Leading Carbon/Ceramics Materials Application research and Industrialization

Shandong STOPART Brake Materials

1 Preparation process

Carbon Ceramic Brake coated discs

Methane CH4 /ˈmeθeɪn/, natural gas
丙烷 propane /ˈprəʊpeɪn/
Hydrogen /ˈhaɪdrədʒən/
螺栓孔 Bolt holes
通风槽 ventilation slot
刻码 Engraving
装配台加工 Assembly table processing
LSI钳修：
锯支点 sawing supporting carbon felt
修内外圆 Repair the inner and outer circle
修定位孔 repair locating hole
炉 furnace
半成品 semi-finished goods/products
形态 morphology /mɔːˈfɒlədʒi/

终加工：
粗磨 rough grinding /ˈgraɪndɪŋ/
扩孔磨圆 hole expansion, rounding
通风孔加工 vent/air hole
精磨机 refining mill
清洗烘干 cleaning，drying
卧式立式 horizontal vertical
装配 assembly
质量检测：
动平衡 dynamic balancing
去重 remove overmuch weight
厚薄差 thickness difference (disc thickness variation)
跳动量 plane flatness (runout)
外观 appearance

Now let's see the preparation/fabrication/manufacturing process of CCB (Carbon Ceramic Brake) coated discs.
Firstly, the 3D needle-punched and structure function integrated fabric preform were prepared by three dimension needling technology.
Nest step involved in deposition of pyrolytic carbon on fabric performs by CVI (Chemical vapor[ˈveɪpə(r)] infiltration) process. The CVI process was conducted at 1000-1200℃ for 200-300 h. Natural gas was served as a precursor in the CVI.
After graphitization at 2000-2550℃, machining (cleaning, drying and roughening) and coating, we can get the coated C-C composites.
Moving on to the next significant procedure, liquid silicon infiltration, started with isolation layer preparation and putting C-C composites into furnace for LSI, ended with finish machining, quality detection and assembly. Finally, a CCB disc was obtained.

