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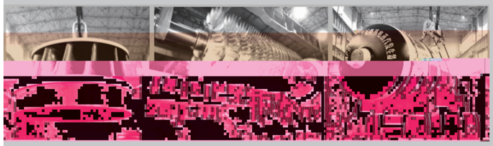

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2021-9-25 Vol. 35 No. 3
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2019YFG0534

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sangzi@ dongfang. com

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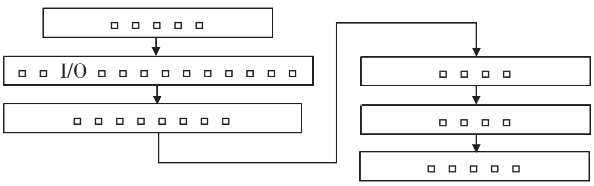
1 TD6000

Ovation



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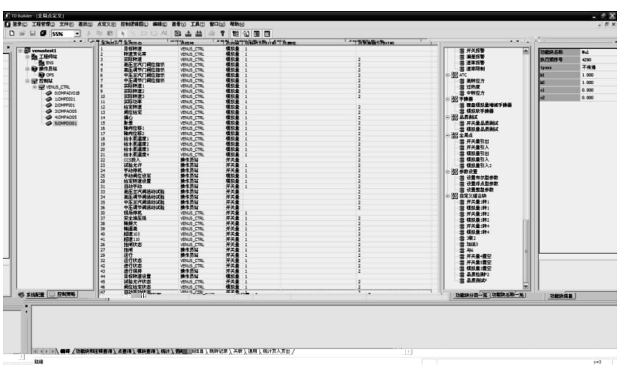

2 TD6000

Ovation Ovation Engineering Tools Ovation Applications Ovation Utilities Windows Unix 3

1 TD6000

TD Builder	
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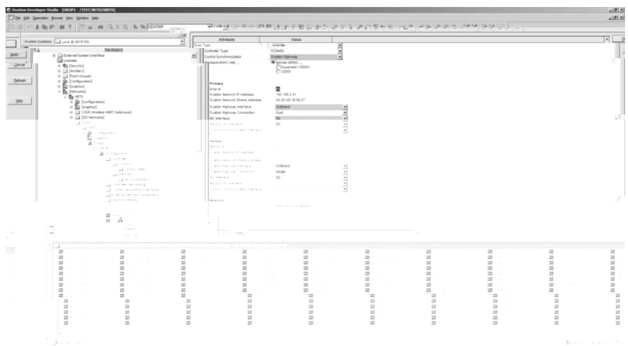
TD User Manager	



3 Ovation

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SignalDiagram	/

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TCP/IP

TD6000 TFTP

Ovation

TD6000 Ovation

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TD6000 TFTP Ovation

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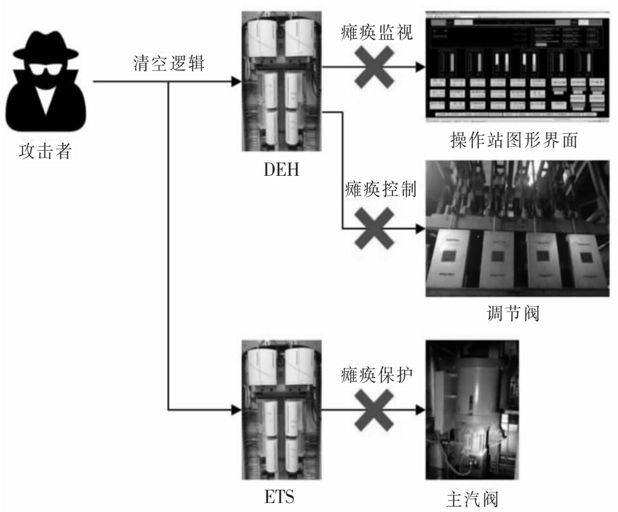

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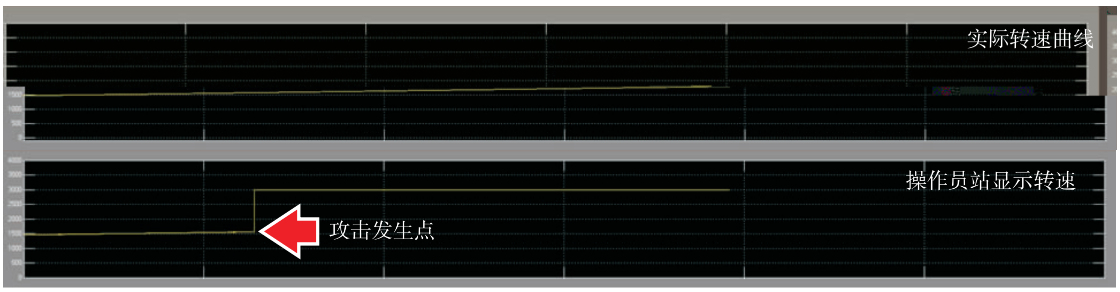

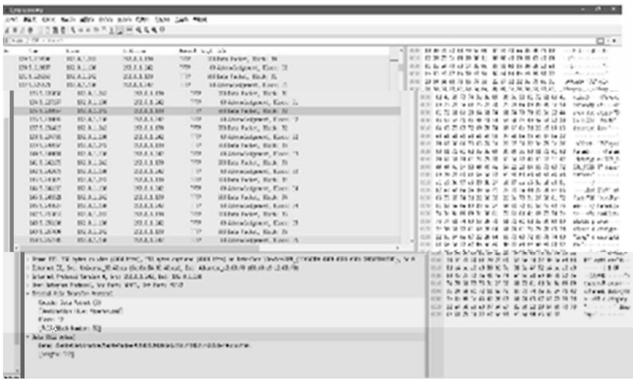

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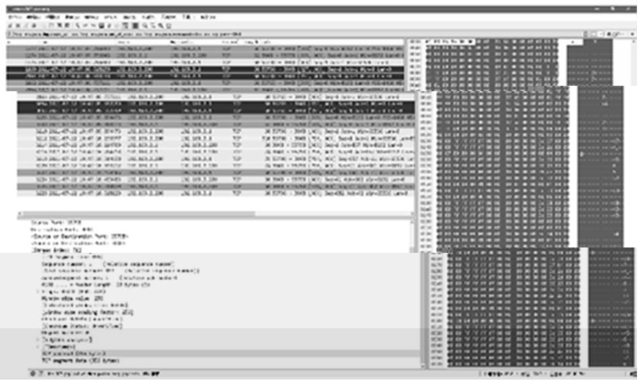

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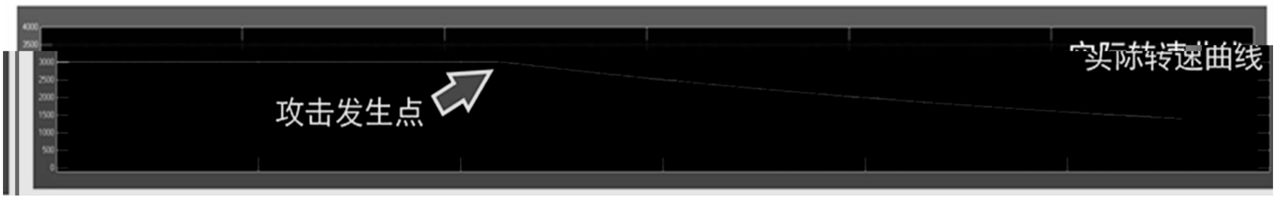

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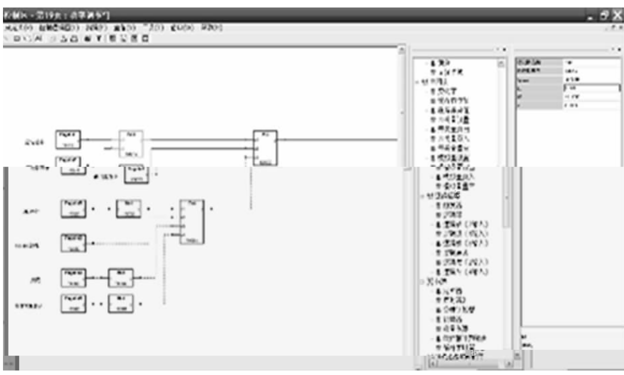

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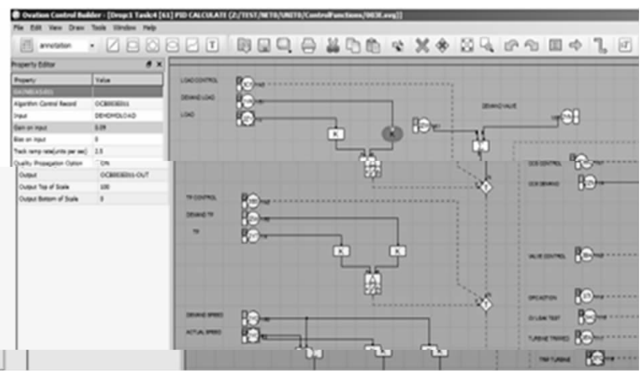

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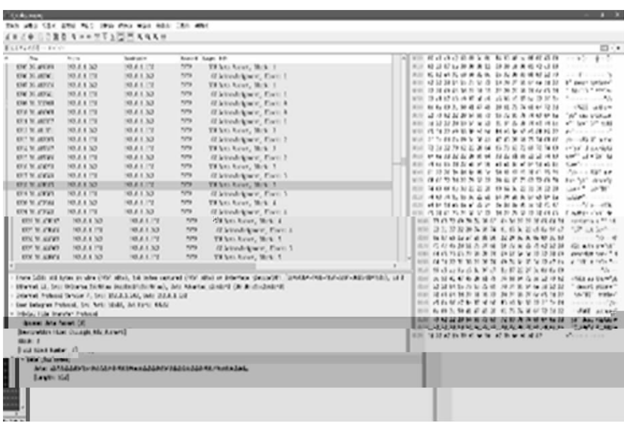

