FUNDAMENTALS OF TOOL DESIGN

Composite Tooling Design

SCENE 1.
FTD01A, CGS: FBI warning
white text centered on black to transparent gradient
FTD01B, motion background

WARNING

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SCENE 2.
continue motion background
FTD02A, CGS: disclaimer
white text centered on black to transparent gradient

Always read the operating manual and safety information provided by the manufacturer before operating any manufacturing equipment.

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

SCENE 3.
FTD03A, SME logo open, with music

SCENE 4.
FTD04A, FTD open, with music
CD04B, edited peter carey narration
CD04C, CM44, 16:19:32:00-16:20:18:00
audio only, sound slug
CD04D, peter carey patch

MUSIC UP AND UNDER

NARRATION (VO):

THE FUNDAMENTALS OF TOOL DESIGN VIDEO SERIES, EXAMINING THE DIVERSE FIELD OF TOOL DESIGN MATERIALS AND TECHNOLOGIES.

SCENE 5.
continue FTD open
CD05A, CGS: Composite Tooling Design
white text, centered on background
FTD05B, blue background

NARRATION (VO):

THIS PROGRAM EXPLORES THE FUNDAMENTALS OF COMPOSITE TOOLING DESIGN.

SCENE 6.
CD06A, FTD44, 17:17:41:00-17:18:04:00
composite tool being laid up
CD06B, CM06, 06:28:42:00-06:28:56:00
fiber being placed in mold
CD06C, CM07, 07:07:07:00-07:07:27:00

NARRATION (VO):

QUALITY TOOLING IS A FUNDAMENTAL REQUIREMENT FOR THE MANUFACTURE OF

composite tool being filled with resin
CD06D, CM07, 07:14:59:00-07:15:16:00
composite part being removed from mold

FIBER-REINFORCED THERMOSETTING POLYMER, OR 'COMPOSITE', PARTS. THIS IS DUE TO THE FACT THAT EVERY STEP IN THE COMPOSITE PART MANUFACTURING PROCESS MUST BE TIGHTLY CONTROLLED TO ENSURE SUPERIOR MATERIAL PROPERTIES AND PREDICTABLE PERFORMANCE IN THE FINAL PRODUCT.

SCENE 7.
CD07A, FTD47, 20:07:29:00-20:07:53:00
c.u., cad design of composite part with tool
CD07B, FTD47, 20:13:58:00-20:14:12:00
c.u., cad design of mold for composite part
CD07C, FTD47, 20:05:09:00-20:05:35:00
c.u., cad design of composite part with tool

NARRATION (VO):

THE USE OF COMPUTER-AIDED DESIGN OR 'CAD' SOFTWARE, HAS ALLOWED TOOL DESIGNERS TO CREATE DIMENSIONALLY ACCURATE DIGITAL PART, TOOL, AND ASSEMBLY FILES IN 3-DIMENSIONS. THIS CAPABILITY TO WORK FROM THE 'AS-ENGINEERED' PART-MODEL HAS GREATLY ENHANCED THE DESIGNERS ABILITY TO EXPLORE THE MANY ASPECTS OF THE PART-TO-TOOL RELATIONSHIP, WHILE CONTROLLING THE VARIABLES SPECIFIC TO MOLDING COMPOSITE PARTS.

SCENE 8.
CD08A, CM20, 20:26:56:00-20:27:10:00
zoom out, tool being laid up
CD08B, CM34, 06:13:52:00-06:14:05:00
pan, pultrusion fiber
CD08C, CM20, 20:04:28:00-20:04:36:00
zoom out, liquid molding operation
CD08D, CM03, 03:05:16:00-03:05:31:00
composite tool being laid up
CD08E, FMP703, 17:02:18:00-17:02:32:00
zoom out, filament winding

NARRATION (VO):

COMPOSITE TOOLING DESIGNERS NOT ONLY HAVE TO BE KNOWLEDGEABLE ABOUT THE VARIETY OF TOOLING MATERIALS AND THEIR PROPERTIES, THEY ALSO NEED TO BE FAMILIAR WITH THE VARIOUS FIBER AND FABRIC FORMS, POLYMER RESINS AND

REACTIVE CHEMISTRIES, AND THE MANY DIFFERENT METHODS AND TECHNIQUES USED IN PROCESSING COMPOSITES.

SCENE 9.
CD09A, FMP687, 03:04:50:00-03:05:05:00
zoom in, sawing of composite part
CD09B, FMP696, 12:17:15:00-12:17:31:00
drilling composite part
CD09C, FMP696, 12:13:36:00-12:13:50:00
zoom out, turning composite part

NARRATION (VO):

ADDITIONALLY, AN UNDERSTANDING OF THE SAWING...,
DRILLING...,
AND MACHINING OF COMPOSITES IS MANDATORY TO DESIGN GOOD WORKING TOOLS.

--- TOUCH BLACK ---

SCENE 10.
CD10A, CM14, 14:23:46:00-14:23:55:00
prepreg being cut
CD10B, CM15, 15:02:06:00-15:02:24:00
prepreg being laid up
CD10C, CM18, 18:14:00:00-18:14:12:00
parts being assembled
CD10D, CM18, 18:17:38:00-18:17:52:00
parts being glued

NARRATION (VO):

FROM RAW MATERIAL HANDLING...,
TO MATERIAL PROCESSING...,
AND ASSEMBLY, WELL DESIGNED COMPOSITE TOOLING ENABLES MANUFACTURERS TO CONTROL EACH STEP OF THE PROCESS, RESULTING IN MORE CONSISTENT PART-PRODUCTION AND UNIFORM ASSEMBLY PRACTICES.

