DEVELOPMENT OF A LONG FIBER REINFORCED COMPOSITE SEAT STRUCTURE FOR MASS TRANSIT APPLICATIONS

Klaus Gleich
Southern Research Institute
Birmingham, AL

Uday Vaidya
University of Alabama at Birmingham
Birmingham AL

OVERVIEW

- Component selection
- Requirements
- Design and prototyping
- Results
- Economic analyses

COMPONENT SELECTION

- Identify potential candidates
- Assess benefits and technical risks
- Select component
- Define requirements
- Preliminary design, fabrication plan, performance and economic analysis

SELECTION CRITERIA

- Weight savings
- Cost saving
- Selected component should demonstrate the production capability of LFT materials
- Demonstration of low cost prototype tooling

BUMPER BEAM

2 PASSENGER SEAT

EXPECTED SAVINGS PER BUS

	Bumper Beam	Seat Structure
Cost Savings	$ 564	$ 2100
Weight Savings	35 lbs.	238 lbs.

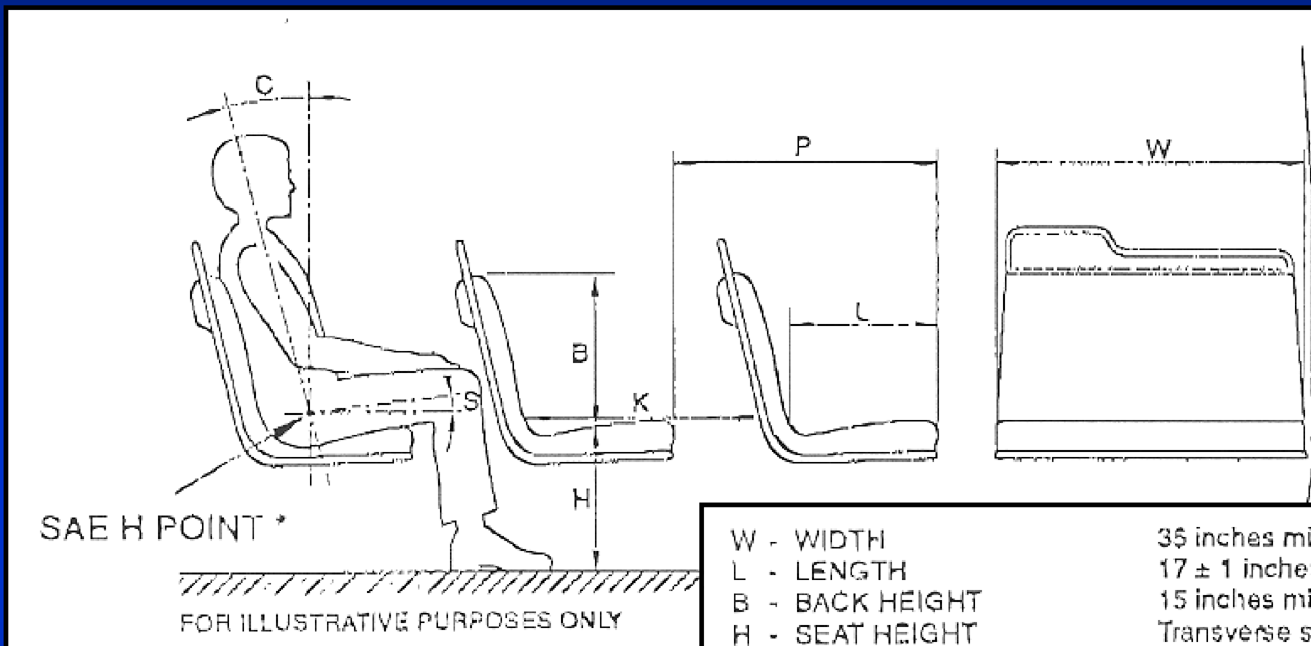
REQUIREMENTS FOR SEAT

- Mechanical requirements (static and dynamic)
- Flame, smoke and toxicity
- Service and maintenance
  - Durability
  - Low gas consumption
  - Easy to service
  - Easy to clean
- Esthetic
  - Surface quality
  - Design

MECHANICAL REQUIREMENTS

- The basic seat dimension was chosen were based upon 'Standard Bus Procurement Guideline', Reference SAE J 826.
- The seat assembly shall withstand static vertical forces of 500 pounds applied to the top of the seat cushion in each seating position with less that ¼ inch-permanent deformation in the seat or its mountings.
- The seat assembly shall withstand static horizontal forces of 500 pounds evenly distributed along the top of the seat back with less that ¼-inch permanent deformation in the seat or its mountings.