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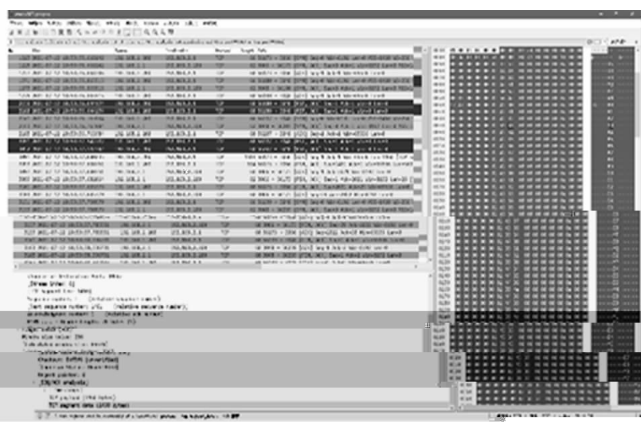

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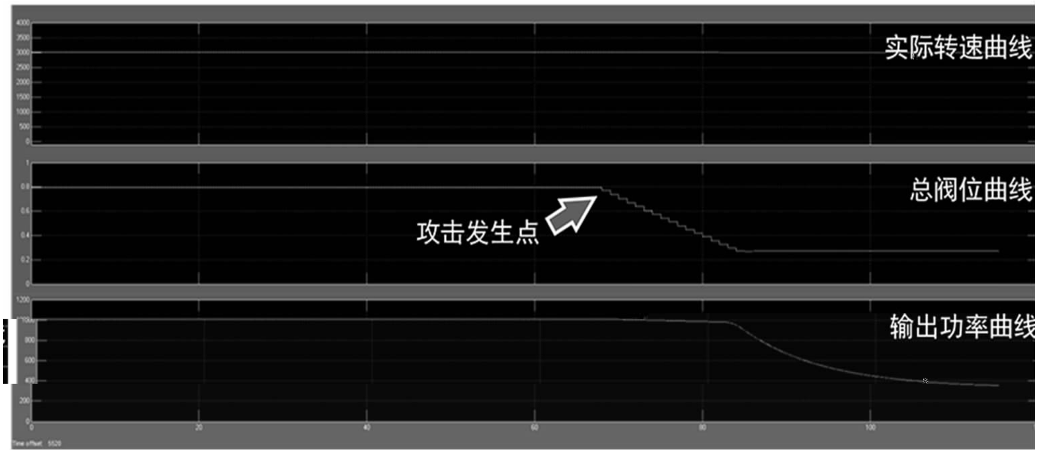

15

4

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

2 . J . 2013 30 3 38 – 42

3 . D . 2013

4 . D . 2015

5 GB/T 26863 – 2011 S . 2011

6 . Linux J . 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 . D . 2006

9 . J . 2018 32 2 15 – 20 + 28

工业控制系统可编程逻辑控制器形式化建模

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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

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1973- yuanxs@dongfang.com

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PLC ICS

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Formal method

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Wang [13]

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

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

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

2 1 U 1

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

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

3 2 U 2

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

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

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LTS

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2 PLC

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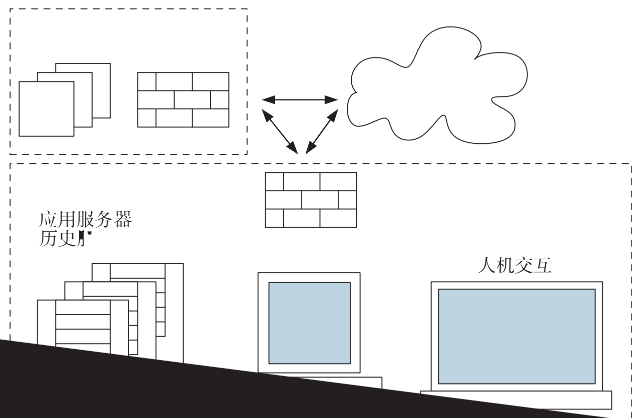

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3. 1. 2 PLC

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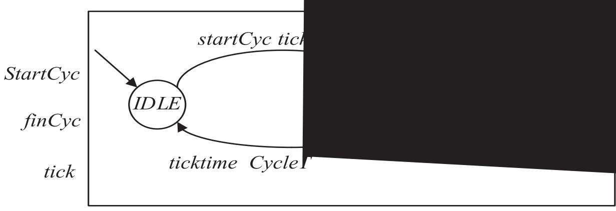

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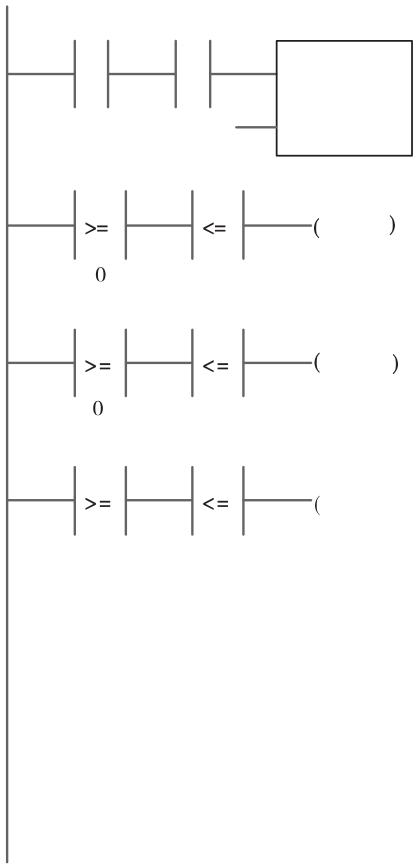

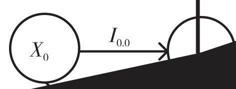

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基于虚假数据注入的发电厂汽轮机网络安全攻击研究

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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

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1973－ 2013

yuanxs@dongfang.com

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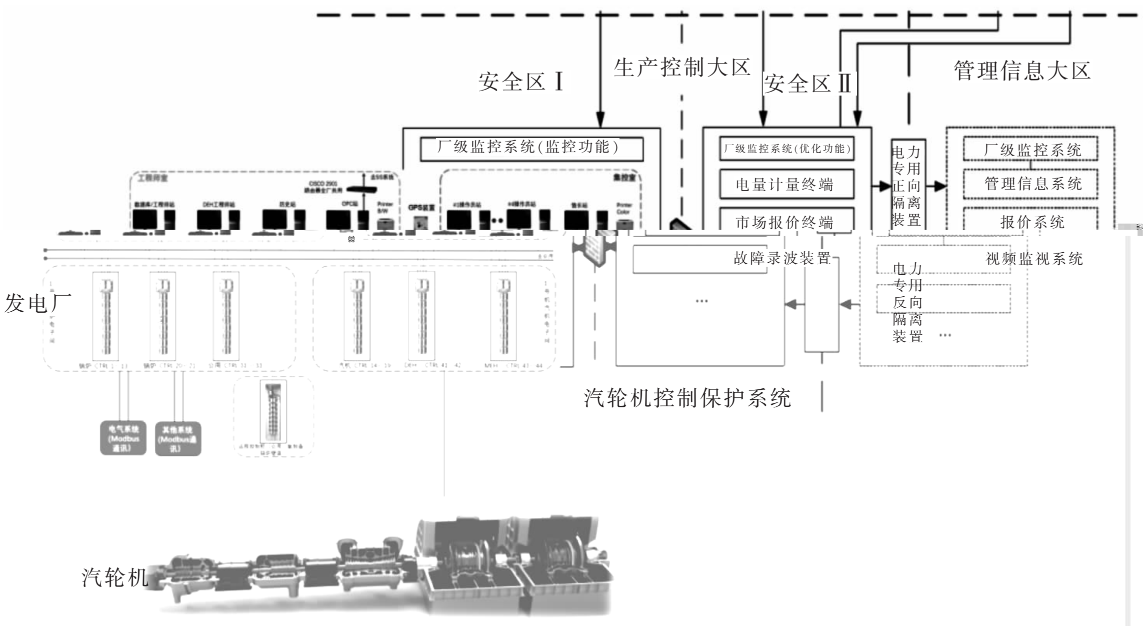

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2.1

FDIAs

[12]

EMS

WAMS

RTU PMU

RTU PMU

2.1.1

$$z = \boldsymbol{H}\boldsymbol{x} + \boldsymbol{e} \quad (1)$$

z $\boldsymbol{H}$

x

e

Weighted Least Squares

WLS

$$J(x)_{\min} = (z - \boldsymbol{H}\boldsymbol{x})^T \cdot \boldsymbol{W}(z - \boldsymbol{H}\boldsymbol{x}) \quad (2)$$

$\boldsymbol{W}$

J x τ J x τ

2. 1. 2

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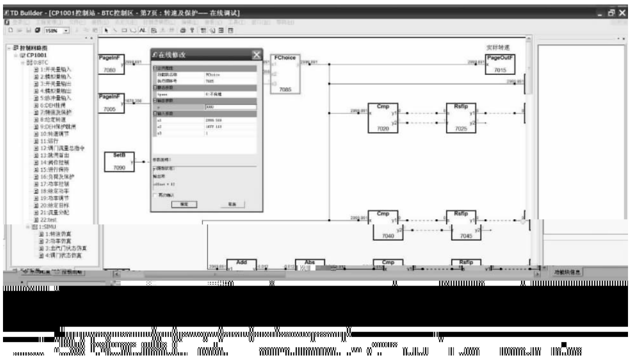

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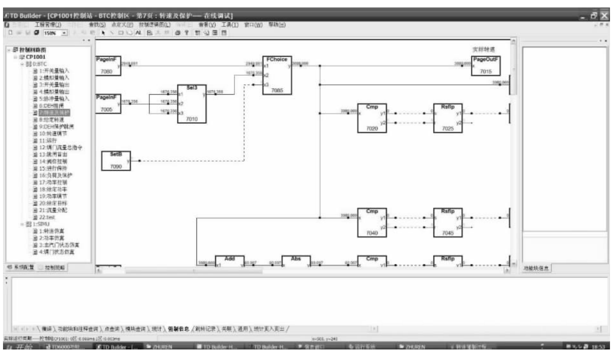

