# COMPOSITES MANUFACTURING

Composite Materials

SCENE 1.
**MA01A**, GRAPHIC: FBI warning
white text centered on black to blue gradient

WARNING

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SCENE 2.
**MA02A**, GRAPHIC: disclaimer
white text centered on black to blue gradient

Always read the operating manual and safety information provided by the manufacturer before operating any composite equipment or when using composite materials.
Make sure all machine guards are in place, and follow all safety procedures when working with or near composite equipment or when using composite materials.

SCENE 3.
**MA03A**, GRAPHIC: EMA/SME screen
white text centered on black to blue gradient

This program was produced using the technical resources of the Engineering Materials Applications Community of SME.
For more information on composites and compression molding, please visit our website at:
www.sme.org

SCENE 4.
**MA04A**, SME logo open, with music

SCENE 5.
**MA05A**, composites manufacturing open, with music
**MA05B**, peter carey narration

**MUSIC UP AND UNDER**

**NARRATION (VO):**

THE COMPOSITES MANUFACTURING SERIES, EXAMINING THE MATERIALS, TOOLS AND TECHNIQUES USED FOR COMPOSITES FABRICATION.

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|---|---|
| SCENE 6.<br>**MA06A**, GRAPHIC: Composite Materials white text centered on black | **NARRATION (VO):**<br><br>THIS PROGRAM IS AN INTRODUCTION TO COMPOSITE MATERIALS. |
| SCENE 7.<br>**MA07A, tape 09, 09:17:58-09:18:14**<br>zoom out, composite spray up operation | **NARRATION (VO):**<br><br>COMPOSITES ARE MATERIALS COMBINING AT LEAST TWO DISTINCT MATERIALS WHICH TOGETHER PROVIDE SUPERIOR PERFORMANCE AND OR LOWER MANUFACTURING COST. |
| SCENE 8.<br>**MA08A, tape 06, 06:12:14-06:12:30**<br>zoom out, reinforcement, matrix poured and spread on it<br>**MA08B**, CGS: Reinforcement<br>**MA08C**, CGS: Matrix | **NARRATION (VO):**<br><br>FIBER-REINFORCED COMPOSITES CONSIST OF A REINFORCEMENT MATERIAL....,<br><br>AND A MATRIX, OR BASE MATERIAL. |
| SCENE 9.<br>**MA09A**, CGS: Reinforcement<br>**MA09B, tape 700, 13:23:16-13:23:34**<br>pan, reinforcement fibers being added to composite lay-up | **NARRATION (VO):**<br><br>THE REINFORCEMENT'S FUNCTION IS TO IMPROVE THE MECHANICAL PROPERTIES OF THE COMPOSITE, AND IS TYPICALLY THE MAIN LOAD-BEARING ELEMENT. |
| SCENE 10.<br>**MA10A**, CGS: Matrix<br>**MA10B, tape 694, 10:09:01-10:09:10**<br>matrix material sprayed onto reinforcement<br>**MA10C, tape 694, 10:06:37-10:06:48**<br>matrix/reinforcement material used in lay-up<br>**MA10D, tape 698, 02:17:18-02:17:26**<br>zoom in, matrix material put under load<br>**MA10E**, ANI: part matrix transferring load exerted upon it to the reinforcement<br>**MA10F, tape 712, 19:02:38-19:02:52**<br>zoom out, matrix protecting reinforcement from adverse environmental effects | **NARRATION (VO):**<br><br>THE MATRIX FUNCTIONS AS A BINDER FOR THE REINFORCEMENT, AND CONTROLS THE PHYSICAL SHAPE AND DIMENSIONS OF THE PART. THE PRIMARY PURPOSE OF THE MATRIX IS TO TRANSFER THE LOAD, OR STRESS, APPLIED TO THE COMPOSITE TO THE REINFORCEMENT. THE MATRIX ALSO PROTECTS THE REINFORCEMENT FROM ADVERSE ENVIRONMENTAL EFFECTS. |
| SCENE 11.<br>**MA11A, tape 697, 01:26:31-01:26:46** | **NARRATION (VO):** |

zoom in, pultrusion operation
**MA11B**, CGS: Fiber-Reinforced Composites

OF THE SEVERAL TYPES OF COMPOSITES, FIBER-REINFORCED COMPOSITES ARE THE MOST WIDELY USED FOR STRUCTURAL AND NONSTRUCTURAL APPLICATIONS.