DESIGN GUIDELINES



W - WIDTH	35 inches minimum
L - LENGTH	17 ± 1 inches
B - BACK HEIGHT	15 inches minimum
H - SEAT HEIGHT	Transverse seats 17 ± 1 inches Longitudinal seats and rear settee 18 ± 2 inches
S - SEAT CUSHION SLOPE	5 - 11 degrees
C - SEAT BACK SLOPE	9 - 17 degrees
K - HIP TO KNEE ROOM	26 inches minimum
P - PITCH	Reference only

* Reference SAE J826

SEATING DIMENSIONS

FLAME RETARDANTS

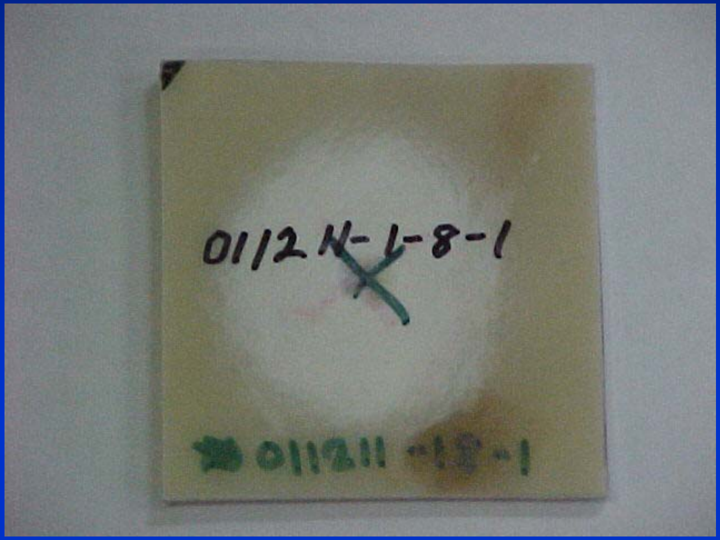
2 basic concepts:

- Flame retardant compounded with the polymer
  - Will influence mechanical properties, especially impact behavior
- Flame retardant as a top coat
  - Scratch resistance and adhesion to basic material of importance

USED FLAME RETARDANTS

- Additives:
  - 2 additives were tested
    - 1 for polypropylene, non-halogenated
    - 1 for nylon
- Coatings:
  - 2 different coatings were selected and tested

INFLUENCE OF FLAME RETARDANT ON A PP/GLASS FIBER COMPOSITE



LFT PPGF 40 without flame retardant

LFT PPGF40 with 5% flame retardant

- 5% of flame retardant reduced the Dynatup impact by appr. 10%
- Impact behavior changed
- Only a non-significant improve in reduction of flammability could be found

RESULTS WITH TOP COATS

- Samples were coated and tested
- Both coatings showed reduction of flame spread and smoke density in preliminary testing
- The top coat which showed better results were selected
- Samples with flame seal FX-PL were sent to an independent test lab

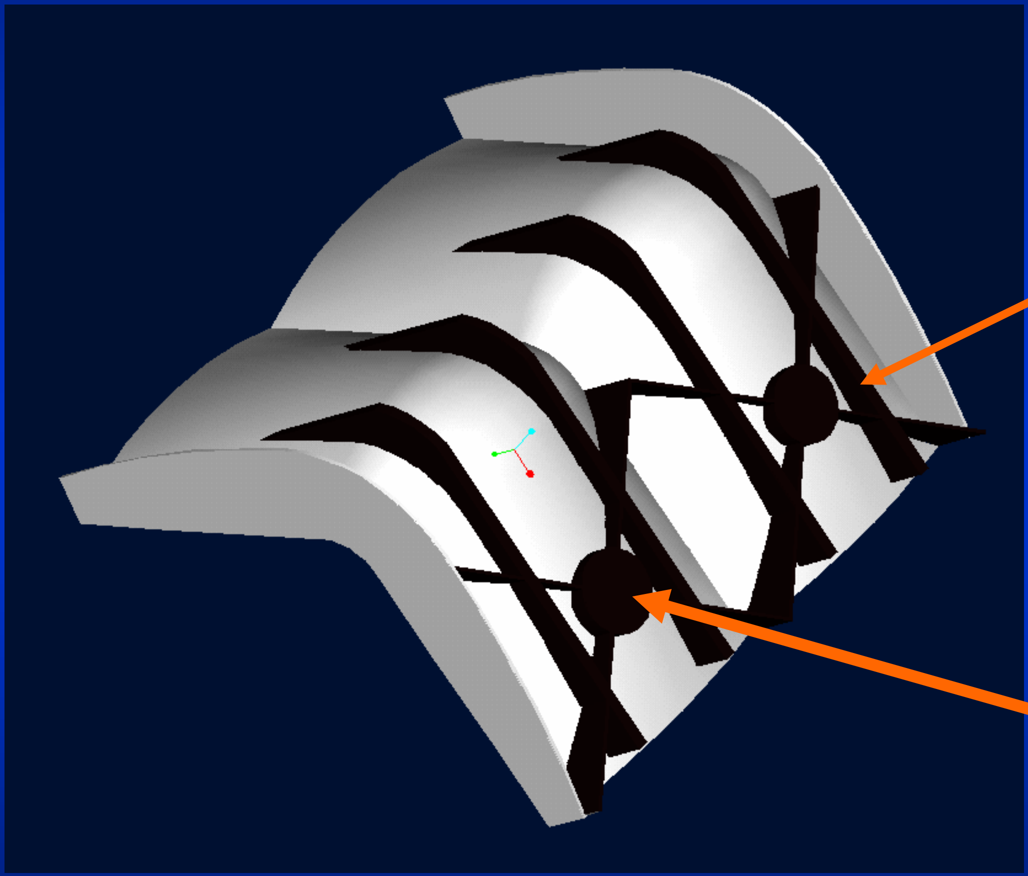
TEST RESULTS

Test Performed	Test Result	Test Requirement
Flame Spread, Is (ASTM E 162-95)	3.01	Is < 35
Smoke Density (ASTM E 662-95) Flaming mode, Ds(1.5), Ds(4)	0.19, 0.96	Ds(1.5) < 100, Ds(4) < 200
Non-flaming mode, Ds(1.5), Ds(4)	0.29, 1.26	Ds(1.5) < 100, Ds(4) < 200