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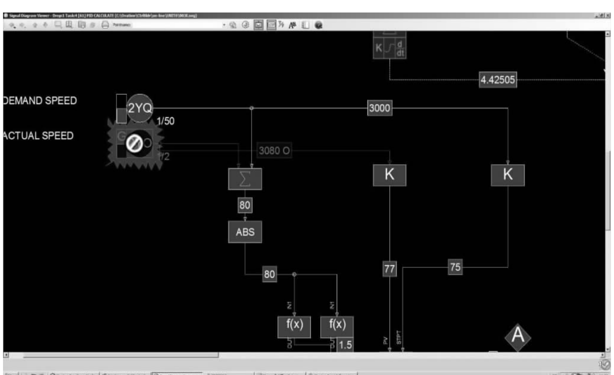

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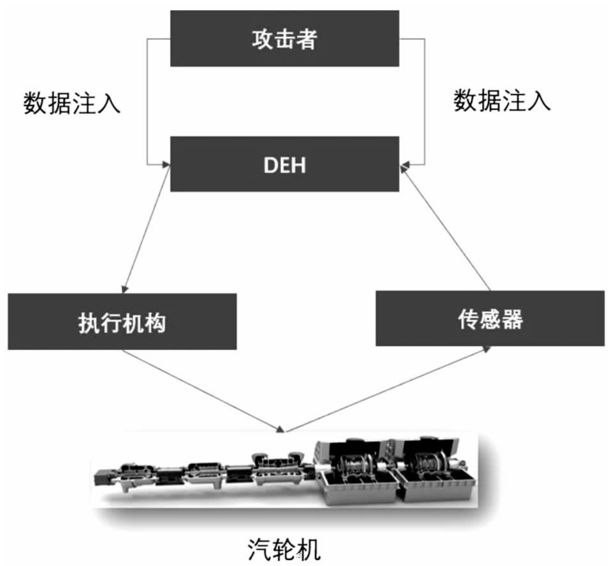

9 FDIAs

FDIAs

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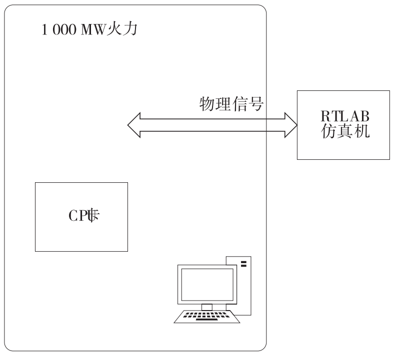
1 000 MW火力
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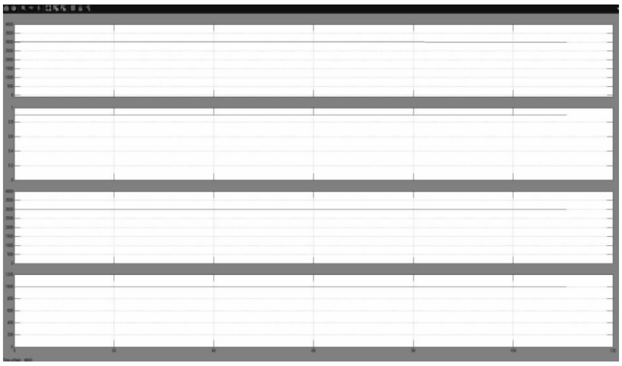
RTLAB
仿真机
CP卡



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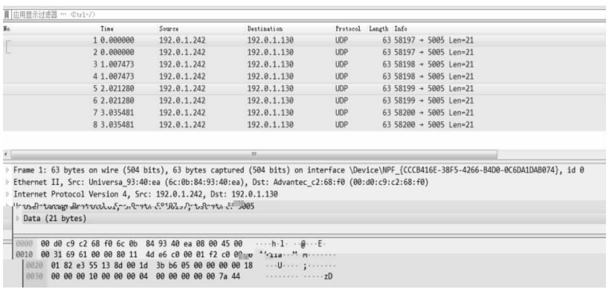
／ 1 000 MW

1 000 17 18



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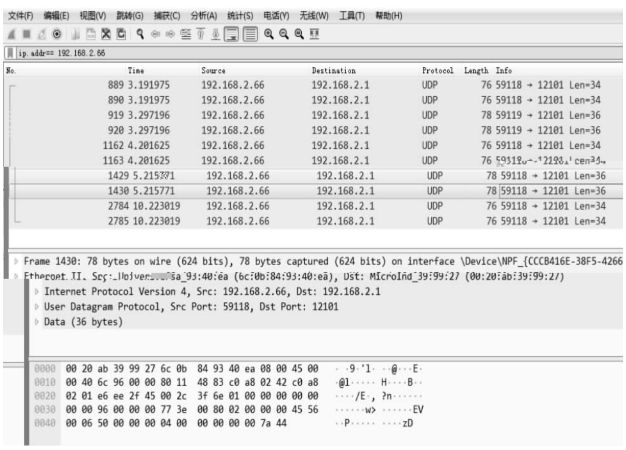

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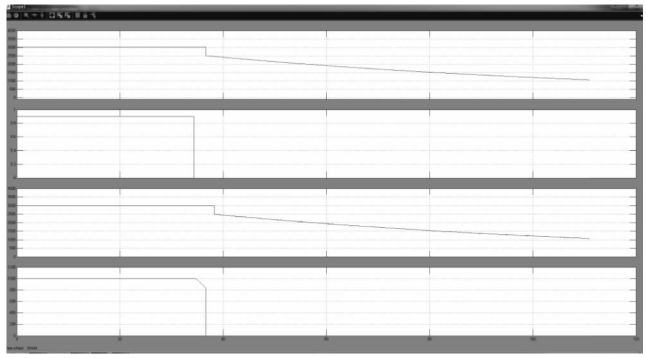

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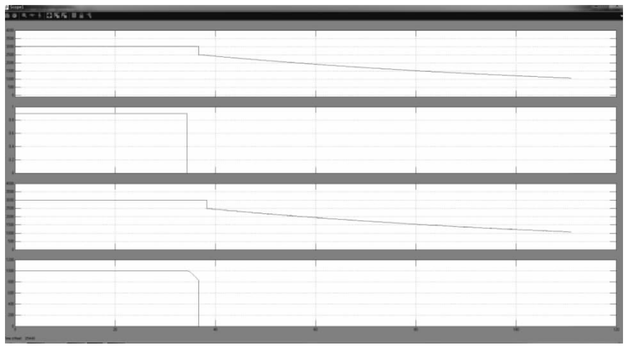

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1 .
J . 2016 40 5 145 – 147
2 .
J . 2019 45 1 5 – 24
3 .
J . 2016 40 17 59 – 69
4 Li F Yan X Xie Y et al. A Review of Cyber-Attack Methods in Cyber-physical Power System C . 2019 IEEE 8th International Conference on Advanced Power System Automation 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 .
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1. 618000 2. 611731

Rivlin

Rivlin

TM911.4 A 1001-9006 2021 03-0025-04

Analysis of Pipeline Sealing Performance of A Fuel Cell Power System

PU Shouwu[1], *LUO Renchao*[2], *LIU Yanping*[2], *ZHANG Hao*[2], *WANG Liang*[2], *ZHANG Tinghua*[2]

(1. Dongfang Turbine Co., Ltd., 618000, Deyang, Sichuan, China;

2. Dongfang Fuel Cell Technology Co., Ltd., 611731, Chengdu, China)

Abstract: There are a large number of silicone rubber pipings in fuel cell power systems. In order to improve the sealing performance reliability of fuel cell power system pipeline, this paper introduces a method to ensure the sealing reliability of silicone rubber pipe joints based on Rivlin model. The finite element analysis and the sealing test is carried. The test results show that using this design method, the sealing requirement of silicone rubber pipe joints is guaranteed.

Key words: fuel cell power system; silicone rubber; Rivlin

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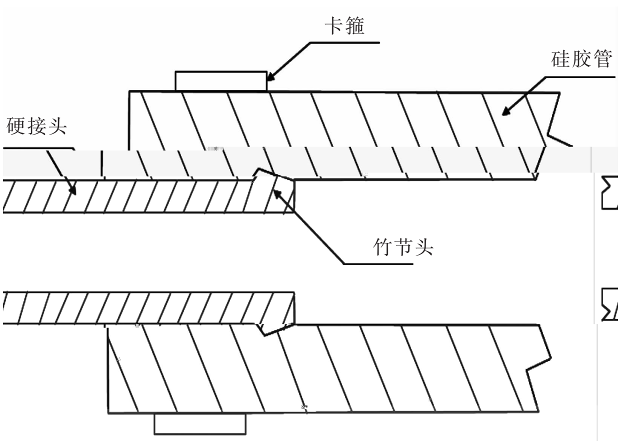

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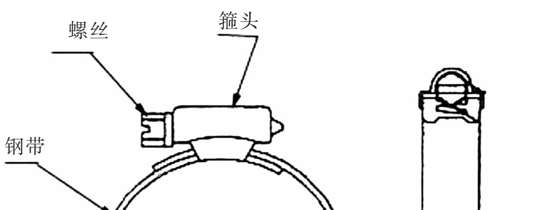

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1 [1]

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

U J_{el} I_1

I_2 C_{ij}

D_i

Mooney-Rivlin

Mooney-Rivlin

1

$N=1$ 1 2

150%

$$U=C_1\left(I_1-3\right)+C_2\left(I_2-3\right) \quad (2)$$

C_1 C_2 3

$$E=6\left(C_1+C_2\right) \quad (3)$$

30 ~ 80 E

4 [2]

$$E=6.72\times10^{-3}\sqrt{H^3} \quad (4)$$

H C_2/C_1

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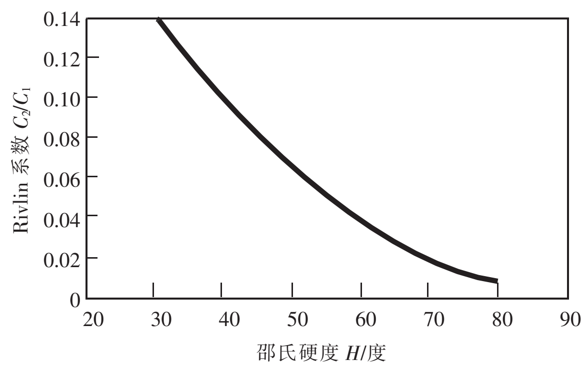