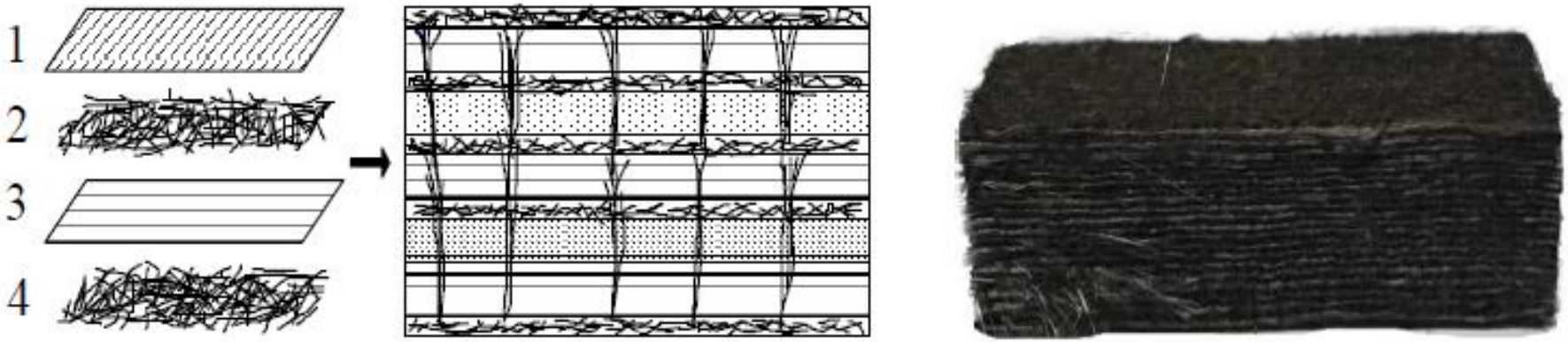
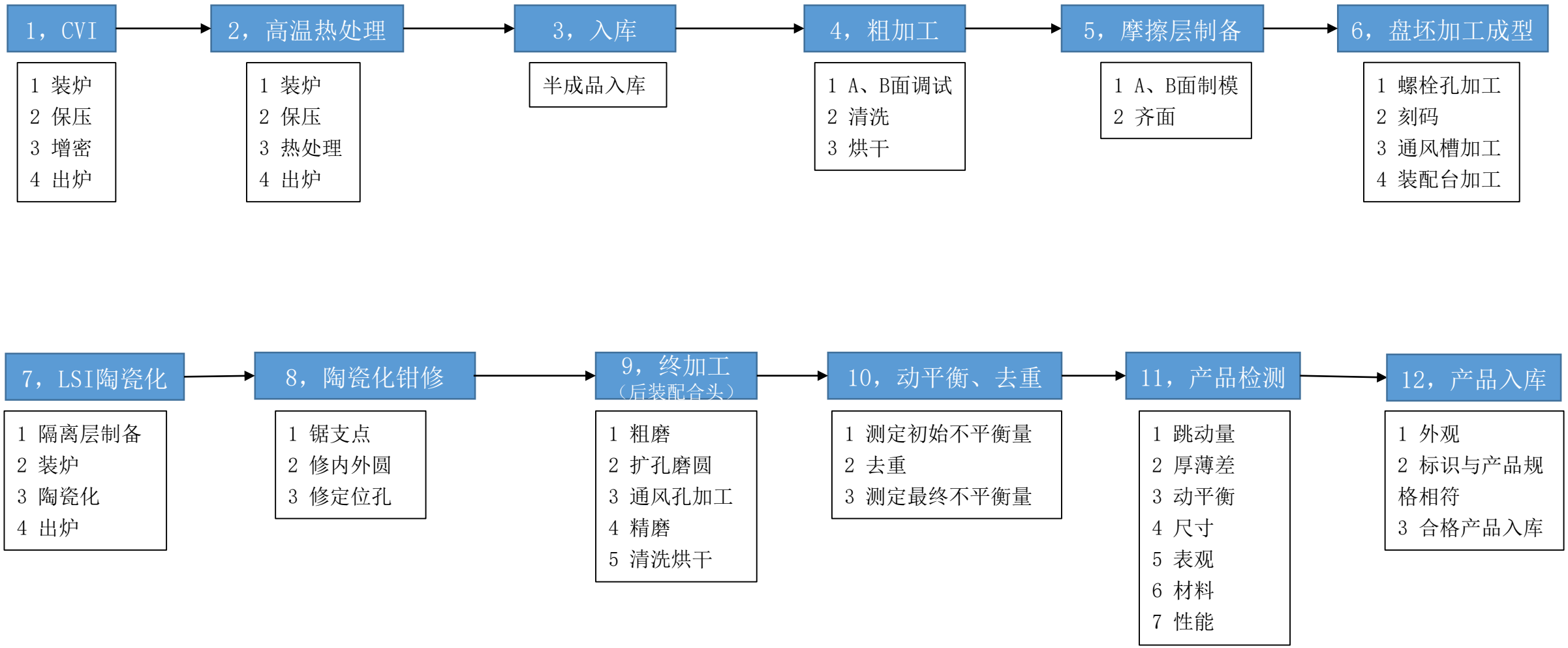


图2.1 无纬布碳毡示意图（1：90° 无纬布，2、4：网胎层，3：0° 无纬布）

Fig. 2.1 Schematic of non-woven fiber cloth carbon felt (1: 0° non-woven fiber cloth, 2、4: short-cut fiber web, 3: 90°non-woven fiber cloth)