SCENE 12.
**MA12A, tape 700, 13:04:17-13:04:32**
mat fabric rolled manually onto mandrel
**MA12B, tape 09, 09:11:14-09:11:24**
wide, tilt up, boat spray up
**MA12C**, CGS: Polymer-Matrix Composites

**NARRATION (VO):**

THE MOST COMMON AND WIDELY USED FIBER-REINFORCED COMPOSITES ARE FIBER-REINFORCED RESINS OR POLYMERS, WHICH ARE COMMONLY REFERRED TO AS POLYMER-MATRIX COMPOSITES, OR 'PMC'S', OR EVEN SIMPLY AS 'REINFORCED PLASTICS'.

SCENE 13.
**MA13A, tape 19, 19:22:13-19:22:34**
glass reinforcement lifted, placed in mold, zoom in
**MA13B, tape 700, 13:10:27-13:10:39**
zoom out, filament winding

**NARRATION (VO):**

THESE COMPOSITES ARE TYPICALLY LIGHTWEIGHT, STRONG AND RIGID, PROVIDE HIGH STRENGTH-TO-WEIGHT RATIOS OR SPECIFIC STRENGTH, AND HIGH RIGIDITY-TO-WEIGHT RATIOS OR SPECIFIC STIFFNESS. ANOTHER MAJOR ADVANTAGE IS THAT FIBER DIRECTION CAN BE ORIENTED TO SUIT THE APPLIED LOAD DIRECTION.

SCENE 14.
**MA14A, tape 14, 14:27:59-14:28:12**
layup of racing part
**MA14B, tape 09, 09:10:03-09:10:12**
layup of boat hull
**MA14C, tape 28, 04:45:12-04:45:32**
automated tape layup of aircraft component

**NARRATION (VO):**

APPLICATIONS FOR POLYMER-MATRIX COMPOSITES INCLUDE AUTOMOTIVE AND PERFORMANCE RACING PARTS...,

BOAT HULLS...,

AIRCRAFT COMPONENTS,

AND MANY MORE.

--- TOUCH BLACK ---

SCENE 15.
**MA15A, tape 19, 19:13:23-19:13:30**

**NARRATION (VO):**

resin poured on glass reinforcement
**MA15B, tape 17, 17:18:17-17:18:42**
wide, s-glass prepreg being used
**MA15C**, CGS: Prepreg

BESIDES BEING AVAILABLE SEPARATELY AND COMBINED IN FABRICATION, REINFORCEMENT FIBERS AND MATRIX ARE ALSO AVAILABLE TOGETHER IN WHAT IS CALLED PREPREG, OR PREIMPREGNATED, MATERIAL.

SCENE 16.
**MA16A, tape 17, 17:08:46-17:09:01**
wide, aramid prepreg being laid up
**MA16B, tape 691, 07:24:48-07:25:03**
pulling prepreg from refrigerator

**NARRATION (VO):**

PREPREG COMBINES PARTIALLY CURED RESIN WITH FIBERS AND MUST BE KEPT REFRIGERATED PRIOR TO USE TO INHIBIT FURTHER CURING.

SCENE 17.
**MA17A, tape 691, 07:06:50-07:07:32**
carbon fiber prepreg layup operation

**NARRATION (VO):**

USE OF PREPREG SIMPLIFIES AND SPEEDS COMPOSITE LAY-UP AND ENSURES HIGHER QUALITY PARTS. FIBER AND MATRIX QUANTITIES ARE MORE ACCURATELY MAINTAINED, PROVIDING MORE CONSISTENT MECHANICAL PROPERTIES. BOTH CONTINUOUS AND SHORT FIBER FORMS OF PREPREG ARE AVAILABLE.

--- TOUCH BLACK ---

SCENE 18.
**MA18A, tape 09, 09:08:56-09:09:15**
zoom out, dry reinforcement sprayed with resin
**MA18B, tape 698, 02:17:31-02:17:41**
composite test part cracking under load

**NARRATION (VO):**

AN IMPORTANT STRUCTURAL ASPECT OF POLYMER-MATRIX COMPOSITES ARE THE TENSILE PROPERTIES, SINCE THEY ARE INDICATORS OF HOW A MATERIAL BEHAVES UNDER LOADING WHILE IN TENSION.

SCENE 19.
**MA19A, tape 692, 08:19:09-08:19:31**
spray up of dry reinforcement
**MA19B**, CGS: Tensile Yield Strength
Tensile Modulus
Ultimate Tensile Strength

**NARRATION (VO):**

THREE OF THE MOST IMPORTANT TENSILE PROPERTIES FOR POLYMER-MATRIX COMPOSITES ARE:

TENSILE YIELD STRENGTH,

TENSILE MODULUS,

AND ULTIMATE TENSILE STRENGTH.

SCENE 20.
**MA20A**, CGS: Tensile Yield Strength
**MA20B**, ANI: composite bar straight, being bent

**NARRATION (VO):**

TENSILE YIELD STRENGTH IS THE TENSILE STRESS REQUIRED TO PERMANENTLY ELONGATE A MATERIAL LOADED IN TENSION.

