Improving Vehicle Fuel Efficiency Through Tire Design, Materials, and Reduced Weight

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Project ID: VSS083

Overview

Timeline

- Project start date: Oct. 1, 2011
- Project end date: Sept. 30, 2014
- Project complete: 50%

Barriers

1) Cost / Premium Product

2) Risk Aversion / Equal Performance

3) Manufacturability

Budget

- Total project funding: $3,294,693
  - DOE share: $1,500,000
  - Contractor share: $1,794,693
- Funding received in FY11 – $ 0
- Funding received in FY12 - $ 422,591
- Funding budgeted for FY13 - $ 578,445
- Funding up to March FY13 - $ 90,449

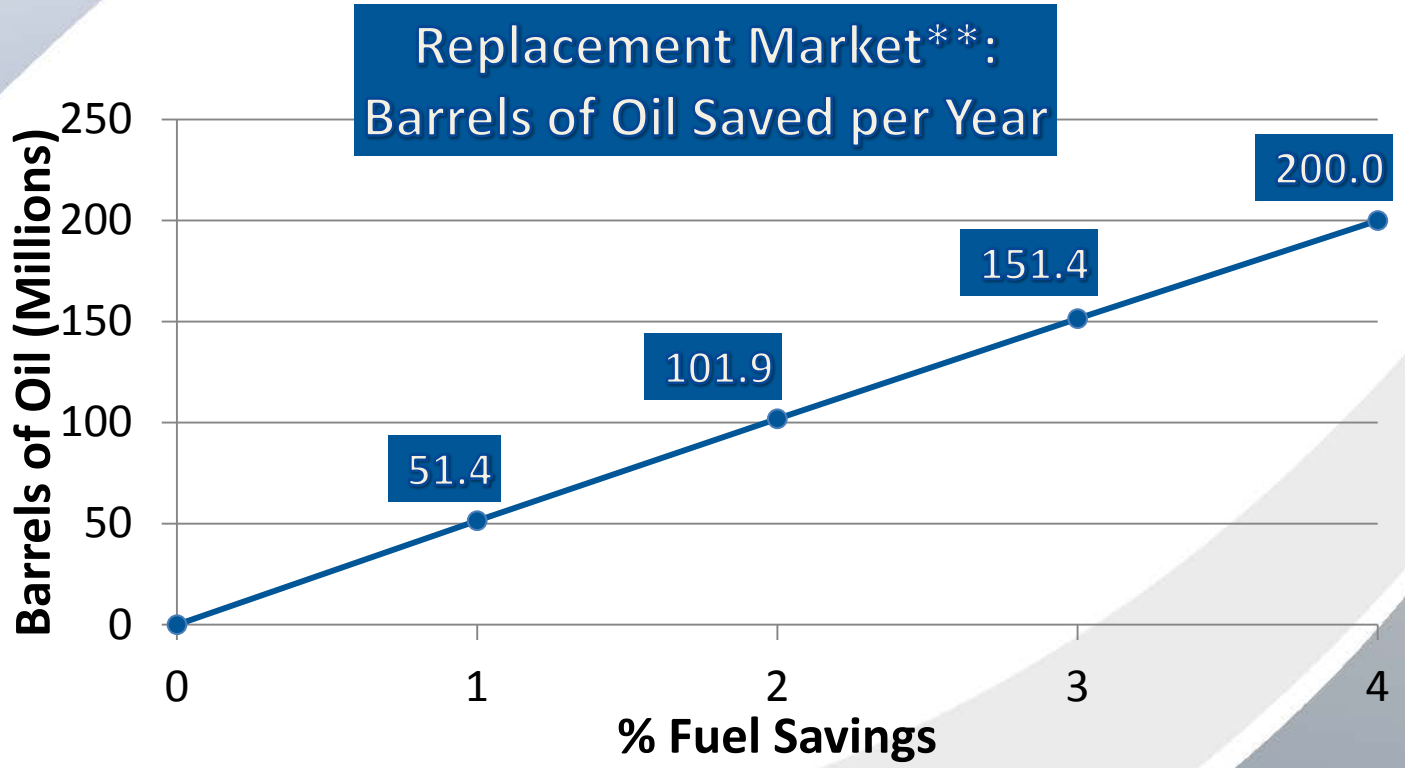
Partners

- National Renewable Energy Lab
- Project Lead - Ray Grout

Project Objectives - Relevance

Overall Program Objective:

To develop a new class of tires in the replacement market that improves fuel efficiency by a minimum of 3% and reduces overall tire weight by 20%.