COMPONENT MANUFACTURING

- Component design and analyses
- Process simulation
- Fabrication planning
- Manufacturing of prototypes

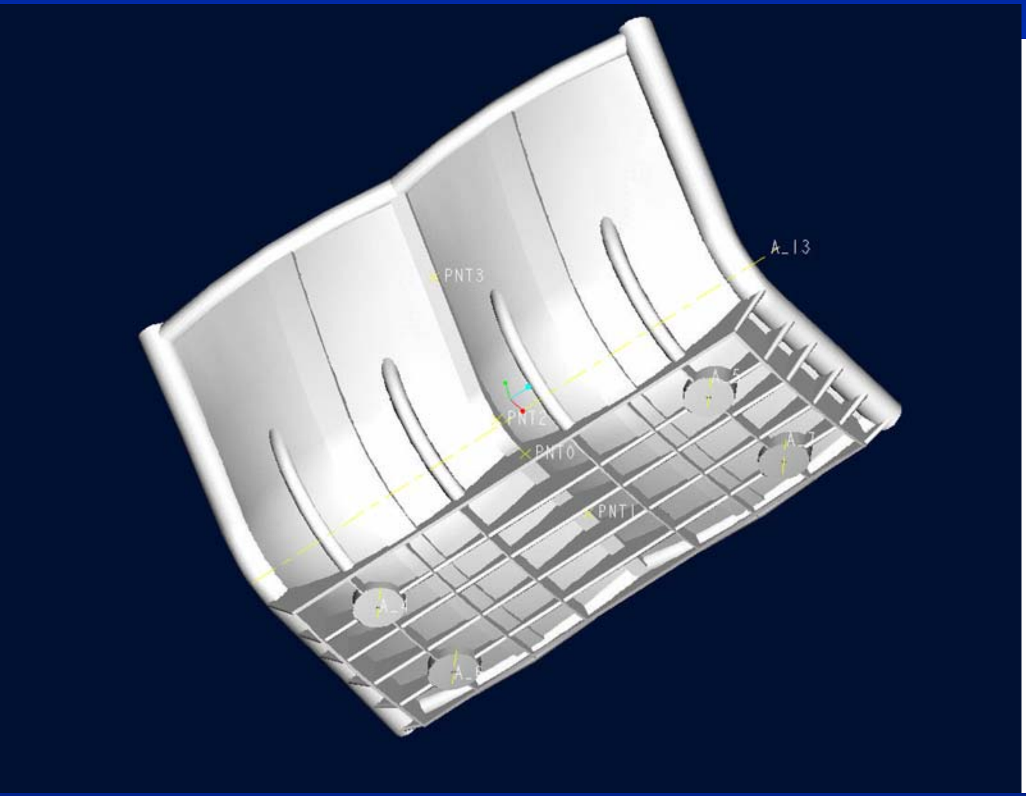
INTEGRATION OF FRAME AND SEAT BODY CONCEPTS

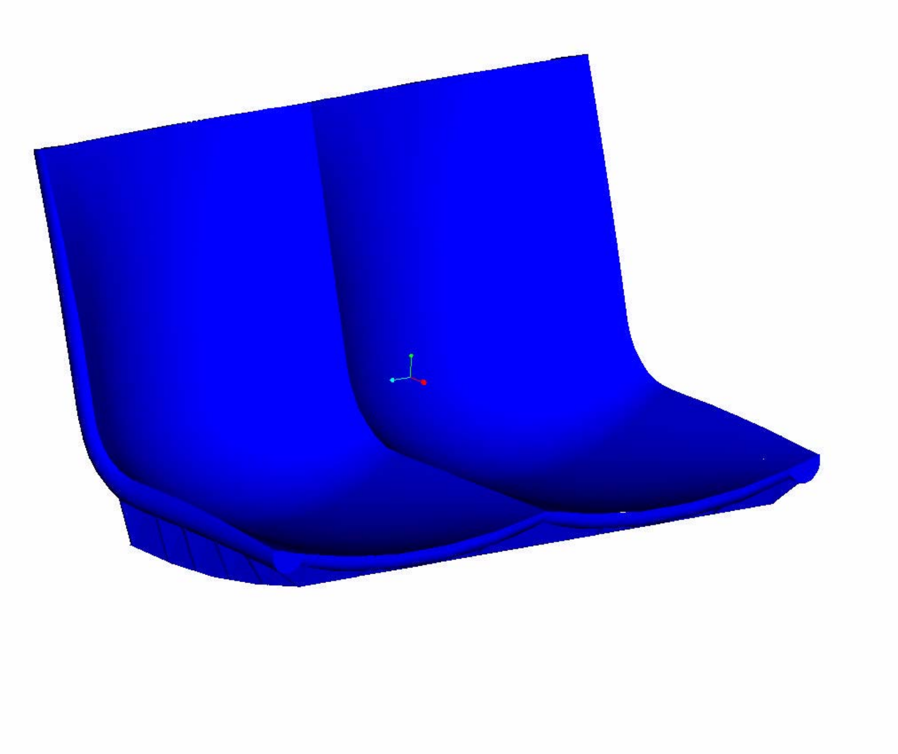


Carbon fiber ribs (depth exaggerated)

Insert

DESIGN & MODELING OF LFT BUS SEAT





PAYOFFS

Possible weight savings

The total weight of the seat, supports and the frame : 47 lbs (21 kgs).