SCENE 21.
**MA21A**, CGS: Tensile Modulus
**MA21B**, ANI: composite bar bent, ghost of straight bar appears, arrow scrolls on showing tensile modulus range
**MA21C, tape 704, 18:05:33-18:05:43**
rtm part pulled from mold

**NARRATION (VO):**

TENSILE MODULUS IS THE RATIO OF TENSILE STRESS TO TENSILE STRAIN FOR STRESSES BELOW THE MATERIAL'S ELASTIC LIMIT. TENSILE MODULUS INDICATES THE MATERIAL'S STIFFNESS OR RIGIDITY.

SCENE 22.
**MA22A**, CGS: Ultimate Tensile Strength
**MA22B**, ANI: bent composite bar, bent further, cracking

**NARRATION (VO):**

ULTIMATE TENSILE STRENGTH IS THE MAXIMUM STRESS A MATERIAL CAN WITHSTAND BEFORE RUPTURING.

--- TOUCH BLACK ---

SCENE 23.
**MA23A, tape 22, 22:03:31-22:03:43**
zoom out, cutting glass fabric
**MA23B**, CGS: Glass
**MA23C, tape 01, 01:12:02-01:12:19**
zoom out, prepreg carbon fiber layup
**MA23D**, CGS: Carbon/Graphite
**MA23E, tape 16, 16:01:16-16:01:25**
pan, template used on aramid fabric
**MA23F**, CGS: Aramid

**NARRATION (VO):**

THE PRINCIPAL TYPES OF REINFORCEMENT FIBERS USED FOR PLASTIC-MATRIX COMPOSITES ARE

GLASS...,

CARBON OR GRAPHITE...,

AND ARAMID.

SCENE 24.
**MA24A**, CGS: Glass
**MA24B, tape 06, 06:03:03-06:03:19**
trimming glass preform for infusion
**MA24C**, CGS: E-Glass
**MA24D, tape 17, 17:19:53-17:20:00**
s-glass being laid up
**MA24E**, CGS: S-Glass

**NARRATION (VO):**

THE TWO PRIMARY TYPES OF GLASS FIBERS AVAILABLE FOR COMPOSITES MANUFACTURING ARE:

E-GLASS...,

AND S-GLASS.

SCENE 25.
**MA25A**, CGS: E-Glass
**MA25B, tape 692, 08:10:18-08:10:38**
zoom out, c.u. e-glass spray up operation

**NARRATION (VO):**

E-GLASS IS AN ABBREVIATION FOR 'ELECTRICAL GLASS', BOROSILICATE GLASS FIBERS. THESE FIBERS HAVE HIGH ELECTRICAL RESISTIVITY, ARE INEXPENSIVE, AND ARE THE MOST PROMINENTLY USED IN POLYMER-MATRIX COMPOSITES.

SCENE 26.
**MA26A**, CGS: S-Glass
**MA26B, tape 17, 17:13:51-17:14:11**
s-glass prepreg material being laid up

**NARRATION (VO):**

S-GLASS, WHICH IS AN ABBREVIATION FOR 'STRUCTURAL GLASS', IS A MAGNESIA/ALUMINA/SILICATE GLASS REINFORCEMENT FIBER DESIGNED TO PROVIDE VERY HIGH TENSILE STRENGTH FOR COMPOSITES.

SCENE 27.
**MA27A, tape 17, 17:19:04-17:19:24**
zoom in, s-glass prepreg material being laid up

**NARRATION (VO):**

THE S-GLASS IS ABOUT 30% STRONGER AND 20% MORE RIGID THAN THE E-GLASS AND IS SLIGHTLY LIGHTER IN WEIGHT. BUT S-GLASS IS FAR MORE COSTLY THAN E-GLASS.

SCENE 28.
**MA28A, tape 03, 03:09:30-03:09:53**
wide, robotic spray up

**NARRATION (VO):**

ALL THE GLASS FIBERS ARE HEAT RESISTANT, RETAINING ABOUT HALF OF THEIR STRENGTH AT TEMPERATURES UP TO 700 DEGREES FAHRENHEIT OR 370 DEGREES CENTIGRADE. THEY ARE MOISTURE RESISTANT AND CORROSION RESISTANT AS WELL, EXCEPT TO STRONG ALKALIS AND HYDROFLUORIC ACID.

