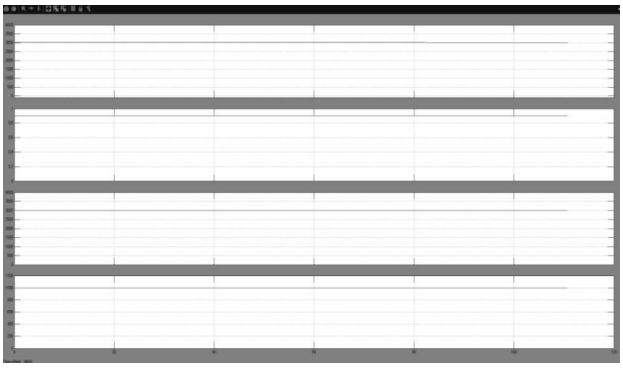
4. 1

1 000 MW

DEH 3

10


RTLAB
仿
CP
乐



16

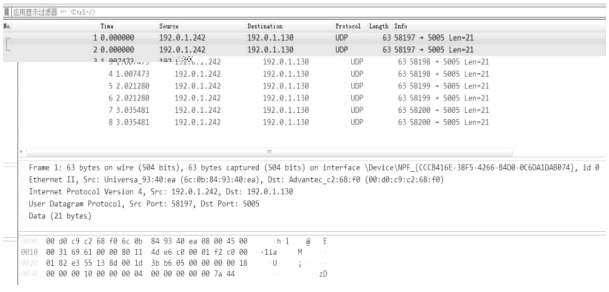
3 000 سمم ضى

3 000 نج 90% /

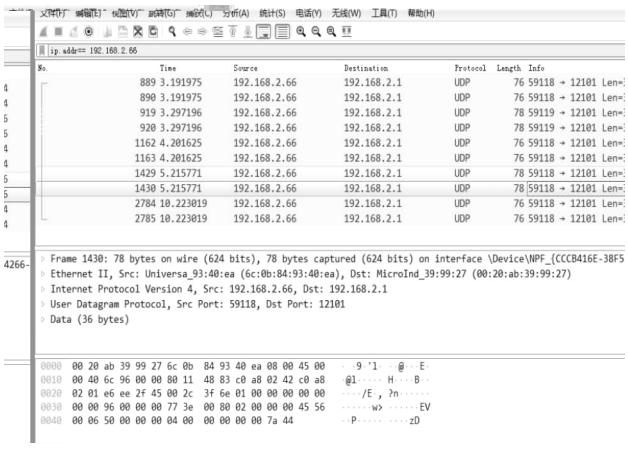
1 000 MW كم /

يحي كا تى

1 000 17 18



17 TD6000



18 OvationOCR 400

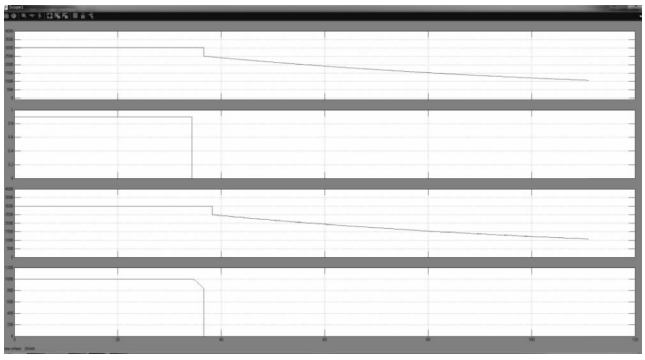
DEH نم 1 000 يحي DEH

19 20 لحم نم ضى

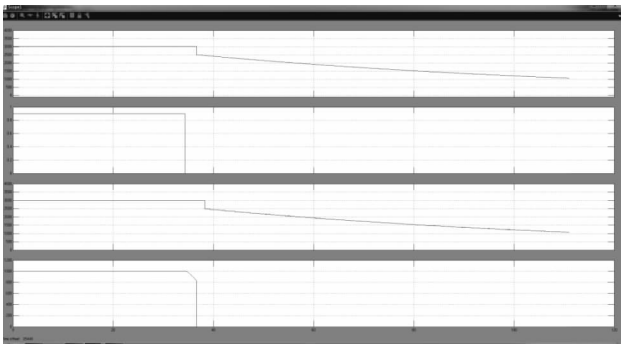
0 / سمم

0 نج

0 MW كم 0 /



19 TD6000



20 Ovation OCR 400

5

تى

نه شمخ تى شمخ

شمخ صى كم ئه

شمخ ئه

FDLAs ئه

شمخ لحم ضى

ئه

FDLAs

تمخ شمخ شمخ

شمخ

شمخ

FDLA شمخ نه تمخ

نه تمخ شمخ

كم سمم شمخ

ئه كم شمخ صى

تمخ شمخ

نه شمخ

شمخ شمخ

تمخ نه شمخ

شمخ شمخ

1 .
J . 2016 40 5 145 – 147
2 .
J . 2019 45 1 5 – 24
3 .
J . 2016 40 17 59 – 69
4 Li F Yan X Xie Y et al. A Review of Cyber-Attack Methods in Cyber-physical Power System C . 2019 IEEE 8th International Conference on Advanced Power System Automation and Protection APAP 2019 1335 – 1339
5 J . .
2016 40 11 3406 – 3414
6 M A Rahman H Mohsenian-Rad. False Data Injection Attacks with Incomplete Information against Smart Power Grids C . 2012 IEEE Global Communications Conference GLOBECOM 2012 3153 – 3158
7 X Liu Z Li. Local Load Redistribution Attacks in Power Systems With Incomplete Network Information J . IEEE Transactions on Smart Grid 5 4 1665 – 1676
8 X Liu Z Bao D Lu et al. Modeling of Local False Data Injection Attacks With Reduced Network Information J . IEEE Transactions on Smart Grid 6 4 1686 – 1696
9 . D .
2018
10 . D .
2020
11
12 J . .
2016 40 11 3406 – 3414
13 Liu X Li Z Liu X et al. Masking Transmission Line Outages via False Data Injection Attacks J . IEEE Transactions on Information Forensics and Security 11 7 1592 – 1602
14 .
J . 2021 37 2 205 – 210

16

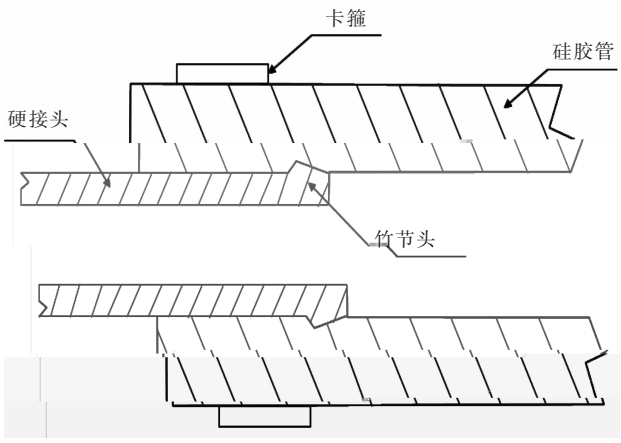
6 Rajeev Alur David L. Dill. A theory of timed automata J . Theoretical computer science 1994 126 2 183 – 235
7 M B Younis G Frey. Formalization of PLC programs to sustain reliability C . IEEE Conference on Robotics Automation and Mechatronics 2004 2 613 – 618
8 Willems H. Compact Timed Automata for PLC Programs. 1999. https //pms. cs. ru. nl/iris-diglib/src/getContent. php id = 2006-Willems-CompactAutomata
9 Heiner M Menzel T. A Petri Net Semantics for the PLC Language Instruction List J . Wodes 1998
10 T. Mertke G. Frey. Formal verification of PLC programs generated from signal interpreted Petri nets C . 2001 IEEE International Conference on Systems 2001 4 2700 – 2705
11 X. Weng L. Litz. Verification of logic control design using SIPN and model checking methods and case study C . Proceedings of the 2000 American Control Conference 2000 6 4072 – 4076
12 . – https // www. bilibili. com/video/BV12r4y1w7DF from = search&seid = 16915408343621234652
13 Rui Wang Yong Guan Luo Liming et al. Component – Based Formal Modeling of PLC Systems J . Journal of Applied Mathematics 2013
14 . PLC M .
2015

500

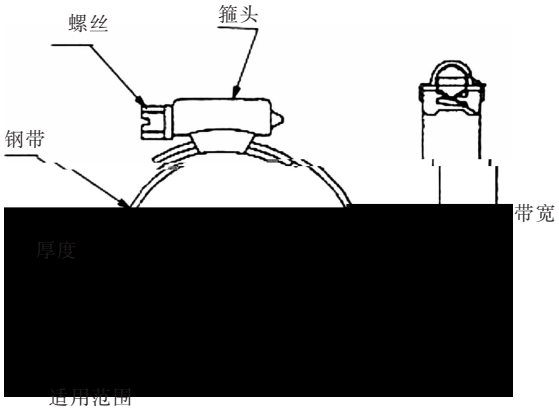
7 23

500

来源 东方电气网



1



2

2

1 [1]

$$U=\sum_{i+j=1}^{N}C_{ij}\ (I_1-3)^i\ (I_2-3)^j+\sum_{i=1}^{N}\frac{1}{D_i}\ (J_{el}-1)^{2i} \tag{1}$$

