张耀平*

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Proposal of Auxilary Pumping Technique Taking-in and Pushing-out Low-Pressure Air with Running Vehicle in Vacuum Tube Transport

Zhang Yaoping*

Institute of Vacuum Tube Transport Xijing University Xi 'an 710123 *China*

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3

1 分析模型、假设

1.1 管道模型

1 2.8 m

1000 km

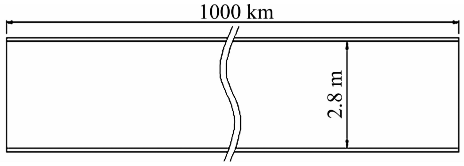

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Fig.1 Schematic diagram of the tube structure in vacuum tube transport

1.2 抽真空阶段模型

5

1 ~ 1/10 1/10 ~ 1/100 1/100 ~ 1/1000 1/1000 ~ 1/10000 1/10000 ~ 1/100000 atm

5

1 $1.101325 \times 10^5 \sim 1.101325 \times 10^4$ Pa

2 $1.101325 \times 10^4 \sim 1.101325 \times 10^3$ Pa

3 $1.101325 \times 10^3 \sim 1.101325 \times 10^2$ Pa

4 $1.101325 \times 10^2 \sim 1.101325 \times 10^1$ Pa

5 $1.101325 \times 10^1 \sim 1.101325 \times 10^0$ Pa

5

5

5000 10000 km/h

6 $1.101325 \times 10^0 \sim 1.101325 \times 10^{-1}$ Pa

1.3 假设

1

2 /

3

2 真空泵排气方式形成真空的功率与能耗

$V =$ 6154400 m^3 6154.4 m^3

1000 km

10 m

1 ~ 10 km 2 ~ 5 km

5 km

$S_e = 5\ m^3/s$

p_0 $p_1 = 1.01325 \times 10^2$ Pa

6

$$t = \frac{V}{S_e}\ln\frac{p_0}{p_1} = \frac{5 \times 6154.4}{5}\ln\frac{1.01325 \times 10^5}{1.01325 \times 10^2}$$

$= 6154.4 \times \ln 1000 =$ 425[illegible]2 s = 11.8 h

V R_1

5 m^3/s

200 kW 5 km 1000 km

200

40000 kW 11.8 h

472000 kWh

1/10 $p_1 = 10132.5$ Pa

$$t = \frac{5\times 6154.4}{5}\ln\frac{101325}{10132.5} = 6154.4\times \ln 10$$
$$= 14171\ \mathrm{s} = 3.94\ \mathrm{h}$$

157600 kWh

[6-8]

2　3　4

5　157600 kWh

3　车辆运行抽气方式形成真空的功率与能耗

3.1　所需储气瓶容积总和计算

V

p_0

p_1　p_0

V_{vp0}　p_0

V_{1p0}　2

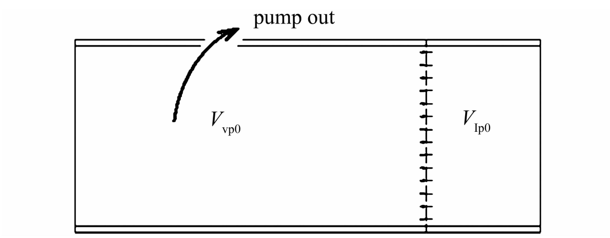

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Fig.2　Schematic illustration of the variations in gas volume

$$V_{vp0} + V_{1p0} = V \qquad (1)$$

$$\frac{p_1}{p_0} = \frac{V_{1p0}}{V} = \frac{V - V_{vp0}}{V} \qquad (2)$$

$$V_{vp0} = V\left(1 - \frac{p_1}{p_0}\right) \qquad (3)$$

p_2　V_2

$$p_0 V_{vp0} = p_2 V_2 \qquad (4)$$

$$V_2 = \frac{p_0 V_{vp0}}{p_2} \qquad (5)$$

3　5

$$V_2 = V\,\frac{p_0 - p_1}{p_2} \qquad (6)$$

1/1000　$p_1 =$ 101.325 Pa　$p_2 = 15$ MPa

6

$$V_2 = 6154400\times\frac{101325 - 101.325}{15\times 10^6} = 41531\ \mathrm{m}^3$$

p_1　10132.5　1013.25　101.325　10.1325　1.01325 Pa　p_2　10　15　20　25　30　35　40 MPa

1

表 1　所需要的储气容器总容积

Tab.1　Required total capacity of the gas storage tanks

p_1/Pa	/m^3						
	10	15	20	25	30	35	40
10132.5	56124	37416	28062	22449	18708	16035	14031
1013.25	61736	41157	30868	24694	20579	17639	15434
101.325	62297	41531	31149	24919	20766	17799	15574
10.1325	62353	41569	31177	24941	20784	17815	15588
1.01325	62359	41573	31179	24944	20786	17817	15590

2.8 m

1 ~ 2.4 m　0.785 ~ 4.5216 m^2　10 m

7.8 ~ 45.216 m^3

2

表 2　所需不同压力级储气瓶数

Tab.2　Required number of the high pressure gas storage tank

p_1/Pa							
	10	15	20	25	30	35	40
10132.5	7150/1241	4766/828	3575/621	2860/497	2383/414	2043/355	1787/310
1013.25	7864/1365	5243/910	3932/683	3146/546	2622/455	2247/390	1966/341
101.325	7936/1378	5290/919	3968/689	3174/551	2645/459	2267/394	1984/344
10.1325	7943/1379	5295/919	3972/690	3177/552	2648/460	2270/394	1986/345
1.01325	7944/1379	5296/919	3972/690	3178/552	2648/460	2270/394	1986/345

