

Laminates: Science or Voodoo

- Gary Bedard Terminolgy & Resources
- Eric Rubie Laminate Design
- Doug Taylor Socket & Coupon Testing
- Todd Anderson Socket Design

Laminates: Science or Voodoo

Part III: Socket & Coupon Testing:



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Tensile Coupon Testing:



Matrix Materials

- Epoxy
- Standard AME
- Acrylic
- C-Acrylic
- Polyester

Tensile Coupon Testing:



Fiber Materials

- Carbon Fiber
- E-Glass
- S-Glass
- Kevlar
- Nylon

Tensile Coupon Testing:



Weave Types

- Unidirectional
- Plain Weave
- 4/4 Twill
- 8 Harness
- Braid
- Knit

Tensile Coupon Testing:

Fiber Orientation

- 0^0
- $0^0/90^0$
- $45^0/45^0$
- $0^0/90^0, 45^0/45^0, 45^0/45^0, 0^0/90^0$ (Quasi-isotropic)

Tensile Coupon Testing:



Processing

- Vacuum Assisted Resin Transfer Molding (VARTM)
- Wet Layup
- Adhesive Pretacking

Tensile Coupon Testing:



Test Methods

- Tensile Testing (ASTM-3039)
- Scanning Electron Microscope
- Microscope
- Differential Scanning Calorimetry (DSC)
- Optical Observation

Tensile Coupon Testing:

Fiber Orientation

Fiber/Resin	Orientation	Stress (KSI)
• Carbon/AME	0 ⁰	135.60
• Carbon/Epoxy	0 ⁰ /90 ⁰	93.85
• Carbon/AME	0 ⁰ /90 ⁰	93.11
• Carbon/Epoxy	Quasi	53.24
• Carbon/Epoxy	45 ⁰ /45 ⁰	18.42

Tensile Coupon Testing:

Fiber Orientation

Fiber/Resin	Orientation	Stress (KSI)
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- Carbon/Epoxy $0^{\circ}/90^{\circ}$ 66.73
- Carbon/Epoxy $35^{\circ}/35^{\circ}$ (Approx.) 21.62
- Carbon/Epoxy $45^{\circ}/45^{\circ}$ 11.16

Carbon Tow Size 12K

Tensile Coupon Testing:

Fiber Orientation

Fiber/Resin	Orientation	Stress (KSI)
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- Fiberglass/Epoxy $0^{\circ}/90^{\circ}$ 32.50
- Fiberglass/Epoxy Quasi 26.39
- Fiberglass/Epoxy $45^{\circ}/45^{\circ}$ 1.12
- Nyglass/Epoxy Knitted .68

Fiberglass Fabric Weight 6 oz.

Tensile Coupon Testing:

Fiber Orientation

Fiber/Resin	Orientation	Stress (KSI)
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- Carbon-S-Glass/ 0⁰/90⁰ Epoxy 53.16
- Carbon-S-Glass/ Quasi 36.71
- Carbon-S-Glass/ 45⁰/45⁰ Hybrid Cloth 16.33

Tensile Coupon Testing:

Resin Type

Resin Orientation Stress (KSI)

- Standard AME $0^0/90^0$ 93.11
- Epoxy $0^0/90^0$ 85.40
- Acrylic $0^0/90^0$ 83.47
- C-Acrylic $0^0/90^0$ 74.11
- Polyester $0^0/90^0$ 70.55

Tensile Coupon Testing:

Weave Type	
Fiber/Resin	Stress (KSI)
Unitape/AME	135.60
Plain Weave/AME	93.11

CARBON Fiber 3K

Tensile Coupon Testing:

Fiber Type

Fiber/Resin

Stress (KSI)

Carbon Fiber/Epoxy

85.40

Kevlar/Epoxy

57.40

Fiberglass/Epoxy

32.50

Nylon/Epoxy

6.12

Nyglass/Epoxy

.68

Tensile Coupon Testing:



Tow Size

Fiber

Stress (KSI)

Carbon Fiber 3K

85.10

Carbon Fiber 12K

66.73

Tensile Coupon Testing:

Fiber Volume

FiberResin

(V_f)

Stress (KSI)

Carbon/AME

46.8%

135.60

Carbon Fiber 12K

19.2%

78.88

Tensile Coupon Testing:

Fiber Volume

FiberResin

(V_f)

Stress (KSI)

Carbon/Epoxy 3K

44.8%

85.40

Carbon Fiber 12K

39.2%

66.73

Tensile Coupon Testing:

Adhesive Pretacking

Fiber/Resin	Super 77	Stress (KSI)
Carbon/Epoxy	None	93.85
Carbon/Epoxy	Liberal	62.85

Tensile Coupon Testing:

Resin Thermal Properties

Resin	(T _g)	Post Cure 200°C
Standard AME	47.3 ⁰ C	79.9 ⁰ C
Orthocryl Sealing	47.5 ⁰ C	47.5 ⁰ C
Orthocryl Laminating	46.6 ⁰ C	62.5 ⁰ C
C-Orthocryl	44.6 ⁰ C	53.0 ⁰ C
West Systems Epoxy	54.5 ⁰ C (28d)	55.1 ⁰ C

Socket Coupon Testing:

Laminated Socket Properties

Kaisha Smith et. al.

Monash University (Australia)

- “Typical” laminations over cylindrical mold
- Stockingette materials and fiberglass weaves
- No carbon used
- Curved flexural specimens
- Cylindrical compression specimens

ISO 10328 Socket Testing:

Transtibial Composite Sockets

Tom Current (Prosthetic resident)

Southern Illinois University

- Load Level A100, Loading Condition II
- Stockinette materials and woven goods
- Nylon, fiberglass, and carbon fibers
- Inexpensive test fixturing
- No sockets passed test condition

ISO 10328 Socket Testing:

Full Testing Program

- Manufacturing literature review
- Prosthetic manufacturing process evaluation
- Prosthetic loading evaluation
- Engineering design
- Coupon testing battery (ASTM)
- Comprehensive socket testing