Gearbox Demonstrator Development

Hervé MOTTE
ARRK Shapers R&D / Innovation Manager
AGENDA

ARRK Company overview

Phase 1 – Motivation and general feasibility

Phase 2 – Engineering

Phase 2 – Manufacturing

Next steps & perspectives
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ARRK AT A GLANCE

Who are ARRK

- International technology group
- Founded 1948
- Turnover 418 M € (2015/16)
- Worldwide > 3,500 employees
- 20 ARRK companies in 15 countries
- Listed on the Tokyo Stock Exchange (TSE)

Capabilities

- Engineering
- Prototyping
- Tooling
- Low Volume Production (LVP)
PRODUCT DEVELOPMENT COMPETENCE

Industries we serve: Automotive, Aerospace, Special and Commercial Vehicles, Transportation and Medical Industry

- Engineering
  - Design
  - CAE & Simulation
  - Test & Validation
  - Electrical & Electronics
  - 7 Centres of Competence

- Prototyping
  - Rapid Prototyping SLA, SLS & 3D Printing
  - Vacuum Castings
  - Block Modelling
  - Rapid CNC Machining
  - Prototyping Project Management

- Tooling
  - Simulation, Moldflow Analysis, Stress Analysis
  - Project Management
  - Prototype & Rapid Tooling
  - Innovative Production Tooling
  - Tooling Maintenance, Modification & Refurbishment

- Low Volume Production (LVP)
  - Injection Moulded Parts
  - Composite Components
  - Low Volume Production Intent Components
  - Low Volume Complex Assemblies
  - Batch Production Runs: 10 – 000’s

Full Integrated Service – Engineering, Prototyping, Tooling & Low Volume Production

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MOTIVATION

• MARKET
  – Light weight design is taken into account mainly for CO2 reduction but electric car autonomy increase is also a critical point.
  – Existing demonstrators with low mechanical strength, or structural parts for car body but not for engine or transmission.

• ARRK Knowhow & skills improvement
  – Design and manufacturing (product and process) based on TP composites technologies.

➢ Decision for gearbox housing demonstrator as a good compromise between complexity and feasibility

• Targets
  – Produce a working demonstrator with an overmolded organo sheet based on an existing part with a conventional material concept (e.g. aluminum)
  – Keep manufacturing costs of existing part in low volume production
PHASE 1 – GENERAL FEASIBILITY

- Reengineering of an existing aluminum gearbox → determination of target values
- Estimation of general feasibility with composite housing

✓ Feasibility confirmed
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Next steps & perspectives
PHASE 2 – 1ST DRAFT

1st concept
- Functional specification
- Function list
- Searching for solutions
- Creating different concepts
- Economical and technical evaluation
- Concept decision

1st draft
- Design 1st draft (design space)
- Topology optimization for load path and divisional plane
- Design revised draft
- Reduced FE-model and layer optimization
- Economical and technical evaluation
- Material decision
- Detailed draft and evaluation
- Approval detailed draft

Detailed design
- Creating detailed design
- Approval design
- Creating design documents
- Approval manufacturing documents
Solution 1

Concept decision

According to smart gearbox costs

Design space
- costs

Circulating lubrication
+ better than alu+steel (regular) combination

Infrared sensor

air drain petcock for refilling oil

Measuring temperature bearings

Measuring temperature surface

Lubrication gears, bearings

Optical Laser Bearing

Modification of current gearing

designed barrier

Connection housing to cover

Axle distance due to mechanical load

Bearing positions

screwed inserts

no inserts

According to smart gearbox

CAD

Solution 2

Axle distance due to thermal expansion

Feasibility study

Seperate or combined with air drain petcock

Description
-30 to 100°C

defined oil volume

Air drain petcock

4

Value/Info

Manufacturing
metal insert bearing seat

ensure compansation overpressure, avoid oil loss

Air drain petcock oil proof

Concept
air drain petcock with labyrinth sealing

Transmission oil

centering surfaces

screwed flanges+sealing

Oil-proof input/output

Measuring defined oil level

new sealing concept

100 °C

10g for x,y,z

surface coating with fluid resistance

dry sump

According to smart gearbox

Solution 3

Contact corrosion

Housing and cover disassemblable

Creating different concepts

Mounting electrical machine

connected bearing seat

Searching and evaluating of

steel/aluminum bearing connector insert

see connection cover to hosuing

Screws

Solution 4

Concept rating

Power transmission

New bearings

According to smart gearbox

Deriving functions

Searching and evaluating of several solutions

Creating different concepts

• Deriving functions
• Searching and evaluating of several solutions
• Creating different concepts