Weight of the bare seat and frame : 39 lbs (17 kgs).

Steel frame from the existing seat : 14 lbs (6.35 kgs) and the cantilever support : 6 lb (2.72 kgs).

Weight of the seat (based on the model) : 22 lbs (10 kgs)

Weight reduction : 39 – 22 / 39 = 43.5% (conservative)

TOOLING CONCEPT FOR BUS SEAT

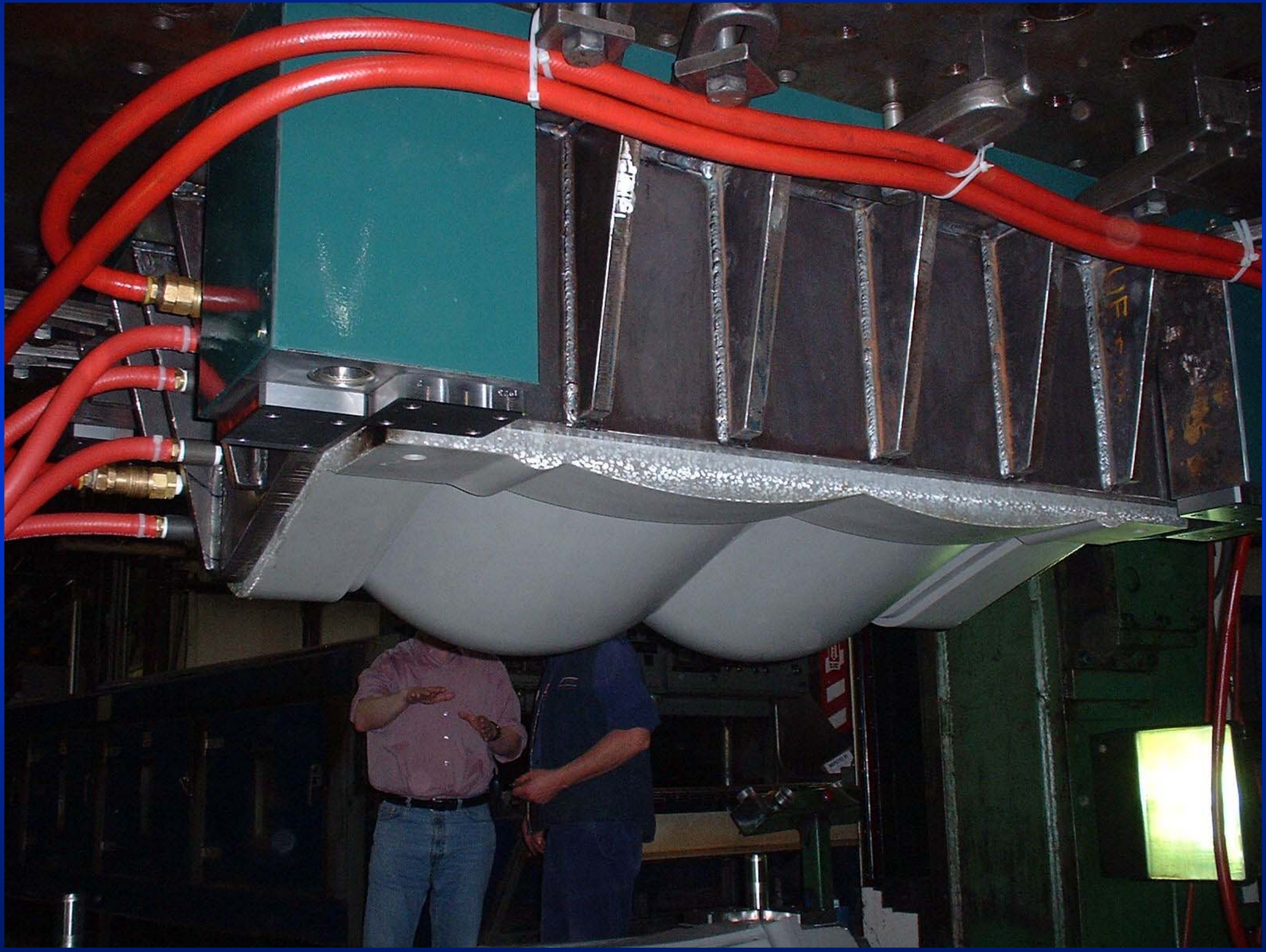
- Master part will be machined from the CAD-data
- Aluminum filled epoxy will be cast around master part
- Cooling/heating lines will be included during the casting
- Epoxy tool will be inserted in a metal frame with all guidance

TOOLING
THE MASTER PART

CASTING

TOOL AFTER CURING

TOOL
UNDER 2000 TON PRESS



MANUFACTURING CONCEPT

- Compression molding with LFT-pellets
- Compression back molding of carbon-fiber reinforced inserts with long glass fiber reinforced pellets
  - Insert will be preheated (if necessary) in an oven and placed in the tool immediately before the compression molding step
- Geometry of plasticated material as a result of flow simulation