SCENE 11.
CD11A, FMP694, 10:06:36:00-10:06:56:00
wet layup operation
CD11B, CM09, 09:13:28:00-09:13:40:00
manual spray up operation
CD11C, CM15, 15:09:15:00-15:09:24:00
carbon fiber manual layup operation
CD11D, CM49, 21:19:02:00-21:19:09:00
zoom out, vacuum infusion process
CD11E, CM55, 05:09:52:00-05:10:11:00
zoom in, resin pumped into rtm mold
CD11F, CM42, 14:14:14:00-14:14:24:00
compression mold opening
CD11G, FMP698, 02:03:00:00-02:03:16:00
wide, zoom in, pultrusion operation
CD11H, FMP700, 13:08:46:00-13:09:06:00
wide, filament winding operation
CD11I, FMP705, 20:28:30:00-20:28:48:00

NARRATION (VO):

COMPOSITE MANUFACTURING METHODS INCLUDE WET LAYUP...,
AND SPRAY-UP...,
PREPREG LAYUP...,
VACUUM RESIN INFUSION...,
RESIN TRANSFER MOLDING...,
COMPRESSION AND MATCHED-PRESS MOLDING...,

zoom out, prepreg being laid up

PULTRUSION...,

FILAMENT WINDING...,

AUTOMATED FIBER AND PLACEMENT,

AND A MULTITUDE OF VARIANT AND HYBRID APPROACHES.

--- TOUCH BLACK ---

SCENE 12.
CD12A, CM01, 01:17:53:00-01:18:36:00
prepreg being automatically cut
CD12B, CGS: Ply & Core Kit-Cutting Templates
Ply & Core Locator Templates
Layup Molds/Mandrels
Trim Fixtures
Drill Jigs & Fixtures

NARRATION (VO):

THERE ARE MANY DIFFERENT TYPES OF TOOLS REQUIRED TO SUPPORT COMPOSITE MANUFACTURING, INCLUDING:

PLY AND CORE KIT-CUTTING TEMPLATES,

PLY AND CORE LOCATOR TEMPLATES,

LAYUP MOLDS OR MANDRELS,

TRIM FIXTURES,

AND DRILL JIGS AND FIXTURES.

SCENE 13.
CD13A, CGS: Ply & Core Kit-Cutting Templates
CD13B, CM16, 16:01:32:00-16:01:45:00
ply cutting with template
CD13C, CM01, 01:06:54:00-01:07:10:00
core cutting with template

NARRATION (VO):

PLY...,

AND CORE KIT-CUTTING TEMPLATES MAY BE REQUIRED TO SUPPORT PRE-LAYUP OPERATIONS.

SCENE 14.
CD14A, CGS: Ply & Core Locator Templates
CD14B, FTD47, 20:25:15:00-20:25:42:00
zoom out, ply template
CD14C, FTD47, 20:28:07:00-20:28:24:00
pan, ply template

NARRATION (VO):

PLY AND CORE LOCATOR TEMPLATES MIGHT BE NECESSARY TO SUPPORT LAYUP OF THE MATERIALS IN THE MOLD OR ON THE MANDREL.

THESE TEMPLATES ARE USUALLY DESIGNED TO

INDEX TO THE MOLD AND HAVE MACHINED COLOR-CODED 'EYEBROW' CUTOUTS ALONG THE PLY OR CORE LOCATIONS TO FACILITATE MARKING THESE LOCATIONS ON THE LAMINATE DURING LAYUP. DETAILED PLY-LAYUP INFORMATION IS OFTEN PROVIDED ON THE TEMPLATE TO AID THE LAYUP TECHNICIAN.

SCENE 15.
CD15A, CM01, 01:20:20:00-01:20:32:00
prepreg being automatically cut
CD15B, FTD55, 06:20:57:00-06:21:10:00
zoom out, laser ply projection system
CD15C, FTD55, 06:12:19:00-06:12:32:00
zoom in, mold with laser placement

NARRATION (VO):

AUTOMATED PLY AND CORE-CUTTING SYSTEMS...,
AND LASER PLY PROJECTION SYSTEMS FOR CONTROLLING PLY AND CORE PLACEMENT AND ORIENTATION VERIFICATION, ARE ALSO COMMONLY USED FOR MANY HIGH-VOLUME OR PRECISION LAYUP OPERATIONS.

SCENE 16.
CD16A, CGS: Layup Molds/Mandrels
CD16B, FTD53, 04:21:20:00-04:21:50:00
layup mold
CD16C, CM02, 02:19:02:00-02:19:34:00
mandrel used in filament winding
CD16D, CM28, 04:15:57:00-04:16:09:00
metal mold for prepreg panel
CD16E, CM01, 01:14:19:00-01:14:33:00
contoured mold being laid up

NARRATION (VO):

LAYUP MOLDS...,
OR MANDRELS PROVIDE THE DESIRED SHAPE FOR PARTS PRODUCTION, AND ARE THE PRIMARY TOOLS USED TO PRODUCE COMPOSITE PARTS OR PANELS. THEY MAY BE A SIMPLE METAL PLATE USED TO MANUFACTURE PANELS...,
OR A MORE COMPLEX, CONTOURED CONFIGURATION NECESSARY TO PRODUCE A COMPLICATED COMPOSITE PART.

SCENE 17.
CD17A, CM01, 01:08:29:00-01:08:56:00
prepreg wrapped around core

NARRATION (VO):

TO PRODUCE HOLLOW PARTS, CORES MAY BE USED FOR MANUAL LAYUP. CORES ARE COMMONLY DESIGNED TO DISSOLVE OR COLLAPSE FOR REMOVAL FROM THE PART AFTER CURING.