Feasibility study

Concept rating

Concept decision

Further investigation only for appropriate concepts

Concept 1

Concept 3
### Concepts Overview

#### Description
- **Low cost concept**: Cage insert concept
- **Cage insert concept**: Separate bearing insert concept
- **Separate bearing insert concept**: Highest precision concept

#### Details
- **Current gears, bearings, sealing**
- **Thermoplastic bearing seat**
- **Glass fiber organosheet**
- **Glued flanges (housing/cover)**
- **No inserts at screws**
- **Center surface housing to cover**
- **Engine screwed to housing, centering by surface**
- **Simple air drain petcock with tube to avoid oil loss**
- **Air drain petcock also used for oil (re)fill**
- **Defined oil volume**
- **Smart lubrication concept**
- **Measuring oil temperature at oil drain plug**
- **Measuring bearing temperature at drilled holes**
- **Direct surface temperature measuring**

#### Pros
- **Lowest costs**
- **Lowest mass**
- **No milling at flanges necessary (compensation with glue)**

#### Cons
- **High costs**
- **High mass**

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### Not suitable to show capability of composite

### Inappropriate costs
1ST CONCEPT

Concept decision

FE-Analysis Basic
- Deriving Composite FE-Model for feasibility analysis
- FE-Analysis

Deriving Variants
- Considering Basic simulation results

Stiffness evaluation
- Comparing with stiffness target (reference housing)

Concept decision
- Concept 3 with CF organo sheet feasible
- Concept 3 with GF organo sheet probably feasible
- Concept 1 not feasible

• Deriving counter measurements (ribs, UD)
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Topology optimization

Setup
- Minimization of strain energy
- Mass constraint
- Stiffness constraints
- Strength constraints

1ST DRAFT
Layer optimization

Setup
- 0/90/45/-45/-45/45/90/0°
- Optimization for CF
- Laminate thickness 0.6 to 6 mm
- Balanced 45°/-45° plies
- Considering stiffness results

Results
- Higher thickness for 45°/-45° plies
- Using especially 45°/-45° plies to further improve stiffness
- Reduction of laminate thickness by mainly using 45° plies
- Further local reinforcement measurements by using UD-Tapes
Further stiffness optimization
Deriving variants based on FE-Otimizations

- Stiffness, evaluation
  - Deriving optimized UD, flange, TP matrix and rib design

- Detailed draft
Feasibility analyses of manufacturing

Injection molding simulation

Stamping simulation
PAM-FORM – Composites Forming Simulation Software

• Validation of preformed stamping process: shear angles

✓ Feasibility confirmed
PAM-FORM – Composites Forming Simulation Software

- Validation of preformed stamping process: net-shape profile

Ply 0° stamping simulation

Ply 0° outer profile

Feasibility denied

Ply 45° stamping simulation

Ply 45° outer profile

Cutting required after stamping
PAM-FORM – Composites Forming Simulation Software

- Validation of preformed stamping process: UD tapes

UD Tapes behaviour during stamping

Tooling design

✓ Feasibility confirmed
PHASE 2 – DETAILED DESIGN

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DETAILED DESIGN

- Detailed design with CF organo sheet
- GF reinforced TP injection molding material
- Aluminum inserts for bearing position
- Metal inserts for screws
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Organo sheet hot stamping process

Organo-sheet
UD tapes  Supplier: TenCate
Support Frame
IR Pre-heating (240°C-260°C)
Stamping tool (T°: 90°C-110°C)
Stamped preform
Cutted Stamped preform
Waterjet cutting (subcontractor: Omega Systemes)

Shapers’ La Séguinière
Overmolding process
DEMONSTRATOR

Assembly

Weight saving **30%** (cover only)

Demonstrator visible on Auto Planet
Booth N80 / Hall6
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**Next steps & perspectives**
FURTHER STEPS

• First test of prototype cover to validate FE simulations
• Mapping of stamping results to consider in FE simulations
  – Take into account fibers orientation after stamping
• Looking for new materials opportunities
  – To reduce thickness
  – To reduce cost material (glass instead of carbon fabrics, removing of UD tapes)
  – To reduce processing costs (netshape preform to remove cutting phase)
• Design Optimization of prototype cover
• Design Optimization of 2nd part of gearbox
• Manufacturing of 2nd part of gearbox
• Testing with complete gearbox assembly
THANKS YOU FOR YOUR ATTENTION

Contact : Hervé MOTTE
R&D / Innovation Manager
herve.motte@arrkeurope.com
Tel +33 251 711 925
Mob +33 607 99 46 28