3 C_2/C_1

79 4 $E=4.7186$ MPa

3 2 $C_1=0.7786$ $C_2=0.0078$

3

4

5

6 [3]

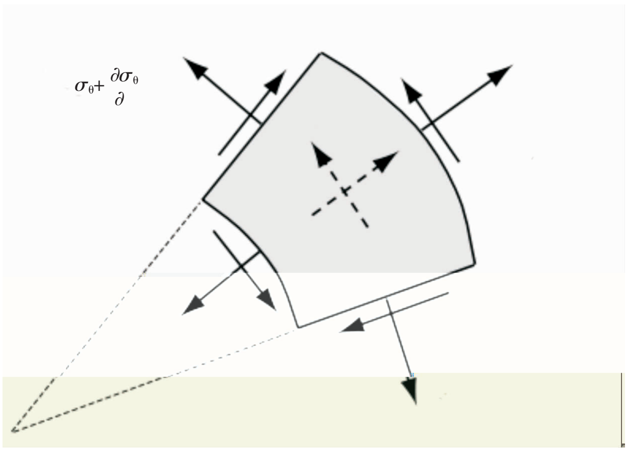
$$\frac{\partial\sigma_r}{\partial r}+\frac{\partial\tau_{r\theta}}{r\partial\theta}+\frac{\sigma_r-\sigma_\theta}{r}+f_r=0 \quad (5)$$

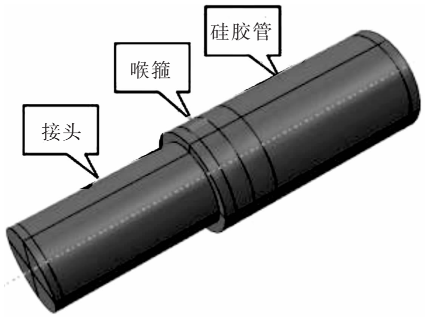
$$\frac{\partial\tau_{r\theta}}{\partial r}+\frac{\partial\sigma_\theta}{r\partial\theta}+\frac{2\tau_{r\theta}}{r}+f_\theta=0 \quad (6)$$

σ_r τ_θ σ_θ

r θ

f_r f_θ





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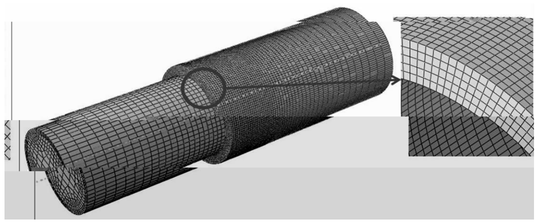
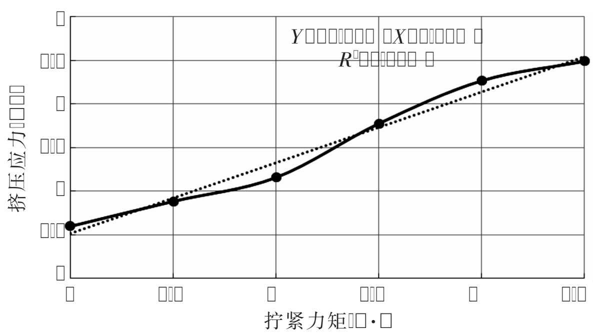


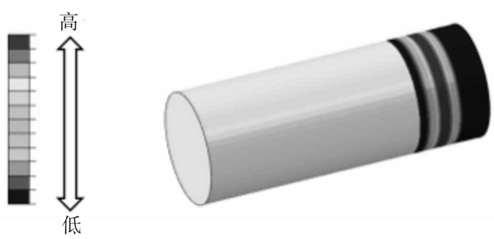
9

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

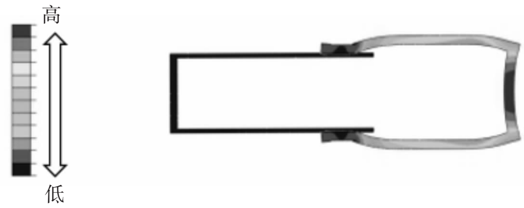


10 –



11

12



13

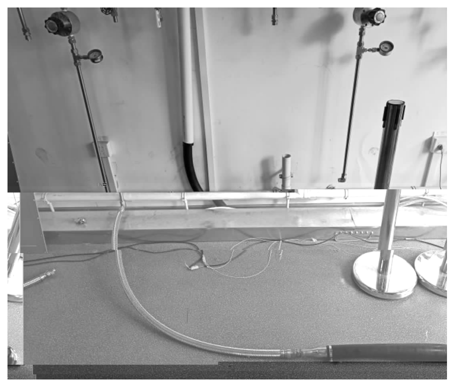
6

14

3 N·m 1 min

270 kPa

1.5 40



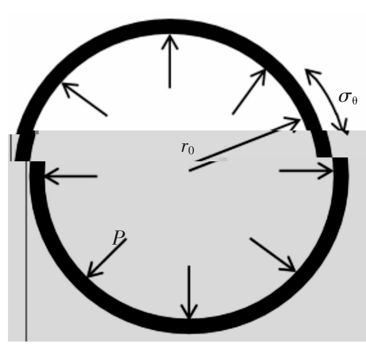
14

7

15

σ_θ P

9 [4]



15

$$\sigma_\theta \approx \frac{P \times r_0}{t} \quad (9)$$

32

蓄电池供电的三相 PWM 变流器直流电容设计

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

[2-3]

r

R_s L_s

[1]

[4]

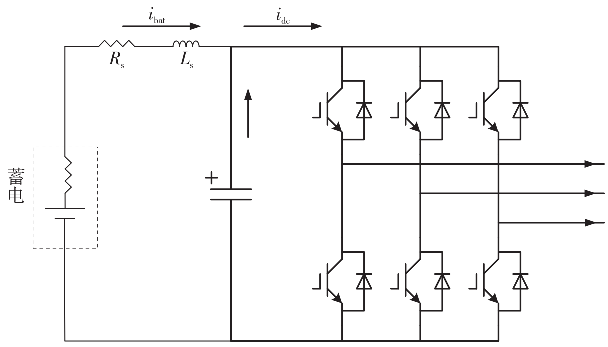
1 PWM

i_{dc}

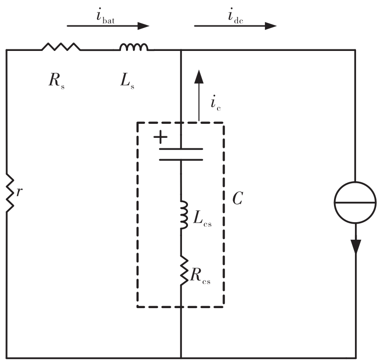
2021-04-02

2020YFG0350

1984- 2011


i_{bat}
i_{dc}
R_s
L_s
蓄电

ESR 4



4

4 $I_c(s)$

$I_{dc}(s)$ $G(s)$ 11

$$G(s) = \frac{s^2 C L_s + sC(r + R_s)}{s^2 C(L_s + L_{cs}) + sC(r + R_s + R_{cs}) + 1} \tag{11}$$

$T_s = 6$ kHz

300 μF 45 A

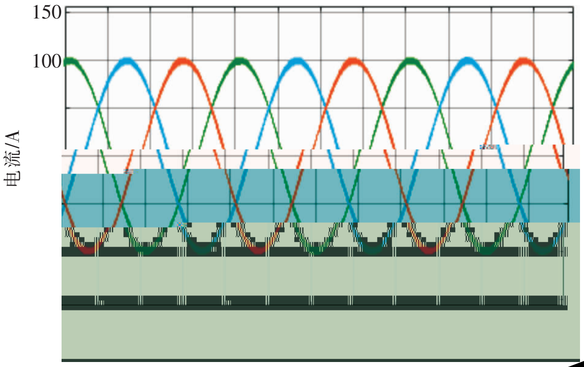
$L_{cs} = 50$ nH ESR $R_{cs} = 2$ mΩ

6 kHz

$R_s = 1.74$ mΩ $L_s = 761.06$ nH $r = 0.05$ Ω 300 μF 600 μF 900 μF

$G(s)$ bode 5

$I_m = 100$ A　　　1　　　7



直流式换热器壳侧流阻特性分析

1 2 1 1

1. 611731 2. 611731

Rehme

CFD

CFD

TK172 A 1001-9006 2021 03-0033-06

Analysis of Flow Resistance Characteristics for Once-through Heat Exchanger

REN Yi[1], *WANG Xiaoding*[2], *LI Qiong*[1], *MO Kun*[1]

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

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

Abstract: Once-through exchanger is a key facility for power and chemical industries. In this paper, a fitted formulas between pressure loss and the Reynolds numbers is proposed based on thermal-hydraulic experimental results of once-through heat exchanger. By contrasting experimental data, the post-correction Rehme' s rod bundle channel model is more accurate in one-dimensional calculation. The CFD simulation results are in agreement with experimental data, and the detail velocity and pressure distribution between support plates provides evidence for safety and thermal analysis of heat exchanger.