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SCENE 18.
CD18A, CGS: Trim Fixtures
CD18B, CM20, 20:21:37:00-20:21:54:00
composite part being trimmed
CD18C, FMP686, 02:11:38:00-02:12:03:00
mold with knife flange being trimmed
CD18E, CM11, 11:18:22:00-11:18:52:00
manual routing operation using jig

NARRATION (VO):

NEARLY EVERY COMPOSITE PART NEEDS TO BE TRIMMED AFTER MOLDING. PROVISIONS FOR TRIMMING RANGE FROM THE INCLUSION OF A 'KNIFE FLANGE' ALONG THE NET-TRIM EDGES OF A LAYUP MOLD TO DESIGNING A SEPARATE, MORE COMPLEX TRIM FIXTURE OR JIG THAT LOCATES AND HOLDS THE PART IN POSITION FOR PROCESSING.

SCENE 19.
CD19A, CM44, 16:09:34:00-16:09:55:00
zoom in, waterjet cutting
CD19B, CM04, 04:01:41:00-04:02:17:00
zoom out, cnc routing operation
CD18D, CM03, 03:25:15:00-03:25:29:00
zoom out, cnc routing operation

NARRATION (VO):

THESE TOOLS MAY ALSO BE USED FOR AUTOMATED PROCESSES SUCH AS WATER JET CUTTING...,
AND 'CNC' ROUTING OPERATIONS. IN THIS CASE THE TOOL MAY ONLY SERVE AS A HOLDING FIXTURE FOR THE PART TO BE LOCATED RELATIVE TO THE MACHINE FOR THE AUTOMATED CUTTING OR TRIMMING OPERATION.

SCENE 20.
CD20A, CGS: Drill Jigs & Fixtures
CD20B, FMP698, 02:26:07:00-02:26:26:00
drill jig being used
CD20C, CM37, 09:02:17:00-09:02:57:00
zoom in, drill jig being used

NARRATION (VO):

DRILL JIGS OR FIXTURES ARE TYPICALLY REQUIRED TO SECURE AND SUPPORT A

COMPOSITE PART AND ASSIST IN ACCURATELY GUIDING A DRILL TO PRODUCE A HOLE. DRILL JIGS COMMONLY UTILIZE SLIP-RENEWABLE BUSHINGS TO MINIMIZE TOOL-WEAR AND SUBSEQUENT REWORK.

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SCENE 21.
CD21A, CGS: Tooling Materials
white text, centered on background
FTD01B, motion background

SCENE 22.
CD22A, CM23, 20:23:42:00-20:23:58:00
invar tool
CD22B, CM01, 01:13:20:00-01:13:30:00
carbon fiber tool
CD22C, CM03, 03:07:26:00-03:08:04:00
zoom out, composite tool being sprayed up
CD22D, CGS: Glass Reinforced Polyester/
Vinyl-Ester Laminated Tooling
Carbon/Glass Fiber Reinforced
Epoxy/Bismaleimide Laminated
Tooling
Invar
Invar Coated Carbon Fiber
Reinforced Tooling
Steel

NARRATION (VO):

THERE IS A WIDE VARIETY OF MATERIALS USED TO CREATE COMPOSITE TOOLING, WITH SOME OF THE MOST COMMON BEING:
GLASS REINFORCED POLYESTER OR VINYL-ESTER LAMINATED TOOLING,
CARBON OR GLASS FIBER REINFORCED EPOXY OR BISMALEIMIDE LAMINATED TOOLING,
INVAR,
INVAR COATED CARBON FIBER REINFORCED TOOLING,
AND STEEL.

SCENE 23.
CD23A, CM17, 17:16:42:00-17:17:19:00
zoom in, small metal mold for carbon fiber layup
CD23B, CGS: Part Production Quantities
Upper Service Temperature

NARRATION (VO):

THE CHOICE OF ONE MATERIAL OVER ANOTHER FOR A GIVEN COMPOSITE TOOL MAY BE DETERMINED BY TWO FACTORS:
THE PART PRODUCTION QUANTITIES REQUIRED OVER THE LIFE OF THE TOOL,

AND THE UPPER SERVICE TEMPERATURE THAT THE TOOL HAS TO WITHSTAND DURING PARTS PROCESSING.

SCENE 24.
CD24A, FMP693, 09:09:53:00-09:10:30:00
zoom out, mold with high cte value curing under heat lamps
CD24B, CGS: Coefficient of Thermal Expansion/CTE
CD24C, CM01, 01:16:29:00-01:16:42:00
zoom out, composite mold with low cte value being laid up

NARRATION (VO):

THE SERVICE TEMPERATURE IS OF CONCERN BECAUSE A MATERIAL EXPANDS WHEN HEATED, ALTERING IT'S DIMENSIONS. THE VALUE GIVEN TO A MATERIAL INDICATING HOW IT REACTS DURING A CHANGE IN TEMPERATURE IS REFERRED TO AS THE COEFFICIENT OF THERMAL EXPANSION OR 'CTE' VALUE. A HIGH 'CTE' VALUE INDICATES A MATERIAL EXPANDS A LOT UNDER ELEVATED TEMPERATURE, WHILE A MATERIAL HAVING A LOW 'CTE' VALUE EXPANDS LESS.