SCENE 29.
**MA29A, tape 10, 10:06:49-10:07:00**

**NARRATION (VO):**

zoom out, worker counting glass fabric layers
**MA29B, tape 697, 01:13:30-01:13:41**
pan, roving used in pultrusion
**MA29C, tape 703, 17:04:33-17:04:41**
zoom in, chopped strand
**MA29D, tape 30, 02:06:17-02:06:23**
zoom out, yarn spools
**MA29E, tape 701, 14:03:30-14:03:40**
zoom out, woven fabric
**MA29F, tape 701, 14:05:13-14:05:22**
zoom out, nonwoven fabric

GLASS FIBERS ARE PRODUCED IN VARIOUS COMMERCIAL FORMS, INCLUDING:

ROVINGS, WHICH ARE A GROUP OF PARALLEL STRANDS GATHERED IN RIBBON FORM AND WOUND ONTO A CYLINDRICAL TUBE. OTHER COMMERCIAL GLASS FIBER FORMS INCLUDE CHOPPED STRANDS...,

YARNS...,

AND WOVEN...,

OR NONWOVEN FABRICS.

SCENE 30.
**MA30A, tape 17, 17:12:03-17:12:23**
hand layup of carbon fiber
**MA30B**, CGS: Carbon/Graphite
**MA30C**, CGS: Pan Carbon
Pitch Carbon

**NARRATION (VO):**

THERE ARE TWO PRINCIPAL CARBON, OR GRAPHITE, FIBERS USED FOR PLASTIC-MATRIX COMPOSITES:

PAN CARBON, WHICH IS THE MORE COMMON AND MUCH MORE COSTLY,

AND PITCH CARBON.

SCENE 31.
**MA31A, tape 15, 15:02:06-15:02:27**
zoom out, hand layup of carbon fiber

**NARRATION (VO):**

BOTH PAN AND PITCH CARBON FIBERS ARE LIGHTER IN WEIGHT THAN GLASS FIBERS BUT HEAVIER THAN THE ARAMID FIBERS. THEIR DENSITY RANGES FROM 61 THOUSANDTHS TO 76 THOUSANDTHS POUNDS PER CUBIC INCH OR 1.7 TO 2.1 GRAMS PER CUBIC CENTIMETER.

SCENE 32.
**MA32A, tape 26, 11:14:11-11:14:22**
automated layup of carbon fiber
**MA32B, tape 01, 01:11:04-01:11:34**
zoom out, manual layup of carbon fiber

**NARRATION (VO):**

THE HEAVIER THE CARBON FIBER, THE GREATER ITS TENSILE MODULUS, RANGING UP TO 75 MILLION POUNDS PER SQUARE INCH OR 517,000 MEGA PASCALS. TENSILE STRENGTH RANGES FROM 220,000

TO 820,000 POUNDS PER SQUARE INCH OR 1,520 TO 5,650 MEGA PASCALS.

SCENE 33.
**MA33A, tape 02, 02:23:06-02:23:25**
zoom in, carbon fiber filament winding operation

**NARRATION (VO):**

THE CARBON FIBERS ARE EXTREMELY BRITTLE, HAVING A STRAIN TO FAILURE OF ONLY 0.3 TO 1.8%. THEY ARE, HOWEVER, QUITE HEAT RESISTANT, HAVING MAXIMUM SERVICE TEMPERATURES AS HIGH AS 1000 DEGREES FAHRENHEIT OR 540 DEGREES CENTIGRADE.

SCENE 34.
**MA34A**, CGS: Aramid
**MA34B, tape 17, 17:04:11-17:04:24**
cutting aramid prepreg
**MA34C, tape 17, 17:06:57-17:07:17**
laying up aramid prepreg

**NARRATION (VO):**

THE ARAMID FIBER IS MUCH LIGHTER THAN THE GLASS. ITS TENSILE STRENGTH CAN MATCH THAT OF THE GLASS AND ITS TENSILE MODULUS CAN BE MUCH GREATER. ITS STRAIN TO FAILURE IS 1.9 TO 4.4% AND ITS COEFFICIENT OF THERMAL EXPANSION LENGTHWISE IS NEGATIVE, WHICH PERMITS MAKING COMPOSITES OF ZERO OR NEAR ZERO THERMAL EXPANSION.

SCENE 35.
**MA35A, tape 19, 19:17:45-19:18:10**
aramid fibers being manually laid up

**NARRATION (VO):**

ARAMID FIBER HAS LIMITED HEAT RESISTANCE AND ITS COMPRESSIVE STRENGTH IS LOW. RESISTANCE TO IONIZING RADIATION AND CHEMICALS OTHER THAN HIGH CONCENTRATIONS OF STRONG ACIDS AND BASES ARE EXCELLENT. HOWEVER, PROLONGED EXPOSURE TO LIGHT AND ULTRAVIOLET ADVERSELY AFFECT MECHANICAL PROPERTIES.

