University of BRISTOL

Composites in Automotive Applications: Review on brake pads and discs

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Research Development: Literature Review
November 12, 2014

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Contents

Brake system

safety

stability

reliability

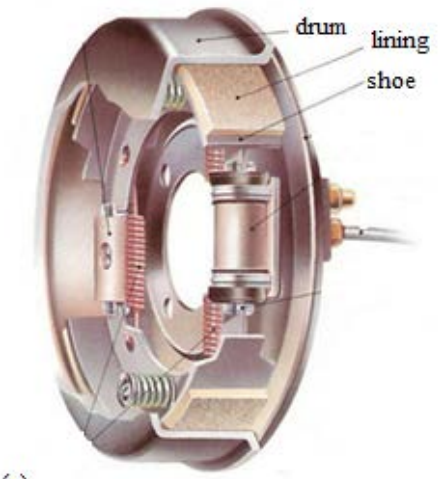
Design requirements

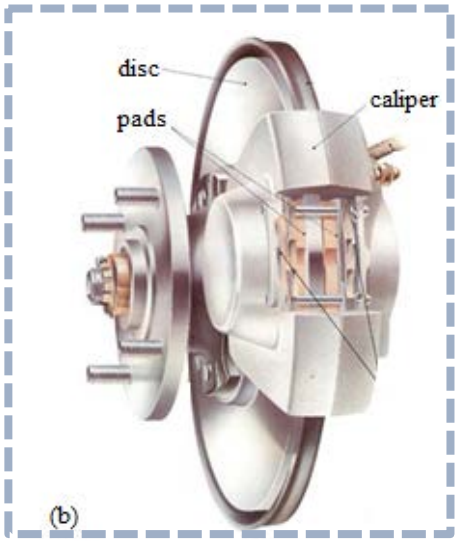
- exceptional frictional properties
- low wear rate
- high thermal conductivity
- resistance to environmental conditions
- increased durability
- low weight, noise production and cost

2 types of brakes

a) the drum/shoe brakes

b) the disc/pad brakes





http://www.howacarworks.com/basics/how-the-braking-system-works, (accessed 30 Sept 2014) / Blau PJ, OAK RIDGE NATIONAL LABORATORY 2001 / Chapman BJ and Rizkallah-Ellis AAM, Wear 1979 / Maleque MA, Dyuti S and Rahman MM, Proc. WCE 2010 / Kinkaid NM, O'Reilly OM and Papadopoulos P, J Sound Vib 2003 / Blau PJ, Jolly BC, Qu J, Peter WH and Blue CA, Wear 2007 / Manoharan S, Suresha B, Ramadoss G and Bharath B, J Mater 2014 / Gutlekin D, Uysal M, Aslan S, Alaf M, Guler MO and Akbulut H, Wear 2010

Brake pads

- Complex structure

- Composite material of 4 main components:
  a. *binder*: holds the components together
  b. *structural materials*: provide strength
     metal, glass, Kevlar, carbon,
     ceramic or natural fibres
  c. *fillers*
  d. *additives*: abrasives and lubricants

Eriksson M and Jacobson S, Tribol Int 2000 / http://de.bosch-automotive.com/en/parts/parts_and_accessories/service_parts_1/brakes_1/ (accessed 21 Oct 2014) / Bassoli E, Atzeni E and Iuliano L, J Manuf Sci Eng 2011

Brake pad materials

- Metallic pads

  metallic matrix reinforced with steel, copper or other metals

high strength

high thermal conductivity

great wear damage

increased squeal noise

vulnerable to corrosion

motorcycle

Chan D and Stachowiak GW, J Automob Eng 2004 / PFC Brakes. De-mystifying Friction Material Terminology (accessed 21 Oct 2014) / How to replace motorcycle brake pads (http://www.sevacall.com/blog/2013/04 accessed 8 Nov 2014)

Brake pad materials

- Semi-metallic pads

  combination of metals and organic materials

good friction properties

high thermal conductivity

high performance cars

significant wear damage

increased squeal noise

vulnerable to corrosion

trucks

Manoharan S, Suresha B, Ramadoss G and Bharath B, J Mater 2014 / Chan D and Stachowiak GW, J Automob Eng 2004 / Borgna B, 2013 (http://www.volvotrucks.com/trucks/na/en-us/news_and_events/, accessed 9 Nov 2014) / http://www.larueauto.com/high-performance/ (accessed 9 Nov 2014)

Brake pad materials

- Non-asbestos organic or Ceramic pads

organic matrix reinforced with aramid, Kevlar, glass or ceramic fibres

high strength

high thermal resistance

high wear resistance

lightweight

low level of noise

quite brittle

increased wear in high temperatures

cars

Chan D and Stachowiak GW, J Automob Eng 2004 / Eriksson M, Bergman F and Jacobson S, Wear 1999 / Mutlu I, Eldogan O. and Findik F, Tribol Int 2006 / Mutlu I, Eldogan O and Findik F, Ind Lubr Tribol 2005 / http://www.shutterstock.com/ (accessed 9 Nov 2014)