碳陶刹车盘机械加工流程

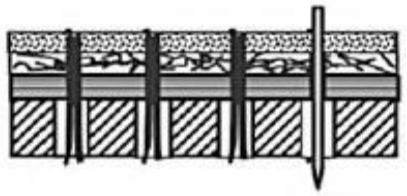


1 Preparation process

Preparation process of CCB (Carbon Ceramic Brake) coated discs

Long Carbon fibers

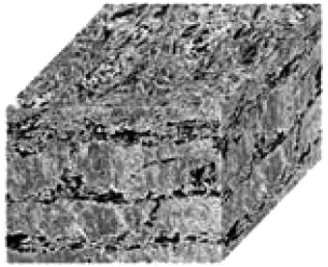
Waving needling



Pre-form

Chemical vapor infiltration

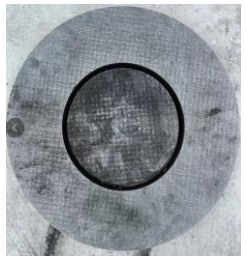
（1000-1200℃）



Porous Carbon-Carbon pre-form

Graphitization

（2000-2550℃）



Initial C-C composites

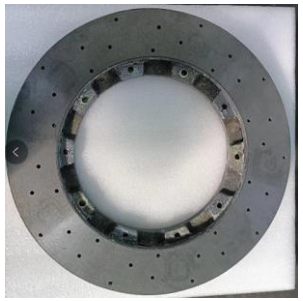
Machining

Coating

Coated C-C composites

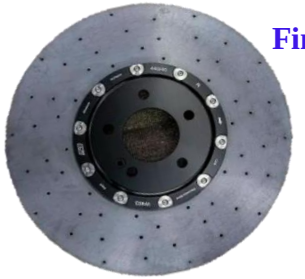
liquid silicon infiltration

（1500-1800℃）

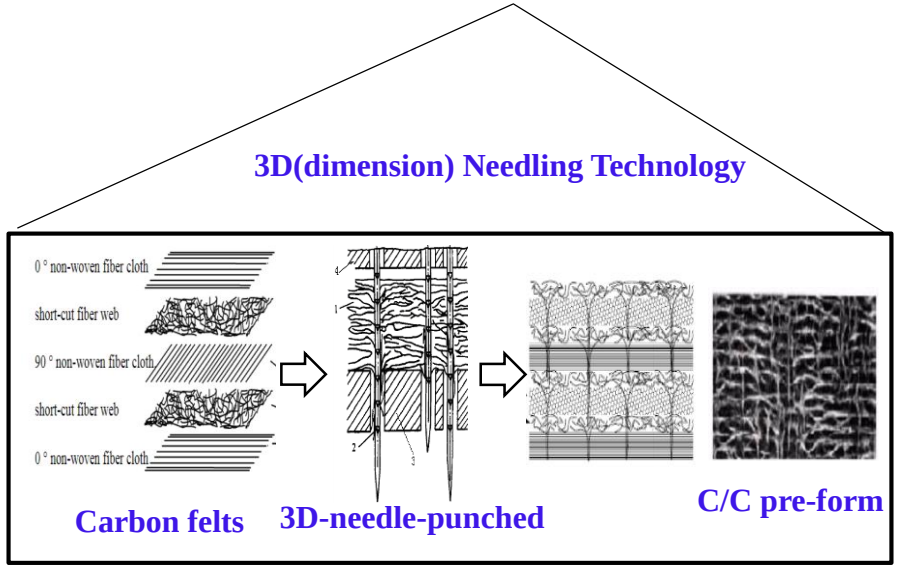


Final C/C-SiC composites

Finish machining
Detection
Assembly

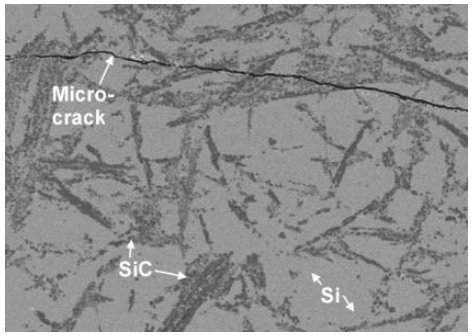


Finished CCB discs



1 Preparation process

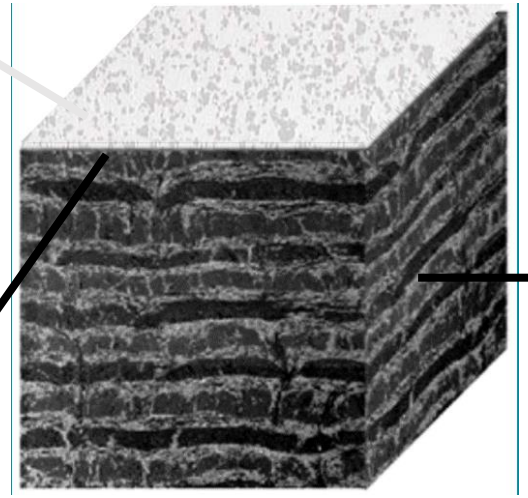
Coating technology



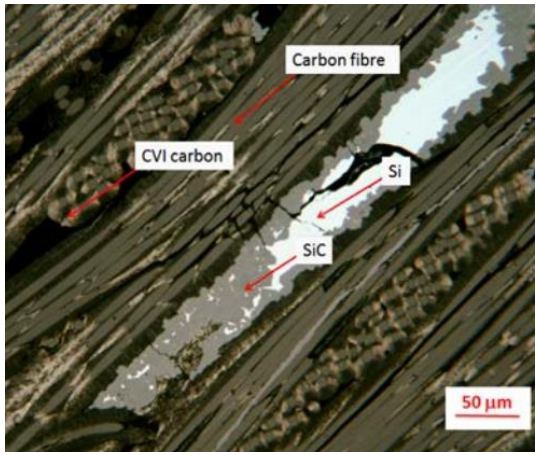
Microstructure of frictional function layer

Phase composition of the structure-function integrated C/C-SiC

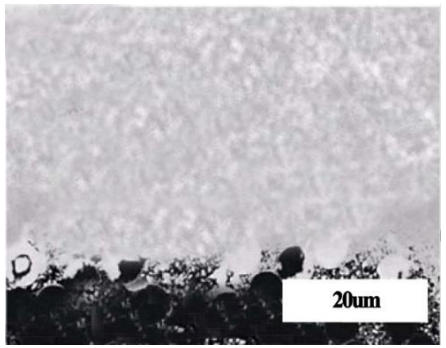
- Long carbon fibers
- SiC
- Si
- CVI carbon



Microstructure of discs



The morphology of interface



Microstructure of cross section (interface) of frictional function layer and C-C composites

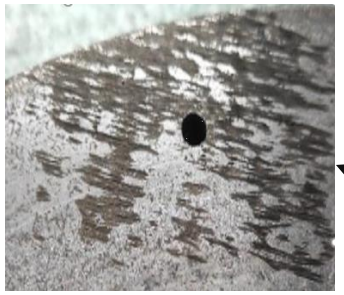
Advantages of SiC in frictional functional layer

- SiC Phase content: more than 80%