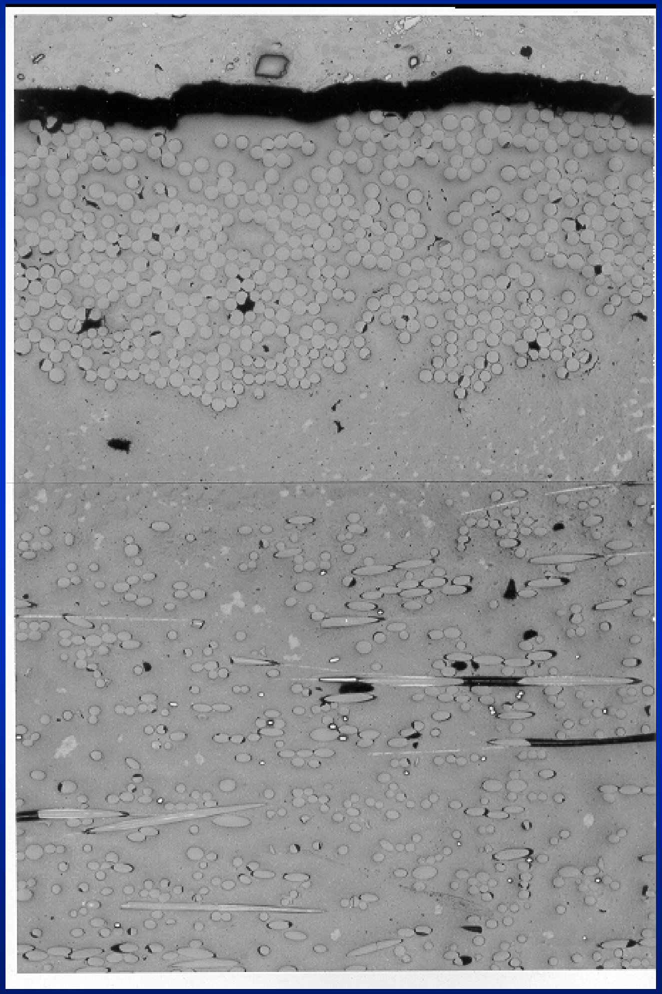
PROCESSING OF INSERTS

PP/fiber tapes back molded with LFT

- Insert at tool side $\Rightarrow$ LFT will not melt the insert enough to get good bonding
- Insert at top of the LFT charge $\Rightarrow$ good bonding