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SCENE 25.
CD25A, CGS: Glass Reinforced Polyester/ Vinyl-Ester Laminated Tooling
CD25B, CM06, 06:25:30:00-06:25:54:00
zoom out, glass reinforced polyester tooling being laid up

NARRATION (VO):

GLASS REINFORCED POLYESTER OR VINYL-ESTER LAMINATED TOOLS HAVE A VERY LOW TEMPERATURE CAPABILITY AND TYPICALLY ARE USED FOR ROOM-TEMPERATURE MOLDING.

SCENE 26.
CD26A, FMP689, 05:17:11:00-05:17:29:00
carbon fiber tooling unloaded from oven
CD26B, CM02, 02:24:12:00-02:24:32:00
metallic mandrel being filament wound

NARRATION (VO):

CARBON OR GLASS FIBER REINFORCED EPOXY OR BISMALEIMIDE LAMINATED TOOLING CAN EASILY SERVICE UP TO 350° FAHRENHEIT, OR 177° CELSIUS. OTHER METALLIC TOOLING MATERIALS SUCH AS INVAR ALLOYS, AND

STEEL CAN ALSO EASILY REACH THAT TEMPERATURE.

SCENE 27.
CD27A, CGS: Carbon Fiber Reinforced Epoxy/ Bismaleimide Tooling
CD27B, FMP691, 07:06:53:00-07:07:21:00
carbon fiber tooling used in prepreg layup
CD27C, FMP691, 07:22:38:00-07:23:27:00
carbon fiber tooling placed in oven
CD27D, zoom in, still, carbon fiber tooling

NARRATION (VO):

CARBON FIBER REINFORCED EPOXY OR BISMALEIMIDE TOOLS HAVE A LOW 'CTE' VALUE, AND ARE VERY LIGHTWEIGHT, HAVING A DENSITY OF AROUND 1.4 GRAMS PER CUBIC CENTIMETER. BECAUSE THEY ARE LIGHTWEIGHT, CARBON MOLDS AND FIXTURES ARE TYPICALLY QUICKER TO HEAT AND COOL THAN METAL TOOLING.

SCENE 28.
CD28A, CGS: Glass Fiber Reinforced Epoxy/ Bismaleimide Tooling
CD28B, CM14, 14:28:01:00-14:28:28:00
carbon fiber being laid up in glass fiber reinforced epoxy tooling
CD28C, CM19, 19:19:12:00-19:19:45:00
zoom in, aramid fiber being laid up in glass fiber reinforced epoxy tooling

NARRATION (VO):

GLASS FIBER REINFORCED EPOXY OR BISMALEIMIDE TOOLS ARE SIGNIFICANTLY HEAVIER THAN CARBON TOOLING WITH A DENSITY AROUND 2.1 GRAMS PER CUBIC CENTIMETER. THESE TOOLS ARE ALSO THERMAL INSULATORS AND HAVE A SIGNIFICANTLY LOWER MODULUS, OR STIFFNESS THAN CARBON, REQUIRING APPROXIMATELY THREE TIMES THE LAMINATE THICKNESS TO MATCH THE STIFFNESS OF CARBON TOOLING.

SCENE 29.
CD29A, CGS: Invar
CD29B, FTD48, 21:03:53:00-21:04:14:00
zoom out, large invar tool
CD29C, FTD47, 20:18:31:00-20:18:46:00
zoom out, invar tooling

NARRATION (VO):

INVAR, WHICH IS A NICKEL/IRON ALLOY, IS AN IDEAL METAL FOR DESIGNING HIGH TEMPERATURE MOLDS, MANDRELS, AND FIXTURES SINCE IT HAS A LOW 'CTE' VALUE

IN THE SAME RANGE AS CARBON FIBER REINFORCED TOOLING. THE DOWNSIDE IS THAT INVAR IS EXTREMELY HEAVY AT 8.12 GRAMS PER CUBIC CENTIMETER AND REQUIRES MORE ENERGY AND TIME TO HEAT AND COOL.

SCENE 30.
CD30A, zoom in, still, fabricated invar tooling
CD30B, zoom out, still, cast invar mandrel

NARRATION (VO):

INVAR COMES IN ROLLED SHEET STOCK THAT CAN BE FORMED, WELDED, AND MACHINED, OR CAN BE CAST AND MACHINED TO SHAPE.

SCENE 31.
CD31A, CGS: Invar Coated Carbon Fiber Reinforced Tooling
CD31B, zoom in, still, invar coated tool being worked on
CD31C, zoom out, still, invar coated tool
CD31D, zoom in, still, photomicrograph of invar coated tool

NARRATION (VO):

INVAR COATED CARBON FIBER REINFORCED TOOLING HAS EMERGED IN THE PAST FEW YEARS TO PROVIDE A LIGHTWEIGHT, HARD, LOW EXPANSION, VACUUM INTEGRAL SURFACE ON A COMPOSITE TOOL. THIS MATERIAL COMBINATION CAN PROVIDE LONGEVITY TO AN OTHERWISE LIMITED TOOL LIFE OF A CARBON FIBER REINFORCED PLASTIC TOOL LAMINATE.

SCENE 32.
CD32A, CGS: Steel
CD32B, FMP689, 05:03:15:00-05:03:43:00 zoom out, steel mold being cleaned
CD32C, CM47, 19:13:27:00-19:13:50:00 steel mold being machined

NARRATION (VO):

STEEL CAN BE USEFUL FOR MANY APPLICATIONS BUT IT IS NEARLY AS HEAVY AS INVAR. WHILE STAINLESS STEEL IS A PREFERRED MATERIAL FOR MOLDING AND RESISTING OXIDATION, IS NOT VERY ECONOMICAL. DEPENDING ON THE ALLOY, STEEL CAN WEIGH-IN AT BETWEEN 7.86 AND 8.02 GRAMS PER CUBIC CENTIMETER AND HAS

A FAIRLY HIGH 'CTE' VALUE.