- Outstanding friction performance
- Higher temperature resistance

1 Preparation process

◆ Coating technology

Unique friction layer preparation technology- higher temperature resistance & better fiction performance



- Surface fibers are exposed
- easy to oxidize
- Unstable friction performance

Carbon ceramic brake disc
(uncoated disc)

VS

Carbon Ceramic Brake disc
(coated disc)

- SiC coating on the surface
- Oxidation resistance
- Surface temperature resistance 1400 ℃
- Abrasion resistance, about 5 times that of the uncoated disc
- Uniform and stable friction coefficient

◆ Ceramic layer over 0.6 mm in thickness performed outstanding frictional performance at 1000 ℃ and -30 ℃.

◆ Prevention inner carbon fibers from high-temperature oxidation, ensuring mechanical properties and safety of brake discs.

1 Preparation process

Mechanical properties of long fiber carbon ceramic brake discs

Items	Short fiber carbon ceramic brake discs	Long fiber carbon ceramic brake discs
Tensile strength (MPa)	20-40	80-165
Elastic modulus (GPa)	30-60	60-120
Flexural strength (MPa)	50-80	150-230
Thermal conductivity (W/m/K)	20-40	40-80

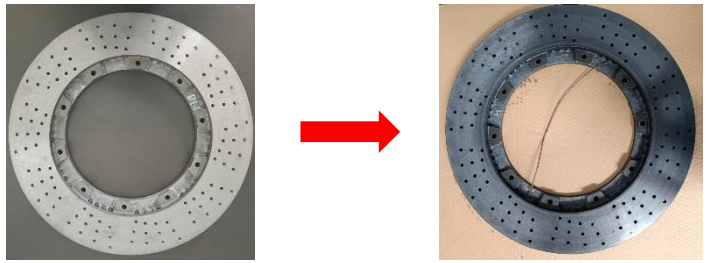
- Higher thermal conductivity, lower service temperature, no fading.
- Excellent mechanical strength can help to increase service life and improve durability.