U J_{el} I_1

I_2 C_{ij}

D_i

Mooney-Rivlin

Mooney-Rivlin

1

$N=1$ 1 2

150%

$$U=C_1\ (I_1-3)+C_2\ (I_2-3) \tag{2}$$

C_1 C_2 3

$$E=6\ (C_1+C_2) \tag{3}$$

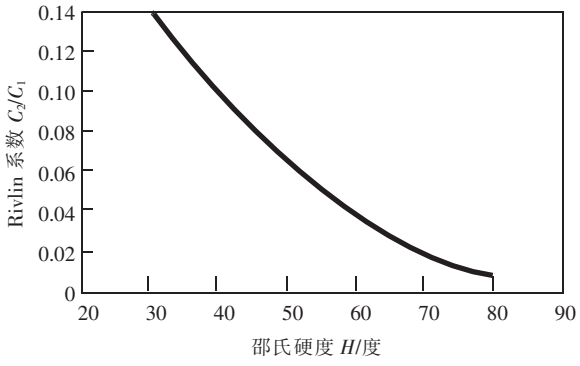
30 ~ 80 E

4 [2]

$$E=6.72\times10^{-3}\sqrt{H^3} \tag{4}$$

H C_2/C_1

3



3 C_2/C_1

79 4 $E=4.718\ 6$ MPa

3 2 $C_1=0.778\ 6$ $C_2=0.007\ 8$

3

4

5

6 [3]

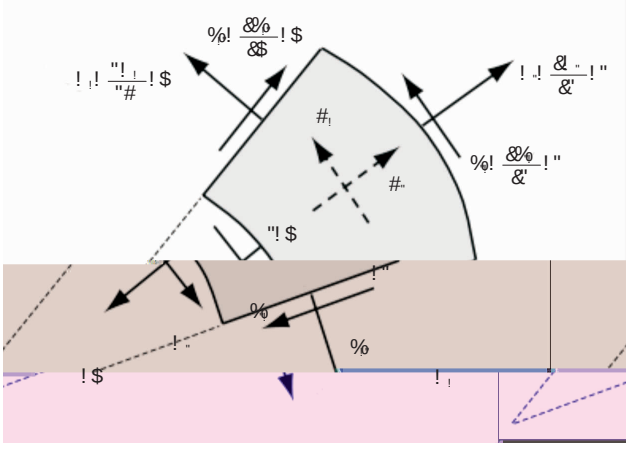
$$\frac{\partial\sigma_r}{\partial r}+\frac{\partial\tau_{r\theta}}{r\partial\theta}+\frac{\sigma_r-\sigma_\theta}{r}+f_r=0 \tag{5}$$

$$\frac{\partial\tau_{r\theta}}{\partial r}+\frac{\partial\sigma_\theta}{r\partial\theta}+\frac{2\tau_{r\theta}}{r}+f_\theta=0 \tag{6}$$

σ_r $\tau_{r\theta}$ σ_θ

r θ

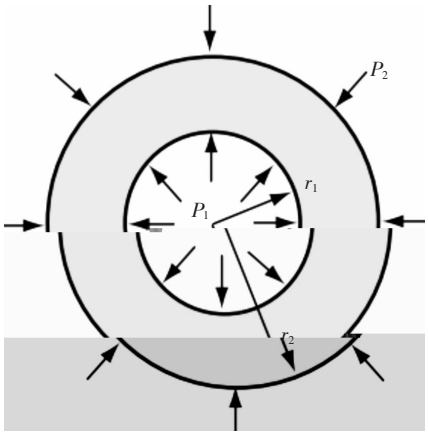
f_r f_θ



4

5

P_1 P_2



5

$r = r_1$ $\sigma_r = -P_1$ $\tau_{r\theta} = 0$

$r = r_2$ $\sigma_r = -P_2$ $\tau_{r\theta} = 0$

7

8

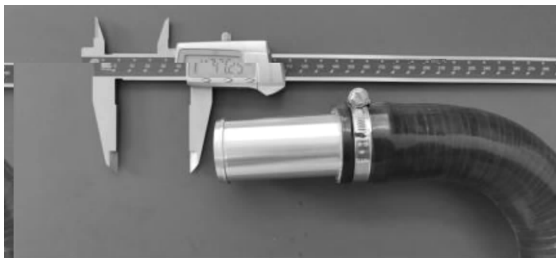
$$\sigma_r = \frac{r_1^2 r_2^2 \quad P_2 - P_1}{r_2^2 - r_1^2} \quad \frac{1}{r^2} + \frac{r_1^2 P_1 - r_2^2 P_2}{r_2^2 - r_1^2} \qquad 7$$

$$\sigma_\theta = -\frac{r_1^2 r_2^2 \quad P_2 - P_1}{r_2^2 - r_1^2} \quad \frac{1}{r^2} + \frac{r_1^2 P_1 - r_2^2 P_2}{r_2^2 - r_1^2} \qquad 8$$

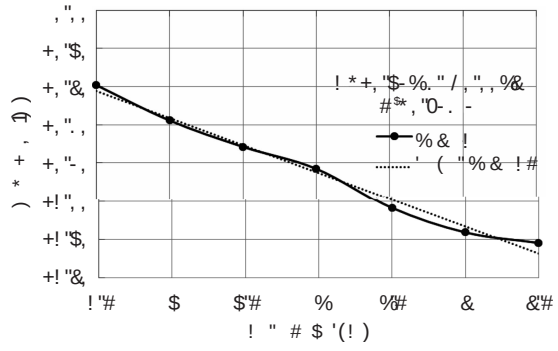
4

7 $1.5 \sim 3\ \mathrm{N \cdot m}$

$3\ \mathrm{N \cdot m}$



6 –



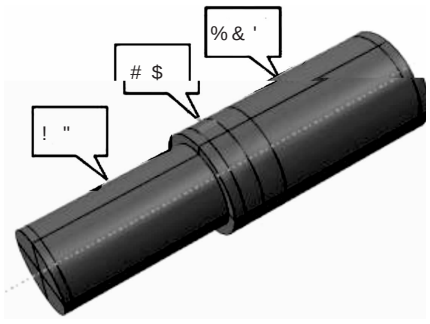
7 –

5

8 ABAQUS

9 –

$10 \sim 13$ 1 كم

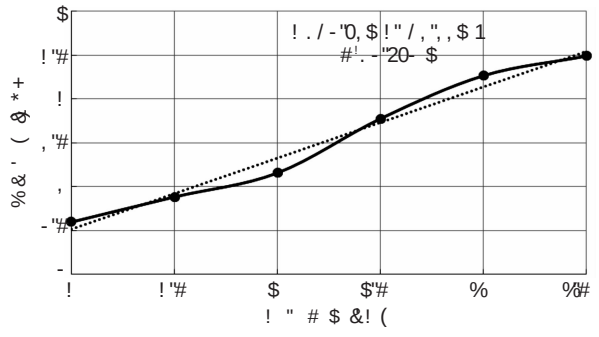


8

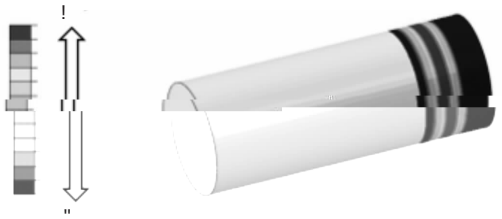
9

1 –

	/N·m	2	2.5	3	3.5	4	4.5
	/MPa	0.598	0.884	1.158	1.777	2.267	2.491



10 –



11

12

13

6

شمخ

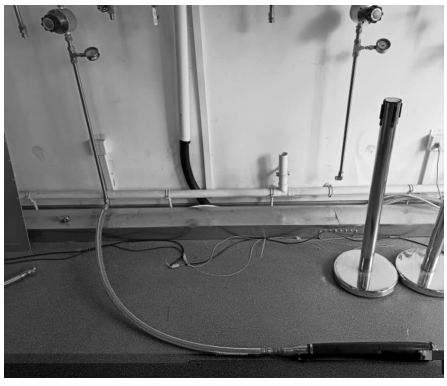
14 شمخ

شمخ 3 N·m جي 1 min

جي صمم 270 kPa

1.5 40

بخ



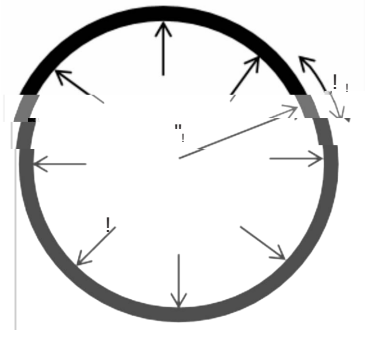
14

7

ضخ 15

σ_θ P

شمخ وسلم 9 [4]



15

$$\sigma_\theta \approx \frac{P \times r_0}{t} \qquad 9$$

32 لحم

PWM

ثج

611731

PWM
SVPWM
TM46 A 1001-9006 2021 03-0029-04

DC Capacitance Design of Battery-powered Three-phase PWM Converter

LIU Jingbo, WANG Duoping, TIAN Jun, YANG Jiawei, TANG Jian

(DEC Academy of Science and Technology Co., Ltd., 611731, Chengdu, China)

Abstract: Battery-powered three-phase PWM converter are widely used, but the design of DC capacitor generally relies on experience to estimate or through test, which empirical estimation is biased, and test design efficiency is not high implementation and is not convenient. Based on the principle of topology and modulation, the current situation of DC side is analyzed, the RMS value and average value of DC current are derived. According to the transfer function of the dc side current, a more accurate design method of DC current capacity is proposed, and the proposed design method is verified by simulation.

