COMPOSITES MANUFACTURING

Composites Post Fabrication & Joining

SCENE 1.
FJ01A, GRAPHIC: FBI warning
white text centered on black to blue gradient

WARNING

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SCENE 2.
FJ02A, 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 post fabrication & joining equipment.

Make sure all machine guards are in place, and follow all safety procedures when working with or near post fabrication & joining equipment.

SCENE 3.
FJ03A, GRAPHIC: PCC/SME screen
white text centered on black to blue gradient

This program was produced using the technical resources of the Plastics, Composites & Coatings Community of SME.

For more information on composites and post fabrication & joining, please visit our website at:

www.sme.org

SCENE 4.
FJ04A, SME logo open, with music

SCENE 5.
FJ05A, composites manufacturing open, with music
FJ05B, peter carey narration

MUSIC UP AND UNDER

NARRATION (VO):

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

SCENE 6. **FJ06A,** GRAPHIC: Composites Post Fabrication & Joining white text centered on black	**NARRATION (VO):** THIS PROGRAM IS AN INTRODUCTION TO COMPOSITES POST FABRICATION AND JOINING.
SCENE 7. **FJ07A, tape 14, 14:03:04-14:03:24** bag pulled off layup **FJ07B, tape 686, 02:13:46-02:13:52** zoom out, spray up operation **FJ07C, tape 700, 13:25:54-13:26:05** filament winding operation **FJ07D, tape 34, 06:01:46-06:01:53** zoom out, pultrusion operation **FJ07E, tape 42, 14:12:55-14:13:04** part pulled from compression molding operation **FJ07F, tape 09, 09:06:37-09:06:50** liquid molding operation **FJ07G, tape 33, 05:04:02-05:04:13** machining operation **FJ07H, tape 44, 16:17:13-16:17:23** adhesive placed on parts **FJ07I, tape 698, 02:18:42-02:18:49** zoom in, mechanical fasteners used to connect composite components **FJ07J, tape 44, 16:19:32-16:20:18** room tone	**NARRATION (VO):** AFTER FIBER-REINFORCED POLYMER COMPOSITE PARTS HAVE BEEN FORMED BY LAYUP..., SPRAY UP..., FILAMENT WINDING..., PULTRUSION..., COMPRESSION MOLDING..., LIQUID MOLDING OR SIMILAR PROCESSES, THEY CAN BE FURTHER PROCESSED BY MACHINING OPERATIONS..., AND JOINED OR ASSEMBLED BY ADHESIVE BONDING..., OR MECHANICAL FASTENING. --- TOUCH BLACK ---
SCENE 8. **FJ08A,** CGS: Machining **FJ08B, tape 03, 03:23:58-03:24:20** zoom out, routing of composite part **FJ08C, tape 696, 12:11:56-12:12:10** turning of composite part **FJ08D, tape 37, 09:03:46-09:04:02** zoom out, sawing of composite part	**NARRATION (VO):** THE MACHINING OF COMPOSITES IS MORE DIFFICULT THAN MACHINING METALS AND ALLOYS BECAUSE OF THE MARKED DIFFERENCES IN THE PROPERTIES AND CHARACTERISTICS OF THE MATRIX POLYMERS AND REINFORCEMENT FIBERS. THESE DIFFERENCES CAUSE THE CUTTING TOOL TO ENCOUNTERS MAJOR CHANGES AS IT PROGRESSES THROUGH A WORKPIECE.
SCENE 9. **FJ09A, tape 18, 18:05:15-18:05:40** hand grinding of carbon fiber part **FJ09B, tape 56, 06:09:32-06:10:20**	**NARRATION (VO):** THE MATRIX POLYMERS, SUCH AS POLYESTER AND

zoom in, machining of aramid part

EPOXY, ARE RELATIVELY SOFT AND PLIABLE. THE REINFORCEMENT MATERIALS SUCH AS GLASS, CARBON OR GRAPHITE, AND BORON FIBERS ARE HARD AND ABRASIVE, WHILE THE ARAMID AND POLYETHYLENE REINFORCEMENT FIBERS ARE STRONG AND HARD TO PULL APART. BECAUSE OF THEIR DIFFERENCES, THE VARIOUS REINFORCEMENT MATERIALS REQUIRE VERY DIFFERENT CUTTING TOOLS AND MATERIALS FOR MACHINING.