2 Carbon Ceramic Brake discs performance test

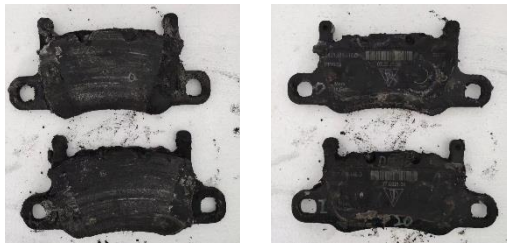
2 CCB discs performance test

BXX Salt Spray Test

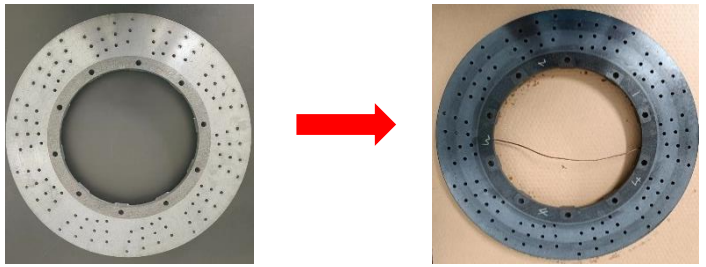
No.	Test	Methods & conditions
1.0	Abrasion	Braking times：50 Braking pressure：25 bar Initial speed：150 km/h Terminal speed：50 km/h Initial temperature：＜150℃
2.0	120 km/h Variable pressure	Braking times：1 Braking pressure：10、20、30、40、60、80、100、120 bar Initial speed：120 km/h Terminal speed：80 km/h Air volume for cooling：2000 m^3/h Initial spray temperature：80℃ spray speed：10 km/h Spray duration：10 s
3.0	200 km/h Variable pressure	Braking times：1 Braking pressure：10、20、30、40、60、80、100、120 bar Initial speed：200 km/h Terminal speed：170 km/h Air volume for cooling：2000 m^3/h Initial spray temperature：80℃ spray speed：10 km/h Spray duration：10 s
4.0	0.6 g High-velocity braking	Braking times：1 Deceleration：0.6 g Initial speed：200 km/h Terminal speed：60km/h Air volume for cooling: 4000 m^3/h Initial temperature：50℃ Maximum braking pressure:160 bar
5.0	0.8 g High-velocity braking	Braking times：1 Deceleration：0.8 g Initial speed：200 km/h Terminal speed：60 km/h Air volume for cooling: 4000m^3/h Initial temperature：50℃ Maximum braking pressure:160 bar
6.0	Cycles	Cycle 3 times in 1-5 steps



Before testing　　After testing



Tested brake pads



Spray device

Conclusion

- After discontinuous spray, the surface of CCB disc is normal and free of wear as well as no corrosion.
- Furthermore, salt spray test result of brake disc has met the Porsche standards.

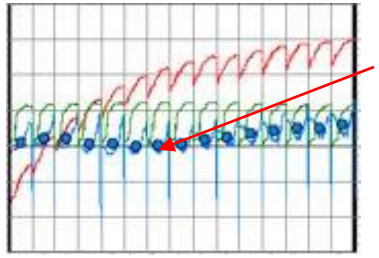
2 CCB discs performance test

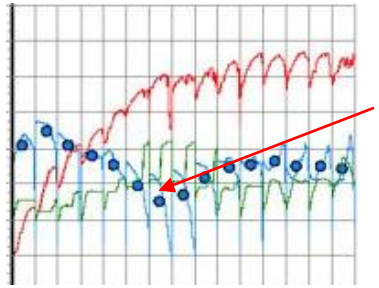
Heat fading test

CCB disc

Steel disc

CCB brake animation





Red: temperature; Green: brake pressure; Blue: friction coefficient

- After passing the heat fading test in line with SAE J2522 standard (start from 100℃ to 650℃ after 15 times of brake), the friction coefficient shows no fading. Moreover, it has excellent brake performance because friction coefficient of mating plate reduced only 3% at 800 ℃.
- The service temperature of carbon ceramic brake disc can reach 1400 ℃, the friction coefficient is stable and there is no fading.