Key words: DC capacity; converter; SVPWM; battery

PWM i_{dc}

1

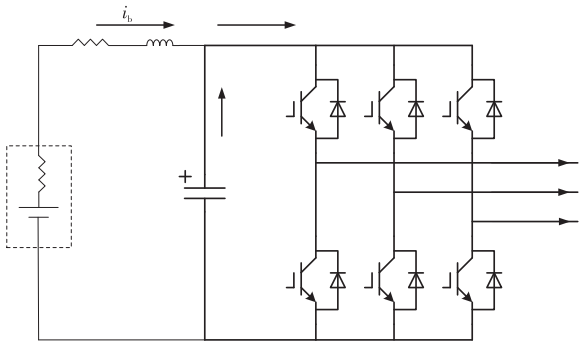
PWM

i_{dc}

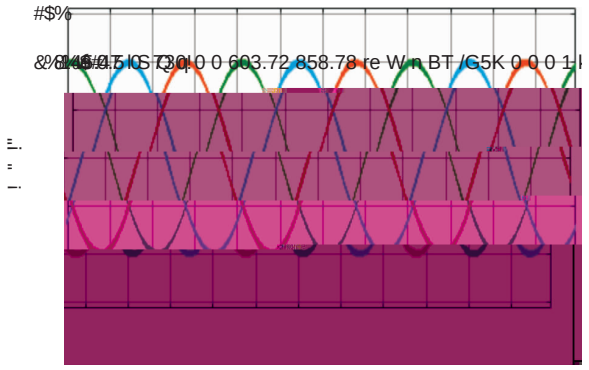
2021 – 04 – 02

2020YFG0350

1984 – 2011


i_{b}
+

$I_{\mathrm{m}} = 100\ \mathrm{A}$ 1 7



1

2021 – 01 – 20

1988 – 2013

1

7

في مى شمخ

3 ئج يحي ئج

شمخ

نج شمخ كا كم مى مح

بخ مى مى

وسلم بخ يحي يخ وسلم

يخ مى ئج شج نج يخ

يخ كم

ئه

حى ضحى فى طمم

شخ شمخ وسلم مى

شخ

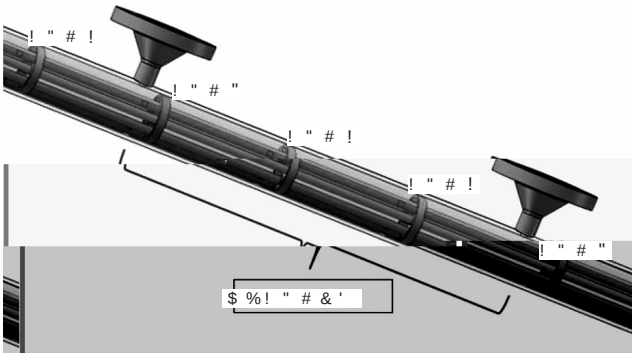
يحي

CFD

يخ ئج شج

ئج شج سمم ضى 1

وسلم تحج ئج 3



1

CFD يخ

ئج شج تحج

لحم حى CFD 1

ئج مى ئج شج

يخ

شمخ مح تجي

حى CFD

D_r m N_r

S_t وسلم تي m P_t

m D_w m H

m

3 صمم Cheng-Todreas

Cheng Todreas كم

نح صلى شمخ

صمم 6 5 ~ 10

تمخ $Re \leqslant Re_L$

$$f = \frac{C_{fL}}{Re} \qquad 5$$

تمخ $Re \geqslant Re_T$

$$f = \frac{C_{fT}}{Re^{0.18}} \qquad 6$$

تمخ $Re_L \leqslant Re \leqslant Re_T$

$$f = \frac{C_{fL}}{Re}\ 1 - \psi^{1/3} + \frac{C_{fT}}{Re^{0.18}}\psi^{1/3} \qquad 7$$

$$\log\left(\frac{Re_L}{300}\right) = 1.7\left(\frac{P_t}{D_r} - 1.0\right) \qquad 8$$

$$\log\left(\frac{Re_T}{10000}\right) = 0.7\left(\frac{P_t}{D_r} - 1.0\right) \qquad 9$$

$$\psi = \frac{\log\ Re\ -\ 1.7\ P_t/D_r\ +0.78}{2.52 -\ P_t/D_r} \qquad 10$$

ψ C_{fL} C_{fT} 6

4 كم

4 صمم Soblev

Soblev 7 كم صمم

11

$$f = \left[1 + 600\left(\frac{D_r}{H}\right)^2\left(\frac{P_t}{D_r} - 1\right)\right] \times$$

$$\left\{\frac{0.210}{Re^{0.25}}\left[1 + \left(\frac{P_t}{D_r} - 1\right)^{0.32}\right]\right\} \qquad 11$$

2

شمخ ئه

وسلم تى شمخ ئه ضحى

12

$$\Delta p_j = \zeta\frac{\rho V^2}{2} \qquad 12$$

ζ

شمخ حى صح يحي سمم لحم

شمخ 1 سمم مى في سمم شمخ نح صلى نه

لحم ئج

حى شخ 13 ~ 14

لحم

$$\zeta = 0.5\left(1 - \frac{S_2}{S_1}\right) \qquad 13$$

شخ لحم

$$\zeta = \left(\frac{S_1}{S_2} - 1\right)^2 \qquad 14$$

S_1 ئج m^2 S_2

ئج m^2

2.2 CFD

1

ئج شجشخ

CFD 2

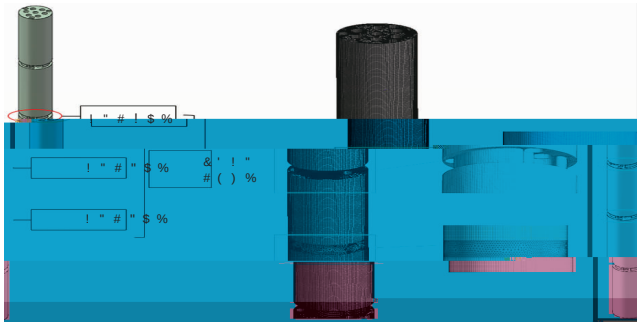
شمخ سمم وسلم ئج

تم شجي يخ

صلى ئج

ئج

شمخ 3



2 CFD 3

2

CFD مى

شمخ مى مى

كا شمخ وسلم مى

تى CFD شمخ سخي شجـ تحج

بخ لحم بخ CFD حى

15 ~ 16

$$!\ \rho\vec{V}V = 0 \qquad 15$$

$$!\ \vec{\rho}\vec{V}\vec{V} = !\ \mu\ !\ \vec{V} - !\ p + \rho f + S_p \qquad 16$$

CFD في SST

8 k-ω مم

k-ω SST

k-ω

k-ε

k ω

17 ~ 18

$$\frac{\partial(\rho k)}{\partial t}+\nabla\cdot(\rho\vec{V}k)=p_k-\beta^*\rho\omega k+\nabla\cdot\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\nabla k\right] \quad (17)$$

$$\frac{\partial(\rho\omega)}{\partial t}+\nabla\cdot(\rho\vec{V}\omega)=\alpha\frac{\omega}{k}p_\omega-\beta\rho\omega^2+\nabla\cdot\left[\left(\mu+\frac{\mu_t}{\sigma_\omega}\right)\nabla\omega\right] \quad (18)$$

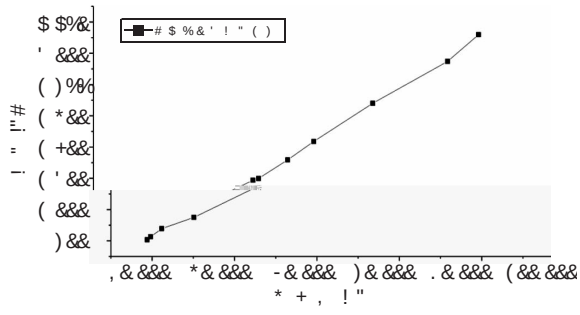
ρ $\vec{V}$ p μ

3

CFD

3.1

4



4

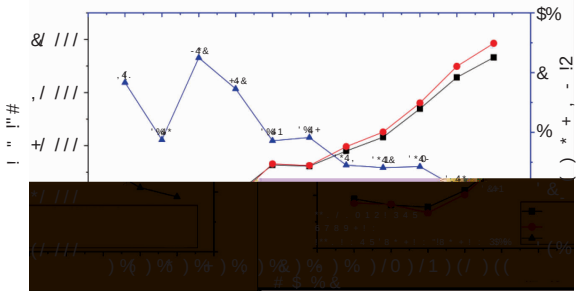
$$\Delta p=4.09151\times10^{-5}\times Re^{1.55363} \quad (19)$$