Key words: a set of support plate; pressure drop model; rod bundle channel; CFD simulation

[1-2] [3]

/

[4]

/

CFD

2021-01-20

1988- 2013

1

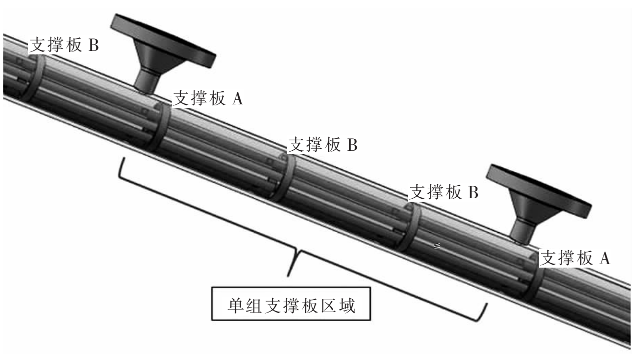
7

3

CFD

1

3



1

CFD

CFD 1

CFD ij ı İ

D_r m N_r

S_t m P_t

m D_w m H

m

3 Cheng-Todreas

Cheng Todreas

[6] 5 ~ 10

$Re \leqslant Re_L$

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

$Re \geqslant Re_T$

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

$Re_L \leqslant Re \leqslant Re_T$

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

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

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

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

ψ C_{fL} C_{fT} 6

4

4 Soblev

Soblev 7

11

$$f=\left[1+600\left(\frac{D_r}{H}\right)^2\left(\frac{P_t}{D_r}-1\right)\right]\times \left\{\frac{0.210}{Re^{0.25}}\left[1+\left(\frac{P_t}{D_r}-1\right)^{0.32}\right]\right\} \tag{11}$$

2

12

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

ζ

1

13 ~ 14

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

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

S_1 m^2 S_2

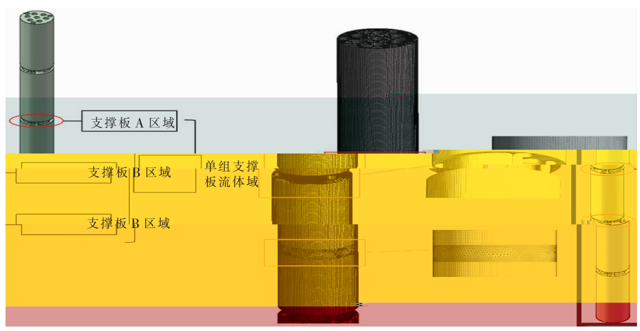
m^2

2.2 CFD

1

CFD 2

3



2 CFD 3

2

CFD

CFD

CFD

15 ~ 16

$$\nabla\cdot(\rho\vec{V})=0 \tag{15}$$

$$\nabla\cdot(\rho\vec{V}\vec{V})=\nabla\cdot(\mu\nabla\vec{V})-\nabla p+\rho\vec{g}+S_p \tag{16}$$

CFD SST

[8] k-ω

k-ω SST

k-ω

k-ε

k ω

17 ~ 18

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

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

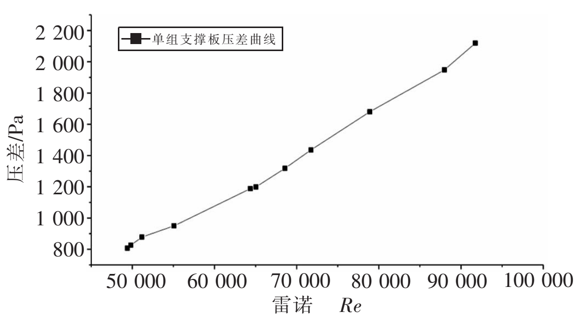
ρ $\vec{V}$ p μ

3

CFD

3.1

4



4

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

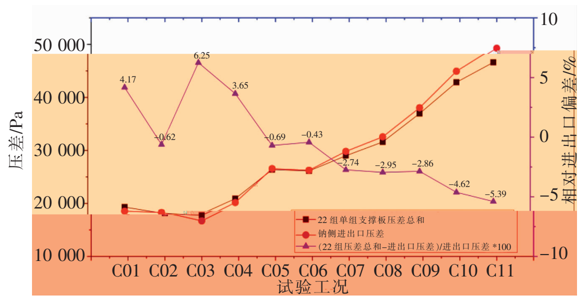
22

22

200 ℃

22

5



5

22

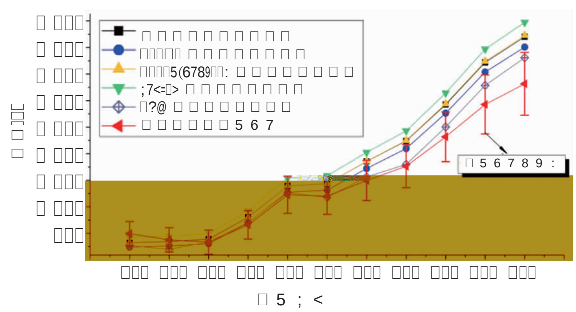
22

±6.5%

CFD

6

CFD



6

CFD CFD

CFD

CFD

6 CFD 7 $X=0$ $Z=0$ $X=-Z$

$X=Z$

Rehme 8

CFD

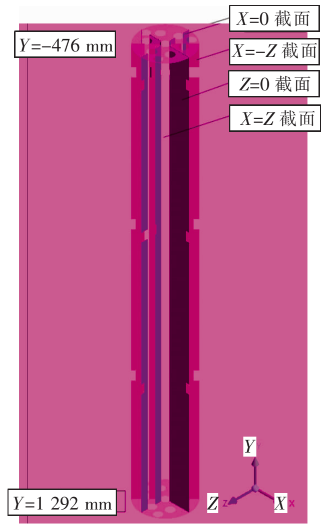
6

280 ℃

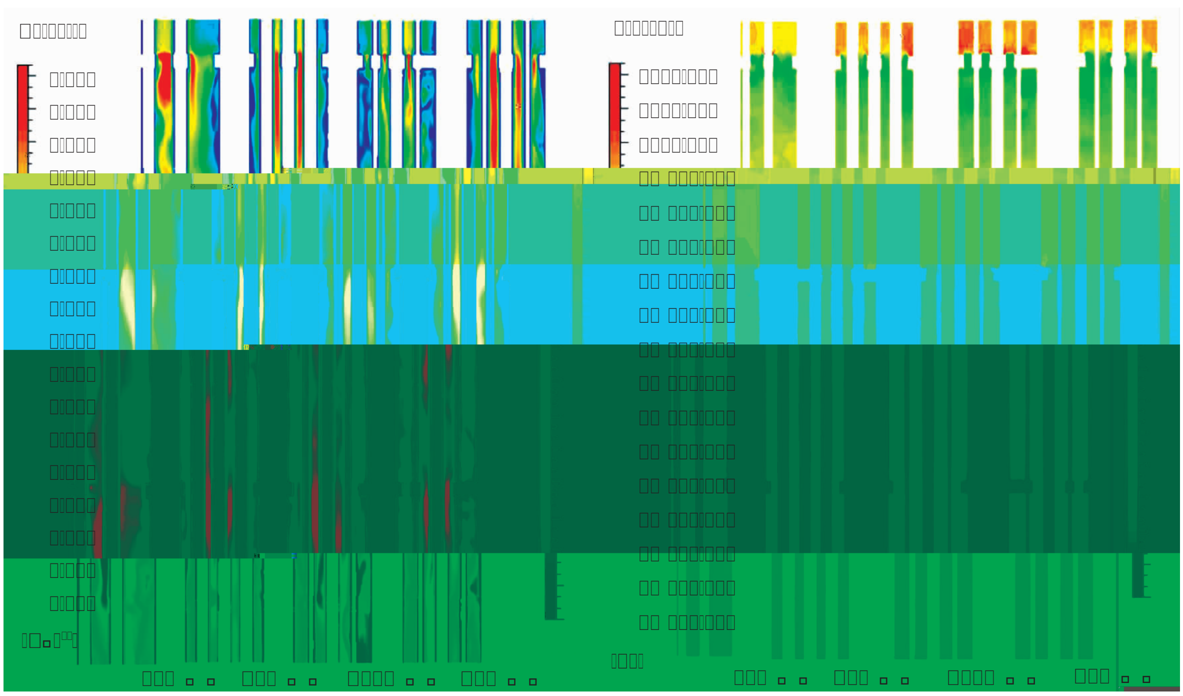
340 ℃

3.2

CFD



7 CFD



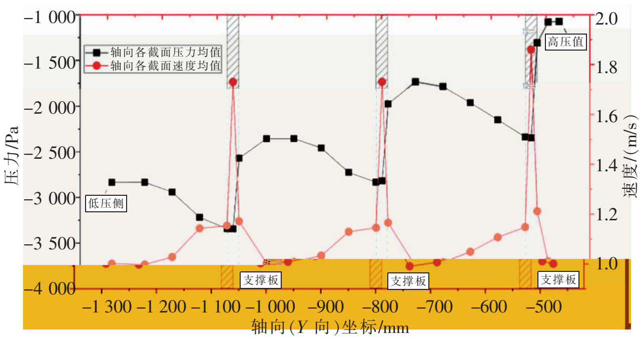
8 CFD

$-Y$

“ ”

7

9



9

Y

CFD

4

CFD

1

6.5%

2

Rehme

3 CFD

CFD

1 .
J . 1997 17 2 97 – 102

2 .
J . 2019 5 71 – 75

3 .
J . 2019 26 5 73 – 77

4 .
J . 2018 17 9 55 – 56

5 Rehme K. Pressure-drop performance of rod bundles in hexagonal arrangements J . International Journal of Heat and Mass Transfer 1972 15 12 2499 – 2517

6 Shih-Kuei C Todreas NE. Hydrodynamic models and correlations for bare and wire-wrapped hexagonal rod bundles-bundle friction factors subchannel friction factors and mixing parameters J . Nuclear Engineering and Design 1986 92 2 227 – 251

7 V Soblev. Fuel Rod and Assembly Proposal for XT-ADS Pre-design Coordination meeting of WPI & WP2 IP EUROTRANS C . Bologna 2006

8 . Transition SST
J . 2017 43 2 207 – 217

浅析海外燃气轮机电厂的首次检修策划

611731

TK47 A 1001-9006 2021 03-0039-04

ů ř Ŵ

A Brief Analysis of Ůƒ ų Őŝ ŐŌŞ

2021 －07 －09

1982 － 2008

3 –4

1. 1

1. 2

1. 3

1. 4

GE

3

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2

2. 1

2. 1. 1

2. 1. 2

2.1.3

A 2 3

1.5 2

2.2

2.2.1

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3

2.2.2

2.3

GE 9E

400

100

1

2 Ÿ ̓Ŝ ṱ Ϝ Ƙ ɔ

東方電氣評論 DONGFANG ELECTRIC REVIEW 2021.9.25 第35卷 Vol.35 总第139期

铜引线冷弯成型工艺研究

618000

R

R

R

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., 618000, Deyang, Sichuan, China)

Abstract: The cold-bending forming of copper lead is widely used in power generation equipment manufacturing. The traditional producing process is that the R value of the workpiece set according to experience and manual bending. The stability of product quality is usually poor. In this paper, the design of R-value of copper cold-bending forming, the requirements of physical properties of materials, the bending process and the rebound phenomenon are analyzed and tested. A set of high-reliability copper cold-bending forming process scheme is proposed.