** Based on miles driven in 2012 at an average of 23.8 miles/gallon
** Based on replacement market being 80% of total market

Project Objectives - Relevance

Project Objectives:

- Identify the features from each of the technology approaches to be used in tire test programs:
  1) Partial replacement of carbon black and/or silica with nano-fiber reinforcement material
  2) Ultra-light weight tire bead bundle
  3) Ultra-light weight tire belt package
  4) Ultra-light weight inner liner (barrier film liner)
  5) Formulation options for ultra-long wearing and low hysteresis tread compound
  6) New design of low hysteresis, energy efficient tire profile
- Investigate each technology for potential barriers related to cost, manufacturability, and performance.

Approach 1: Nano-fiber Reinforcement

- **Strategy**
  - Evaluate nano-fiber reinforcement materials as a partial replacement for carbon black and/or silica.
    - Lower specific gravity – reduce component weight/volume/cost
    - Lower overall compound filler content to reduce hysteresis and improve fuel efficiency
- **Milestones - Status**
  - Develop lab scale masterbatch technology for nanofiber material in natural rubber and SBR polymer systems – 4th Qtr 2012 (Complete)
  - Develop tire compounds from nano-fiber natural rubber and SBR polymer systems – 2nd Qtr 2013 (On Schedule)
  - Conduct 1st tire test program – 4th Qtr 2013 (On Schedule)
- **Go/No-Go**
  - Determine cost/performance feasibility of manufacturing the nano-fiber material – 3rd Qtr 2013.

Approach 2: Light Weight Bead Bundle

- **Strategy**
  - Investigate alternate light weight materials as replacements for standard steel beads
    - High strength pre-manufactured fiber rings
    - Fiber cord utilizing the same bead manufacturing process as steel cord
- **Milestones - Status**
  - Procure 1st generation light weight beads with similar strength to steel beads – 3rd Qtr 2012 (Complete)
  - Perform initial testing of tires manufactured with 1st generation light weight beads – 4th Qtr 2012 (Complete)
  - Procure 2nd generation light weight beads with similar strength to steel beads – 1st Qtr 2013 (On Schedule)
  - Conduct additional tire tests with 2nd generation light weight beads – 3rd Qtr 2013 (On Schedule)
- **Go/No-Go**
  - Evaluate tire performance and manufacturing feasibility in comparison to steel beads – 4th Qtr 2013

Approach 3: Light Weight Belt Package

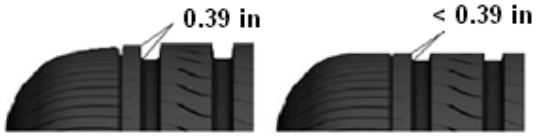
- **Strategy**
  - Evaluate alternate light weight materials as replacements for standard steel belts.
- **Milestones - Status**
  - Arrange meetings with light weight cord makers to discuss development and trials of high strength cords – 1st Qtr 2012 (Complete)
  - Perform 1st tire test program to evaluate light weight belt tire performance - 2nd Qtr 2012 (Complete)
  - Conduct 2nd tire test program with refinements to 1st tire test program design to meet tire performance requirements. – 4th Qtr 2012 (Complete)
- **Go/No-Go**
  - Based on performance, light weight belts are favorable – 1st Qtr 2013 (Complete)

Approach 4: Barrier Film Liner

- **Strategy**
  - Evaluate a light weight barrier film material as a replacement for standard halo-butyl inner liner.
- **Milestones - Status**
  - Lab test validation of the barrier film's air permeation resistance and rubber adhesion – 4th Qtr 2011 (Complete)
  - Conduct initial tire build for identification of any production process issues – 2nd Qtr 2012 (Complete)
  - Run 2nd tire build to further evaluate production process issues and to evaluate film performance. – 4th Qtr 2012 (Complete)
  - Perform 3rd tire build to evaluate film performance. – 3rd Qtr 2013 (On Schedule)
- **Go/No-Go**
  - Determine if film can meet manufacturing and performance requirements needed to meet program goals. – 4th Qtr 2013

Approach 5: Ultra-long Wearing Tread

- **Strategy:**
  - Develop technologies for an ultra-long wearing and ultra-fuel efficient tread compound to reduce tire weight and rolling resistance.



