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710123

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

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Abstract A novel technique was proposed tofurther remove the low pressure air in the vacuum tube pumped down from atmosphere to ~ 10^4 Pa via the stationary pumqing stations by means of the running vehicle in vacuum tube transport. In the proposed pumping scheme the fast-runing vehicletakes air in and stores the compressed air in its mobile storage tanks while pushing out the air in the tube through the openings constructed along the tube wall. The impact of the technical factors including but not limited to the compressor 's energy consumption number of mobile storage tank pumping capacity construction cost and possible technical problems to be solved on the pumping efficiency and feasibility of the proposed technique was tentatively discussed in a though provoking way. We suggest that the novel auxiliary pumping method may be of some basic and technological interest in development of vacuum tube transport.

Keywords Vacuum tube transport Pumping by vacuum pump Pumping by running vehicle Gas storage bottle Mending pumping

摘要

1.01325×10^5 1.01325×10^4 Pa 90%

1.01325×10^4 Pa 1/10

10%

关键词

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Vacuum Tube Transport VTT

“ ” Vacuum Tube High-[2-4]

speed Maglev Transport

[1]

1

600 ~ 1000 km/h

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“

” [5]

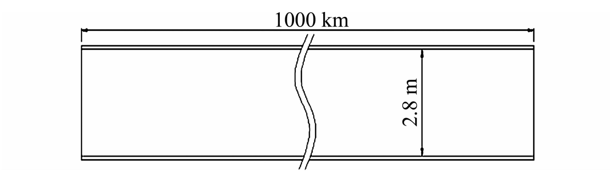
3

1 分析模型、假设

1.1 管道模型

1 2.8 m

1000 km



1

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 $1.101325\times10^{5}\sim1.101325\times10^{4}$ Pa

2 $1.101325\times10^{4}\sim1.101325\times10^{3}$ Pa

3 $1.101325\times10^{3}\sim1.101325\times10^{2}$ Pa

4 $1.101325\times10^{2}\sim1.101325\times10^{1}$ Pa

5 $1.101325\times10^{1}\sim1.101325\times10^{0}$ Pa

5

5

5000 10000 km/h

6 $1.101325\times10^{0}\sim1.101325\times10^{-1}$ 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 $p_1 = 1.01325\times10^{2}$ Pa

6

$$t = \frac{V}{S_e}\ln\frac{p_0}{p_1} = \frac{5\times6154.4}{5}\ln\frac{1.01325\times10^{5}}{1.01325\times10^{2}}$$

$$= 6154.4\times\ln1000 = 425[illegible]2\ \text{s} = 11.8\ \text{h}$$

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

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

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

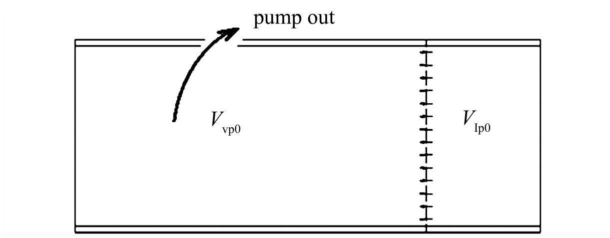


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Fig.2 Schematic illustration of the variations in gas volume

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

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

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

p_2 V_2

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

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

3 5

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

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

6

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

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	/m³						
	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 m²

10 m

7.8～45.216 m³

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

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

1/10

90%

1/10 1/100

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

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	$10^5 \rightarrow 10^4$	$10^4 \rightarrow 10^3$	$10^3 \rightarrow 10^2$	$10^2 \rightarrow 10^1$	$10^1 \rightarrow 10^0$
/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 m^3/min 10 ~

100 MPa 250

kW 1000 kWh

1/10

5538960 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 × 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

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