Key words: copper lead; cold-bending forming; design of R-value; rebound phenomenon

R

1

R

1

1

/

1 R

2

2021 - 07 - 09

1976 - 2001 2015

5 mm 0.1 mm

R8 R5

R8 R5

ASME PT

1 R8 R5 7

a R8 b R5

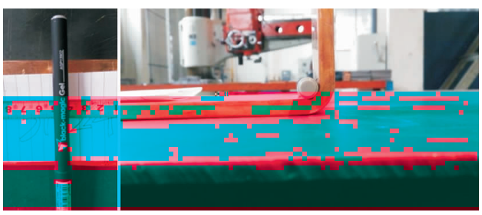
7

2 8

a R8 b R5

8

3 9



9

4 PT 10

ASME

10 R PT

R

PT

5

1

2 3 R_{min}

3 6

4

5

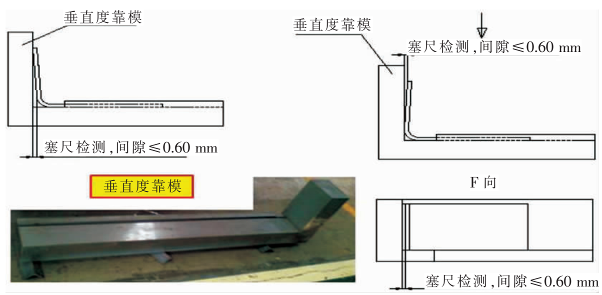
6

11

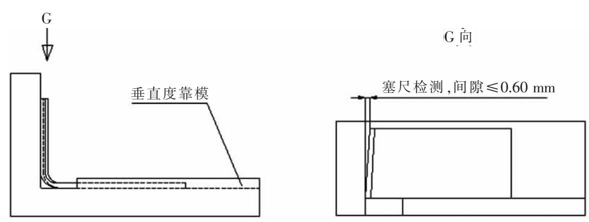
Cu-ETP R300

0.1 ~0.4 mm

0.6 mm



(a)垂直度的检测



(b)扭斜检测

11

3

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			

启动扩容器的选型计算

611731

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

600 MW

1

1.1 D

1 X

2021-07-09

1982- 2007

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

H kJ/kg H' kJ/kg H'' kJ/kg

2 W_s

$$W_s = WXa \quad (2)$$

W_s t/h W t/h a 1.03

3 A_{sd}

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

A_{sd} m^2 V_1 m^3 v m/s

4 D

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

D mm

1

<a>

8 /s 2.44 m/s 4 /s

1.22 m/s

<b> HG/T 20570.8-1995 –

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

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

	u 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

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

R m^3/ h·m^3 v_1 m^3/kg

V_2

3 ~ 5

[4] 30%

$V = V_1 + V_2$

30%

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

62

交流电机 VPI 模具对线圈介质损耗因数影响的研究

618000

VPI ANSYS

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

VPI

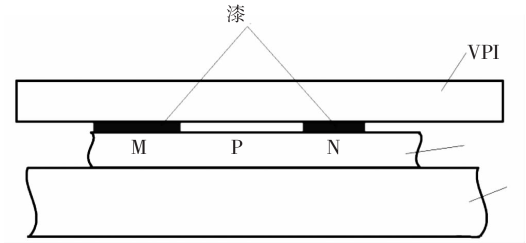
JB/T 50133 JB/T 56085

M

M

50 60 TD

4



4

VPI

VPI

M N

6

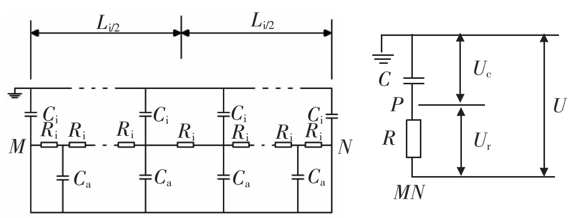
4 5 a

R_i

C_a C_a R_i

5 a

5 b



(a)分布参数电路 (b)集中参数电路

5 MN

C_i C_a

R_i C

MP NP R MP

NP

MN

P

P

1

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

d ε_r

ρ_s L_i

3

VPI

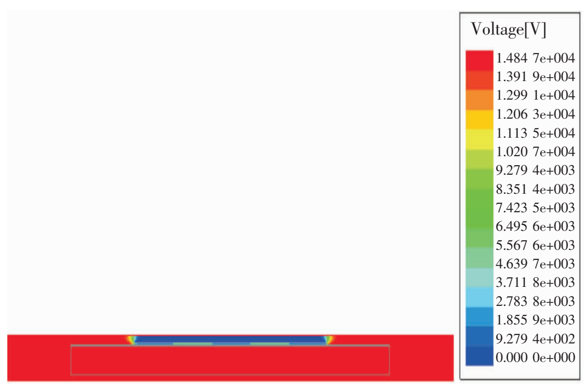
ANSYS

3.1

6

6

7



7

3.2

10.5 ×

1.414 kV 0.1 mm ~ 1.0 mm

VPI

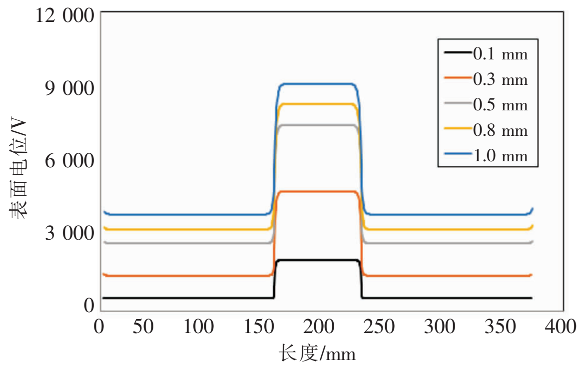
25 mm ~ 125 mm

3.2.1

VPI

75 mm 0.1 mm 1.0 mm

8



8

VPI

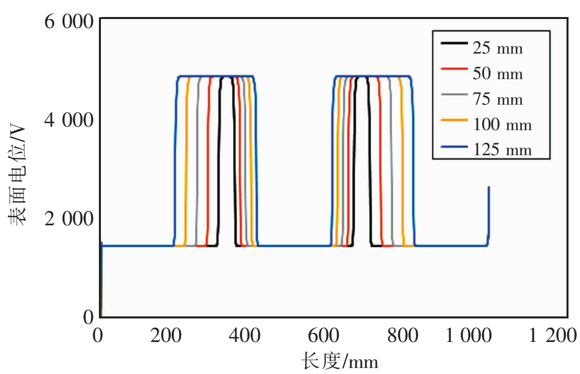
3.2.2

0.3 mm VPI

25 mm 125 mm

9

”



9

VPI

VPI

0³ ³U ¥ 0³ 0³ , , ¥

³ \

” ” ” ”

4

4.1 A

2 1 VPI

4.2 B

2 2

1

7 – 8

4.3 C

2 3

9

4.4 D

2 4

tan δ~ U

«, 0³ B

M U U 10

5

” 0³ , U ³ U ³

1 8 , U’U 0³ U 2829

回转式空气预热器波纹板换热元件片的三维设计及数值模拟计算探讨

611731

PROE

ANSYS

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

／

／ ／

[2－5]

[1]

／ α_h／α_u

／ β_h／β_u mm

2021－07－09

1972－ 1995

SHS m^2/m^3 *SD* kg/m^3

DE mm σ

1 PROE

PROE

/

"FRONT" " " "RIGHT"

" " / " "

" "

" "

" "

" "

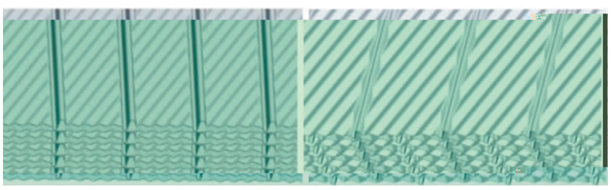
" "

" "

" " "

"