$\Rightarrow$ Insert should be preheated directly before processing

PROCESSING OF INSERTS

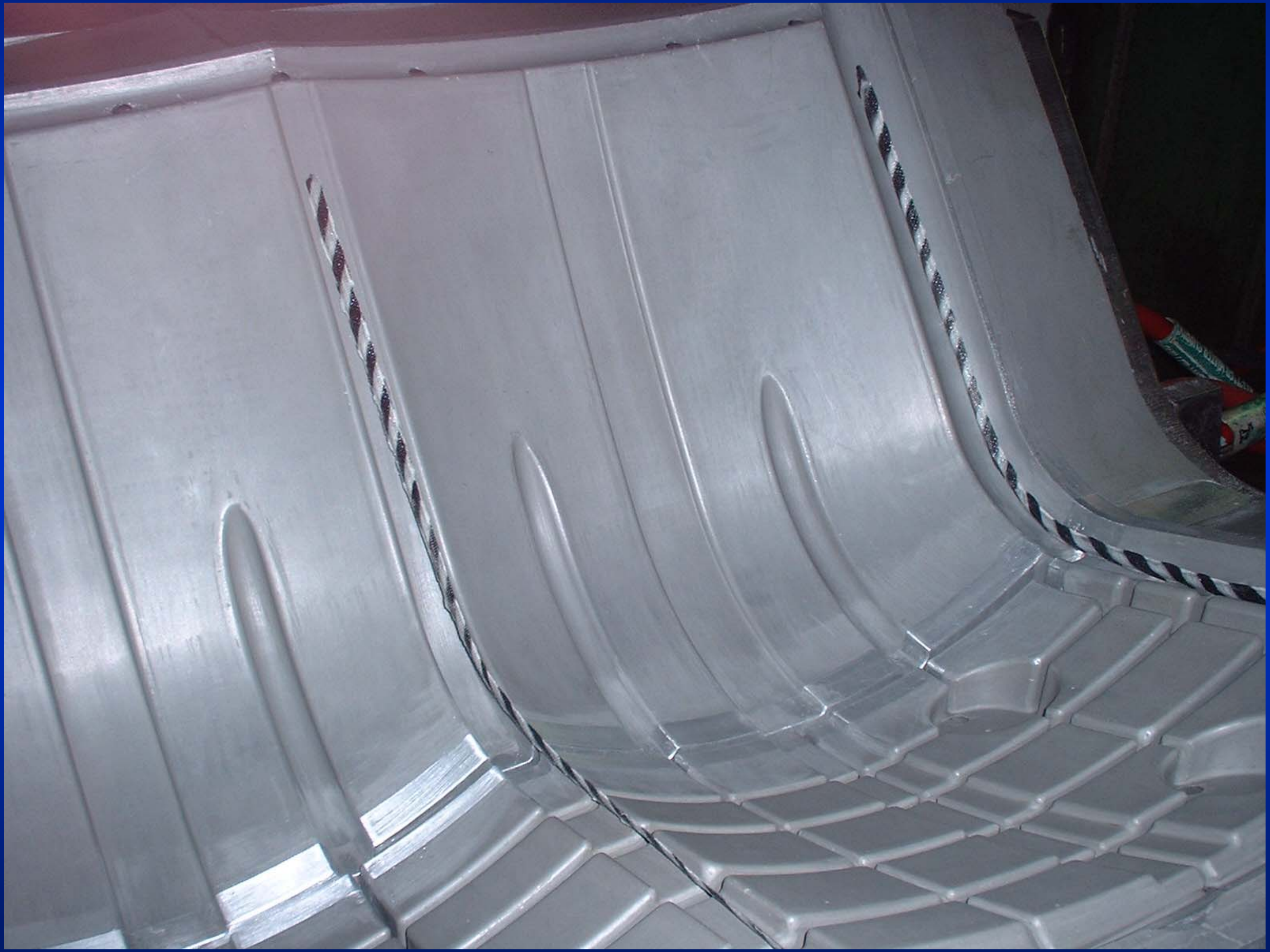


Fibers of the inserted tape, cut against fiber direction

PP rich area

LFT, random fiber orientation

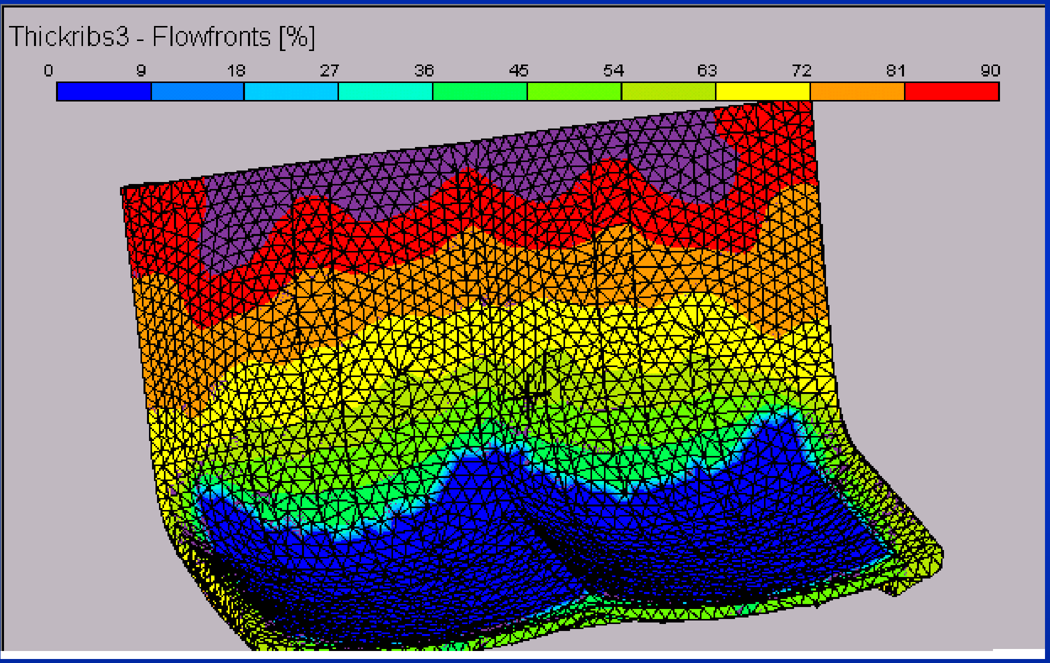
SEAT TOOL WITH INSERTS



COMPONENT EVALUATION

- Evaluate quality, uniformity and molding characteristics
  - Mold filling characteristics, fiber orientation and fiber distribution
- Compare performance data with model / requirements
- Economic analyses

