University at Buffalo

2010 SAE Clean Snowmobile Challenge

DESIGN: A **High-Performance** **Clean** Turbo Diesel Snowmobile

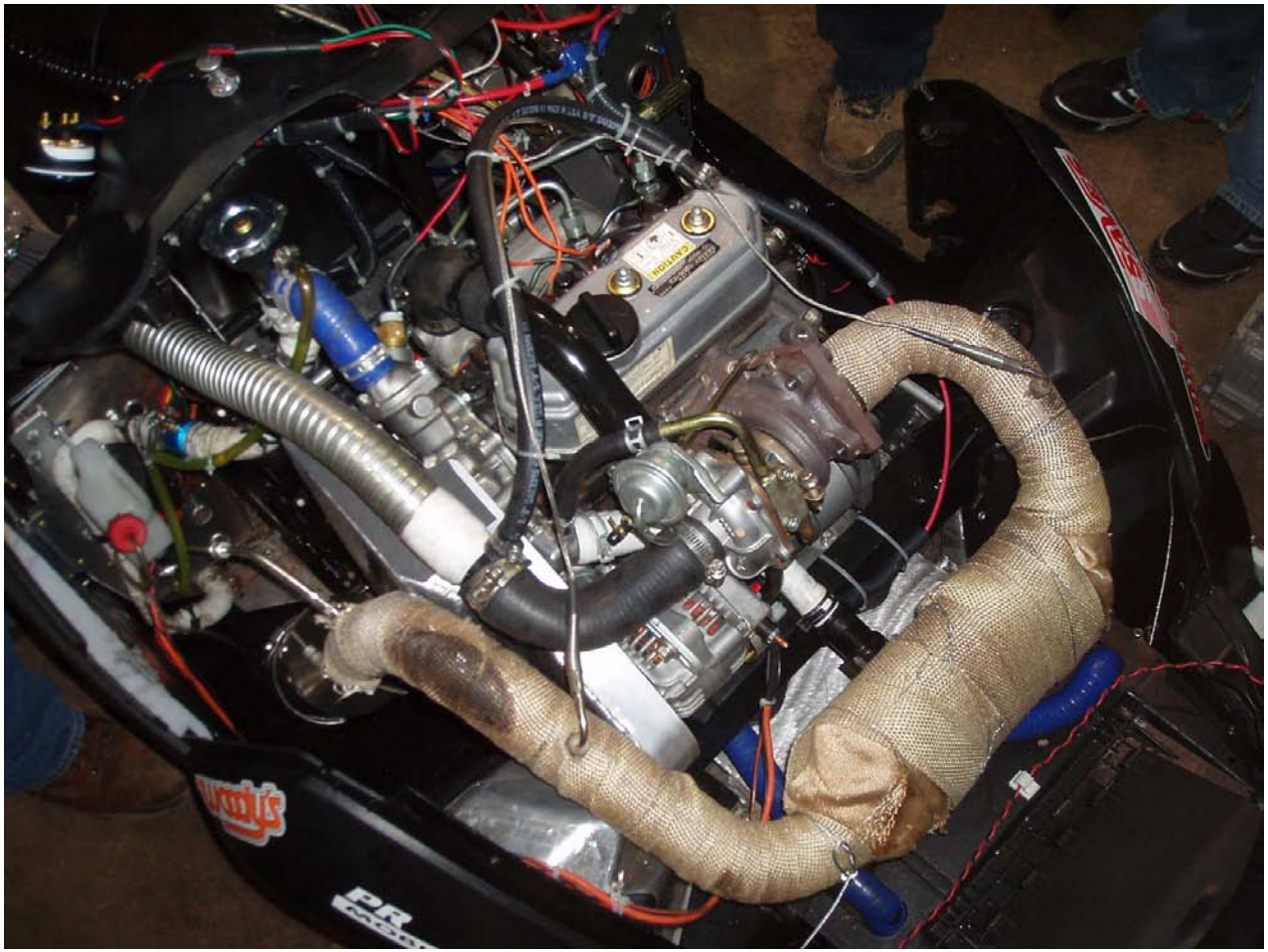
Design Overview

- Performance and Handling
- Noise and Emissions
- Marketability

Base Engine

- Briggs and Stratton/Daihatsu three cylinder liquid cooled four stroke IDI turbo diesel
- Intended for industrial use- not optimized for high performance
- Extensively re-engineered for 2010 CSC to meet performance demands of snowmobile market