Reduced Tread Depth

- **Milestones – Status**
  - Perform compound studies to evaluate new polymer and new silane technologies – 3rd Qtr 2012 (Complete)
  - Conduct 1st tire test program to evaluate new polymer and new silane technologies independently – 4th Qtr 2012 (Complete)
  - Perform 2nd tire test program to evaluate new compounds with reduced RR and increased tread wear – 1st Qtr 2013 (Complete)
  - Carry out compound studies combining the polymer and silane technologies for a 3rd tire test program – 2nd Qtr 2013 (On Schedule)
  - Conduct 3rd tire test program – 3rd Qtr 2013 (On Schedule)

- **Go/No-Go**
  - Determine if compound formulation is optimized to meet all tire performance goals. – 4th Qtr 2013

Approach 6: Low Hysteresis Tire Profile

- **Strategy:**
  - Use Finite Element Analysis (FEA) Modeling to predict Rolling Resistance (RR)
- **Milestones – Status:**
  - Create new RR model for RR prediction – 1st Qtr 2012 (Complete)
  - Validate RR model using tire data – 4th Qtr 2012 (Complete)
  - Perform design of experiments on tire profile – 1st Qtr 2013 (Complete)
  - Optimize tire profile to improve RR – 2nd Qtr 2013 (On Schedule)
  - Design and build new mold using improved profile – 2nd Qtr 2013 (On Schedule)
  - Use new mold profile in conjunction with tread compound evaluation tire test program – 3rd Qtr 2013 (On Schedule)
- **Go/No-Go**
  - Determine if mold profile is fully optimized and meets required performance criteria. – 4th Qtr 2013

Accomplishments

Approach 1: Nano-fiber Reinforcement

- Hired PhD with nano-fiber experience to coordinate development.
- Produced lab samples of Natural Rubber and SBR masterbatch with up to 20 phr nano-fiber.
- Developed compounds with nano-fiber masterbatch that match properties of carbon black compounds but with improved hysteresis.

Approach 2: Light Weight Bead Bundle

- Procured, built and tested tires using 1st generation materials for two different strategies to produce fabric bead rings.
- One strategy showed equivalent results to steel beads with 1st generation material and the 2nd strategy did not meet performance of steel beads with 1st generation material.
- Ordered additional 1st generation material for the 1st strategy and ordered 2nd generation material for the 2nd strategy.
- Identified manufacturing issues to be addressed for both bead strategies.

Accomplishments

Approach 3: Light Weight Belt Package

- Two tire programs have been completed such that the light weight belts meet the required performance.
  - Weight was reduced by about 8% and rolling resistance was reduced by 3%-6%.
- Light weight belt package is ready to be built into development programs with the other technologies.