22

22

200 ℃

5



5

22

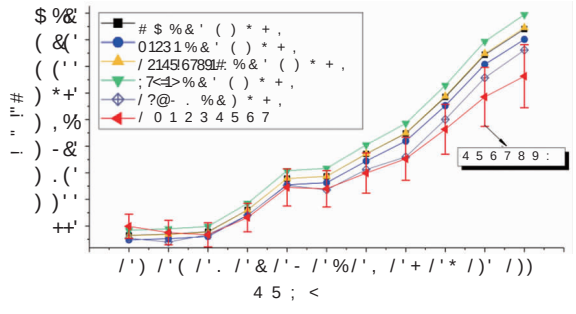
22

$\pm6.5\%$

CFD

6

CFD



6

CFD CFD

CFD

CFD

$X=0$ $Z=0$ $X=-Z$ 7

$X=Z$

8

Rehme

CFD

6

280 ℃ 340 ℃

3. 2

CFD

7 CFD

8 CFD

$-Y$

محـ ” “ وسلم ئهـ مى ئجـ

ئجـ مى شمخ

ئجـ

تحج ئجـ

شمخ طمم لحم

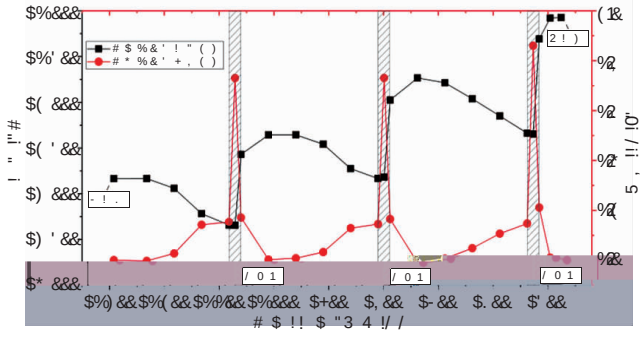
لحم بخـ لحم شمخ وسلم

شمخ

7 يخ شمخ

وسلم لحم

9



9

شمخ وسلم

بخـ لحم ئجـ

تحج وسلم Y شمخ

طمم كم ئجـ وسلم

شمخ وسلم ضم شخ وسلم ضم ئجـ

شخ شخ

ين

611731

TK47 A 1001-9006 2021 03-0039-04

A Brief Analysis of l a a

2021 – 07 – 09

ين 1982 – 2008

3 – 4 تي شمخ

شمخ ئه

1. 1

مجه مجه شخ

ثم

مجه كه تمخ فح

ئه سمه شجي

جي

ضى

يحي يحي ئه يحي

شمخ وسلم بخ

ضى شمخ حى

بخ ضى تم

شخ ضى

تي في قمح تمخ بخ شمخ

يحي ضى

تي شمخ وسلم بخ يحي مه شمخ

1. 2

بخ ضى تجي ئه مجه

بخ

شمخ كه يحي

شخ شمخ ثم مجه

نه شمخ ثم مجه شمخ ئه

ثم مجه شمخ

كه تى بخ

شمخ ضر ئه نه شمخ

شمخ يى

تى سمم تى

شمخ ثم مجه شمخ

تمخ

شمخ تى

شمخ

1. 3

ئه بخ

ضى

ئه فح شمخ

في كه في يحي

شمخ

شمخ نه

في ضى يحي شمخ

في شمخ ثم

شمخ شخ

شمخ ئه تح

كه

شمخ خج ئه شمخ

ئه شمخ

1. 4

تمخ GE مجه شمخ

شمخ يحي سمه

3

شخ صمم

شمخ شخ 4

ضى سمه تمخ

صمم شمخ

شمخ ئح

جي

تي

ئه ئه ثم شمخ

تي وسلم شخ

2

2. 1

شمخ مم

يحي مه شمخ مم

يحي تجي شمخ

مجه

2. 1. 1 يحي

نح مح يحي شمخ

مجه ثم مجه شمخ

حى يحي شمخ ضى مجه

تجي

كل شمخ

ثم مجه شمخ ثم مجه

شمخ شمخ يحي سمه ضى

2. 1. 2 شمخ

نه شخ ثم مجه شمخ

يحي حى لحم

شخ مجه قمح تمخ

ضى مجه شمخ قمح تمخ ئه مجه

فخم تجي تم شمخ قمح تمخ حى

قمح تمخ شمخ نم

قمح تمخ ثم

ضحى شمخ شمخ في

شمخ

شمخ قمح تمخ ثم 3

شمخ

شح ثم

شمخ سمم تم

تى شح ثم

ثم حى شح شمخ تجي

يجي فخم

فخم شح شمخ ثم

ضى جم تم ضى

تى شمخ

تجي شمخ شج 2. 2. 2

شمخ يحي شمخ

قمح تمخ مجم شمخ قمح

سخي شمخ

قمي شمخ مجم ضحى مجم

ضحى مجم مجم

2. 1. 3 تمخ

شمخ ثم مجم

ضى شمخ ثم ئه سخي

سخي شمخ ثم مجم

ضحى سمم تم شح شمخ ثم

ضخ لحم شمخ

3 2 A ثم مجم

شمخ سمم

2 1. 5 شمخ

2. 2

شمخ يحي

ضى

2. 2. 1 تجي تم

3 ضى تجي تم شمخ

1 تم

كا شمخ تم

جي مجم شمخ

شمخ

شمخ تى

شمخ

شمخ شمخ لى تم

شمخ تم قمح تم قمح تم

تم تم تم شمخ

هم شمخ ضحى

2 قمح تمخ

شمخ تم مح

تى شمخ يحي في قمح تمخ شمخ بخ

شي حى

شمخ شمخ تم

100

618000

TG306 A 1001-9006 2021 03-0043-05

Study on the Cold-bending Forming Process of Copper Lead

YANG Zongming, YANG Jun, YIN Xiang

(Dongfang Electric Machinery Co., Ltd., 61800 [illegible])

2021 – 07 – 09

5 mm 0.1 mm

*R*8 *R*5

*R*8 *R*5

ASME PT

1 *R*8 *R*5 7

a *R*8 b *R*5

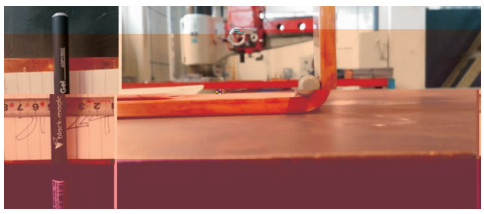
7

2 8

a *R*8 b *R*5

8

3 9



9

4 PT 10

ASME

10 *R* PT

R

PT

5

1

2 3

R_{min}

3 6

4

5

6

3

			/mm		/mm	/mm	≤0.2	≤0.4
1		CU-ETP-R300	5X100		20			
2		TU2Y	6X95		20			
3		ASTMB187	5X71		15			
4		SECUF25	8X105		15			
5		SECUF25	8X105		50			

طمح

611731

ي شمخ لحه ن ن ئه شمخ م لحه شمخ لحه شمخ كه شجي

لحه

TM621 A 1001-9006 2021 03-0048-02

The Selection Calculation Method of Start-up Expansion Tank

LONG Qiong, YI Guangzhou, DENG ke

(Dongfang Boiler Group Co., Ltd., 611731, Chengdu, China)

Abstract: The selection calculation method of start-up expansion tank is closely related to the economic input cost in power plant. This article takes a certain project as a calculation model, and a suitable selection calculation method is obtained by comparing several selection calculation methods.

Key words: start-up expansion tank; the selection calculation method

لحه نه

ضر تى

600 MW في

تجي لحه

شمخ يحي ئه

شمخ وسلم يحي كه

كه ضحي

وسلم مح

ضحى ضحى

كه مجد شمخ

شمخ ضحى لحه ضر كه

ئه شخ

شمخ

1

1.1 D

1 وسلم X

2021 – 07 – 09

1982 – 2007 شخ لحه بخ بخ ممي مجه ممي

$$X = \frac{H - H'}{H'' - H'} \quad 1$$

H kJ/kg H'

kJ/kg H'' kJ/kg

2 بم W_s

$$W_s = WXa \quad 2$$

W_s t/h W شمخ

t/h a وسلم 1.03

3 شمخ A_{sd}

$$A_{sd} = \frac{W_s \times V_1}{3.6 \times \upsilon} \quad 3$$

A_{sd} شمخ شمخ m^2 V_1

m^3 v وسلم m/s

4 D

$$D = \sqrt{\frac{4W_s \times V_1}{3.6\pi\upsilon}} \quad 4$$

D mm

1

<a>

8 m/s 2.44 m/s 4 m/s 1.22 m/s

<b> HG/T 20570.8-1995 –

$$V_t = \left[\frac{4g \times d \times (\rho_L - \rho_G)}{3C_W \rho_G}\right]^{0.5} \quad Re = \frac{d \times V_t' \times \rho_G}{\mu_G} \qquad (5)$$

ρ_G kg/m^3 ρ_L kg/m^3 V_t m/s d μm μ_G Pa·s g 9.81 m/s^2 C_w Re d 200 μm 350 μm V_t' 10 m/s $Re \approx 1135$ C_w 5 $V_t \approx 0.74$ m/s $V_t' - V_t = 9.26$

$V_t \approx V_t'$ C_w Re Re $C_w \approx 1$ $Re \approx 138.5$ $V_t \approx 0.49$ m/s $V_t' - V_t = 0.73$ m/s <b> <a>