--- TOUCH BLACK ---

SCENE 36.
**MA36A, tape 13, 13:12:48-13:13:08**
zoom out, spray up operation
**MA36B**, CGS: Fiber Orientation Angle
Fiber Architecture

**NARRATION (VO):**

TWO IMPORTANT PARAMETERS GOVERNING OVERALL PROPERTIES OF REINFORCEMENT MATERIALS FOR PLASTIC-MATRIX COMPOSITES ARE:

FIBER ORIENTATION ANGLE,

AND FIBER ARCHITECTURE.

SCENE 37.
**MA37A**, CGS: Fiber Orientation Angle
**MA37B, tape 15, 15:04:48-15:05:16**
zoom out, layup of carbon fiber
**MA37C**, CGS: 0° Along or Parallel to Loading
90° Transverse to Loading
Plus or Minus 45° for such Angular Placement Relative to the Loading Direction

**NARRATION (VO):**

FIBER ORIENTATION ANGLE IS THE ANGLE OF THE FIBERS RELATIVE TO THE LOADING DIRECTION, FOR EXAMPLE ZERO DEGREE ALONG OR PARALLEL TO LOADING, 90 DEGREES TRANSVERSE TO LOADING, AND PLUS OR MINUS 45 DEGREES FOR SUCH ANGULAR PLACEMENT RELATIVE TO THE LOADING DIRECTION.

SCENE 38.
**MA38A**, CGS: Fiber Architecture
**MA38B, tape 703, 17:00:58-17:01:44**
filament hoop winding
**MA38C, tape 15, 15:10:29-15:10:40**
fabric layup

**NARRATION (VO):**

FIBER ARCHITECTURE PERTAINS TO FIBER ARRANGEMENT, WHICH CAN BE LINEAR...,

OR TWO-DIMENSIONAL OR THREE-DIMENSIONAL.

SCENE 39.
**MA39A, tape 697, 01:15:14-01:15:26**
pan, continuous pultrusion roving
**MA39B, tape 686, 02:15:33-02:15:43**
zoom out, discontinuous fiber spray up operation
**MA39C, tape 700, 13:07:58-13:08:12**
zoom out, continuous fiber filament winding operation
**MA39D, tape 688, 04:05:15-04:05:28**
c.u. zoom out, discontinuous fiber spray

**NARRATION (VO):**

IN LINEAR FORM, THE FIBERS CAN BE CONTINUOUS...,

OR DISCONTINUOUS.

WITH CONTINUOUS FIBERS, ORIENTATION CAN BE PRECISELY CONTROLLED. WITH DISCONTINUOUS FIBERS, LITTLE IF ANY ORIENTATION CONTROL IS POSSIBLE.

SCENE 40.
**MA40A**, still, carbon fiber two-dimensional fabric
**MA40B**, still, carbon -aramid three-

**NARRATION (VO):**

TWO-...,

dimensional fabric
**MA40C**, still, aramid fabric
**MA40D, tape 687, 03:14:33-03:14:45**
zoom out, glass fabric
**MA40E, tape 10, 10:18:14-10:18:24**
lay up using fabric

AND THREE-DIMENSIONAL ARRANGEMENTS CONTAIN CONTINUOUS FIBERS THAT ARE INTERLACED, INTERTWINED AND INTERLOPED. THESE MATERIALS PROVIDE GOOD CONTROL OF FIBER PLACEMENT AND ORIENTATION AND CAN BE USED TO PRODUCE COMPLEX SHAPES.

--- TOUCH BLACK ---

SCENE 41.
**MA41A, tape 695, 11:02:40-11:02:55**
thermoset resin being mixed
**MA41B, tape 625, 05:19:44-05:19:56**
zoom out, fiber reinforced thermoplastic parts degated
**MA41C, tape 06, 06:22:11-06:22:19**
thermoset resins being poured

**NARRATION (VO):**

THE MATRIX MATERIALS FOR FIBER-REINFORCED PLASTIC-MATRIX COMPOSITES CAN BE THERMOSET RESINS...,

OR THERMOPLASTIC RESINS,

WITH THE THERMOSETS BEING THE MOST WIDELY USED.

SCENE 42.
**MA42A**, CGS: Thermosets
**MA42B, tape 687, 03:07:23-03:07:36**
reverse pan, composite parts curing at room temperature

**NARRATION (VO):**

THERMOSET RESINS REQUIRE CURING TO DEVELOP THEIR DESIRED MECHANICAL PROPERTIES.