注：　1 m　2.4 m

2 $p_2 = 40$ MPa

2.4 m 10 m

1/1000 344

100

1000 km 3.5

3.2 排出气体量计算

3 1/10

$$V_{vp0} = V\left(1 - \frac{p_1}{p_0}\right) = 6154400 \times (1 - 0.1) = 5538960\ \mathrm{m^3}$$

1/10

90%

1/10 1/100

$$V_{vp0} = V\left(1 - \frac{1013.25}{101325}\right) - 5538960$$
$$= 6154400 \times (1 - 0.01) - 5538960$$
$$= 553896\ \mathrm{m^3}$$

1/10 1/10

3

3 3 2

1/10 5 1/10000

1/100000 1

1/10 1/

10000

表 3　各阶段排气量及所占总量的百分比

Tab.3　Percentage of the gas pumped out in each stage

	1	2	3	4	5
/1.101325 Pa	$10^5 \rightarrow 10^4$	$10^4 \rightarrow 10^3$	$10^3 \rightarrow 10^2$	$10^2 \rightarrow 10^1$	$10^1 \rightarrow 10^0$
/$\mathrm{m^3}$	5538960	553896	55389.6	5538.96	553.896
/%	90	9	0.9	0.09	0.009

3.3 运行排气方式形成真空功耗计算

100 $\mathrm{m^3}$/min 10 ~

100 MPa 250

kW 1000 kWh

1/10

5538960 $\mathrm{m^3}$

55390 min 923 h

923 h

250 kW

1000 kWh

1/10 923 × 500

= 461500 kWh 923 × 2000 = 1846000 kWh

1 1/10

1

1

2

1

2

1 1/10

2 1 1/10

46150 kWh 3 4615

kWh 4 5 461.5

46.15 kWh

1000

kW 2

500 kW 2

92.3 × 1500 = 138450 kWh

2

4 真空泵站与运行抽气相结合的抽真空方式

p_0 1/1000 $p_1 = 101.325$ Pa

11.8 h 1/10

$p_1 = 10132.5$ Pa 3.94 h

1/10 / 1/1000

/ 1/3

1/

10 1 90%

1

2 1/10

$\Phi 2.4 \times 10$ m * 40 MPa

310 $\Phi 1 \times 10$ m 15 MPa

4766

2

100 m^3/min 10 ~

100 MPa

1/10 5538960 m^3

55390 min

1/10 1/

100 $\Phi 2.4 \times 10$ m 40 MPa 31

$\Phi 1 \times 10$ m 15 MPa 477

5539 min

1/10 1/100

1/10

1/10

1/10

1

2 1/10

1/100 1/10

/

5 恢复真空补抽气时的功率消耗

9

1/1000 1/100

5 km $S_e = 5$

m^3/s 1013.25 Pa 102.325 Pa

3.94 h 157600 kWh

3 2.8 m 1000 km

1013.25 Pa 102.325 Pa

$$V_{vp0} = V_t\left(1 - \frac{101.325}{101325}\right) - V_t\left(1 - \frac{1013.25}{101325}\right)$$

$$= 615440 \times (0.01 - 0.001)$$

$$= 609286 \times 0.009$$

$$= 5484\ m^3$$

6 15 MPa

$$V_2 = 5484 \times \frac{101325}{15 \times 10^6} = 37\ m^3$$

40 m^3 15 MPa

100 m^3/min 10 ~

100 MPa 1/100

1/1000 54.84 min

9 1000

km/h 1/100

150 kN

2000 kW

250 kW 200

km/h 5 h

11250 kWh

1000 Pa

1000 km 200

“ + 40 m^3 15 MPa

+ ”

6 上述估算分析的可信度

6.1 能耗估算结果可信度及其对研究结论的影响

1

2 5 km

2.8 m

[6-8,11]

3 5 m^3/s 200

kW

4 250 kW

$157600 \times 3 = 472800 > 461500$ kWh

1

2

6.2 建设成本估算结果可信度及其对研究结论的影响

1

2

1

2

7 结论

1 1/10 1

90%

2

1

3 1

4 1/10 1/100

2

10%

5 1/100 1/1000

3

1%

4 5

6

2

①

② 1

2

③

参 考 文 献

1 . J .
2015 17 3 23 – 27

2 .
J . 2015 52 3 26 – 31

3 . —
J . 2015 52 5 23 – 27

4 Daryl OSTER Masayuki KUMADA Yaoping ZHANG. Evacuated tube Transport Technologies ET3 tm a Maximum Value Global Transportation Network for Passengers and Cargo M . Chengdu Journal of Modern Transportation 2011 19 1 42 – 50

5 .
P . 2009103059627 2009-8-24

6 . M .
2006 349

7 . 3 M .
2006 773 – 775

8 . 2 M .
2007 562

9 Zhang Yaoping Yu Jianye Shen Maoxing et al. Affecting Factors and Numerical Value Calculation Relating to Vacuumizing Time in Evacuated Tube Transportation C . The 6th International Forum on Strategic Technology IFOST 2011 Harbin 2011 8 246 – 249

10 Zhang Yaoping. Numerical Calculation and Analyses on Aerodynamic Drag of Subsonic Train in Evacuated Tube Transportation J . Chengdu Journal of Modern Transportation 2012 20 1 44 – 48

11 . M .
2014 45 – 46