Brake pad materials

- Carbon-carbon pads

  similar to ceramics but with superior properties

high friction properties

high thermal resistance

high wear resistance

lightweight

not efficient at low temperatures

high cost (material & manufacture)

race cars

aerospace

PFC Brakes, De-mystifying Friction Material Terminology (accessed 21 Oct 2014) / Zhuan L, Peng X, Xiang X and Su-hua Z, Trans Nonferous Met Soc China 2008 / http://www.formula1.com/inside_f1/understanding_f1_racing/5284.html (accessed 20 Oct 2014) / http://www.formula1.com/gallery/race/2014/935/general/sunday.html (accessed 9 Nov 2014) / http://www.electric-vehiclenews.com/2012/02/aircraft-of-future-could-capture-and-re.html (accessed 9 Nov 2014)

Brake pad materials

- Eco-friendly materials

  use of natural fibres such as sisal, flax, hemp kenaf, jute, coconut shell, banana peels or palm kernel fibres as reinforcement

high mechanical properties

stable friction

high wear resistance

lightweight

low environmental impact

low cost

tend to agglomerate at mixing

wear from environmental conditions

John MJ and Thomas S, Carbohyd Polym 2008 / Ashori A, Bioresource Technol 2008 / Netravali AN and Chabba S, Mater Today 2003 / Xu X, Cheng G and Liu F, Wear 2007 / Sloan M, Savage L, Evans K and Hooper B, In: Proc 24th Annual Brake Colloquium and Exhibition, 2006 / Yun R, Filip P and Lu Y, Tribol Int 2010 / Idris UD, Aigbodion VS, Abubakar IJ and Nwoye CI, Journal of King Saud University – Engineering Sciences 2013 / Ikpambese KK, Gundu DT and Tuleum LT, Journal of King Saud University – Engineering Sciences 2014

Brake discs

Characteristics

- high friction properties
- low wear rate
- high thermal capacity to prevent distortion or cracking

- Cast iron
  - \+ *high strength*
  - \+ *high thermal conductivity*
  - \+ *high wear resistance*
  - \+ *low cost*
  - \- **heavy weight**

Maleque MA, Dyuti S and Rahman MM, Proc. WCE 2010 / Pevec M, Lerher T, Potrč I and Vranešević D, Adv Eng 2010 / Cueva G, Sinatora A, Guesser WL and Tschiptschin AP, Wear 2003 / http://www.whyhighend.com/carbon-ceramic-brakes.html (accessed 23 Oct 2014)

Brake discs

Al-metal matrix composites

- \+ *high strength*
- \+ *high thermal conductivity*
- \+ *high wear resistance*
- \+ *lightweight*
- \+ *high rate of heat dissipation*

Ti-metal matrix composites

- \+ *resistance to corrosion*
- \- low wear resistance
- \- low load capacity ⇨ surface modification

Ceramic composites

- \+ *high friction properties*
- \+ *high thermal properties*
- \+ *lightweight*
- \+ *perform at high temperatures*
- \- brittle

high performance & sports cars

Carbon-carbon composites

- \+ *thermal conductivity*
- \+ *lightweight*
- \- high cost

aircrafts & sports cars

Blau et al, Wear 2007 / Gutlekin D et al, Wear 2010 / Telang AK et al, J Eng Res Stud 2010 / Nakanishi H et al, JSAE Review 2002 / Straffelini G et al, Wear 2004 / Chen R et al, Wear 1997 / Daoud A and Abou El-khair MT, Tribol Int 2010 / Prasad SV and Asthana R, Tribol Lett 2004 / Qu J, Blau PJ and Jolly BC, Wear 2009 / Duraiselvam M et al, Wear 2014 / Bansal DG et al, Wear 2013 / Dietrich G et al, US Patent 6261981, 2001 / Windhorst T and Blount G, Mater Des 1997 / Ozcan S and Filip P, Wear 2005 / Lei B et al, Wear 2011 / Hao M et al, Wear 2014

Conclusions

Composites are widely used in the automotive brake system

- *ceramic composites* are the most commonly used brake *pads*
- *carbon-carbon pads* exhibit superior properties but their cost is currently very high
- *eco-friendly materials* in brake *pads* seems promising, though there are still issues that need to be addressed (ie. wear from environmental conditions)
- *metal matrix, ceramic matrix* and *carbon-carbon composites* are mainly used in brake *discs*
- *carbon-carbon discs* are very expensive, used only in sports cars

The *combination* of the material of the pads and that of the disc is critical to achieve the desirable performance of the system.

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Thank You!

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