2 CCB discs performance testing

Efficiency – strength test

Tested vehicle model	6*6
Information	Vehicle full-loaded quality Ga：8000 kg Load of front axle in full-loaded condition：3600 kg Wheel rolling radius (r)：0.502 m Rated pressure: 13 MPa Unloaded quality：6000 kg Front and rear braking force distribution ratio: 0.64 : 0.36 Maximum speed：120 km/h Rated braking torque: 6600 N▪m
Quantity	CCB disc: 1 piece
Device	Heavy vehicle brake test bench 8010
Reference standard	QC/T239-2015 <Commercial vehicle running brake technology requirements and test method> Test address：襄阳达安汽车检测中心有限公司

制动初速 km/h	制动压力 MPa	制动力矩 N▪m					
		第一次效能	第一次常温效能	第二次效能	第三次效能	第二次常温效能	第四次效能
60	3	1548	——	2015	2317	——	2353
	5	2468	——	3078	3464	——	3513
	7	3391	——	4022	4494	——	4637
	9	4370	——	4950	5506	——	5702
	11	5399	——	5955	6617	——	6887
	13	6168	——	6947	7706		8097
95	3	——	——	2277	2476	——	2572
	5	——	——	3654	3938	——	4033
	7	——	——	4824	5163	——	5375
	9	——	——	5764	6118	——	6414
	11	——	——	6443	6746	——	7129
	13	——	——	6996	7263	——	7614

Conclusion

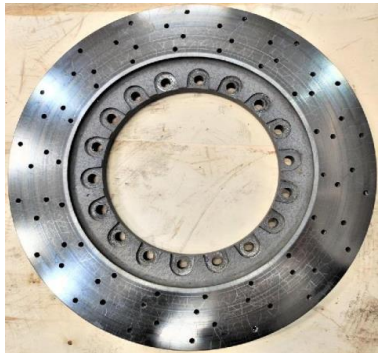
- The maximum braking torque is 8097 N.m.
- The body of CCB disc and accessories have no permanent deformation and damage.

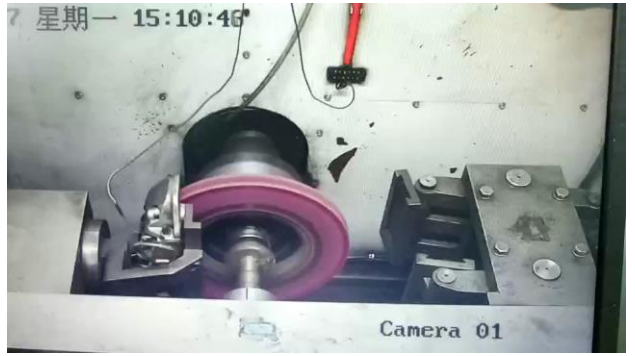
2 CCB discs performance test

Efficiency– abrasion test

Tested vehicle model	6*6
Information	Vehicle full-loaded quality Ga：8000 kg Load of front axle in full-loaded condition：3600 kg Wheel rolling radius (r)：0.502 m Rated pressure: 13 MPa Unloaded quality：6000 kg Front and rear braking force distribution ratio: 0.64 : 0.36 Maximum speed：120 km/h Rated braking torque: 6600 N▪m
Quantity	CCB disc: 1 piece
Device	Heavy vehicle brake test bench 8010
Reference standard	QC/T239-2015 <Commercial vehicle running brake technology requirements and test method> Test address：襄阳达安汽车检测中心有限公司

制动初速 km/h	制动压力 MPa	制动力矩 N▪m					
		第一次效能	第一次常温效能	第二次效能	第三次效能	第二次常温效能	第四次效能
60	3	1548	——	2015	2317	——	2353
	5	2468	——	3078	3464	——	3513
	7	3391	——	4022	4494	——	4637
	9	4370	——	4950	5506	——	5702
	11	5399	——	5955	6617	——	6887
	13	6168	——	6947	7706		8097
95	3	——	——	2277	2476	——	2572
	5	——	——	3654	3938	——	4033
	7	——	——	4824	5163	——	5375
	9	——	——	5764	6118	——	6414
	11	——	——	6443	6746	——	7129
	13	——	——	6996	7263	——	7614





Conclusion

- The maximum braking torque is 8097 N.m through 890 times braking at the variable pressure and speed conditions.
- Actual abrasion value is 0.002 mm, which means there is no obvious wear.