SCENE 43.
**MA43A, tape 07, 07:13:39-07:13:48**
cured part pulled from mold at room temperature
**MA43B, tape 692, 08:20:10-08:20:18**
composite parts curing in room with heaters
**MA43C, tape 702, 16:14:38-16:14:50**
heated-platen press for curing
**MA43D, tape 698, 02:01:35-02:01:43**
pultrusion coming out of die
**MA43E, tape 703, 17:16:27-17:16:46**
cured composite parts coming out of oven
**MA43F, tape 14, 14:01:53-14:02:07**
zoom out, composite part being removed from autoclave

**NARRATION (VO):**

CURING MAY BE AT ROOM TEMPERATURE...,

OR WITH AN OPEN AIR HEAT ASSIST.

CURING IS ALSO ACHIEVED USING HEATED-PLATEN PRESSES...,

DIES...,

OVENS...,

OR AUTOCLAVES.

ONCE CURED, OR SET, THERMOSETS CANNOT BE REPROCESSED.

SCENE 44.
**MA44A, tape 692, 08:16:12-08:16:27**
pan, large parts curing with heat assist
**MA44B, tape 02, 02:06:28-02:07:00**
part placed in oven

**NARRATION (VO):**

CURING CYCLES FOR COMPOSITES CAN BE LONG, RANGING FROM AN HOUR, TO HALF A DAY OR MORE. THE PROCESS IS TYPICALLY FASTER IN PRESSES OR DIES THAN IN OVENS OR AUTOCLAVES, BUT OVENS AND AUTOCLAVES CAN ACCOMMODATE MUCH LARGER PARTS OR MANY SMALL ONES.

SCENE 45.
**MA45A, tape 688, 04:19:02-04:19:48**
resin poured on reinforcement
**MA45B**, CGS: Epoxy
Polyester
Vinyl Esters
Phenolic
Cyanate Esters
Bismaleimide
Polyimide

**NARRATION (VO):**

THERMOSET POLYMERS ARE GENERALLY MORE THERMALLY STABLE AND CHEMICALLY RESISTANT, LESS COSTLY, AND, WITH A FEW EXCEPTIONS, MORE HEAT RESISTANT THAN THE THERMOPLASTICS. SOME OF THE PRIMARY THERMOSET MATRIX MATERIALS ARE:

EPOXY,

POLYESTER,

VINYL-ESTERS,

PHENOLIC,

CYANATE-ESTERS,

BISMALEIMIDE,

AND POLYIMIDE.

SCENE 46.
**MA46A, tape 24, 22:03:48-22:04:22**
automated carbon fiber layup

**NARRATION (VO):**

OF THESE MATRIX MATERIALS, THE EPOXIES HAVE FOUND THE GREATEST USE IN HIGH-PERFORMANCE APPLICATIONS, INCLUDING MARINE, AIRCRAFT, AND AEROSPACE APPLICATIONS. THEIR PRINCIPAL ADVANTAGES ARE PROCESSING EASE, GOOD MECHANICAL PROPERTIES, AND LOW COST.

--- TOUCH BLACK ---

SCENE 47.
**MA47A**, CGS: Thermoplastics
**MA47B, tape 422, 16:05:57-16:06:12**
pan injection molding operation, looped twice
**MA47C, tape 41, 13:22:37-13:22:42**
c.u. part ejected from mold
**MA47D, tape 398, 02:09:32-02:09:40**
plastic being recycled

**NARRATION (VO):**

THERMOPLASTICS ARE LESS BRITTLE THAN THE THERMOSETS, HAVING A GREATER STRAIN TO FAILURE OR CRACK RESISTANCE, AND HIGHER IMPACT STRENGTH OR TOUGHNESS. THEY ALSO HAVE UNLIMITED STORAGE LIFE, ARE PROCESSED MORE QUICKLY, CAN BE SOFTENED REPEATEDLY, AND, UNLIKE THERMOSETS, THERMOPLASTICS CAN BE RECYCLED FOR REUSE.

SCENE 48.
**MA48A, tape 41, 13:24:13-13:24:25**
zoom out, black plastic pellets with discontinuous fibers
**MA48B, tape 41, 13:25:50-13:26:00**
pan injection molding system
**MA48C, tape 41, 13:27:27-13:27:52**
zoom out, small parts being produced

**NARRATION (VO):**

DISCONTINUOUS FIBERS ARE MORE COMMONLY USED THAN CONTINUOUS ONES WITH THERMOPLASTICS AND INJECTION MOLDING IS WIDELY USED FOR PRODUCT MANUFACTURING. THE PARTS MADE OF THERMOPLASTICS, HOWEVER, ARE TYPICALLY MUCH SMALLER THAN THOSE MADE OF THERMOSETS.