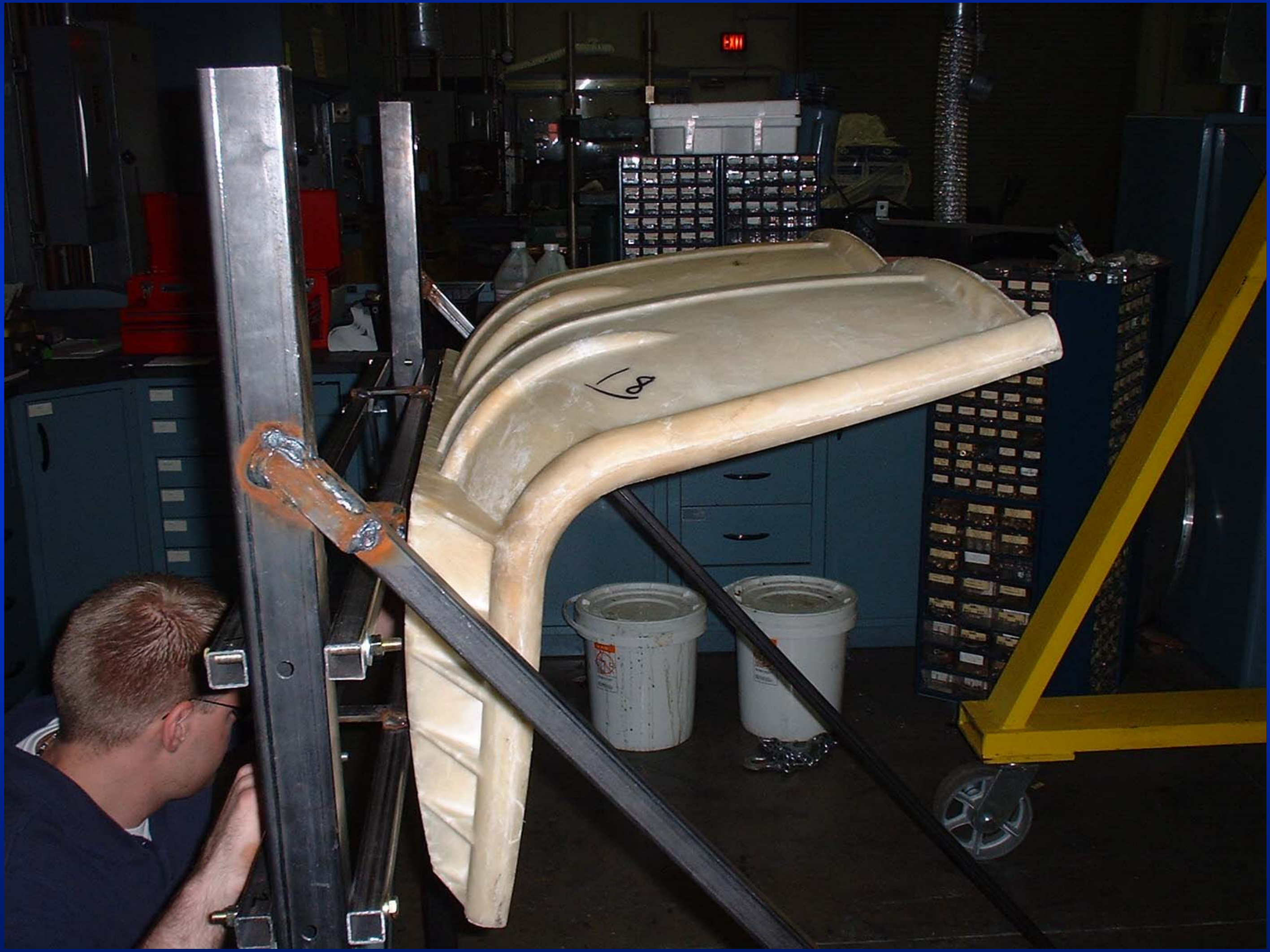
COMPARISON OF FILLING BEHAVIOR AND FLOW SIMULATION



Result of flow simulation

Short shot shows filling behavior

TEST FIXTURE WITH SEAT



RESULTS

- 227 kg applied to the top of the seat cushion on each seat (total 454kg / 500 lbs.)
- 454 kg (500 lbs.) applied as a line load to the seat back
- in both cases no notable permanent deflection ⇒ the 6.35 mm (1/4”) permanent deflection criteria is fulfilled