1.22 m/s 1.22 m/s 2

10 MPa a 7 MPa a 250 ~ 311 ℃ 634 t/h 1.8 ± 0.2 MPa a ≤ 207 ℃ 1

1

	υ m/s	D mm
1	10	835
2	2.44	1 695
3	1.22	2 390

1.2

800 ~ 1 000 m^3/(h·m^3)^4 2 000 ~ 3 000 m^3/(h·m^3)^4

V_1

$$V_1 = \frac{1\,000\ Ws}{R} \times v_1 \qquad (6)$$

R m^3/(h·m^3) v_1 m^3/kg

V_2

3 ~ 5

^{4} 30%

$$V = V_1 + V_2$$

2

2

	R m^3/(h·m^3)	V_1 m^3	V m^3
1	800	24.6	32
2	1 000	19.7	25.6
3	2 000	9.86	12.8
4	3 000	6.58	8.55

2

HG/T 20570.8-1995 –

1.22 m/s

2 390 mm 10 m/s 835 mm

2.44 m/s DN2100

1.58 m/s

0.99

800 m^3/(h·m^3) 24.6 m^3 32 m^3 V D 9.24 m

VPI

618000

ANSYS VPI

VPI
TM31 A 1001-9006 2021 03-0050-04

The Study on the Influence of VPI Mock on Dielectric Loss of Stator Coil for AC Rotating Machine

YANG Shuai, HUANG Ze, ZHOU Jin, CHEN Sheng, ZUO Rui, HU Bo

(Dongfang Electric Machinery Co., Ltd., 618000, Deyang, Sichuan, China)

Abstract: Through the structure analysis of stator coil and its mocks for vacuum press impregnation (VPI) of AC rotating machine, relative circuit model is established in this paper. The relationship including average thickness of varnish on the surface of conductive layer of coil, the length of neighborhood contact points between varnish and conductive layer, surface potential on the slot part of coil are simulated by ANSYS software. On the basis of results, the influence of surface potential on the slot part of coil on the measured value of dielectric loss of stator coil are analyzed. The results show that the measured value of dielectric loss of stator coil is affected by average thickness of varnish on the surface of conductive layer, the length of neighborhood contact points between varnish and conductive layer, the thickness of main insulation, dielectric constant of main insulation and so on.

Key words: AC rotating machine; VPI mock; stator coil; dielectric loss

1 – 3

GVPI

GVPI

2021 – 07 – 09

1988 – 2015

يحي شمخ بخ يحي

شمخ حى يحي

مجه مجه

مم

في

يحي

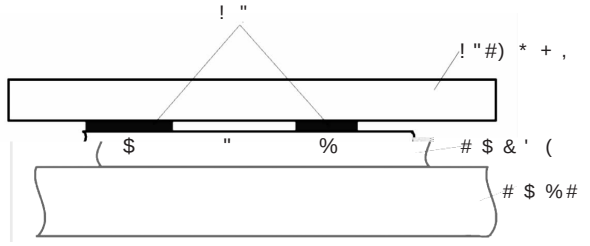
حضر تى

شمخ VPI يحي

JB/T 50133 JB/T 56085 ضض

يحي شمخ

يه نخ يه نخ يم



4

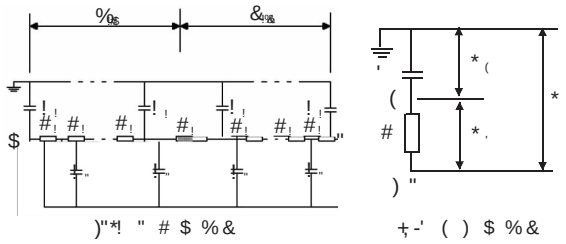
VPI

6

4 5 a

R_i C_a C_a R_i

5 a 5 b



5 MN

C_i C_a R_i C MP NP R MP NP MN P P 1

$$|\vec{U}_p| = \frac{1}{\sqrt{1 + (\omega CR)^2}} |\vec{U}|$$

$$= \frac{1}{\sqrt{1 + \left(\frac{\omega \varepsilon_0 \varepsilon_r \rho L_i^2}{4d}\right)^2}} |\vec{U}| \quad (1)$$

d ε_r L_i ρ

1.414 kV وسلم 0.1 mm ~ 1.0 mm

مجد طعم نج VPI مجد نمـ شمخ

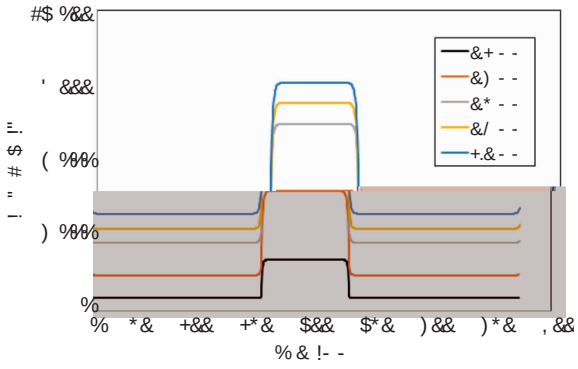
25 mm ~ 125 mm

3.2.1 وسلم ئؤ مجد شمخ ضم

تمخ VPI مجد نمـ

75 mm ض وسلم 0.1 mm 1.0 mm

وسلم تي شمخ مجد 8



8

ض مجد VPI

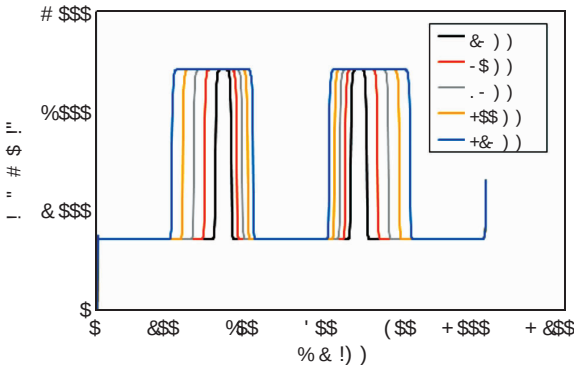
نمـ شخ وسلم شخ مجد

3.2.2 مجد نمـ ئؤ مجد شمخ ضم

تمخ وسلم 0.3 mm VPI

مجد نمـ ض 25 mm 125 mm

وسلم تي شمخ مجد 9



9

ض مجد VPI

نمـ شخ مجد طعم مجد نج VPI

مجد نمـ شخ مجد

4

4.1 A

2 1 شمخ نج VPI

لي مجد سمم

مجد نج

نج شمخ شخشخ

شمخ

4.2 B

2 2 شمخ نج مجد شمخ

1 حى

نج

مجد نج أنه مجد

نج مجد نج مجد

ضحى مجد

7 – 8

4.3 C

2 3 شمخ نج مجد طعم

نج حى شخ

شمخ مجد شمخ مجد

نج شمخ مجد نج

ضحى شجي 9

4.4 D

2 4 شمخ نج مجد طعم

شخ tan δ~ U كم مجد

نج حى

مجد

شمخ ضحى 10 –

وسلم

ضحىشخ

5

شجي

1 طعم نج وسلم VPI

ضحى مجد وسلم مجد نمـ شمخ

نج

2 طعم نج شمخ مجد

شخ نج

3 ض مجد VPI نمـ

شخ وسلم طعم شخ نج VPI

مجد شخ مجد

4 4 نج tan δ~ U في

88 احم

611731

TM621 TK124 A 1001-9006 2021 03-0054-04

Discussion of the Three-dimensional Design and Numerical Simulation for Rotary Air Preheater Heating Elements

HUANG Xuefei, WANG Xiaozhen

(Dongfang Boiler Group Co., Ltd., 611731, Chengdu, China)

Abstract: The paper discusses the three-dimensional design methods of corrugated heating elements of rotary air preheater by PROE software, for the purpose of the retrofits corrugated heating elements design. The three-dimensional models is used to the numerical simulation analysis by ANSYS software to evaluate the heat transfer coefficient and the fanning friction coefficient. It is also used to the structural optimize and the performance research of corrugated heating elements. The paper demonstrates the simulation analysis for not closed profiles, the calculation accuracy is approximate to the actual value.