SCENE 10.
FJ10A, tape 18, 18:13:28-18:13:45
zoom out, machining of carbon fiber part
FJ10B, tape 56, 06:03:14-06:03:40
zoom in, machining of aramid part

NARRATION (VO):

CARBIDE AND DIAMOND 'ABRASIVE GRIT-EDGE' TOOLS ARE OFTEN USED TO MACHINE CARBON AND GLASS REINFORCED COMPOSITES, WHILE TUNGSTEN CARBIDE AND DIAMOND 'COATED' TOOLS ARE OFTEN PREFERRED FOR MACHINING ARAMID AND POLYETHYLENE FIBERS, AND FOR DRILLING ALL TYPES OF COMPOSITES.

SCENE 11.
FJ11A, tape 696, 12:16:41-12:17:15
zoom out, drill with coolant being used to cut composite part

NARRATION (VO):

COOLANT IS OFTEN RECOMMENDED TO MINIMIZE HEAT BUILDUP AND TO PROLONG TOOL LIFE WHEN MACHINING COMPOSITES, BUT PRECAUTIONS TO PREVENT COOLANT CONTAMINATION WITHIN THE COMPOSITE PART MUST BE ADDRESSED.

SCENE 12.
FJ12A, tape 693, 09:12:23-09:12:59
sharp tool cutting composite part

NARRATION (VO):

ALSO, THE NEED TO MAINTAIN SHARP TOOLS TO PREVENT DELAMINATION OF THE COMPOSITE PART OR PREMATURE FAILURE OF THE CUTTING TOOL DURING MACHINING CANNOT BE OVER-STRESSED.

SCENE 13.
FJ13A, tape 699, 03:08:26-03:08:40
composite part being secured to workholding fixture, being machined

NARRATION (VO):

WORKHOLDING FIXTURES SHOULD PROVIDE PROPER PART BACKUP TO PREVENT BACKSIDE MATERIAL BREAKOUT IN VARIOUS OPERATIONS.

SCENE 14.
FJ14A, tape 687, 03:03:32-03:03:47
zoom out, sawing of composite part
FJ14B, tape 02, 02:13:24-03:13:32
zoom out, routing of carbon fiber part
FJ14C, tape 02, 02:10:57-02:11:04
drilling of carbon fiber part
FJ14D, tape 44, 16:11:42-16:11:53
waterjet cutting of composite part
FJ14E, tape 42, 14:21:28-14:21:37
sanding of composite part

NARRATION (VO):

THERE ARE NUMEROUS METHODS OF MACHINING POLYMER-MATRIX COMPOSITES WITH SOME OF THE MOST COMMON BEING:

SAWING...,

ROUTING...,

DRILLING...,

WATERJET CUTTING...,

AND SANDING.

--- TOUCH BLACK ---

SCENE 15.
FJ15A, CGS: Sawing
FJ15B, tape 33, 05:04:31-05:04:51
sawing of composite part
FJ15C, tape 37, 09:08:18-09:08:31
sawing of composite profile

NARRATION (VO):

SAWING IS A COMMON OPERATION USED TO TRIM EXCESSIVE WASTE MATERIAL FROM COMPOSITE PARTS...,

AND TO REDUCE IN SIZE COMPOSITE PROFILES FOR SUBSEQUENT FABRICATION.

SCENE 16.
FJ16A, tape 689, 05:05:31-05:05:49
zoom out, bandsaw used to cut composite part
FJ16B, tape 696, 12:06:10-12:06:24
circular saw used to cut composite part
FJ16C, tape 51, 23:11:37-23:11:45
saber saw used to cut composite part

NARRATION (VO):

SAWING IS GENERALLY PERFORMED USING GRIT-EDGE BLADES OR FINE, OFFSET, HIGH-STRENGTH BLADES ON BANDSAWS...,

CIRCULAR AND RADIAL SAWS...,

AND SABER SAWS.

SCENE 17.
FJ17A, tape 56, 06:05:58-06:06:22
zoom in, sawing of composite part

NARRATION (VO):

SAWING FEED RATES ARE DEPENDENT ON THE COMPOSITE LAMINATE THICKNESS, AND SHOULD BE SLOW ENOUGH TO PREVENT HEAT BUILD-UP IN THE LAMINATE, AND THUS RISK DAMAGING THE POLYMER MATRIX.

