A History and Introduction to Amorphous Iron Motors

January 2014
Andrew Hirzel
Radam Motors LLC
First Question: What is Amorphous Iron?

- Metglas (Hitachi Metals) and AT&M provide all of the world’s amorphous iron
- It is a ~25 micron, 0.001 inch, thick metal ribbon
- Produced in annual volume of over 100,000 tons

This material has not yet been commercially exploited for electric motors.

http://www.metglas.com/

http://www.atmcn.com/english
Molecules of iron typically form a 3-D cubic crystal structure.

But compare these 2-D layouts:

- **Crystalline iron**, is orderly, strongly resists magnetic flux change, has a density of 7.8 g/cc.
- **Amorphous iron**, is non-orderly, weakly resists magnetic flux change, is less dense at 7.2 g/cc.

This non-orderly amorphous structure allows magnetic flux to alternate **very** efficiently.

No Really: What **IS** Amorphous Iron?
Who uses Amorphous Iron today?
Here’s the best explanation, taken from their site

There is clear benefit for AMDT’s *(Amorphous Metal Distribution Transformers)* when studying Total Ownership Cost (TOC) – even at low line frequencies of 50/60 Hz

FROM http://www.metglas.com/index.asp
Sources


2003 **US Patent 6603237 High frequency electric motor or generator including magnetic cores formed from thin film soft magnetic material**, Caamano, August 5, 2003

2006 **Practical Design and test of High Torque Density/High Frequency Electric Motors**, Hirzel A., American Society of Naval Engineers, EMTS May 2006 Phila. USA

2006 **Investigation of Axial Field Permanent Magnet Motor Utilizing Amorphous Magnetic Material**, Liew G. et al,


2009 **Development of an Axial Gap motor with Amorphous Metal Cores**, Wang Z. et al,


Amorphous Losses

Fig. 4. Ring test losses for the three test stators.

2006

Fig. 1 Core material losses as a function of peak flux density.
Amorphous Iron Properties

Either stacking or winding amorphous ribbon yields very similar losses.

The extremely narrow hysteresis says it all (that vertical line!).

Fig. 2. Iron loss of stacked core and wound core under different fields. The corresponding field strengths for the three sets of data shown in the graph are, from top to bottom, 1.0 T, 0.5 T and 0.1 T, respectively.
1981 & 1982

- Induction
- Radial
- Staggered and overlapping lamination sections
- Tested data
1983

- A proposal only
- Would it be possible to cast amorphous iron as a helical ribbon?
- Not yet....
- But this does show the extreme interest in this material
1989

- Synchronous reluctance
- Radial
- Chemically etched laminations
- Tested data
1992

- Permanent magnet brushless
- Axial
- Dual rotor
- Single toroidally wound stator
- Coiled ribbon core
- Tested data

Fig. 1. Two-pole machine topology. J denotes stator current path, and H denotes magnetic field intensity.

Fig. 2. Axial view of (a) rotor showing location of PM's and (b) stator showing three-phase winding pattern.
1998

- Permanent magnet brushless
- Axial
- Single rotor
- Dual slotted stators
- Tested data
1999

- Some ideas that were perhaps a little too optimistic on the amorphous iron properties
• Radial
• Prismatic blocks
• Never constructed
2003

- Permanent magnet brushless
- Radial
- Individual phase horseshoe segmented stator cores
- Double-row magnet rotor
- Tested data

Figure 4
2006

- Permanent magnet brushless
- Axial
- Single rotor
- Dual slotted stators
- Tested data

Figure 1: Typical Motor Construction

Figure 3: Example of Active OD and ID
2006

- Permanent magnet brushless
- Axial
- Single rotor
- Single slotted stator
- Tested data

Figure 5: a) Photos of stator with windings, rotor with 2 pole magnets and back iron, b) AFPM motor configuration without back iron, c) AFPM motor configuration with back iron.

Figure 6: Test rig that contains the AFPM motor with adjustable airgap and the loading DC machine.
2008

- Switched reluctance
- Radial
- Tested data

Fig. 5. Test machine iron cores.
2009

- Permanent magnet brushless
- Axial
- Dual rotor
- Single stator, segmented cores
- Concentrated coils
- Tested data
2010

- Permanent magnet brushless
- Axial
- Dual rotor
- Single stator segmented cores
- Concentrated coils
- Tested data

Fig. 7. (a) Rotor of the motor, (b) Stator of the motor.

Fig. 8. (a) Wrapping process, (b) Molded AMM core.

Fig. 9. (a) AMM wound stator core, (b) Assembly of AMM core and copper coil.
2011

- Permanent magnet brushless
- Induction
- Radial

Fig. 1 A family of amorphous metal cores of AT&M
2011

- Permanent magnet brushless
- Radial
- Segmented stator
- Concentrated coils
- Tested data
Radam Motors LLC

- Tested data
- 10,000 hours under PWM operation
- Thermal verification

www.radamllc.com
Thank you for your attention;

Questions?

Additions?

Corrections?