



# Wisconsin-Rotax ACE 674 (WRACE 674)

SAE Clean Snowmobile Challenge  
Design Presentation 2019



**University of Wisconsin-Madison**  
**Presenters: Matthew Massman and Blake Bomkamp**



# Team Management

- Clean Snowmobile Team has competed since 2002
- Team Structure
  - President – Matt Massman
  - Mechanical lead – Blake Bomkamp
  - Electrical lead – Brandon Riehle

# Team Outreach

- Fundraising and Sponsor Relations
  - SAE Milwaukee Chapter Meeting
  - Annual Presentation at UWGP
  - Shop tours for sponsors
- Community Outreach
  - Engineering Bash
  - Homecoming Parade
  - Engineering Expo





# Design Considerations:

## Our 2018 Survey of 25 Wisconsin Snowmobile Clubs

- Customers Want:
  - Trail Handling
  - Fuel Economy
- Historical Best Sellers
  - Ski-Doo Rev XP 600 SDI
  - Polaris Rush 600

Characteristic	Rank
Handling	1
Price	2
Fuel Economy	3
Acceleration	4
Emissions	5
Sound	6

# Engine Selection

## Focus Points:

- Fuel Economy
- Tailpipe Emissions
- Adequate Power

Base Snowmobile	Power (kW)	Weight (kg)	Fuel Economy (km/L)	Emissions (g/kW-hr)		
				HC	CO	NOx
Ski Doo ACE 600	42	41.1	12.5	6	90	N/A
Ski Doo ACE 900	64.5	51.8	10	6	75	N/A
Ski Doo 1200 4tec	92	60	8.85	8	130	N/A
Polaris 600 Cleanfire	97	35	5.3	60	175	N/A

\*Manufacturer reported values

\*Polaris represents Two-Stroke for comparison

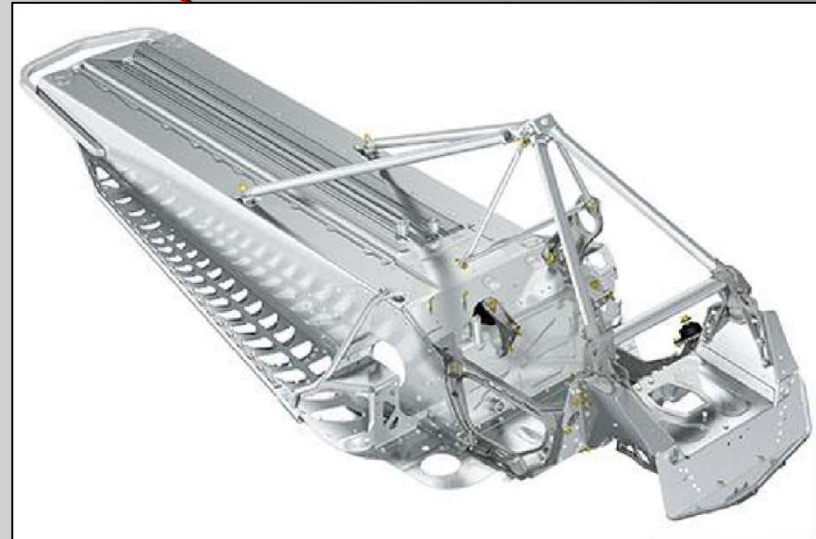


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# Chassis Selection

## 2015 Ski-doo MXZ Sport

- Lightweight
- Rider-forward ergonomics
- Cost-effective
- New XS Chassis





# Engine Management

- Visteon/Mototron PCM112
  - Automotive/Marine environments
  - -40 to 105 °C
  - 50 g Shock Load
- Submersible up to 3 meters
- MATLAB/Simulink engine modeling
- MotoHawk automatic code generation



# Design Goals for 2019 CSC

- Integrate PCM112
- Reduce noise levels
- Increase performance with higher CR
- Reduced tailpipe emission







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# PCM112 Integration

- Improved packaging and decreased controller size
- Better software support
- Full software update





# Redesigned Intake

- The subjective judges noticed intake noise from bell mouth intake
- Directed intake away from rider
- Added K&N Air filter
- Built air box to deflect pressure pulses



# Anechoic Chamber Testing

- 30 independent microphones pinpointed where noise generation occurred in engine bay
- Intake noise reduced from 88 dBa to 64 dBa
  - Measured at distance of 3 meters
- Became aware of noisy fuel pump

