TS-SSC 92-084

Alternate End Part Materials

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Objectives

- Cut the cost of the machined end parts by utilizing mass production processes such as injection molding or die-casting.

- Maintain or improve the performance criteria of the machined G-10 end parts.

End Parts - Present Activities

- **Molding of organic materials**
  a. **Resin transfer molding (RTM)**
  b. **Compound transfer molding (CTM)**
  c. **Injection mold**
  d. **Compression mold**

- **Coating of casted part**
  a. **Chemical vapor deposition (CVD)**
  b. **Dip coating**
  c. **Hard coating/anodyzing**

RTM and CTM Development Program - Part I
(Completed July 1990)

Objectives:

To evaluate and study the feasibility of using RTM and CTM processes for producing end parts.

Resin System Used:

Dow Tactix 123 - epoxy resin with Tactix curing agents.

Reinforcement:

RTM - Continuous fiber E-glass - identical in content and weave to that used in G-10 CR. + webbed adhesive.

CTM - Chopped glass - 1/16" milled E-glass fiber. (40% by weight)

Results:

Both RTM and CTM proved to be capable of producing end parts using the Tactix resin. Yet there is much room for improvement in quality. Parts were tested successfully in a short magnet.

RTM and CTM Development Program - Part II
(Completed August 1991)

Objectives:

To evaluate and study the effects of replacing Tactix resin system with two resin systems (CTD-101 and CTD-102). Developed for working at low temperatures and high levels or radiation.

Resin Systems Used:

CTD-101 - Anhydride cured epoxy DGEBA based (400 cp; 60 hrs pot life @ 40°c processing temp)

CTD-102 - Anhydride cured epoxy NOVOLAC based (450 cp; 50 hrs pot life @ 40°c processing temp)

Reinforcement:

RTM - Continuous fiber E-glass - identical in content and weave to that used in G-10 CR + adhesive.

CTM - Chopped glass - 1/16" milled E-glass fiber

Results:

Visually - the parts look better with less voids. No production difficulties were reported.

Future Activities for RTM & CTM

RTM

- Inquire about 3D woven preforms (using S glass)
- Inquire about improving the quality and reliability of the process towards preproduction run.
- Test parts in test coils and short magnets

CTM

- Inquire about using various fillers to improve strength
- Test parts in test coils and short magnets

Injection Molding

Materials:

- Amoco Torlon 5030 - 30% glass fiber. Poly (amide-imide) - thermoplastic

- Green Tweed - Arlon 1160 - 30% glass fiber - Polyetheretherketone - (PEEK) - Thermoplastic

Summary of Properties

	Torlon 5030	Arlon 1160
Flexural modulus 23°C (73°F)	17.0×10^5 psi	14.95×10^5 psi
Flexural modulus 250°C (480°F)	14.3×10^5 psi	3.33×10^5 psi
Flexural modulus 321°F	20.4×10^5 psi	
Compressive strength 23°C (73°F)	38.3×10^3 psi	31.2×10^3 psi
Coefficient of thermal expansion	9.0×10^{-6} in/in/F	12×10^{-6} in/in/F°
Heat distortion temperature (264 psi)	539 F°	600 F°
Glass transition temperatures	527 F°	289 F°

Future Activities for Injection Molding

- Test Torlon and PEEK parts, machined out of injection molded tubes in a short test magnet.

- Mold a set of return end parts of Torlon and PEEK.

- Use molded parts in test coils then section and analize

- Use parts in short test magnet.

Compression Molding

- We have compression molds for return end saddle, spacer, and key.

- Test parts were made using Green Puddy and Stycast and were placed in test coi[illegible]

- As per General Dynamics [illegible] [illegible] compression moldi[illegible]

Future activities for compression molding

- Provide parts out on Spaceland [illegible]

- Place parts in test coils and short magnet.