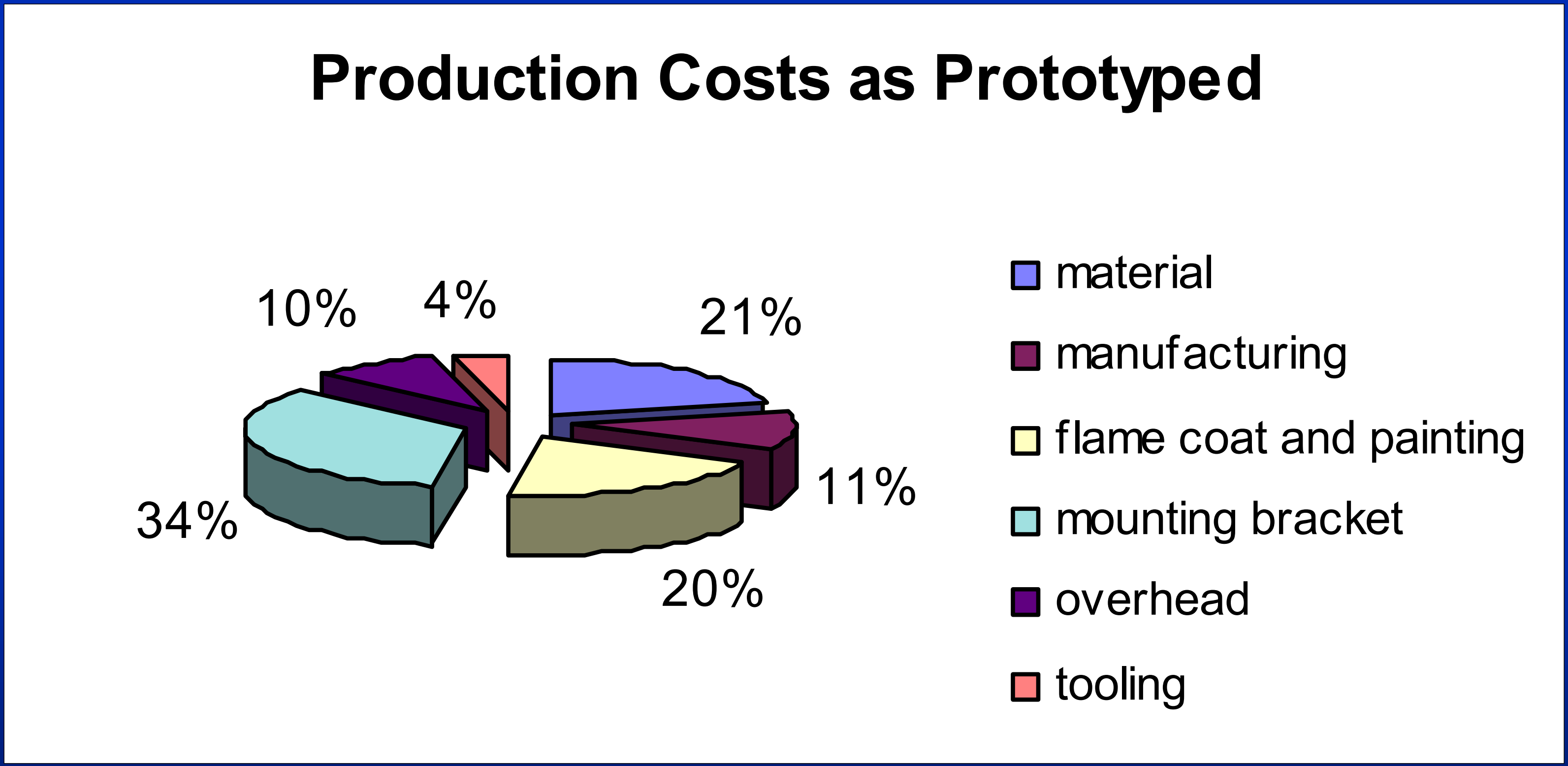
POSSIBLE CHANGES

- Reduce material amount in outside frame and ribs by using
  - Slides
  - Gas assist compression molding
  - Automated fixing of inserts or replace inserts by a material mix

→ Reduce weight by additional approx. 20%

Reduce cycle time (target: 60 - 90 sec. total)

ECONOMIC ANALYSES - SUMMARY



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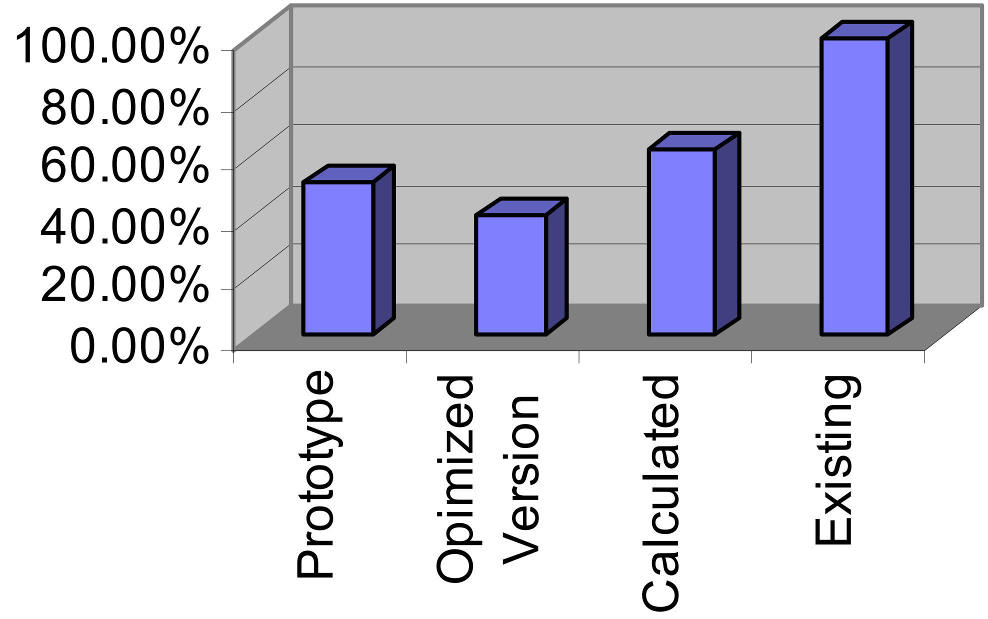

TECHNOLOGY TRANSFER

- Discussion with bus seat manufacturers for transfer seat structure into production.
- Final bus seat will be assembled in a bus for Altoona-test (Penn State Univ.)
- Technology can be transferred easily to other components

SUMMARY

- An all composite 2-Passenger Bus Seat was designed and analyzed.
- Prototypes were manufactured.
- Molding operation was simulated and successfully compared to manufacturing.
- Seat fulfilled the requirements including flammability and smoke density.
- A 40% weight reduction and a 50% cost reduction could be achieved.

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for help in compression molding the prototypes

Vantico
for assistance with epoxy tooling

THE TEAM

- FTA - Program Management & Oversight, Technical Guidance
- SRI - Project Management, Materials Technology, Fabrication Technology, Component Fabrication
- UAB - Process Modeling, Component Design & Analysis, Composite Mechanics
- Lawton - Extrusion/plasticator Equipment, Tooling Technology, Fabricate Tools.
- NABI - Component Selection, Requirements, Evaluation