SCENE 49.
**MA49A, tape 41, 13:30:18-13:30:42**
zoom out, nylon fiber reinforced pellets
**MA49B**, CGS: Acetyls
Polypropylene
Nylon
Polyethylene Terephthalate
Polybutylene Terephthalate
Polycarbonate

**NARRATION (VO):**

AMONG THE MOST COMMON FIBER REINFORCED THERMOPLASTICS ARE THE ACETYLS,

POLYPROPYLENE,

NYLON,

POLYETHYLENE TEREPHTHALATE,

POLYBUTYLENE TEREPHTHALATE,

AND POLYCARBONATE.

--- TOUCH BLACK ---

SCENE 50.
**MA50A**, GRAPHIC: Review white text on black
**MA50B**, peter carey narration
**MA50C**, review music

**MUSIC UP AND UNDER**

**NARRATION (VO):**

LET'S REVIEW THE MATERIAL CONTAINED IN THIS PROGRAM.

SCENE 51.
**MA51A, tape 06, 06:12:14-06:12:30** zoom out, reinforcement, matrix poured and spread on it
**MA51B**, CGS: Reinforcement
**MA51C**, CGS: Matrix

**NARRATION (VO):**

FIBER-REINFORCED COMPOSITES CONSIST OF A REINFORCEMENT MATERIAL....,

AND A MATRIX, OR BASE MATERIAL.

SCENE 52.
**MA52A**, CGS: Reinforcement
**MA52B, tape 700, 13:23:16-13:23:34** pan, reinforcement fibers being added to composite lay-up

**NARRATION (VO):**

THE REINFORCEMENT'S FUNCTION IS TO IMPROVE THE MECHANICAL PROPERTIES OF THE COMPOSITE, AND IS TYPICALLY THE MAIN LOAD-BEARING ELEMENT.

SCENE 53.
**MA53A**, CGS: Matrix
**MA53B, tape 694, 10:09:01-10:09:10** matrix material sprayed onto reinforcement
**MA53C, tape 694, 10:06:37-10:06:48** matrix/reinforcement material used in lay-up
**MA53D, tape 698, 02:17:18-02:17:26** zoom in, matrix material put under load
**MA53E**, ANI: part matrix transferring load exerted upon it to the reinforcement
**MA53F, tape 712, 19:02:38-19:02:52** zoom out, matrix protecting reinforcement from adverse environmental effects

**NARRATION (VO):**

THE MATRIX FUNCTIONS AS A BINDER FOR THE REINFORCEMENT, AND CONTROLS THE PHYSICAL SHAPE AND DIMENSIONS OF THE PART. THE PRIMARY PURPOSE OF THE MATRIX IS TO TRANSFER THE LOAD, OR STRESS, APPLIED TO THE COMPOSITE TO THE REINFORCEMENT. THE MATRIX ALSO PROTECTS THE REINFORCEMENT FROM ADVERSE ENVIRONMENTAL EFFECTS.

SCENE 54.
**MA54A, tape 697, 01:26:31-01:26:46** zoom in, pultrusion operation
**MA54B, tape 700, 13:04:17-13:04:32** mat fabric rolled manually onto mandrel
**MA54C**, CGS: Polymer-Matrix Composites

**NARRATION (VO):**

THE MOST COMMON AND WIDELY USED FIBER-REINFORCED COMPOSITES ARE FIBER-REINFORCED RESINS OR POLYMERS, WHICH ARE COMMONLY REFERRED TO AS POLYMER-MATRIX COMPOSITES, OR

'PMC'S', AND EVEN SIMPLY AS 'REINFORCED PLASTICS'.

SCENE 55.
**MA55A, tape 19, 19:13:23-19:13:30**
resin poured on glass reinforcement
**MA55B, tape 17, 17:18:17-17:18:42**
wide, s-glass prepreg being used
**MA55C**, CGS: Prepreg

**NARRATION (VO):**

BESIDES BEING AVAILABLE SEPARATELY AND COMBINED IN FABRICATION, REINFORCEMENT FIBERS AND MATRIX ARE ALSO AVAILABLE TOGETHER IN WHAT IS CALLED PREPREG, OR PREIMPREGNATED, MATERIAL.

--- TOUCH BLACK ---

SCENE 56.
**MA56A, tape 22, 22:03:31-22:03:43**
zoom out, cutting glass fabric
**MA56B**, CGS: Glass
**MA56C, tape 01, 01:12:02-01:12:19**
zoom out, prepreg carbon fiber layup
**MA56D**, CGS: Carbon/Graphite
**MA56E, tape 16, 16:01:16-16:01:25**
pan, template used on aramid fabric
**MA56F**, CGS: Aramid

**NARRATION (VO):**

THE PRINCIPAL TYPES OF REINFORCEMENT FIBERS USED FOR PLASTIC-MATRIX COMPOSITES ARE

GLASS...,

CARBON OR GRAPHITE...,

AND ARAMID.