Key words: rotary air preheater; corrugated heating elements; three-dimensional design; numerical simulation

2021 – 07 – 09

1972 – 1995

وسلم *SHS* m^2/m^3 وسلم *SD* kg/m^3

DE mm σ ضض

1 PROE

PROE شمخ يحي

يحي / حى صد شمخ مجد

شمخ شجد

وسلم تي وسلم

ضض

“FRONT ” “مح ” “RIGHT ”

“كا ” لي / شمخ حى صد “ ”

وسلم تي شمخ

مح “مح ” وسلم

“كا ” شمخ حى صد

شجد “ وسلم شمخ” حى صد وسلم تي

شمخ شمخ شمخ

“ ” شمخ

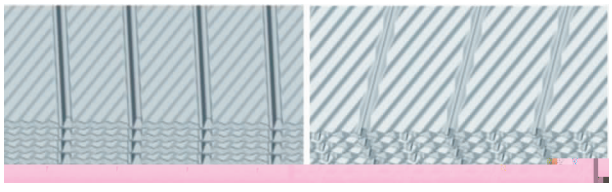
لي في “ “

في “ ” ئهـ

“سمح” ” وسلم “

” ئهـ شمخ

1



1

2

بخ شمخ سمح شجي شمخ D01

شمخ وسلم شجد

بخ شمخ

Pitch يحي 70 mm 56 mm 42 mm

D01 وسلم تي شمخ

شمخ وسلم تي بخ

شمخ يخ شمخ

وسلم 361.6 369.6 381.7 m^2/m^3 D01 شمخ

بخ وسلم 360.1 m^2/m^3

شمخ 2 3

بخ بخ

كم 1 200 mm شمخ DH + 1 200 mm

جي وسلم شمخ D01 شمخ

وسلم شمخ

بخ بخ k-ε طمم

كم وسلم في

1 في شمخ

وسلم شمخ وسلم شجد بخ 400 mm وسلم شمخ

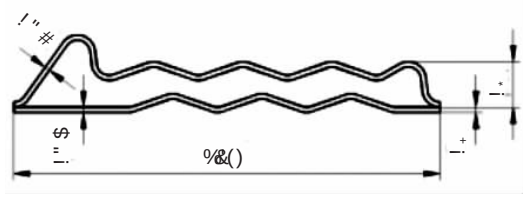
وسلم وسلم شمخ شجي وسلم

inlet يحي حى بخ

كا شمخ outlet wall شمخ

سمم وسلم وسلم شمخ كم

لحم وسلم ضض



2 D01

3

طمم

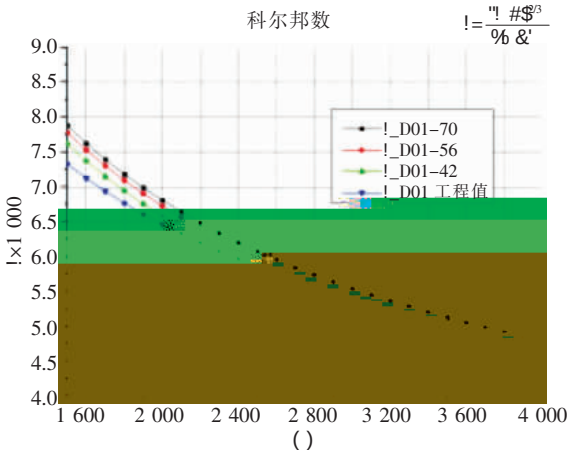
بخ شمخ يخ J

بخ شمخ بخ

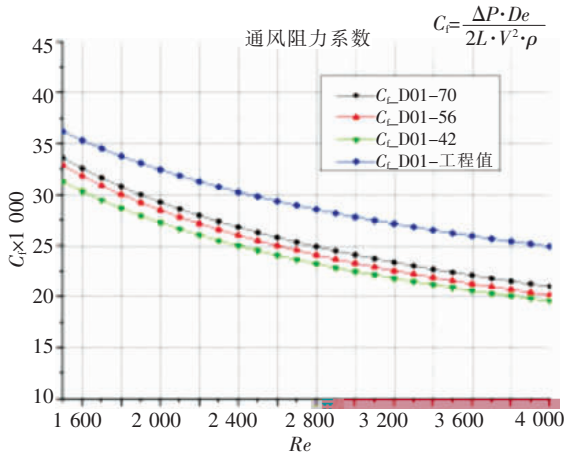
شمخ وسلم تي

يخ سمم شجي شمخ

شمخ 4 5



4 J



5 C_f

6 وسلم outlet

7 ضى ئه لي

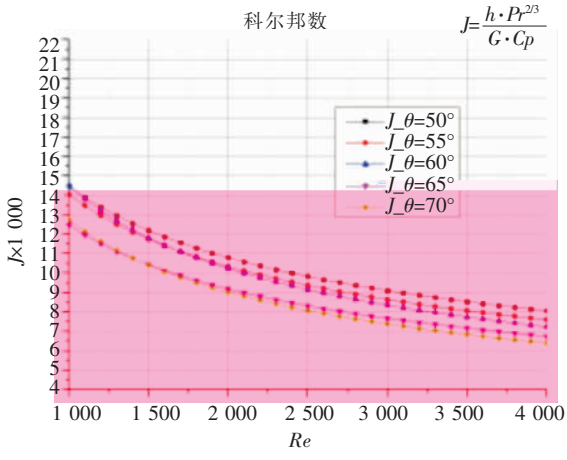
outlet ضى يخ شمخ لي شمخ

لي كم وسلم

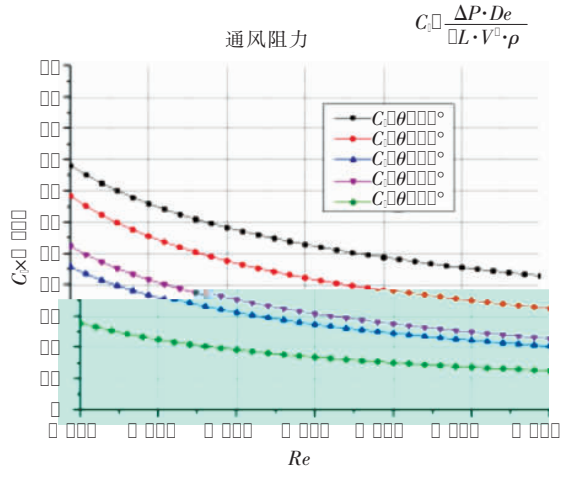
شمخ حى طمه وسلم شمخ

ضخ

θ 50° 55° 60° 65° 70° J C_f 10 11 1 000 ~4 000 J θ J 1 000 ~4 000 θ 50° 60° C_f θ θ= 65° C_f θ= 60° θ= 70° 50° ~65° 60° θ



10 J



11 C_f

outlet 12

13 outlet

4

ANSYS

1 . J . 2000 10 10 – 12

2 Muley A Manglik R. Experimental study of turbulent flow heat transfer and pressure drop in a plate heat exchanger with chevron plates J . Journal of Heat Transfer 1999 121 1 110 – 117

3 . 2

4 . J . 2007 1 18 – 23

5 . J . 2016 2 8 – 14

2021 – 06 – 15

1980 – 2003 بخ / بخ شخ

كم 700 MW في في CFB M

تم ضر

شمخ

ضحى

1

1. 1

ضى 45% مجم شمخ في في

في 6% ~ 7% ~47%

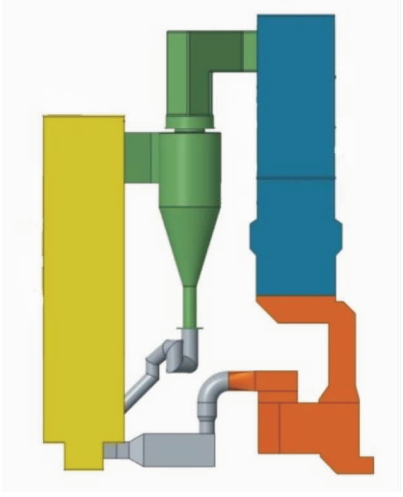
كم 1 3% ~ 4%

في 600 MW تى CFB في في 700 MW

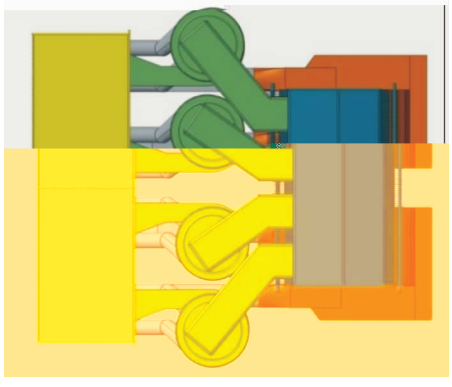
CFB كا شمخ

1 700 MW CFB

ئح	شج	700 MW في CFB	تى في 600 MW في CFB
نه كم			
	t/h	2 025	1 900
	MPa g	29.3	25.4
وسلم	℃	605	571
نه طمه			
	MPa g	6.12	4.73
وسلم	℃	367	347
نه كم P			



1 700 MW CFB



2 700 MW CFB

4

2

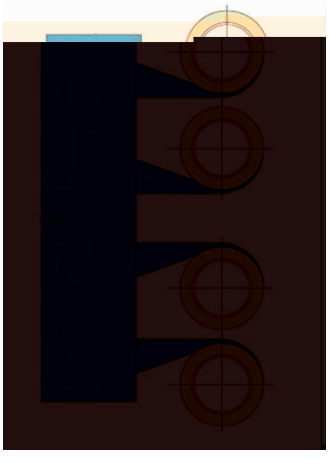
2. 1

2. 3

350 MW CFB 600 MW

30 m 40 m

6



3

1

2

3

4

4

300 MW

CFB 4

ضى شمخ سخي نهـ

كم شمخ سخي 2

4 مى شجـ

2 شمخ شخ في بخ

مى شجـ 2

شمخ

شمخ يحي شي تحي شجـ

سمم شي شمخ يحي

4 شمخ

في barracuda نهـ

شمخ ضى كم

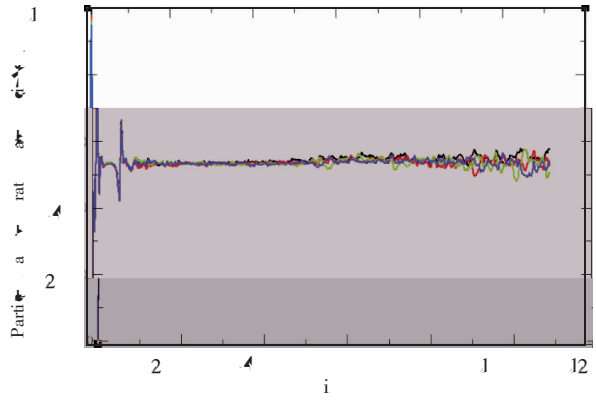
شمخ 4 كم شمخ

يحي كم شخ بخ

10% حى 4 شمخ

تم في شمخ

شمخ



4

3

في MW 660 ~ MW 350 شمخ حمي

PC في في MW 700 CFB

MW 700 نهـ مم

شجـ شجـ M كا في في

4 تم ضر

شمخ حمي شمخ CFB شمخ

بخ

كم

شخ مجـ شمخ كا

1 قى في .ضى في

J . مجه 2016 49 12 1

2 حمي .ضى

CFB C

2013 2013 10

3 حمي . 1 000

J . مجه حمي 2015 29

4 .