1



1

2

D01

Pitch 70 mm 56 mm 42 mm

D01

361.6 369.6 381.7 m^2/m^3 D01

360.1 m^2/m^3

2 3

1 200 mm DH + 1 200 mm

D01

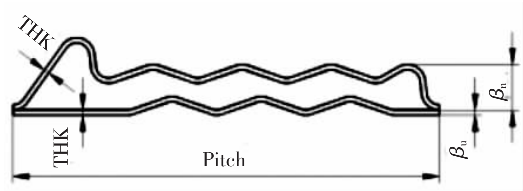
k-ε

1

400 mm

inlet

outlet wall

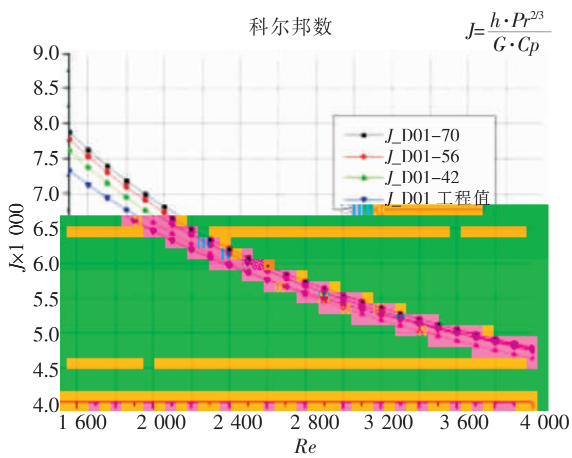


2 D01

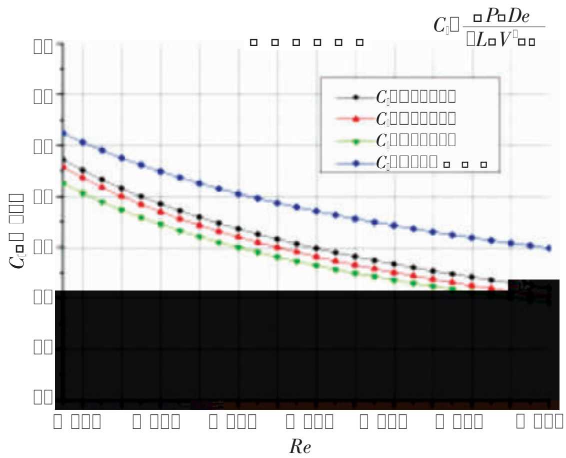
3

J

4 5



4 *J*



5 C_f

outlet 6

7

outlet

1 200 mmDH + 1 200 mmD01

θ 50°

55° 60° 65° 70° J C_{f} 10 11

1 000～4 000 J

θ θ J

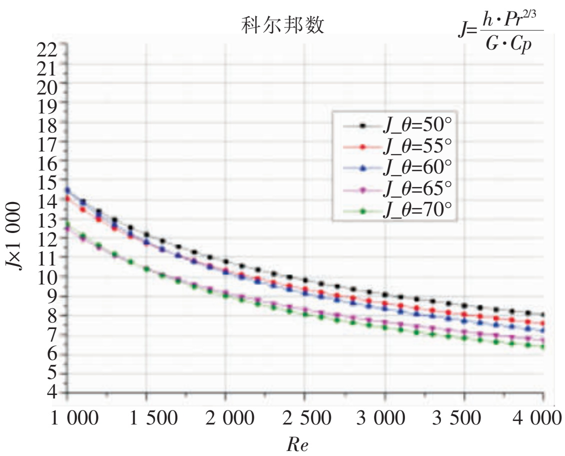
1 000～4 000 θ 50° 60°

C_{f} θ θ=65° C_{f}

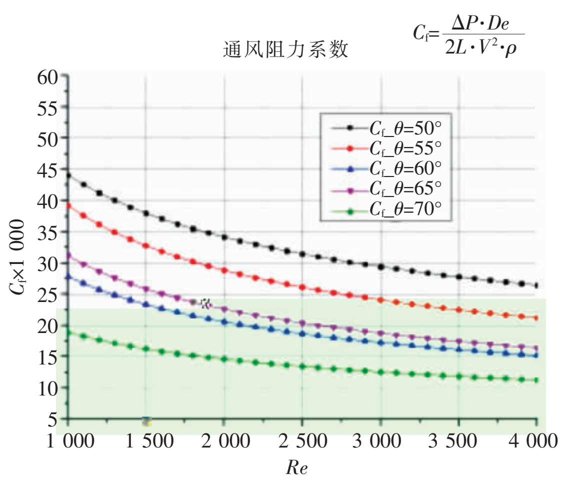
θ=60° θ=70°

50°～65° 60° θ

θ



10 J



11 C_{f}

东方 700 MW 高效超超临界 CFB 锅炉的开发

1 2 1 2 1 2 1 2 1 2 1 2

1. 611731 2. 643001

700 MW CFB 350 MW ~ 660 MW CFB
700 MW CFB M

CFB
700 MW CFB
TM621 A 1001-9006 2021 03-0058-05

Development of 700 MW High Efficiency Ultra-supercritical CFB Boiler

GONG Liming[1,2], *DENG Qigang*[1,2], *LIU Jie*[1,2], *REN Yanli*[1,2], *LU Jiayi*[1,2], *SU Hu*[1,2]

(1. Clean Combustion and Flue Gas Purification Key Laboratory of Sichuan Province, 611731, Chengdu, China;

2. Dongfang Boiler Group Co., Ltd., 643001, Zigong, Sichuan, China)

Abstract: According to the design conditions of 700 MW h

2021 -06 -15

1980 - 2003 /

700 MW CFB M

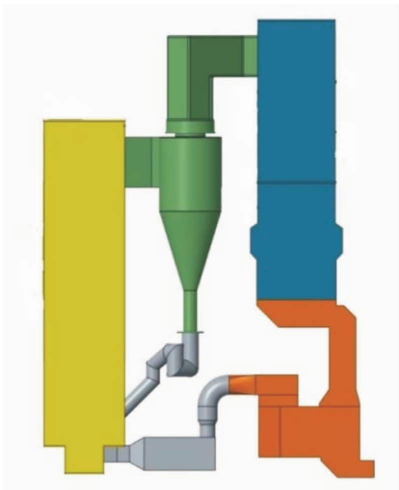
1

1.1

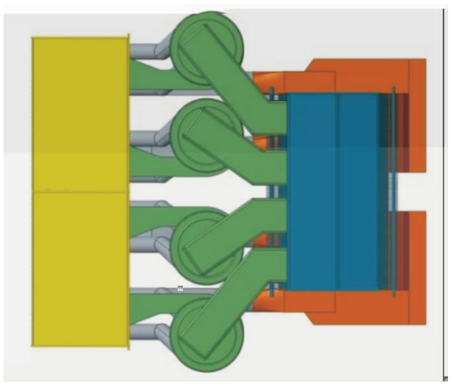
45%

~47%

1 2



1 700 MW CFB



2 700 MW CFB

4

2

2.1

5

350 MW ~ 660 MW CFB 700 MW

PC

1

2

700 MW CFB

350 MW ~ 660 MW CFB

700 MW PC

700 MW

CFB

2.2

605 ℃

623 ℃

2. 3

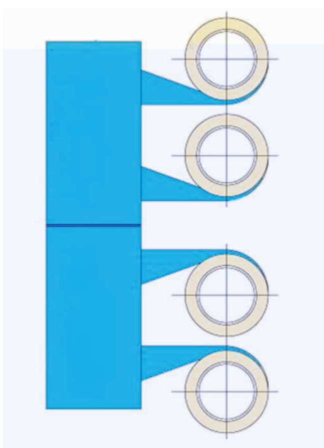
350 MW CFB

600 MW

350 MW CFB

30 m 40 m

[6]



3

1

2

CFB

3

4

3

4

300 MW

CFB 4

2

4

2

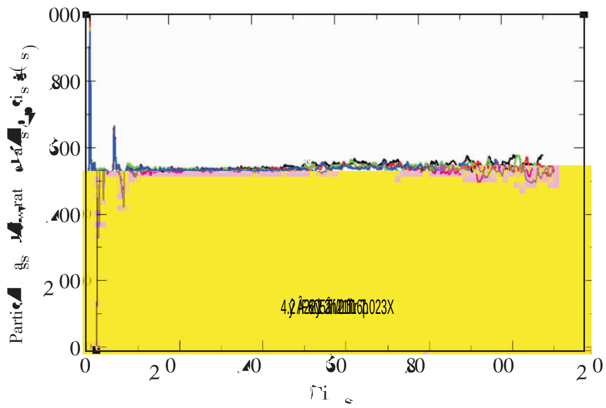
2

4

barracuda

4

10% 4



4

3

350 MW ~ 660 MW

CFB 700 MW PC

700 MW

M

4

CFB

CFB

1 .
J . 2016 49 12 1 – 7

2 . 660 MW ~ 1 000 MW
CFB C .
2013 2013 10

3 . 1 000 MW
J . 2015 29 4 26 – 30

4 . M .
2003

5 . 660 MW CFB
J . 2019 35

重载滑动轴承顶轴设计

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

2

3

1

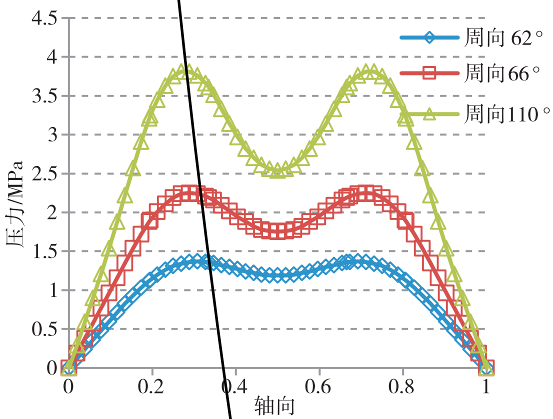
2

A B

1

2021 - 07 - 09

1981 - 2007

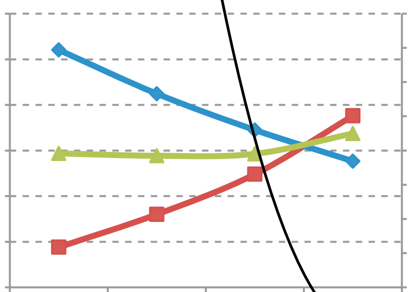


6

5#

α

7



6

筒形汽缸隔板结构对其变形特性的影响研究

618000

i Q

4

i

TK263 A 1001-9006 2021 03-0066-04

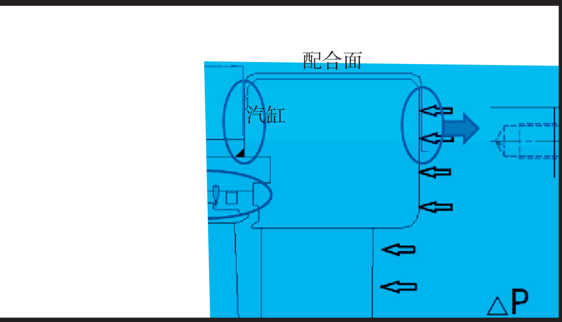
Study on the Influence of Diaphragm Structure of Cylindrical Casing on Its Deformation Characteristics

ZHANG Yan, LIU Dongqi, ZHAO Shizhi, CHEN Tiening

(Dongfang Turbine Co., Ltd., 61

2021 – 07 – 09

1983 – 2006



配合面
汽缸
△P

6

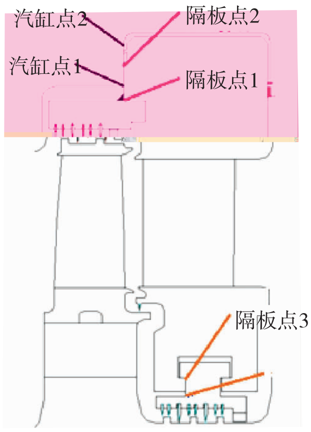
HP5

7 ①

②

③

0.6 ~ 0.9 0.8 ~ 1.1



350 MW 水氢氢汽轮发电机定子水路漏氢分析与处理

618000

QFSN-350-2-20

350 MW
TM311 A 1001-9006 2021 03-0070-04

Analysis and Treatment of Hydrogen Leakage from Water Cooled Stator Windings Circuit of 350 MW

JIN Xuliang, LI Feng, SONG Qingsong

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

Abstract: This paper introduces the check and treatment of hydrogen leakage of stator of type QFSN-350-2-20 turbine generator in a power plant, and puts forward the preventive measures, which provides a reference for subsequent units to deal with similar problems.