--- TOUCH BLACK ---

SCENE 57.
**MA57A, tape 695, 11:02:40-11:02:55**
thermoset resin being mixed
**MA57B, tape 625, 05:19:44-05:19:56**
zoom out, fiber reinforced thermoplastic parts degated
**MA57C, tape 06, 06:22:11-06:22:19**
thermoset resins being poured

**NARRATION (VO):**

THE MATRIX MATERIALS FOR FIBER-REINFORCED PLASTIC-MATRIX COMPOSITES CAN BE THERMOSET RESINS...,

OR THERMOPLASTIC RESINS,

WITH THE THERMOSETS BEING THE MOST WIDELY USED.

SCENE 58.
**MA58A**, CGS: Thermosets
**MA58B, tape 688, 04:19:02-04:19:48**
resin poured on reinforcement
**MA58C**, CGS: Epoxy
Polyester
Vinyl-Esters

**NARRATION (VO):**

THERMOSET POLYMERS ARE MORE THERMALLY STABLE AND CHEMICALLY RESISTANT, LESS COSTLY, AND,

Phenolic
Cyanate-Esters
Bismaleimide
Polyimide

WITH A FEW EXCEPTIONS, MORE HEAT RESISTANT.

SOME OF THE PRIMARY THERMOSET MATRIX MATERIALS ARE:

EPOXY,

POLYESTER,

VINYL-ESTERS,

PHENOLIC,

CYANATE-ESTERS,

BISMALEIMIDE,

AND POLYIMIDE.

SCENE 59.
**MA59A, tape 692, 08:20:10-08:20:18**
composite parts curing in room with heaters
**MA59B, tape 07, 07:13:39-07:13:48**
cured part pulled from mold at room temperature

**NARRATION (VO):**

THERMOSET RESINS REQUIRE CURING TO DEVELOP THEIR DESIRED MECHANICAL PROPERTIES. ONCE CURED, OR SET, THERMOSETS CANNOT BE REPROCESSED.

--- TOUCH BLACK ---

SCENE 60.
**MA60A**, CGS: Thermoplastics
**MA60B, tape 422, 16:05:57-16:06:12**
pan injection molding operation, looped twice
**MA60C, tape 41, 13:22:37-13:22:42**
c.u. part ejected from mold
**MA60D, tape 398, 02:09:32-02:09:40**
plastic being recycled

**NARRATION (VO):**

THERMOPLASTICS ARE LESS BRITTLE THAN THE THERMOSETS, HAVING A GREATER STRAIN TO FAILURE OR CRACK RESISTANCE, AND HIGHER IMPACT STRENGTH OR TOUGHNESS. THEY ALSO HAVE UNLIMITED STORAGE LIFE, ARE PROCESSED MORE QUICKLY, CAN BE SOFTENED REPEATEDLY, AND, UNLIKE THERMOSETS, THERMOPLASTICS CAN BE RECYCLED FOR REUSE.

SCENE 61.
**MA61A, tape 41, 13:30:18-13:30:42**
zoom out, nylon fiber reinforced pellets

**NARRATION (VO):**

AMONG THE MOST COMMON FIBER REINFORCED

**MA61B**, CGS: Acetyls
Polypropylene
Nylon
Polyethylene Terephthalate
Polybutylene Terephthalate
Polycarbonate

THERMOPLASTICS ARE THE ACETYLS,

POLYPROPYLENE,

NYLON,

POLYETHYLENE TEREPHTHALATE,

POLYBUTYLENE TEREPHTHALATE,

AND POLYCARBONATE.

--- FADE TO BLACK ---

SCENE 62.
**MA62A**, CG, ROLL: credits white text on black, fade up mid-screen

Produced By:
Society of Manufacturing Engineers

Executive Producer:
Steven R. Bollinger

Producer/Director/Cameraman:
Jerome T. Cook

Written By:
John A. Vaccari

Graphics By:
Jerome T. Cook
Dennis Summers,
Quantum Dance Works

Equipment Access Provided By:
Belding Tank Technologies, Inc.
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Technical & Editorial Consulting:
Dave Dickson,
Boeing Commercial Airplanes

Production Assistance Provided By:
Diane Korona
David Rembiesa
Lance Rosol
Karen Shifferd

Video Editing:
Jim O'Donnell

SCENE 63.
**MA63A**, GRAPHIC: disclaimer white text centered on black

Some machinery in this program had safety equipment removed to allow better recording of certain processes.
Always read the safety information provided in the manufacturers' manual before machine operation.

SCENE 64.
**MA64A**, SME logo open, with music