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SCENE 33.
CD33A, CGS: Tooling Design
white text, centered on background
FTD01B, motion background

SCENE 34.
CD34A, CM37, 09:18:36:00-09:18:56:00
zoom out, pultrusion tool
CD34B, CM17, 17:19:53:00-17:20:16:00
zoom in, hand layup mold
CD34C, FTD50, 23:14:28:00-23:14:53:00
infusion molding
CD34D, CM11, 11:15:08:00-11:15:23:00
zoom out, routing using fixture guide
CD34E, CM08, 08:21:57:00-08:22:08:00
mold being gel coated
CD34F, FMP700, 13:11:35:00-13:11:53:00
mandrel used for filament winding
CD34G, FMP700, 13:16:48:00-13:17:08:00
mandrel used for filament winding

NARRATION (VO):

THERE ARE MANY THINGS TO CONSIDER WHEN DESIGNING TOOLS FOR THE VARIETY OF COMPOSITE MANUFACTURING PROCESSES. WHILE MANY COMMON TOOL DESIGNS ARE USED FOR POST-MOLDING OPERATIONS, ACTUAL MOLD..., OR MANDREL DESIGNS DIFFER CONSIDERABLY DEPENDING ON THE PROCESSES THAT THEY ARE DESIGNED TO SERVE.

SCENE 35.
CD35A, CM15, 15:14:08:00-15:14:34:00
zoom out, part being laid up
CD35B, CM15, 15:23:50:00-15:24:00:00
part being vacuum bagged
CD35C, CM15, 15:27:25:00-15:27:36:00
part placed in autoclave for curing, dissolve to next image
CD35D, CM15, 15:27:49:00-15:27:59:00
autoclave closed

NARRATION (VO):

THE PRIMARY TOOLING REQUIREMENTS FOR MOLDING FIBER REINFORCED PLASTIC PARTS ARE THAT PROVISIONS BE MADE FOR THE

LAYUP...,

COMPACTION...,

AND CURING OF THE PARTS.

SCENE 36.
CD36A, FTD43, 16:23:06:00-16:23:25:00
zoom out, mold element with draft angle
CD36B, FTD51, 01:18:00:00-01:18:12:00
zoom out, multi-piece molds

NARRATION (VO):

ALL MOLD AND MANDREL DESIGNS SHOULD ALLOW FOR SUFFICIENT DRAFT-ANGLE SO THAT THE CURED PART CAN BE REMOVED FROM THE TOOLING AFTER THE MOLDING PROCESS. WITH COMPLEX GEOMETRIES, THIS MIGHT MEAN

USING MULTI-PIECE TOOLS.

SCENE 37.
CD37A, CM17, 17:13:18:00-17:13:47:00
hand layup of carbon fiber in metal mold
CD37B, ANI: spring-in of carbon fiber material in 90 degree mold, carbon fiber springing to 88 degrees
CD37C, ANI: spring-in of carbon fiber material in adjusted 92 degree mold, carbon springing to 90 degrees
CD37D, CM51, 23:15:12:00-23:15:40:00
zoom out, spray up of mold

NARRATION (VO):

ADDITIONALLY, A COMBINATION OF INNER SURFACE FIBER TENSION AND RESIN SHRINKAGE CONTRIBUTES TO 'SPRING-IN' OF COMPOSITE ANGLES MADE AT ELEVATED PRESSURES. 'SPRING-IN' IS ADDRESSED BY ADDING TO THE ANGLE REQUIREMENT OF A COMPOSITE TOOL. TYPICALLY ONE-HALF TO TWO DEGREES OF CORRECTION IS REQUIRED, DEPENDING ON THE SPECIFIC ANGLE, RADII, AND THE MATERIALS AND PROCESSES BEING UTILIZED.

SCENE 38.
CD38A, CM06, 06:11:12:00-06:11:34:00
zoom out, mold being laid up

NARRATION (VO):

A LAYUP MOLD USED FOR 'HAND' OR 'CONTACT' LAYUP WITH NO VACUUM BAG OR ELEVATED TEMPERATURE CURE-REQUIREMENTS MIGHT BE DESIGNED TO SIMPLY CONTROL THE PART SHAPE AND NET-DIMENSIONS AT ROOM TEMPERATURE.

SCENE 39.
CD39A, CM08, 08:17:51:00-08:18:19:00
zoom out, mold being laid up
CD39B, CGS: Wood
Tooling Board
Foam
Metal
Composites
CD39C, CM03, 03:13:54:00-03:14:30:00
mold being sprayed up robotically

NARRATION (VO):

THE MATERIAL SELECTION FOR THIS TYPE OF MOLD IS BROAD SINCE THE TOOL DOES NOT NEED TO SEE ELEVATED TEMPERATURES OR MAINTAIN VACUUM INTEGRITY THROUGHOUT A PROCESS. ANY MATERIAL SUCH AS WOOD, TOOLING BOARD, FOAM, METAL, OR

COMPOSITES MAY BE UTILIZED FOR A MOLD OF THIS TYPE, AND MAY BE CHOSEN MORE-SO ON THE SURFACE QUALITY REQUIREMENTS FOR THE END-PART THAN ON ANY OTHER PROCESS CONSIDERATIONS.