Key words: 350 MW turbine generator; water cooled stator windings circuit; hydrogen leakage; insulated water piping

350 MW QFSN-350-2-20

“ ”

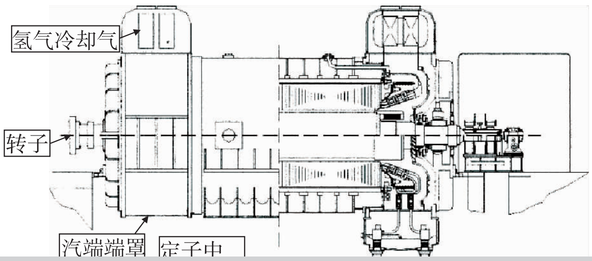
1

2021－04－19
1987－ 2012
1971－ 1996
1980－ 2003

2014

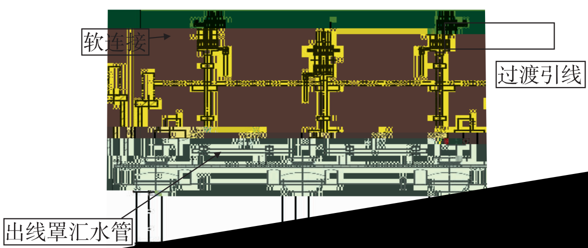
4

1 350 MW



350 MW

2



东电“十三五”水电技术发展与“十四五”前景展望

618000

“ ”

“ ” “ ”

F426 A 1001-9006 2021 03-0074-06

The Development of Hydropower Technology in the 13th Five-Year Plan and the Prospect of the 14th Five-Year Plan of Dongfang Electric

YU Xiaobo

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

Abstract: After continuous technological progress during the 13th Five-Year Plan period, Dongfang Electric makes great technological leaps and improvements in the R&D and manufacturing of hydropower units, and the development of large-scale hydropower products reaches the world's leading level. This paper briefly reviews the achievements of the hydropower technology development of Dongfang Electric during the 13th Five-Year Plan period, analyzes the situation of the 14th Five-Year Plan period, and looks forward to the development prospect.

Key words: hydropower; technology; development; looking forward to

“ ”

“ ”

1 000 MW

75 MW

“ ”

“ ”

1

——

2021－05－11

1964－ 1996

“ ” ” ” 2019

170

“ ” 100 “

1 579.65 kW ”

“800 ”

1

1 “ ”

	2016
	2016
06Cr16Ni5Mo	2016
400 MW	2017
770 MW	2017
	2017
600 MW	2019
600 MW	2019
800 MW	2019
	2019
300 MW	2019
770 MW	2019
800 MW	2019
770 MW	2020
	2020
	2020
300 MW	2020
700	2020
	2020

1.1

“ ”

16 1 000 MW

8

1 000 MW

8

800 MPa

99%

“ ”

2020 9 235 MW

3

1. 2

75 MW

“ ”

22

8 50 MW

“ ”

1. 3

“ ”

“

”

“6 +6 ”

a ”a

a

”

VR VR

19.7 8.5% 1.64

“ ” 8 50 MW

21.7 m 27.2 m 27.9 m

50 MW

2013 10

2017 12 9 2018 10 21

70 2018 “ ”

8 11

“ ”

“ ”

3.5

230 km

35 km 2 115 MW 9 235 MW

1 650 MW 3

1 870 MW

1.4

4 “ ”

4.1

2017 1.7

11 945 1.7%

3 057 26.3% 1 182

78.6% 794

22.7%

2017—2020 3.41 3.7

“ ”

“

”

4.3

GE

GE

5 “ ”

5.1

5.2 “ ”

5.3

6

“ ”

2030 2060

200

“ ”

“ ”

“ c ḳ

小型模块化核反应堆集成供货的项目管理

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

2021 －07 －09

1985 － 2010

[5]

1

[6]

1

LOCA

2

LOCA

3

ABV

ITIS NHR－200

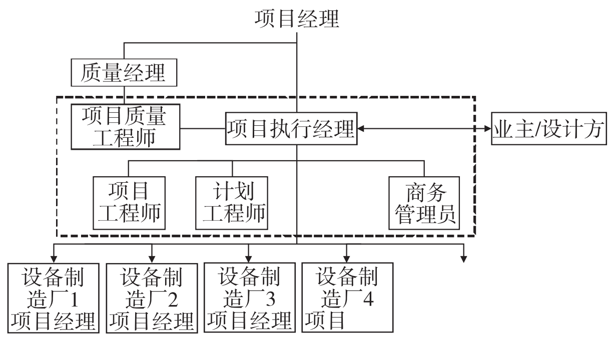
4

5

2

HAF003

1



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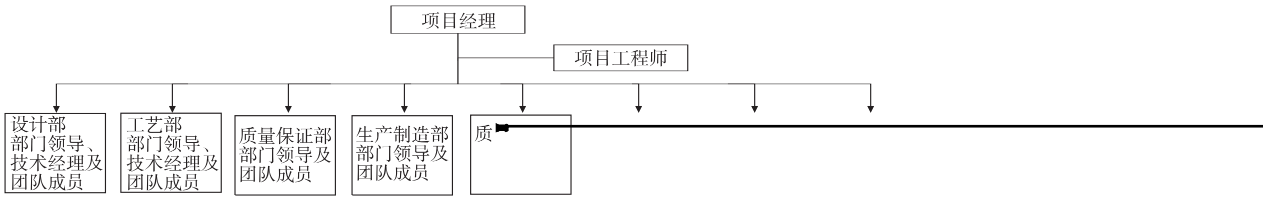

项目经理
项目工程师
设计部
部门领导、
技术经理及
团队成员
工艺部
部门领导、
技术经理及
团队成员
质量保证部
部门领导及
团队成员
生产制造部
部门领导及
团队成员
质

CAP1000 核电堆内构件出口管嘴焊接防变形控制技术

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

SC－3 QSA1 Ⅰ

3 m

50 mm 8 m 4

3

2021－07－09

1988－ 2010

1973－ 1997

1988－ 2010

Z2CN19 － 10 ＋ N2

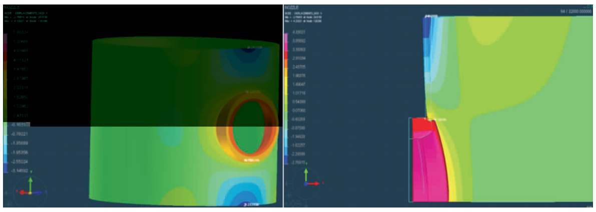
1/3

50%

1

1

2



2

4

3

26.5 mm 1 540 ± 3.2 mm 5.03 mm

2

3

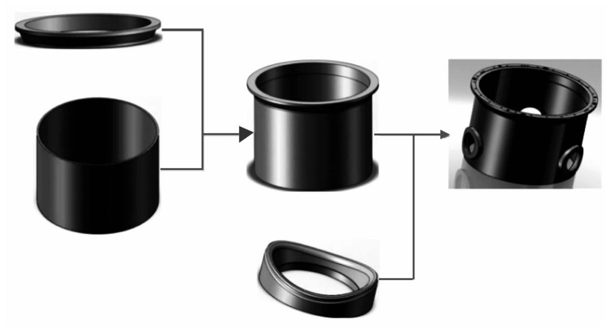
CAP1000

4.1

1

3

4



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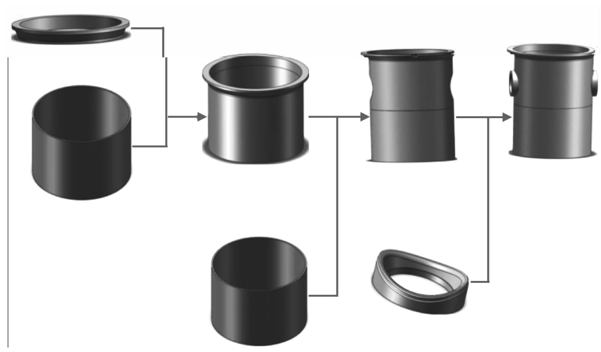

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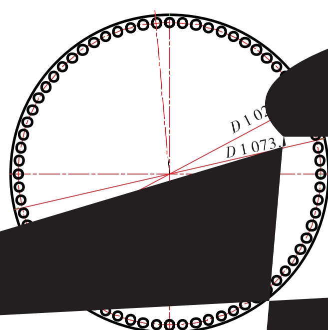

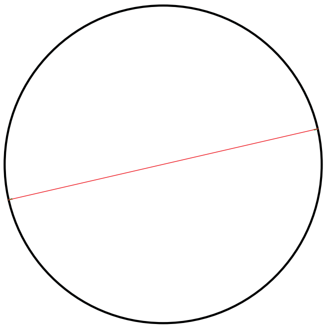

5

CAP1000

1 . M . 1986
2 .
C . · 3 2009 6

53

1 . J .
2002 5 37 －38 ＋40
2 . J . 1999
2 32 －37
3 赟 .
C .
2017 328 －332
4 .