SCENE 18.
FJ18A, tape 686, 02:17:14-02:17:31
cutting part with band saw
FJ18B, tape 689, 05:04:17-05:04:32
zoom out, bandsaw used to cut composite part
FJ18C, tape 694, 10:18:02-10:18:14
zoom out, circular saw used to cut composite part
FJ18D, tape 51, 23:12:30-23:12:48
zoom out, saber saw used to cut composite part

NARRATION (VO):

BANDSAWING BLADE SPEEDS WITH HIGH-SPEED-STEEL BLADES RANGE FROM 4,000 TO 6,500 FEET, OR 1,220 TO 1,980 METERS PER MINUTE AT FEEDS OF 6 TO 12 INCHES, OR 150 TO 300 MILLIMETERS PER MINUTE...,
WITH CIRCULAR AND RADIAL SAWS, THE BLADE SPEED RANGE IS BROADER STILL: 2,000 TO 10,000 FEET, OR 610 TO 3,050 METERS PER MINUTE...,
BLADE SPEEDS OF 2,500 STROKES PER MINUTE ARE SUGGESTED WITH SABER SAWS.

--- TOUCH BLACK ---

SCENE 19.
FJ19A, CGS: Routing
FJ19B, tape 03, 03:23:11-03:23:28
wide, router trimming off waste material
FJ19C, tape 11, 11:21:08-11:21:18
routing out opening

NARRATION (VO):

ROUTING IS USED TO TRIM EXCESSIVE WASTE MATERIAL FROM POLYMER-MATRIX COMPOSITE PARTS...,
AND FOR CREATING OPENINGS, SUCH AS WINDOWS, SLOTS, AND GROOVES.

SCENE 20.
FJ20A, tape 03, 03:28:52-03:29:09
zoom out, cutter to robot
FJ20B, tape 11, 11:18:40-11:18:53
manual routing

NARRATION (VO):

ROUTING IS MOST EFFECTIVE USING FLUTED CARBIDE END-MILLING CUTTERS, CARBIDE OPPOSED-HELICAL

ROUTER BITS, AND GRIT-EDGE ROUTER BITS AND CAN BE PERFORMED AUTOMATICALLY USING NUMERICALLY CONTROLLED INDUSTRIAL ROBOTS...,
OR MANUALLY.

--- TOUCH BLACK ---

SCENE 21.
FJ21A, CGS: Drilling
FJ21B, tape 698, 02:26:13-02:26:26
dual drilling

NARRATION (VO):

DRILLING IS THE MOST COMMON MACHINING OPERATION APPLIED TO POLYMER-MATRIX COMPOSITE PARTS.

SCENE 22.
FJ22A, tape 51, 23:24:32-23:24:56
drilling three holes
FJ22B, tape 51, 23:03:36-23:03:43
c.u. drilling of composite part

NARRATION (VO):

DRILLING PRODUCES CYLINDRICAL HOLES TYPICALLY BY ROTATING A HELICALLY FLUTED DRILL AND LINEARLY FEEDING IT INTO A STATIONARY WORKPIECE. MATERIAL IS REMOVED FROM THE HOLE IN THE FORM OF CHIPS CUT BY THE DRILL'S CUTTING LIPS.

SCENE 23.
FJ23A, tape 37, 09:01:21-09:01:48
zoom out, multiple holes being drilled using drill press

NARRATION (VO):

DRILL SPEED FOR DRILLING POLYMER-MATRIX COMPOSITES RANGE FROM 2,000 TO 25,000 ROTATIONS PER MINUTE, AND FEED RATES RANGE FROM TWO THOUSANDTHS TO FIVE THOUSANDTHS INCHES, OR FIVE HUNDREDTHS TO THIRTEEN HUNDREDTHS MILLIMETERS PER REVOLUTION.

SCENE 24.
FJ24A, tape 20, 20:23:04-20:23:19
zoom out, hand drilling multiple holes

NARRATION (VO):

DRILLS MAY BE MADE OF HIGH-SPEED-STEEL, BUT CARBIDE AND INDUSTRIAL DIAMOND TOOLS ARE GENERALLY PREFERRED.