2 CCB discs performance test

Temperature rise test - Heat capacity

Test	CCB discs Temperature rise test
Standard	《Internal temperature rise test standard》
Quantity	CCB disc: 1 piece
Device	LINK3000 Braking performance bench
Test condition	Braking times：2000 Retardation：0.8 g Initial speed：234 km/h Terminal speed：90 km/h Cooling air volume：4000 m^3/h Initial braking temperature：formula maximum temperature：725℃
Temperature rise	26℃

Conclusion

- Temperature rise is 26℃ in working condition.
- Due to CCB disc's large heat capacity, single braking temperature rise is low and not prone to fading.

Test Request #: 210689-01

LINK

Customer Ref: C-0762

Stop #	Brake Speed kph	Release Speed kph	Stop Time sec	Stop Distance meter	Average Decel (Torque) g	Average Decel (Time) g	Torque Min N·m	Torque Average (Dist) N·m	Torque Average (Time) N·m	Torque Max N·m	Pressure Min bar	Pressure Average (Dist) bar	Pressure Average (Time) bar	Pressure Max bar	Average Eff. (Dist) unitless	Average Eff. (Time) unitless	Brake Temp Initial °C	Brake Temp Final °C
1	207.89	103.50	3.858	170.97	0.83	0.85	1265.99	1405.48	1408.55	1489.06	68.72	79.11	78.58	82.62	0.289	0.292	611	684
2	207.89	90.12	4.335	183.49	0.81	0.81	1228.71	1373.01	1380.88	1487.33	59.97	69.80	69.49	74.36	0.320	0.324	621	653
3	207.89	90.42	4.319	182.83	0.82	0.81	1255.23	1377.43	1385.88	1498.28	60.76	72.41	72.05	76.79	0.310	0.314	624	654
4	207.30	89.98	4.312	181.28	0.82	0.83	1253.50	1382.81	1390.68	1487.33	63.07	74.20	73.92	78.10	0.303	0.306	626	656
5	207.89	89.98	4.313	182.07	0.82	0.82	1308.64	1393.76	1398.56	1486.75	64.14	75.22	74.71	77.93	0.301	0.305	627	662
6	207.74	90.42	4.337	183.24	0.82	0.81	1247.16	1378.58	1386.07	1490.98	64.33	74.29	74.04	77.59	0.302	0.305	627	655
7	208.33	90.12	4.365	184.79	0.82	0.81	1255.80	1380.31	1387.03	1478.30	65.30	74.52	74.28	77.89	0.301	0.304	627	654
8	207.59	89.98	4.346	183.22	0.82	0.81	1259.84	1378.00	1384.73	1482.72	65.24	74.53	74.29	77.25	0.301	0.303	628	654
9	207.74	90.27	4.308	181.87	0.82	0.81	1241.97	1381.84	1388.57	1493.28	66.27	75.04	74.80	77.62	0.299	0.302	628	654
10	207.89	90.42	4.310	182.12	0.82	0.82	1244.08	1389.15	1394.33	1486.18	65.22	75.63	75.24	78.95	0.299	0.302	628	653
11	207.74	89.98	4.343	183.15	0.82	0.82	1226.79	1387.03	1393.76	1492.71	64.79	75.51	75.11	78.85	0.299	0.302	628	653
12	207.89	89.98	4.330	183.07	0.82	0.84	1225.83	1387.03	1393.76	1500.59	64.76	75.91	75.53	79.38	0.297	0.300	628	653
13	208.03	89.98	4.374	184.69	0.82	0.83	1247.54	1383.77	1390.30	1498.47	65.28	76.12	75.74	78.65	0.296	0.299	628	652
14	208.18	90.27	4.355	184.69	0.82	0.82	1251.57	1383.38	1390.68	1511.15	66.86	76.84	76.56	79.21	0.293	0.295	628	651
15	207.74	90.42	4.342	183.44	0.82	0.81	1288.47	1391.26	1397.22	1507.12	66.25	77.07	76.58	79.11	0.294	0.297	628	655
16	207.89	89.98	4.326	182.63	0.82	0.83	1268.48	1393.57	1398.94	1509.23	66.88	78.01	77.56	80.89	0.290	0.293	628	652

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