SCENE 40.
CD40A, CM14, 14:01:51:00-14:02:14:00
mold pulled from autoclave
CD40B, CM14, 14:02:50:00-14:03:22:00
autoclaved mold being pulled apart

NARRATION (VO):

ON THE OTHER HAND, A LAYUP MOLD DESIGNED FOR VACUUM BAGGING AND ELEVATED TEMPERATURE/PRESSURE PROCESSING REQUIRES CAREFUL MATERIAL SELECTION AND PERHAPS SPECIAL DIMENSIONAL OFFSETS TO MITIGATE THE EFFECTS OF THERMAL EXPANSION.

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SCENE 41.
CD41A, CM49, 21:15:02:00-21:15:31:00
zoom out, vacuum infusion process at beginning of infusion
CD41B, CM53, 02:06:14:00-02:06:32:00
zoom out, resin pulled to vacuum source

NARRATION (VO):

SINGLE SIDED MOLDS DESIGNED FOR VACUUM INFUSION PROCESSING, OR ‘VIP’, AND VACUUM ASSISTED RESIN TRANSFER MOLDING, OR ‘VARTM’ UTILIZE A FLEXIBLE VACUUM BAG. THESE MOLDS COMMONLY REQUIRE ADDITIONAL FLANGE AREA OUTSIDE OF THE PART-AREA TO SUPPORT PLACEMENT OF THE VACUUM SEALS AND/OR RESIN INJECTION PLUMBING.

SCENE 42.
CD42A, CM52, 01:10:30:00-01:10:47:00
pan, flow medium secured in mold
CD42B, CM53, 02:03:49:00-02:04:08:00
zoom out, flow medium allowing the resin to flow
CD42C, CM09, 09:03:40:00-09:04:03:00
flexible bag infusion molding

NARRATION (VO):

SOME DESIGNERS MAY CHOOSE TO PROVIDE CHANNELS AND TROUGHS OR EVEN BUILT-IN PLUMBING TO FACILITATE THESE NEEDS.

VACUUM AND SERVICE-TEMPERATURE REQUIREMENTS DRIVE THE MATERIAL SELECTION FOR THESE TYPES OF MOLDS. OFTEN, TWO PIECE INFUSION MOLDS MAY BE DESIGNED WITH A SOLID OUTER MOLD HALF AND A FLEXIBLE INNER MOLD HALF WITH SILICONE RUBBER SEALS TO VACUUM DOWN THE INNER TOOL AND CLAMP IT IN PLACE PRIOR TO THE INFUSION PROCESS.

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SCENE 43.
CD43A, FMP703, 17:23:11:00-17:23:27:00
zoom out, rtm core lowered into cavity
CD43B, CM55, 05:10:58:00-05:11:13:00
rtm mold being filled
CD43C, CM32, 04:12:54:00-04:13:12:00
rtm mold loaded with reinforcement fiber mat
CD43E, CM55, 05:09:10:00-05:09:35:00
zoom in, resin pumped into mold, mold plugged

NARRATION (VO):

MOLDS FOR RESIN TRANSFER MOLDING, OR 'RTM' PROCESSES ARE TYPICALLY DESIGNED TO RESIST MEDIUM TO HIGH INTERNAL HYDRAULIC PRESSURES. THESE TOOLS ARE DESIGNED WITH TWO MAIN CONSIDERATIONS IN MIND; FIRST, PROPERLY SECURING THE DRY PREFORM TO PREVENT HYDRAULIC 'WASHOUT' AND SECOND, ADEQUATE PLACEMENT OF RESIN-INLET SPRUES WITH PLENTY OF VENTS TO PRODUCE A PROPER RESIN FLOW PATTERN.

SCENE 44.
CD44A, CM55, 05:23:55:00-05:24:10:00
large rtm mold closed
CD44B, FMP687, 03:20:50:00-03:21:09:00
composite rtm mold core lowered
CD44C, CM55, 05:26:49:00-05:27:12:00
large rtm mold opening

NARRATION (VO):

'RTM' TOOLS ARE BUILT MUCH LIKE MATCHED DIE SETS AND CAN BE USED WITHIN A PLATEN PRESS TO HELP OFFSET THE INTERNAL PRESSURES. 'RTM' TOOLS CAN BE MADE FROM COMPOSITE MATERIALS BUT ARE NORMALLY

MADE FROM SELECTED METALS. HEATING AND COOLING SYSTEMS ARE OFTEN INTEGRATED INTO THE DESIGN OF THESE MOLDS TO FACILITATE RESIN CURING.

SCENE 45.
CD45A, CM09, 09:04:44:00-09:05:12:00
zoom out, tubing for vacuum infusion process

NARRATION (VO):

WITH 'RTM' AND 'VARTM' OR 'VIP' TOOLING, IT IS IMPORTANT TO DESIGN SIMPLE REPLACEABLE HARDWARE THAT INCORPORATE PASS-THROUGH SLEEVES OR OTHER FEATURES THAT ALLOW FOR TUBING AND LOW-COST INSERTS TO BE REMOVED AND REPLACED BETWEEN RUNS.

--- TOUCH BLACK ---

SCENE 46.
CD46A, CM23, 20:18:46:00-20:19:09:00
wide, prepreg being laid up
CD46B, FMP705, 20:15:50:00-20:16:18:00
wide, fiber placement machine placing prepreg on mold

NARRATION (VO):

TOOLING AND MANDRELS FOR AUTOMATED FIBER PLACEMENT AND TAPE-LAYING PROCESSES TYPICALLY ARE DESIGNED TO PROVIDE THE APPROPRIATE INNER-MOST-LOFT OR OUTER-MOST-LOFT SURFACE. TOOLS AND MANDRELS OF THIS TYPE MAY BE DESIGNED TO INDEX ON AN AUTOMATED TRUNNION OR MACHINE-BED PLATFORM FOR USE WITH AUTOMATED FIBER PLACEMENT OR TAPE-LAYING EQUIPMENT.