SCENE 25.
FJ25A, tape 51, 23:02:09-23:02:33
zoom out, drilling with high helix bit
FJ25B, tape 696, 12:15:08-12:15:25
drilling using coolant

NARRATION (VO):

LARGE, POSITIVE RAKE ANGLES ARE RECOMMENDED TO REDUCE THE PENETRATING FORCE AND, THUS, HEAT BUILDUP. DRILLS SHOULD ALSO HAVE A HIGH HELIX ANGLE AND WIDE, POLISHED FLUTES TO ASSIST CHIP LIFTING AND REMOVAL. COOLANTS MAY ALSO BE NECESSARY TO HELP LUBRICATE THE CUT, COOL THE DRILL POINT AND WORKPIECE, AND FLUSH OUT CHIPS.

SCENE 26.
FJ26A, CGS: Trepanning
FJ26B, tape 51, 23:01:44-23:01:53
c.u. trepanning of large hole
FJ26C, tape 51, 23:21:05-23:21:32
zoom in, trepanning of large hole

NARRATION (VO):

TREPANNING IS AN ALTERNATIVE TO DRILLING FOR GENERATING LARGE HOLE DIAMETERS. INSTEAD OF DRILLING AWAY ALL THE SOLID MATERIAL IN A HOLE, THE TREPANNING BIT MAKES A RING-SHAPED CUT TO PRODUCE THE HOLE, LEAVING A SOLID CORE. ONCE THE TREPANNED HOLE IS CUT, THIS SOLID CORE OF MATERIAL IS REMOVED.

SCENE 27.
FJ27A, tape 37, 09:15:16-09:15:26
drilling of multiple holes
FJ27B, tape 703, 17:11:47-17:11:58
composite part with hole being reamed
FJ27C, tape 686, 02:19:49-02:19:59
composite part with hole being threaded

NARRATION (VO):

ONCE POLYMER-MATRIX COMPOSITE PARTS HAVE BEEN DRILLED THERE ARE NUMEROUS HOLE FINISHING OPERATIONS THAT CAN BE PERFORMED, WITH TWO OF THE MOST COMMON BEING:

REAMING...,

AND TAPPING.

--- TOUCH BLACK ---

SCENE 28.
FJ28A, CGS: Waterjet Cutting
FJ28B, tape 44, 16:09:16-16:09:52
zoom in, waterjet cutting system

NARRATION (VO):

WATERJET CUTTING INVOLVES THE USE OF A FINE,

HIGH-PRESSURE JET OF WATER OR WATER AND ABRASIVE PARTICLES TO CUT SIMPLE OR COMPLEX PATTERNS IN COMPOSITE PARTS. WATERJET CUTTING SYSTEMS ARE TYPICALLY INTEGRATED WITH NUMERICALLY CONTROLLED INDUSTRIAL ROBOTS.

SCENE 29.
FJ29A, tape 44, 16:12:38-16:12:50
flop image, waterjet cutting of composite part

NARRATION (VO):

THE PROCESS REQUIRES ONLY CLAMPING OR FIXTURING TO SUPPORT PARTS BEING CUT, AND DOES NOT CAUSE A HEAT-AFFECTED ZONE ALONG THE CUT.

SCENE 30.
FJ30A, tape 44, 16:07:26-16:08:08
zoom out, waterjet cutting operation

NARRATION (VO):

WATERJET NOZZLES ARE MADE OF TUNGSTEN CARBIDE OR BORON CARBIDE. THE USUAL ABRASIVES FOR THE WATER ARE GARNET,
ALUMINUM OXIDE,
OR SILICON CARBIDE.
THE HARDER THE ABRASIVE THE MORE EFFECTIVE IT IS, BUT NOZZLE WEAR INCREASES.

SCENE 31.
continue previous shot

NARRATION (VO):

WATERJET CUTTING SPEEDS VARY DEPENDING UPON THE WORKPIECE MATERIAL AND WORKPIECE THICKNESS.

SCENE 32.
FJ32A, tape 44, 16:18:40-16:18:56
adhesive applied to part

NARRATION (VO):

ADDITIONALLY, A POST DRYING OPERATION MAY BE REQUIRED AFTER WATERJET CUTTING IF SECONDARY ADHESIVE BONDING AND OR PAINTING IS NEEDED.