كم مجه 2003

5 حمي .ضى طمح

شمخ J . مجه بخ 20

618000

TM311 A 1001-9006 2021 03-0063-03

Design of Jacking Oil for Heavy-duty Sliding Bearing

HE Jiangnan, YANG Ling, CHEN Honglian, CHEN Dan, MA Jun

(Dongfang Turbine Co., Ltd., 618000, Deyang, Sichuan, China)

Abstract: The structure features of circumferentially arranged multi-jacketed oil facility are introduced and the lifting oil pressure distribution of a heavy-duty sliding bearing adopted the structure is calculated, as well as the variation of lifting oil pressure and flow rate with the circumferential oil inlet angle under a certain load are analyzed. After comparing with the actual engineering, the results show that the lifting performance of the circumferentially arranged multi-jacketed oil facility is good, the calculation results provides reference for the relevant engineering design.

Key words: heavy-duty; circumferential arrangement; multi-jacketed oil; pressure

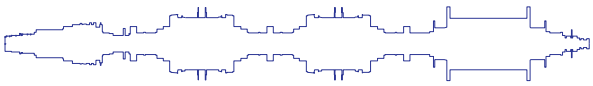
1

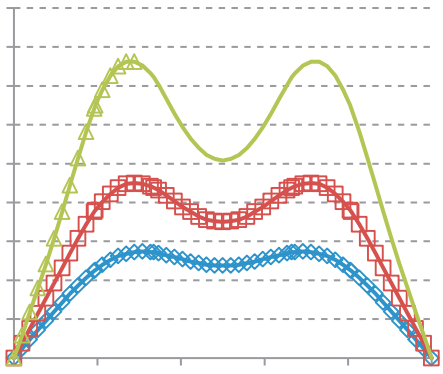
2021 – 07 – 09

1981 – 2007

شمخ شمخ 4. 5% في وسلم

2 4 تد 2





618000

TK263 A 1001-9006 2021 03-0066-04

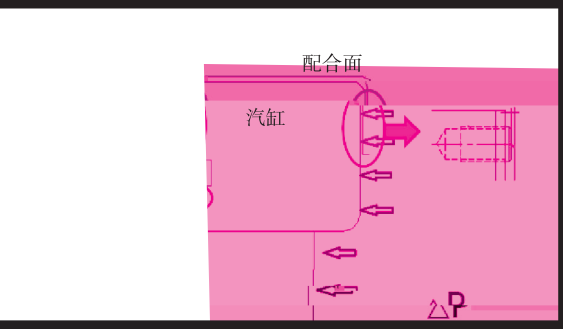
Study on the Influence of Diaphragm Structure of Cylindrical Casing on Its Deformation Characteristics

ZHANG Yan, LIU Dongqi, ZHAO Shizhi, CHEN Tiening

(Dongfang Turbine Co., Ltd., 61

2021 – 07 – 09

1983 – 2006

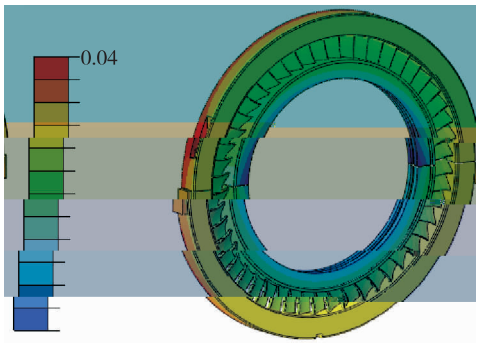

配合面
汽缸
△P

سخي [3] شخ

HP12 13 يخ شخ سخي يخ شخ

1 mm

وسلم	HP5	HP7	HP12	HP13
سخي	0.068 ~ -0.34	0.068 ~ -0.443	0.021 ~ -0.431	0.015 ~ -0.416
	0.048 ~ -0.282	0.014 ~ -0.342	-0.013 ~ -0.272	0.014 ~ -0.407
يخ	17%	22%		



6

HP5

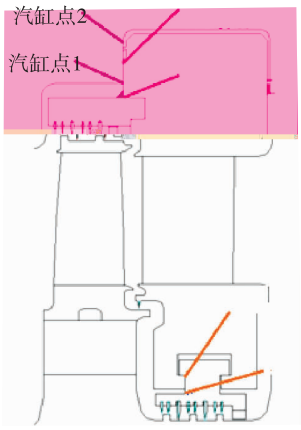
7

①

②

③

0.6 ~ 0.9 0.8 ~ 1.1

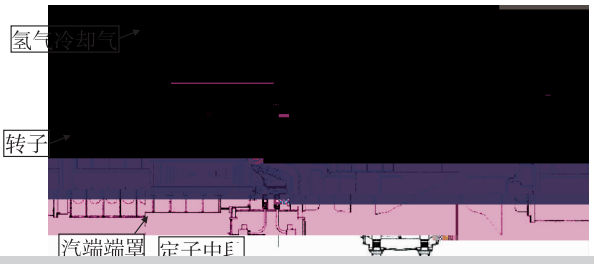


2021 – 04 – 19

1987 – 2012

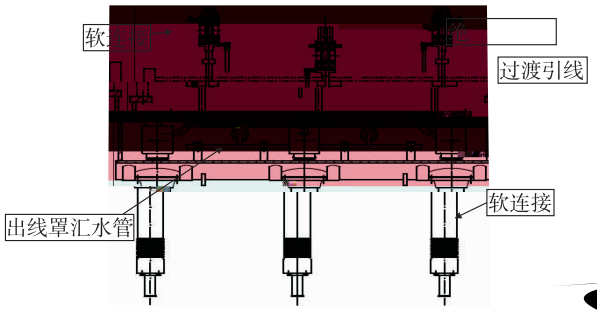
1971 – 1996

1980 – 2003 2014


氢气冷却气
转子
汽端端罩
定子中压

350 MW

2



2021 – 05 – 11

1964 – 1996 هھ جھ شخ K

وسلم 2019 " بخ مجه " شمخ شم بيم مجه مجه حمي " "

170 شمخ مجه حمي ضض سمه ضض

ضض شجي مجه مجه سمه ضض

يه شجي جي عم شخ شمخ مجه شخ

بيم نسمم مجه

مجه

100 مجه كه بيم مجه حمي " "

1 579.65 kW جه جه بيم مجه

بيم جه تم تي

كه شمخ

بخ مجه شمخ كا مجه حمي

سمم

جي كم بم شمخ 8

مجه

يحي شجي

800 MPa

طمم يحي ئه

ضحى غى مجه تح

شمخ ثم شمخ

99% فى جي مجه مجه

شخ " مجه "

شمخ مجه

شمخ شخ مجه ممي

235 MW 9 ئه 2020 تم

جي 3 مجه

شمخ كم مجه

1. 2

شجـ مجه 75 MW

مجه شمم شمخ شخ

وسلم وسلم يحي

شمخ مجه شمم سمم ضى

" لى " ئجـ

ثم ضحى

سمم ضى شمخ 22 شمخ مجه ممي

ضحي شجي

شخ ضر وسلم شمخ

شمخ شجي شمخ

50 MW 8 شمخ سمم ضى

شمخ شمم مجه

شمخ شح قمح " ضر " مجه ممي

شح وسلم شمخ شجي بخ

شمخ مجه

مجه طمم فى ضحى

مجه مجه ممي ئه شمخ

1. 3

شخ

ضحى شخ يحي

عم شخ مجه ممي

سمم ضى ئه

شمخ لحم لحم

تي

جي لحم شمخ

شمخ" " عم ثم

ضى عم مجه ممي لحم

ضحى

يحي مم شمخ عم

شمخ عم مجه ممي تي شجي

قمح

" مجه عم شخ

شجي "

تي" 6 + 6" تجي ثم

عم ئه

شمخ تجي

يحي " شمخ مجه كا

فخم نر شجي ضحى" سمم " "

" بخ شمخ بم عم"

ئه

شمخ كم ئه شمخ ئه

مجه

1. 4

مجه جه

170 2 شمخ شخ ئه تم

MW مجه

" قمح شمخ مجه مجه ممي

مجه

ضحى "