--- TOUCH BLACK ---

SCENE 47.
CD47A, FMP697, 01:15:13:00-01:15:32:00
pan, fiber materials for pultrusion operation
CD47B, FMP697, 01:26:31:00-01:26:46:00
zoom in, roving and mat impregnated in

NARRATION (VO):

PULTRUSION MACHINES ARE DESIGNED TO COLLIMATE PRE-TENSIONED FIBERS, STITCHED

thermosetting resin
CD47C, FMP697, 01:28:14:00-01:28:26:00
pan, resin impregnated roving and mat going into die
CD47D, FMP698, 02:01:17:00-02:01:29:00
zoom out, part coming out of die
CD47E, CM36, 08:26:22:00-08:26:40:00
pan, high production pultrusion operation

MAT AND/OR CONTINUOUS FILAMENT MAT...,
INTRODUCE RESIN TO SATURATE AND IMPREGNANT THE MATERIALS...,
AND PROCESS OR CURE THESE MATERIALS INTO A CONSTANT CROSS-SECTION THROUGH A HIGHLY SPECIALIZED DIE-SET AND MACHINE-MOLDING PROCESS. THESE DESIGNS OFTEN CROSS-OVER INTO THE MACHINE DESIGN CATEGORY AS THEY ARE TYPICALLY USED FOR A MOLDING A SPECIFIC SHAPE IN HIGH-VOLUME PRODUCTION.

SCENE 48.
CD48A, FTD45, 18:10:36:00-18:10:45:00
zoom out, single pultrusions being produced
CD48B, FTD45, 18:15:03:00-18:15:27:00
zoom out, pultrusions coming out of multiple dies
CD48C, CGS: die with floating segment
CD48D, CM34, 06:09:42:00-06:09:51:00
zoom out, hollow part coming out of pultrusion operation
CD48E, CM38, 10:13:51:00-10:14:10:00
grinding of pultrusion die

NARRATION (VO):

PULTRUSION DIES RANGE FROM SINGLE PIECE DIES...,
TO MULTI-PIECE DIES...,
AND HAVE A FLOATING OR MOVABLE SEGMENT, SUCH AS AN INTERNAL MANDREL TO PRODUCE HOLLOW PARTS.
PULTRUSION DIES ARE MOST COMMONLY MADE OF A MOLD STEEL SUCH AS P20 TOOL STEEL.

SCENE 49.
CD49A, CM34, 06:03:00:00-06:03:21:00
zoom out, pultrusion die
CD49B, CM38, 10:02:02:00-10:02:30:00
zoom in, flying cut off saw in operation

NARRATION (VO):

PULTRUSION DIES COMMONLY INTEGRATE HEATING AND COOLING SYSTEMS TO FACILITATE CURING OF THE COMPOSITE MATERIALS. MANY TIMES THE PULTRUSION MACHINE WILL INCLUDE A CUTOFF SAW TO CUT THE PROCESSED PIECES TO SPECIFIC LENGTHS.

--- TOUCH BLACK ---

SCENE 50.
CD50A, FTD51, 01:06:07:00-01:06:30:00
zoom out, part model being sanded
CD50B, FTD51, 01:11:03:00-01:11:23:00
pan, part model

NARRATION (VO):

WHEN MOLDING A COMPOSITE TOOL LAMINATE, A MASTER OR PART MODEL IS REQUIRED THAT IS THE OPPOSITE GENDER THAN THAT OF THE FINAL MOLD. THIS MODEL MUST INCLUDE ALL OF THE VARIOUS PART FEATURES, FLANGES, AND INDEXES THAT MUST BE MOLDED IN THE FINAL LAMINATED TOOL.

SCENE 51.
CD51A, FTD52, 02:32:24:00-02:32:54:00
laying up mold from part model
CD51B, FTD52, 02:35:58:00-02:36:17:00
laying up mold from part model

NARRATION (VO):

IN AN EFFORT TO MINIMIZE THE EFFECT OF THERMAL EXPANSION WHEN MOLDING THE TOOL LAMINATE FROM THE MODEL, DESIGNERS TEND TO SELECT MATERIALS THAT CAN BE CURED AT LOW TEMPERATURES AND THEN POST CURED TO PERFORM AT HIGHER TEMPERATURES IN SERVICE.

SCENE 52.
CD52A, FTD52, 02:44:35:00-02:44:55:00
zoom in, next layer of resin added to mold
CD52B, FTD52, 02:47:51:00-02:48:32:00
next layer of reinforcement material added to mold
CD52C, FTD53, 03:10:43:00-03:10:55:00
mold pulled from part model

NARRATION (VO):

WITH ALL COMPOSITE TOOLS, NOT ONLY IS THE LAMINATE DESIGN IMPORTANT TO THE PERFORMANCE OF THE COMPOSITE TOOL, BUT THE WORKMANSHIP, MATERIALS, AND PROCESS THAT GO INTO THE ACTUAL LAMINATE FABRICATION ARE OF UTMOST IMPORTANCE TO THE QUALITY AND LONGEVITY OF THE PRODUCT.

SCENE 53.
CD53A, FTD43, 16:05:16:00-16:05:34:00

NARRATION (VO):

zoom out, mold being laid up off master model
CD53B, FTD43, 16:24:54:00-16:25:16:00
pan, mold pulled from master

THE GOAL OF ANY MANUFACTURED COMPOSITE TOOL LAMINATE IS TO ACHIEVE A HIGH FIBER TO RESIN RATIO WITH A VERY LOW VOID VOLUME, PREFERABLY LESS THAN 0.5%. IN ADDITION, THE TOOL SURFACE MUST BE JUST RESIN RICH ENOUGH SO AS NOT TO HAVE FIBER PRINT TRANSFER TO PARTS PRODUCED FROM THE TOOL.