--- TOUCH BLACK ---

SCENE 33.
FJ33A, CGS: Sanding
FJ33B, tape 42, 14:19:40-14:19:49
zoom out, deflashing part by sanding
FJ33C, tape 21, 21:17:50-21:18:00
finishing machined edge with sanding

NARRATION (VO):

SANDING IS A COMMON OPERATION PERFORMED TO REMOVE FLASH FROM COMPOSITE PARTS, AS WELL AS, TO FINISH PART SURFACES AND EDGES ONCE OTHER MACHINING HAS BEEN COMPLETED.

SCENE 34.
FJ34A, tape 46, 18:28:12-18:28:29
sanding of part, using two different types of sand paper

NARRATION (VO):

FOR FINER FINISHES, SANDING CAN BE DONE AT 4,000 TO 20,000 REVOLUTIONS PER MINUTE OR FASTER WITH DRY, 80-GRIT, ALUMINUM OXIDE OR 240- TO 320-GRIT SILICON CARBIDE AND WATER.

--- TOUCH BLACK ---

SCENE 35.
FJ35A, CGS: Joining/Assembling
FJ35B, tape 36, 08:10:27-08:10:48
adhesive being applied to composite element
FJ35C, tape 703, 17:13:26-17:13:33
mechanical fastening of composite elements

NARRATION (VO):

THE TWO PRINCIPAL METHODS FOR JOINING OR ASSEMBLING POLYMER-MATRIX COMPOSITE PARTS ARE ADHESIVE BONDING...,
AND MECHANICAL FASTENING.

SCENE 36.
FJ36A, CGS: Adhesive Bonding
FJ36B, tape 690, 06:24:07-06:24:25
composite part being laid on another
FJ36C, tape 690, 06:25:04-06:25:12
c.u. composite parts being bonded together

NARRATION (VO):

ADHESIVE BONDING JOINS SURFACES TOGETHER BY USING A LIQUID OR SOLID ADHESIVE THAT RESISTS INTERFACIAL SEPARATION BETWEEN THE TWO SURFACES OF CONTACT...,
ADHESIVE BONDING FORMS PERMANENT JOINTS.

SCENE 37.
FJ37A, tape 690, 06:25:54-06:26:11
composite part elements being cleaned for bonding
FJ37B, tape 698, 02:11:05-02:11:15
pultrusion being abraded before bonding

NARRATION (VO):

SURFACE CLEANLINESS IS CRITICAL FOR OPTIMUM ADHESIVE BONDING PERFORMANCE. ALL GREASE, MOLD RELEASE AND OTHER CONTAMINANTS MUST BE REMOVED

FROM THE CONTACT SURFACES, OR JOINT REGION BEFORE ADHESIVE APPLICATION. ABRADING THE REGION FIRST IS BETTER STILL.

SCENE 38.
FJ38A, tape 698, 02:28:43-02:29:22
adhesive being applied to composite element
FJ38B, CGS: Epoxies
Bismaleimides
Acrylics
Polyimides
Polysulfides
Epoxy-Phenolics
Urethanes

NARRATION (VO):

COMPOSITE BONDING ADHESIVES ARE NUMEROUS AND INCLUDE:

EPOXIES,

BISMALEIMIDES,

ACRYLICS,

POLYIMIDES,

POLYSULFIDES,

EPOXY-PHENOLICS,

AND URETHANES.

SCENE 39.
FJ39A, tape 693, 09:01:40-09:02:25
adhesive being applied to composite elements
FJ39B, tape 693, 09:04:16-09:04:25
workpieces placed in fixture after the adhesive is applied
FJ39C, tape 693, 09:04:43-09:04:56
workpieces pressed together in fixture

NARRATION (VO):

ONCE THE BONDING ADHESIVE IS APPLIED, THE WORKPIECES MAY BE PLACED IN A FIXTURE...,

AND THEN PRESSED TOGETHER TO REMOVE TRAPPED AIR AND CURED...,

SOME ADHESIVES CURE AT ROOM TEMPERATURE BUT MANY REQUIRE ELEVATED TEMPERATURE.

SCENE 40.
FJ40A, tape 18, 18:10:30-18:10:49
zoom out, adhesive applied to joint

NARRATION (VO):

CURE TIME FOR ADHESIVES CAN RANGE FROM A FEW MINUTES FOR NON-CRITICAL JOINTS TO MANY HOURS FOR LARGE PERFORMANCE-CRITICAL JOINTS.