Old Engine



New Engine

Performance

GOALS

- Raise power output
- Higher torque
- Faster throttle response
- Reduce weight
- Improve handling
- Maintain clean emissions and noise
- Increase strength of critical engine components

SOLUTION

- Governor spring
- Bored cylinders
- Flywheel -13lbs.
- Suspension, fuel tank
- Skis, suspension
- New catalyst/DPM and cowl foam
- Forged aluminum pistons
- Forged steel h-beam rods

Power/Torque

- Base engine redline : 3950 rpm
- New engine redline : 6500+ rpm
- Allows higher power output and clutching advantages
- Cylinders bored 0.040” over
- Garrett variable nozzle turbocharger added
- Charge air cooler added
- New intake and exhaust manifold design

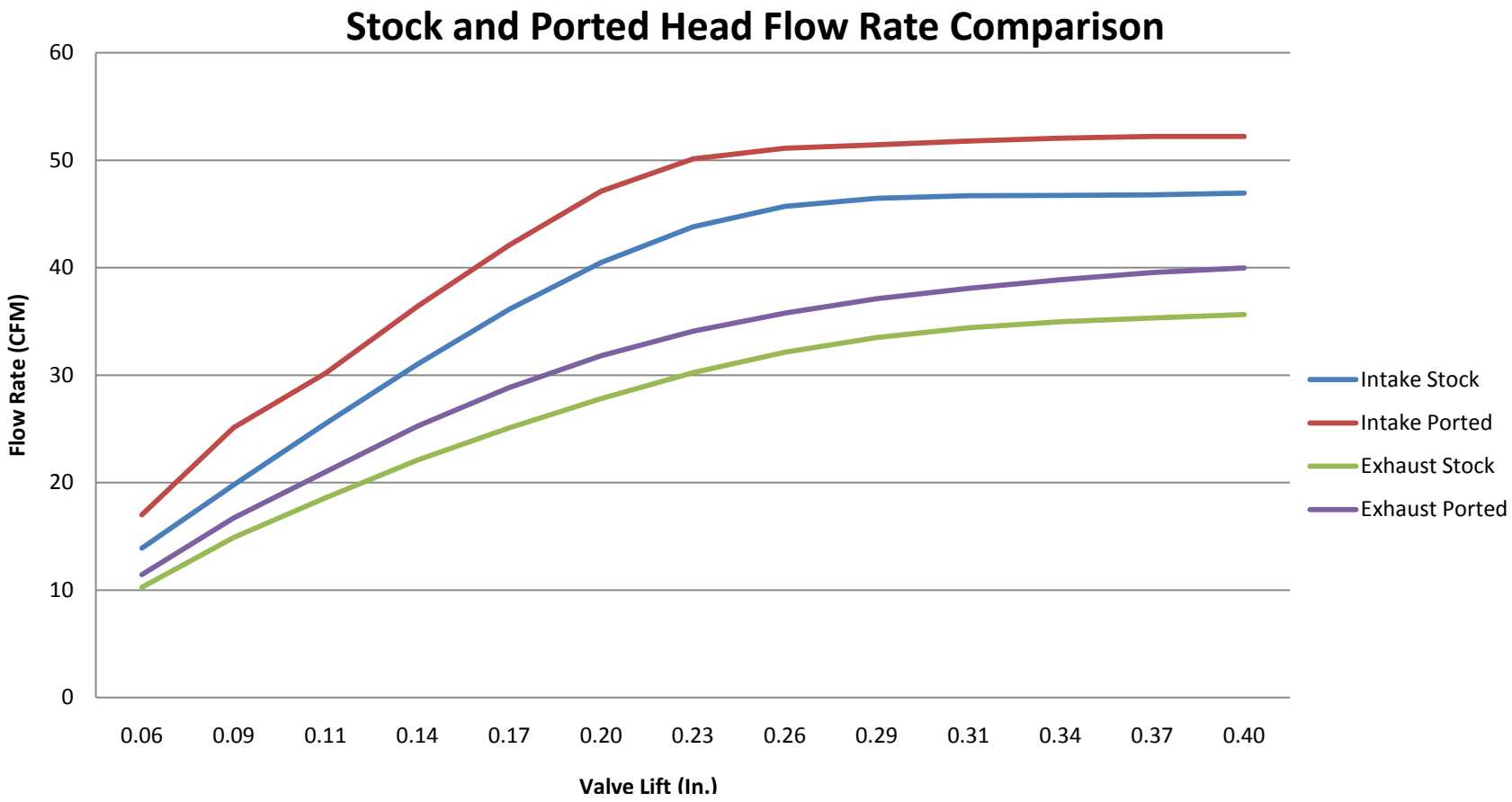
Turbocharger Installed

Exhaust Manifold Comparison

Power/Torque

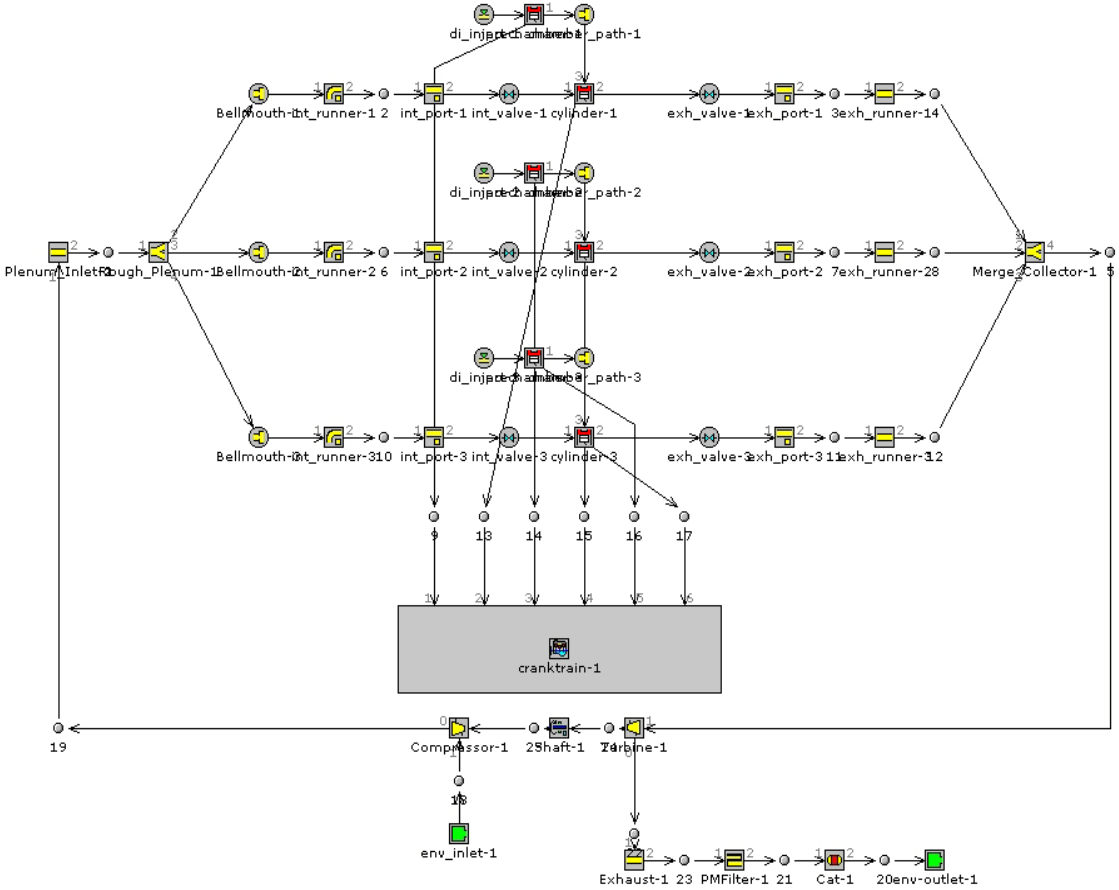
- Ported cylinder head
- Flow tested before and after