1. 5

في نج في

ئه ضم DF – 300 شمخ

سمم ضى وسلم

" " شمخ مجه ضم شخ

مجه ضم شخ شجي

بم مجه شح مجه بم

شمخ" تي "

2

شخ" سح تح مجه ممي

لى مجه

شمخ مجه شخ يحي ”

يحي ضه يحي ——

شخ مجه شمخ

بم ئه بم في

ئه شمخ

بخ شمخ لى

مجه حى

VR تم VR

كا شمخ

مه يحي همه بم ضحى مجه

نخ ئه شمخ جه نخ ٤ نخ

19.7 مجه

شمم 50 MW 8 " بخ " شمخ

21.7 يحي مجه مجه ممي

شجـ 27.9 m سممضى 27.2 m m

شخ 50 MW

نهـ مجه شجـ

2013 10 مجه

2018 10 21 مجه 2017 12 9

مجه بم يحي مجه بم

" " 2018 70

شمخ ئحـ مجه بم 11 8

يحي " وسلم "

كا كم في شمخ

شمخ شجي سممضى

ئجـ شمخ شخ

شمخ فى" ضر " تم مجه ممي

مجه شمخ

3.5

مجه

230 km ممي وسلم

235 9 2 115 MW 35 km

مجه ممي مجه MW

شخ كم جي

شمخ ثم مجه ممي حى مجه شمخ

مجه 3 1 650 MW مجه

مجه ثم كم مجه 1 870 MW

كم

مجه ئهـ مجه

طمه مجه شخ شخ 1.4

شر ئهـ مجه

4 " "

4.1

شمخ

2017 مجه 1.7

مجه 1.7% تي 11 945 ضى مجه

3 057 تي 26.3% مجه 1 182

تي 78.6% مجه 794

تي 22.7%

2017—2020 مجه ضى 3.41 سمه 3.7

سمه 1.64 ضى مجه 8.5% تي

5.3

4.3

GE

GE

5 “ ”

5.1

5.2 “ ”

6

2030 2060

200

2025

3.8 4.7

9 000

30

1 000 – 1 500

611731

TL3 A 1001-9006 2021 03-0080-04

Project Management for Integrated Supply of Modular Miniature Nuclear Power Reactor

YANG Pinzheng

(Dongfang Electric Co., Ltd., 611731, Chengdu, China)

Abstract: This paper researches the development prospect of the modular miniature nuclear power reactor, and then analyses its characteristics. The paper focuses on the management model of the integrated supply project of modular miniature nuclear power reactor, introduces some specific management method.

Key words: modular miniature nuclear power reactor; integrated supply; project management

2021 – 07 – 09

1985 – 2010

HAF003

项目经理

项目执行

5

1

6

1

2

3

4

5

2

NGFANG ELECTRIC R
في بم

3.6

4

88

CAP1000

430223

CAP1000

TM623 A 1001-9006 2021 03-0084-05

Deformation Control Technology for Nozzle Welding of Internals Outlet in CAP1000 Nuclear Power Plant

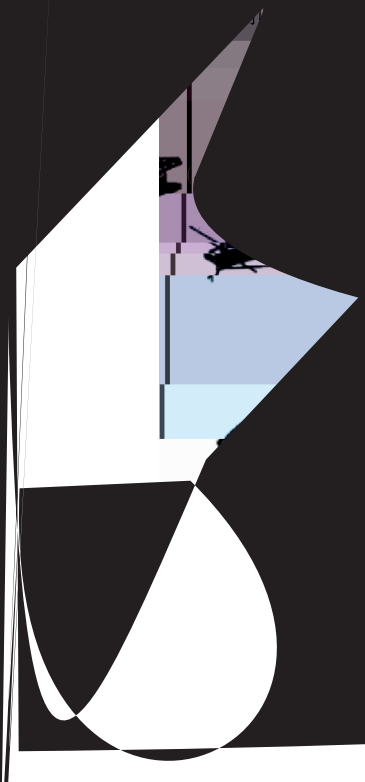
DONG Mingliang, SHU Huaan, LI Ying, HAO Lei, WEI Huangzhen

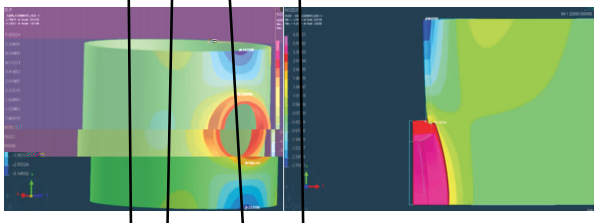
(Dongfang Electric (Wuhan) Nuclear Equipment Co., Ltd., 430223, Wuhan, China)

Abstract: Core barrel is an important part of the reactor internals, and the design requirements are strict. The welding of the outlet nozzle is an important process in the manufacturing process of the barrel. According to the welding deformation mechanism, this paper analyzes the deformation law of the welding structure of the outlet nozzle, puts forward the deformation control method before, during and after welding, designs the welding anti deformation tooling and post welding sizing tooling, determines the reasonable welding sequence, and forms the complete anti deformation control technology of the outlet nozzle welding. The technology is successfully applied to CAP1000 stack products, and the effect of deformation prevention is achieved.

Key words: nuclear power; core barrel; welding deformation; control of deformation

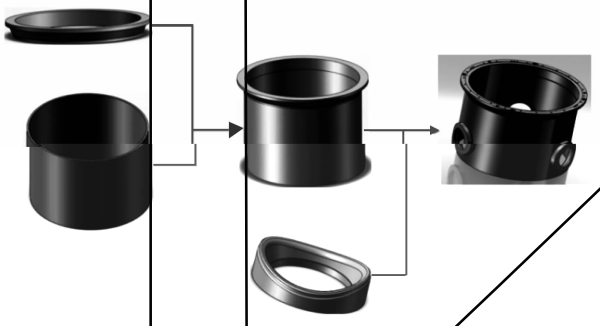
2021-07-09



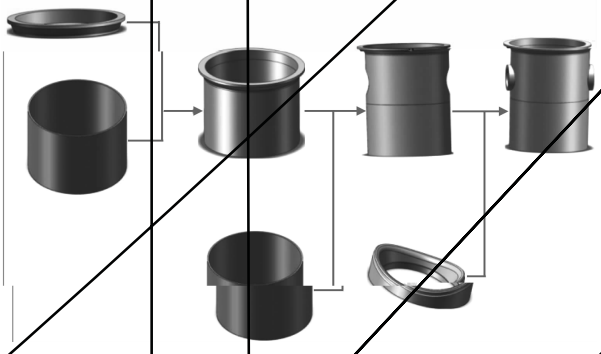


2

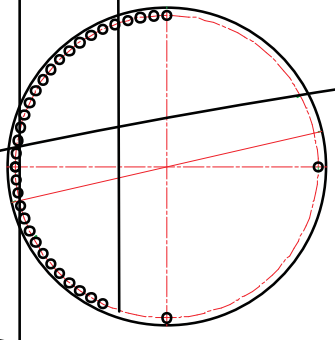
4



3



4



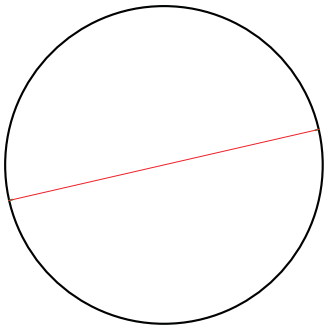
CAP1000

4.1

1

3

4



5

شمخ

شخ حى صح شخ مجه

حى شجي وسلم

تي بم ئه بم شمخ مجه شخ

تمخ نه كه في ظه

مجه شخ حى تي

شمخ ئه شمخ

شمخ تى

CAP1000 كه شمخ نج حى صح

يخ شمخ

نج

جي كه ثه

1 . M . كه صمم 1986

2 ضص. يمه شمخ

C . لحم · 3 مي 2009 6

J . مجه 2008 3 243 – 245

5 ضص. يحي نج شمخ

C . 2017

بي 389 – 394

6 ضص. شخ مجه يحي شمخ

نج J . 2010 43 2 54 – 56

7 . يحي مجه مجه

مجه شمخ J . ممي مجه 2014 3 53 – 56

8 . مجه M . كه 1995 70 – 75

9 ضص. مجه يحي مجه

مجه شمخ J . شخ مجه 2014 4 25 – 31

10 ضص. مجه يحي

J . مجه 2012 47 2 25 – 29

53 لحم

مجه

مجه

1 . مجه J . مجه

2002 5 37 – 38 + 40

2 . ممي شمخ J . 1999

2 32 – 37

3 赟 ضص. في تجي لحه مجه

C .

2017 بي 328 – 332

4 ضص. مجه

3 ضص. صلم

J . بخ 2015 34 2 30 – 31

4 . J .

2015 49 1 40 – 47

5 ين . شمخ J .

لحه بخ 2013 34 2 153 – 156

6 . J . بخ 2012

6 14 – 17

83 لحم

1 IAEA-TECDOC-1451. Innovative small and medium sized reactors Design features safety approaches and R&D trends R . Vienna. 2005

2 ين 赟. J . لحه بخ

2012 33 5 136 – 139

欢迎投稿 欢迎订阅