SCENE 41.
continue previous shot
FJ41A, CGS: Single Lap
FJ41B, tape 711, 00:01:28-00:01:37
ANI: single lap joint
FJ41C, CGS: Double Lap

NARRATION (VO):

JOINT TYPES FOR ADHESIVE BONDING INCLUDE:

SINGLE LAP...,

FJ41D, tape 711, 00:01:58-00:02:07
ANI: double lap joint
FJ41E, CGS: Stepped Lap
FJ41F, tape 711, 00:02:28-00:02:37
ANI: stepped lap joint
FJ41G, CGS: Single Overlay
FJ41H, tape 711, 00:02:58-00:03:07
ANI: single overlay joint
FJ41I, CGS: Double Overlay
FJ41J, tape 711, 00:03:28-00:03:37
ANI: double overlay joint
FJ41K, CGS: Scarf
FJ41L, tape 711, 00:03:58-00:04:07
ANI: scarf joint

DOUBLE LAP...,

STEPPED LAP...,

SINGLE OVERLAY...,

DOUBLE OVERLAY...,

AND SCARF.

SCENE 42.
FJ42A, tape 702, 16:09:35-16:09:47
zoom out, adhesive bonding of bushing

NARRATION (VO):

ADHESIVE BONDING CAN ALSO BE USED TO BOND SURFACE-MOUNTED FASTENERS AND BUSHINGS, THUS COMBINING ADHESIVE BONDING AND MECHANICAL FASTENING.

SCENE 43.
FJ43A, CGS: Mechanical Fastening
FJ43B, tape 37, 09:12:35-09:12:51
zoom in, mechanical fastening using rivets
FJ43C, tape 702, 16:10:16-16:10:21
mechanical fastening using pins
FJ43D, tape 51, 23:19:39-23:19:52
zoom out, mechanical fastening using bolts

NARRATION (VO):

MECHANICAL FASTENING INVOLVES THE USE OF RIVETS...,

PINS...,

BOLTS, NUTS AND OTHER FASTENER TYPES TO JOIN COMPOSITE COMPONENTS TOGETHER.

SCENE 44.
FJ44A, tape 51, 23:03:21-23:03:28
zoom out, holes being drilled for mechanical fasteners

NARRATION (VO):

MECHANICAL FASTENING REQUIRES PRECISION HOLEMAKING.

SCENE 45.
FJ45A, tape 20, 20:13:13-20:13:27
zoom out, metal fastener holding part together
FJ45B, tape 686, 02:21:55-02:22:04
use of polymer-matrix composite fasteners

NARRATION (VO):

STEEL, ALUMINUM AND OTHER MORE EXOTIC METALS ARE OFTEN USED FOR FASTENERS, BUT POLYMER-MATRIX COMPOSITE FASTENERS ARE ALSO AVAILABLE.

SCENE 46.
FJ46A, tape 51, 23:04:09-23:04:27
mechanical fasteners being tightened

NARRATION (VO):

MECHANICAL FASTENING CLAMPING LOADS SHOULD BE SUFFICIENT TO CLOSE GAPS BUT NOT SO MUCH AS TO CAUSE DISTORTION OR BREAKAGE.

--- FADE TO BLACK ---

SCENE 47.
FJ47A, GRAPHIC: Review white text on black
FJ47B, peter carey narration

MUSIC UP AND UNDER

NARRATION (VO):

LET'S REVIEW THE MATERIAL CONTAINED IN THIS PROGRAM.

SCENE 48.
FJ48A, tape 33, 05:04:02-05:04:13 machining operation
FJ48B, tape 36, 08:10:27-08:10:48 adhesive being applied to composite element
FJ48C, tape 698, 02:18:42-02:18:49 zoom in, mechanical fasteners used to connect composite components
FJ48D, review music, up and under

NARRATION (VO):

AFTER FIBER-REINFORCED POLYMER COMPOSITE PARTS HAVE BEEN FORMED, THEY CAN BE FURTHER PROCESSED BY MACHINING OPERATIONS...,
AND JOINED OR ASSEMBLED BY ADHESIVE BONDING...,
OR MECHANICAL FASTENING.