Coatings of Metal Casting End Parts

Metal Casting:

- Stainless steel
- Bronze
- Aluminum

Secondary Operations (possibly):

- Hole drilling
- Electro-polishing

Electrically Insulating Coating Process:

- Dip, spray, etc.
- Hard coat anodizing
- Chemical vapor deposition (CVD)

Coating Material:

- Polyimide enamel
- Epoxyester
- Aluminum oxide (Al_2O_3)

Comparison: Machining versus RTM, CTM, Injection Molding and Metal Coating

Process	Strength (Flexural)	Production Complexity	Parts Uniformity	Parts Quality	Radiation Resistance	Tooling Cost (Saddle)	Parts Cost (Saddle)
RTM	3rd best (35-45 ksi)	4th least complex	worst	worst	2nd best	most expensive (50-60K)	4th least expensive
CTM	worst (15-18 ksi)	3rd least comples	4th best	4th best	4th best	4th least expensive (35-40K)	2nd least expensive (20-25)
Injection Molding	4th best (25-30 ksi)	least complex	best	best	worst	3rd least expensive (20-25K)	least expensive (10-15)
Metal Coating	could be strongest	2nd least complex	could be 3rd best	could be 3rd best	could be best	2nd least expensive (8-10K)	3rd least expensive (30-35)
Machined G-10 CR	2nd best (65-75 ksi)	most complex	2nd best	2nd best	3rd best	least expensive (3-4K)	most expensive (200-250)

Material Development Lab Tests

- **Flextural strength**
- **Coeffiecient of thermal expansion**
- **Insulation breakdown**

Test Result

	Machined	RTM	Injection Mold	
	G-10 CR	CTD-101	Torlon	PEEK
Flextural strength (Ksi)	70.0	60.0	48.3	33.8
Coeeficient of thermal contraction 10^{-5} in/in/K	1.15	1.21	1.62	2.20

Insualtion breakdown test - aluminum coated key

Coil #	Coating	First Breakdown (Volts)	Second Breakdown (Volts)
129	Polymide, Dupont RK692, 2 coats	2800	600
126	Polyohenylene Sulfide, one coat	2600	600
128	Polymide, Dupont R5069, two coatsts	1500	1200
130	Polymide, Dupont RK692, one coat	1500	600
127	Epoxy Ester, one coat	1200	1200

Cost Comparison - Machined versus Other Processes

	Machined (Material & Labor	RTM CTD-101	RTM CryoRad	CTM CTD-101	Injection Mold Torlon	Injection Mold PEEK
	$150	$51.0	$205.0	$31.0	$11.0*	$37.0*
Tooling:		$58,500	$54,000	$45,000	$23,000*	$12,000*

* These prices are for 40 mm end parts and are about 1 year old.

Fiscal 1992 FNAL Suggested End Parts Material and Process Development Plan

1)	Preproduction RTM parts (Designed and built by Spaulding Fiber ot other). This includes all tooling and parts for several complete magnets worth.	$40,000
2)	Injection molding of PEEK and Torlon. Tooling and 5 magnets worth of return end parts.	$40,000
3)	Developmenmt and production of several magnet's worth of 2 parts using RTM by a vendor other than Spaulding for comparison.	$20,000
4)	Metals with coating. Tooling for [illegible] design and fabrication Technician time for [illegible] Machine aluminum parts and outer keys both ends (20 each) Cast aluminum (inner keys) Coating aluminum (Saturn) Cast stainless and bronze (inner keys) Coating stainless and bronze (Chromaloy)	$40,000
5)	Birl Research coatings for stainless	$15,000
6)	Research by Composite Technology Development	$10,000
7)	Inspection of end parts: Tooling: Time for inspection department	$0* $0*
8)	Engineering time for managing and analysis	$70,000
9)	Technician time for potting and sectioning	$30,000
	Total	$265,000

*Cost associated with these functions is already paid by another related project.

Fiscal 1992 FNAL Suggested End Parts Development Plan

- Produce 2 parts via RTM process by a selected vendor (other than Spaulding)
- Preproduction of return ends using RTM process (tooling and parts for several magnets)
- Injection mold temporary tooling for return end parts using Torlon and PEEK
- Compression mold of 3 differernt parts using several materials?
- Dip coat and test hipotaluminum and stainless steel keys (machined and casted)
- Research for CVD coating on stainless steel or bronze
- Continue using CTD (Composite Technology Developmetn) consulting services
- Attempt stress analysis of end parts assembly?
- Continue managing the program in coordination with SSCL and General Dynamics

Future Plans:

- After the magnets and coils specified are finished and analyzed a smaller number of the materials will be chosen to test for radiation.

- Some of the preferred materials could be placed in the final 50mm long magnets (after the General Dynamics magnets are complete).

- A material could be chosen to make complete sets of magnet parts. These parts could be used in short magnets during the next fiscal year.