Flow Test Results



Simulation

- Custom Indirect Injection Combustion Model
- GT does not support IDI due to lack of use
- Each cylinder modeled as a pre-chamber with injector, pre-chamber opening, and cylinder
- DI injector into pre-chamber
- Pre-chamber has bore of diameter of actual pre-chamber, ~0 stroke, and TDC clearance to give appropriate volume
- Constantly open valve between with CD determined by flow testing
- Predictive engine models cannot be used
- Two separate EngCylCombDIWiede models used with separate burn rates
- Allows power output to be measured accurately while taking into account losses
- Garrett GT15V Turbo
- Compressor and Turbine Maps from Garrett
- Compressor side has fixed efficiency map
- Turbine map has multiple rack positions that correlate to maps provided by Garrett at various openings
- GT interpolates data between these points and is controlled by intake pressure reference
- Will allow predictions of power output, emissions, fuel economy and can even predict noise output from the exhaust (both dB and actual sound) at varying loads.



Engine Simulation

GT Power Model

Performance Results

- Top speed: 80 mph (1.4:1 gear ratio) - ↑ 30 mph
- 0-60: 6 seconds -↑ 6 sec.
- Boost pressure: 25 psig - ↑10 psig

Handling

- Fox Float front suspension
- Highly adjustable/lightweight
- M-10 Airwave rear suspension
- Greater travel than stock
- Allows adjustability for engine weight distribution
- C&A Pro Trail XT skis

Ergonomics

- Vibration reducing hand grips
- Simple two gauge cluster

Emissions Control

- Diesel engine won 2007 CSC emissions
- Emitec oxidation catalyst
- Emitec diesel particulate filter
- After-glow cold starting : complete combustion
- Reduced compression ratio
- Charge air cooling ↓ No_x
- Soot Limit: Aimed for 23:1 A/F ratio at full load

EPA 2012 Emissions Standards (2)

Emission Standards:	HC (g/kW-hr)	CO (g/kW-hr)
Max Allowable	150	400
Standard	75	275
UB CSC Diesel	**0.52**	**62.07**

Fuel Mileage

- During testing 32 mpg was achieved
- Range of 384 miles per tank
- Far superior to any available snowmobile with similar performance

2009/2010 Model Year Comparison(1)

	4-STROKE				2-STROKE		
	2010 Ski-Doo® (GSX LE 4-TEC)	2009 Yamaha™ (RS Vector)	2009 Polaris™ (IQ Dragon Turbo™)	2009 Arctic Cat™ (Z1)	2010 Ski-Doo® (MX Z Adrenaline 600 H.O. E-TEC)	2009 Polaris™ (600 IQ)	2009 Arctic Cat™ (F6 Sno Pro)
Fuel Efficiency U.S. mpg (l/100 km)	18 (12.8)	17.1 (13.8)	15.8 (15)	17 (13.8)	21 (11.3)	15 (15.7)	11 (21.4)
Weight lb (kg)	529 (240)	570 (259)	580 (263)	575 (261)	431 (196)	483 (219)	495 (225)
Oil Efficiency* mi/qt (l/100 km)	470 (0.125)	470 (0.125)	470 (0.125)	470 (0.125)	346 (0.17)	147 (0.4)	101 (0.58)
Fuel Range mi (km)	195 (313)	164 (264)	160 (257)	183 (295)	220 (354)	172 (277)	134 (223)

	UW-Madison (2009 winner) (5)	SUNY Buffalo
Fuel Efficiency (mpg)	11.47	**42.92**
Weight (lbs)	694	**720**
Oil Efficiency (mi/qt)	470	**470**
Fuel Range (miles)	137.64	**515.04**

Noise Reduction

- American Acoustical hood foam
- Cost effective, visually pleasing
- Noise not noticeably louder than stock engine – scored 2nd in sound CSC 2009
- Low frequency mechanical noise dissipates quickly

Maintenance/Reliability

- No spark plugs!
- Parts and service available from diesel shops
- Robust design for longevity
- Fuel readily available
- Simple electrical system – mechanical fuel injection
- Mechanical control scheme is easy to troubleshoot

Marketability

- Higher initial MSRP ($11,710) will be offset by reduced fuel consumption and longevity as well as resale value
- Showroom attractiveness - will fill new high efficiency trail sled niche
- Maintains stock appearance – engine type does not affect snowmobile style

Design Result

- Innovation
- Unprecedented fuel economy
- The future of recreational engines

Questions?

- Thank you!