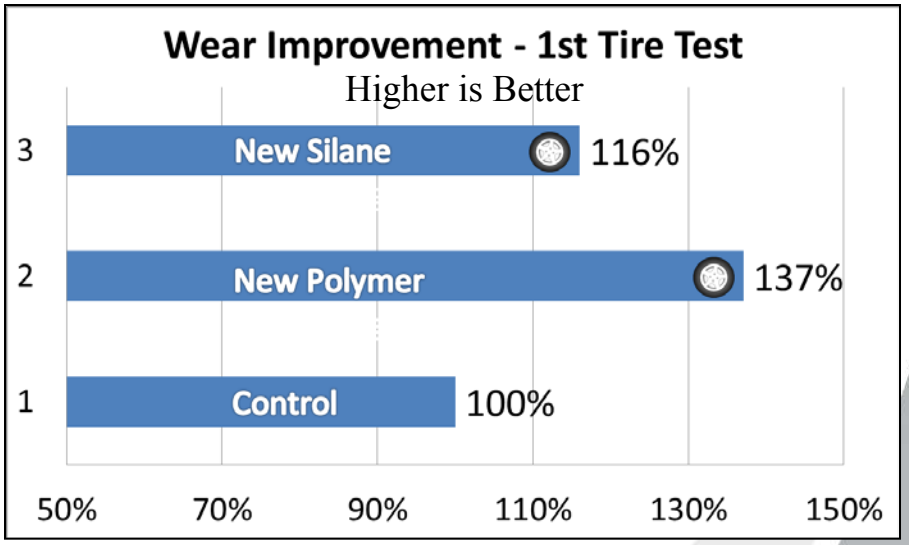
Approach 4: Barrier Film Liner

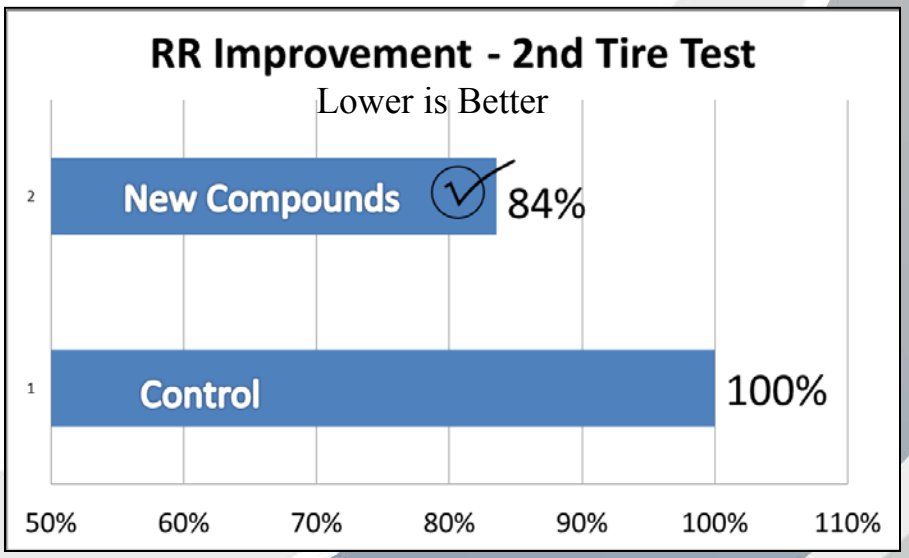
- Made progress producing tires with barrier film using current tire building equipment.
- Confirmed that air permeation with barrier film in the tire is equivalent to current technology.
- Determined that fatigue properties of 1st and 2nd Generation barrier films are not sufficient to meet current performance requirements.

Accomplishments

Approach 5: Ultra-long Wearing Tread

- First tire test program was completed.
  - New silane technology indicated 16% wear improvement with equivalent rolling resistance
  - New Polymer technology indicated 37% wear improvement with equivalent rolling resistance
- Second tire test program was completed.
  - New compounds showed a rolling resistance improvement of 16% and an increased wear of 25%-35%.