--- TOUCH BLACK ---

SCENE 49.
FJ49A, CGS: Machining
FJ49B, tape 03, 03:23:58-03:24:20 zoom out, routing of composite part
FJ49C, tape 696, 12:11:56-12:12:10 turning of composite part
FJ49D, tape 37, 09:03:46-09:04:02 zoom out, sawing of composite part

NARRATION (VO):

THE MACHINING OF COMPOSITES IS MORE DIFFICULT THAN MACHINING METALS AND ALLOYS BECAUSE OF THE MARKED DIFFERENCES IN THE PROPERTIES AND CHARACTERISTICS OF THE MATRIX POLYMERS AND REINFORCEMENT FIBERS. THESE DIFFERENCES CAUSE THE CUTTING TOOL TO ENCOUNTERS MAJOR CHANGES AS IT PROGRESSES THROUGH A WORKPIECE.

SCENE 50.
FJ50A, tape 18, 18:05:15-18:05:40 hand grinding of carbon fiber part
FJ50B, tape 56, 06:09:32-06:10:20 zoom in, machining of aramid part

NARRATION (VO):

THE MATRIX POLYMERS, SUCH AS POLYESTER AND

EPOXY, ARE RELATIVELY SOFT AND PLIABLE. THE REINFORCEMENT MATERIALS SUCH AS GLASS, CARBON OR GRAPHITE, AND BORON FIBERS ARE HARD AND ABRASIVE, WHILE THE ARAMID AND POLYETHYLENE REINFORCEMENT FIBERS ARE STRONG AND HARD TO PULL APART. BECAUSE OF THEIR DIFFERENCES, THE VARIOUS REINFORCEMENT MATERIALS REQUIRE VERY DIFFERENT CUTTING TOOLS AND MATERIALS FOR MACHINING.

SCENE 51.
FJ51A, tape 18, 18:13:28-18:13:45
zoom out, machining of carbon fiber part
FJ51B, tape 56, 06:03:14-06:03:40
zoom in, machining of aramid part

NARRATION (VO):

CARBIDE AND DIAMOND 'ABRASIVE GRIT-EDGE' TOOLS ARE OFTEN USED TO MACHINE CARBON AND GLASS REINFORCED COMPOSITES, WHILE TUNGSTEN CARBIDE AND DIAMOND 'COATED' TOOLS ARE OFTEN PREFERRED FOR MACHINING ARAMID AND POLYETHYLENE FIBERS, AND FOR DRILLING ALL TYPES OF COMPOSITES.

SCENE 52.
FJ52A, tape 696, 12:16:41-12:17:15
zoom out, drill with coolant being used to cut composite part

NARRATION (VO):

COOLANT IS OFTEN RECOMMENDED TO MINIMIZE HEAT BUILDUP AND TO PROLONG TOOL LIFE WHEN MACHINING COMPOSITES, BUT PRECAUTIONS TO PREVENT COOLANT CONTAMINATION WITHIN THE COMPOSITE PART MUST BE ADDRESSED.

SCENE 53.
FJ53A, tape 693, 09:12:23-09:12:59
sharp tool cutting composite part

NARRATION (VO):

ALSO, THE NEED TO MAINTAIN SHARP TOOLS TO PREVENT DELAMINATION OF THE COMPOSITE PART OR PREMATURE FAILURE OF THE CUTTING TOOL DURING MACHINING CANNOT BE OVER-STRESSED.

SCENE 54.
FJ54A, tape 699, 03:08:26-03:08:40
composite part being secured to workholding fixture, being machined

NARRATION (VO):

WORKHOLDING FIXTURES SHOULD PROVIDE PROPER PART BACKUP TO PREVENT BACKSIDE MATERIAL BREAKOUT IN VARIOUS OPERATIONS.

SCENE 55.
FJ55A, tape 33, 05:04:31-05:04:51
sawing of composite part
FJ55B, CGS: Sawing
FJ55C, tape 02, 02:13:24-03:13:32
zoom out, routing of carbon fiber part
FJ55D, CGS: Routing
FJ55E, tape 02, 02:10:57-02:11:04
drilling of carbon fiber part
FJ55F, CGS: Drilling
FJ55G, tape 44, 16:07:26-16:08:08
zoom out, waterjet cutting operation
FJ55H, CGS: Waterjet Cutting
FJ55I, tape 42, 14:21:28-14:21:37
sanding of composite part
FJ55J, CGS: Sanding

NARRATION (VO):

THERE ARE NUMEROUS METHODS OF MACHINING POLYMER-MATRIX COMPOSITES WITH SOME OF THE MOST COMMON BEING:

SAWING...,

ROUTING...,

DRILLING...,

WATERJET CUTTING...,

AND SANDING.