SCENE 54.
CD54A, FTD42, 15:13:45:00-15:14:04:00
zoom out, mold being repaired
CD54B, FTD42, 15:28:04:00-15:28:34:00
zoom out, mold being repaired
CD54C, FTD42, 15:26:21:00-15:26:32:00
cracks being filled with gel coat mixture

NARRATION (VO):

MANY CHOP-SPRAY GLASS-MAT REINFORCED POLYESTER AND VINYL-ESTER TOOLS WITH HEAVILY GEL-COATED SURFACES ALMOST ALWAYS EXHIBITS CRACKING IN THE GEL COAT AFTER A FEW RUNS. THIS MUST BE REPAIRED BY REMOVING THE CRACKS AND BUBBLES IN THE DAMAGED AREAS AND REPAIRING THEM WITH A MIXTURE OF MILLED FIBERGLASS AND GEL COAT.

--- TOUCH BLACK ---

SCENE 55.
CD55A, FTD42, 15:21:28:00-15:21:44:00
zoom out, composite tool with welded support structure
CD55B, FTD42, 15:11:40:00-15:12:08:00
welding support structure
CD55C, FTD42, 15:36:57:00-15:37:12:00
attaching support structure to composite tooling

NARRATION (VO):

IF THE COMPOSITE TOOL REQUIRES A SUPPORT STRUCTURE, THEN THE TOOL DESIGNER IS TASKED TO DESIGN A TORSION-RESISTANT SUBSTRUCTURE AND/OR A FRAME THAT WILL PROVIDE A RIGID PLATFORM FOR THE TOOL LAMINATE TO SIT ON DURING PART LAYUP AND PROCESSING.

SCENE 56.
CD56A, FTD48, 21:19:09:00-21:19:28:00
zoom out, large invar tool on substructure

NARRATION (VO):

FOR ELEVATED TEMPERATURE SERVICE, THESE SUBSTRUCTURES ARE USUALLY MADE FROM THE SAME MATERIAL AS THE PARENT TOOL, BUT CAN ALSO BE MADE FROM DISSIMILAR MATERIALS SUCH AS STEEL, INVAR, OR ALUMINUM.

SCENE 57.
CD57A, FTD43, 16:10:04:00-16:10:24:00
pan, composite tool with steel frame
CD57B, FTD44, 17:20:56:00-17:21:15:00
zoom out, large boat mold on trunnion

NARRATION (VO):

WHEN A TOOL IS NOT GOING TO BE SUBJECTED TO ELEVATED TEMPERATURE, THEN DISSIMILAR MATERIALS SUCH AS STEEL TUBING CAN BE USED TO PRODUCE A CRADLE OR SUBSTRUCTURE TO REINFORCE THE TOOL LAMINATE. OFTEN WITH VERY LARGE TOOLS THESE STRUCTURES CAN BE ADAPTED TO A TRUNNION SO AS TO ALLOW THE MOLD OR FIXTURE TO BE ROTATED INTO THE BEST WORKING POSITION.

SCENE 58.
CD58A, FTD43, 16:09:22:00-16:09:35:00
zoom out, composite tools on wheels
CD58B, CM54, 04:07:23:00-04:07:39:00
zoom out, mold with lugs

NARRATION (VO):

IN ADDITION TO TOOLING SUPPORT, TRANSPORTATION AND HANDLING FEATURES MUST ALSO BE CONSIDERED PART OF THE TOOL DESIGN. TOOL LIFT LUGS SHOULD BE POSITIONED IN SUCH A MANNER SO AS NOT TO ALLOW THE LIFTING STRAPS OR CHAINS TO LOAD OR DAMAGE THE TOOL.

SCENE 59.
CD59A, FTD47, 20:33:22:00-20:33:38:00
zoom out, tool having fork life provisions
FTD CXM, credit music

NARRATION (VO):

FOR LARGE TOOLS, FORK LIFT PROVISIONS

SHOULD BE DESIGNED SO AS NOT TO ALLOW THE FORK LIFT TINES OR RAILS TO CONTACT OR DAMAGE THE PRIMARY TOOL BODY OR LAMINATE.

--- FADE TO BLACK ---

SCENE 60.
continue music, up and under
CD CRX, CGS, ROLL: credits
white text, fade up mid-screen
FTD EXM, extended motion background

Produced By:
Society of Manufacturing Engineers

Executive Producer:
Steven R. Bollinger

Producer/Director/Cameraman:
Jerome T. Cook

Written By:
Louis C. Dorworth,
Abaris Training Resources, Inc.

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

Equipment Access Provided By:
Abaris Training Resources, Inc.
Assembly Guidance Systems, Inc.
Composite Technologies
Composite Tooling Ltd
Gold Shield of Indiana, Inc.
Integran Technologies Inc.
Major Tool & Machine, Inc.
Remmele Engineering, Inc.
Röchling Glastic Composites

Roush Advanced Composites
Stemergy
Tiara Yachts
Virtek Vision International Inc.
Waukesha Foundry, Inc.

Production Assistance Provided By:
Lance Rosol
Victoria Townsend

Video Editing:
Jerome T. Cook

SCENE 61.
continue motion background
FTD DIS, CGS: disclaimer
white text, centered on background

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 62.
FTD03A, SME logo open, with music