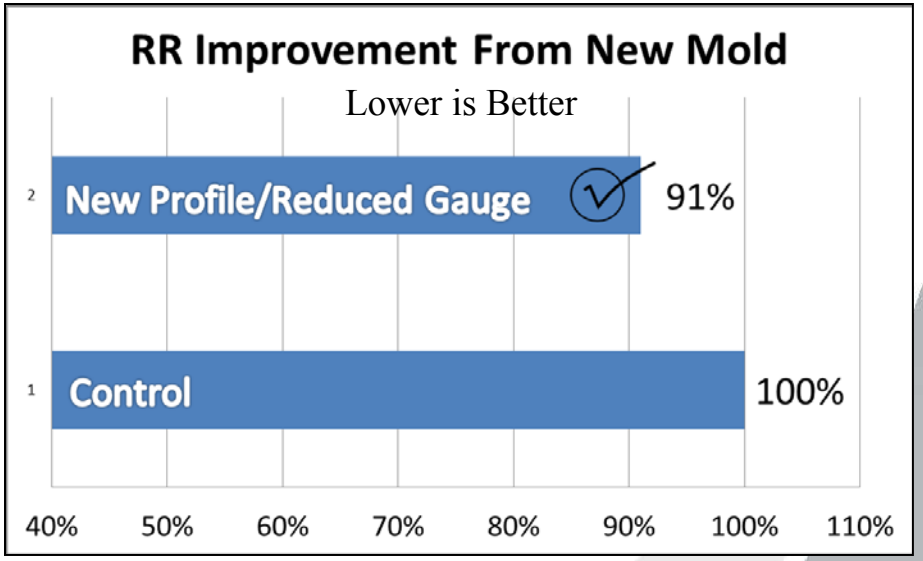


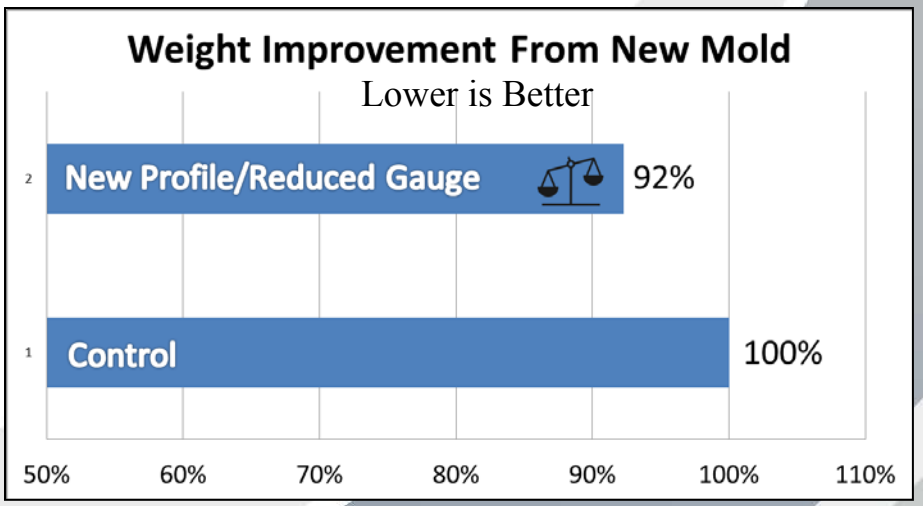


Accomplishments

Approach 6: Low Hysteresis Tire Profile

- Refined and validated new Rolling Resistance Model using 7 different tires sizes and designs.
- Low Rolling Resistance profile was developed and built into a mold for tire testing.
  - This profile resulted in a 9% Rolling Resistance improvement
- Developed and completed a design of experiments which resulted in 4 new low rolling resistance profiles.
  - The rolling resistance model indicates improvement is possible.





Collaboration

National Renewable Energy Laboratory:

- Subcontract agreement finalized in March 2012 to collaborate on light weight tire FEA model.
- Cooper has advanced in our FEA capabilities and computing capacity.
  - Cooper has already completed several tasks originally planned for NREL
- NREL given 30 day notice in March 2013 to end current contract.

Future Work FY13 & FY14

Approach 1: Nano-fiber Reinforcement

- Continue to develop compounds that meet performance criteria.
- Evaluate production viable materials and confirm tire performance advantages for weight and RR.

Approach 2: Light Weight Bead Bundle

- Continue to develop two light weight bead technologies for steel bead replacement.
- Conduct tire test programs to confirm light weight beads perform equivalent to steel beads.

Approach 3: Light Weight Belt Package

- Combine this technology with the other light weight technologies to investigate cumulative results.

Future Work FY13 & FY14

Approach 4: Barrier Film Liner

- Work with supplier to solve fatigue issues.
- Build and test additional tires with newly improved fatigue material.

Approach 5: Ultra-long Wearing Tread

- Perform additional lab studies to combine compound strategies that have shown potential to improve wear.
- Complete a 3rd tire test program where features will attempt to optimized tread compounds for rolling resistance, wear and traction.
- Continue to investigate alternative materials to optimize cost.

Approach 6: Low Hysteresis Tire Profile

- Optimize mold profile using FEA rolling resistance model
- Investigate changes in material properties in FEA modeling to optimize compounds for rolling resistance.

Summary

- Tire projects have been built and tested for each of the technologies except the light weight nano-fiber.
- Testing conducted to date indicates Cooper is on track to meet the goals of 20% weight reduction and 3% fuel savings.

Features	Contribution To Weight Reduction	Contribution To Low RR
Light weight Nano-fiber	Minimal	TBD
Light weight Bead	2% - 4%	Minimal
Light weight Belt	8%	4%-6%
Light weight Inner Liner	8%	TBD
Ultra-Long Wearing & Ultra-Low RR Tread	1% - 2%	16%
Low RR Tire Profile	8%	9%
Total	**20% - 28%**	**~ 30%**