--- TOUCH BLACK ---

SCENE 56.
FJ56A, CGS: Adhesive Bonding
FJ56B, tape 690, 06:24:07-06:24:25
composite part being laid on another
FJ56C, tape 690, 06:25:04-06:25:12
c.u. composite parts being bonded together

NARRATION (VO):

ADHESIVE BONDING JOINS SURFACES TOGETHER BY USING A LIQUID OR SOLID ADHESIVE THAT RESISTS INTERFACIAL SEPARATION BETWEEN THE TWO SURFACES OF CONTACT...,

ADHESIVE BONDING FORMS PERMANENT JOINTS.

SCENE 57.
FJ57A, tape 690, 06:25:54-06:26:11
composite part elements being cleaned for bonding
FJ57B, tape 698, 02:11:05-02:11:15
pultrusion being abraded before bonding

NARRATION (VO):

SURFACE CLEANLINESS IS CRITICAL FOR OPTIMUM ADHESIVE BONDING PERFORMANCE. ALL GREASE, MOLD RELEASE AND OTHER CONTAMINANTS MUST BE REMOVED FROM THE CONTACT SURFACES, OR JOINT REGION BEFORE ADHESIVE APPLICATION. ABRADING THE REGION FIRST IS BETTER STILL.

SCENE 58. **FJ58A, tape 698, 02:28:43-02:29:22** adhesive being applied to composite element **FJ58B,** CGS: Epoxies Bismaleimides Acrylics Polyimides Polysulfides Epoxy-Phenolics Urethanes	**NARRATION (VO):** COMPOSITE BONDING ADHESIVES ARE NUMEROUS AND INCLUDE: EPOXIES, BISMALEIMIDES, ACRYLICS, POLYIMIDES, POLYSULFIDES, EPOXY-PHENOLICS, AND URETHANES.
SCENE 59. **FJ59A, tape 18, 18:10:30-18:10:49** zoom out, adhesive applied to joint	**NARRATION (VO):** CURE TIME FOR ADHESIVES CAN RANGE FROM A FEW MINUTES FOR NON-CRITICAL JOINTS TO MANY HOURS FOR LARGE PERFORMANCE-CRITICAL JOINTS.
SCENE 60. **FJ60A, tape 702, 16:09:35-16:09:47** zoom out, adhesive bonding of bushing	**NARRATION (VO):** ADHESIVE BONDING CAN ALSO BE USED TO BOND SURFACE-MOUNTED FASTENERS AND BUSHINGS, THUS COMBINING ADHESIVE BONDING AND MECHANICAL FASTENING.
SCENE 61. **FJ61A,** CGS: Mechanical Fastening **FJ61B, tape 37, 09:12:35-09:12:51** zoom in, mechanical fastening using rivets **FJ61C, tape 702, 16:10:16-16:10:21** mechanical fastening using pins **FJ61D, tape 51, 23:19:39-23:19:52** zoom out, mechanical fastening using bolts	**NARRATION (VO):** MECHANICAL FASTENING INVOLVES THE USE OF RIVETS..., PINS..., BOLTS, NUTS AND OTHER FASTENER TYPES TO JOIN COMPOSITE COMPONENTS TOGETHER.
SCENE 62. **FJ62A, tape 20, 20:13:13-20:13:27** zoom out, metal fastener holding part together	**NARRATION (VO):** STEEL, ALUMINUM AND OTHER MORE EXOTIC METALS

FJ62B, tape 686, 02:21:55-02:22:04
use of polymer-matrix composite fasteners

ARE OFTEN USED FOR FASTENERS, BUT POLYMER-MATRIX COMPOSITE FASTENERS ARE ALSO AVAILABLE.

SCENE 63.
FJ63A, tape 51, 23:04:09-23:04:27
mechanical fasteners being tightened

NARRATION (VO):

MECHANICAL FASTENING CLAMPING LOADS SHOULD BE SUFFICIENT TO CLOSE GAPS BUT NOT SO MUCH AS TO CAUSE DISTORTION OR BREAKAGE.

--- FADE TO BLACK ---

SCENE 64.
FJ64A, CG, ROLL: credits
white text on black, fade up mid-screen

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SCENE 65.
FJ65A, 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 66.
FJ66A, SME logo open, with music