# Anechoic Chamber Testing



Old Intake



New Intake

# Fuel Pump Change

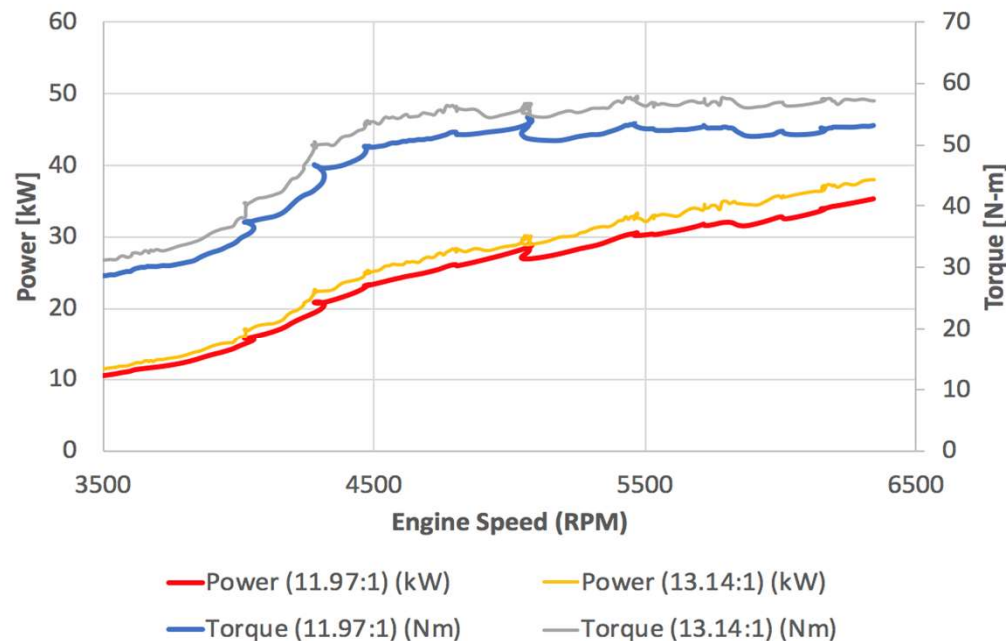
- Swap external fuel pump to in-tank fuel pump
- Verified pump pressure was sufficient
- Used A-Weighted sound pressure level meter to determine sound reduction



# Increased Compression Ratio



- Raised CR from 11.97:1 to 13.14:1
- Recalibrated spark maps
- Improved peak power by 8%
- Increased peak torque by 12%







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# Exhaust Design

- Scan from Exact Metrology
- CAD modeled
- Reduced back pressure
- Balance cylinder output
- Increased catalytic volume
- Optimized exhaust location in air stream

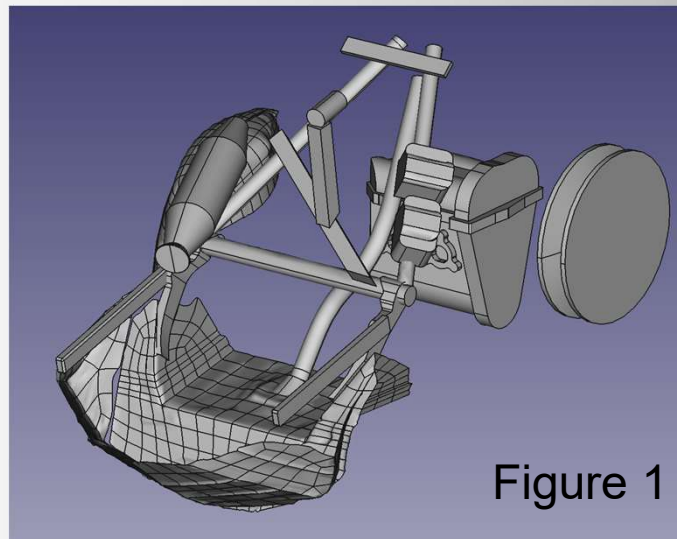


Figure 1

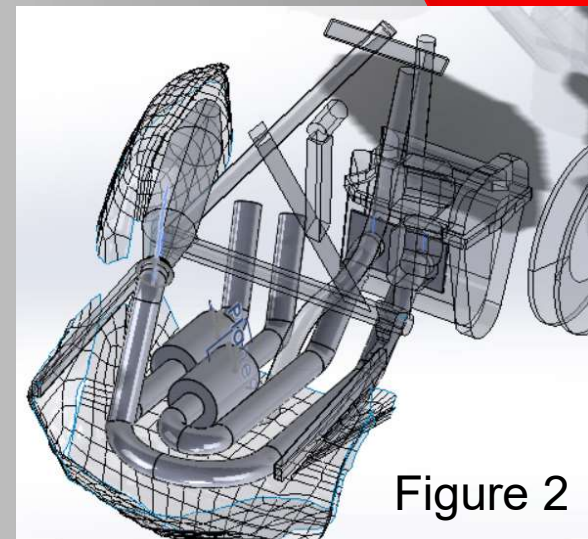


Figure 2



# Catalyst Selection

- Lean to rich fuel oscillation around stoichiometric fueling led to use of three-way catalyst

	2018 Catalyst	2019 Catalyst
Washcoat	W. C, Heraeus GmbH	W. C, Heraeus GmbH
Substrate	Emitec Metal Honeycomb	Emitec Metal Honeycomb
Diameter	92 mm	80 mm
Length	168 mm	130 mm
Foil thickness	0.03 mm	0.03 mm
Density	400 cpsi	400 cpsi
Loading	Platinum 11.1 g/ft <sup>3</sup>	Platinum 25 g/ft <sup>3</sup>
	Palladium 55.6 g/ft <sup>3</sup>	Palladium 0 g/ft <sup>3</sup>
	Rhodium 8.3 g/ft <sup>3</sup>	Rhodium 25 g/ft <sup>3</sup>

# Improved Catalytic Efficiency

- Increased reactor volume from 1,117 cm<sup>3</sup> 1,307cm<sup>3</sup>
- Calibrated EGR target position maps
- Projected E-Score increase of 0.3 from testing

	HC	CO	NO <sub>x</sub>	Projected E-Score
2019 Catalysts	99.9%	96.3%	33.9%	206.2
2018 Catalyst	99.9%	92.4%	34.2%	205.9





# Drive By Sound Testing

- Able to obtain 66.2 dBa compared to our 72 dBa last year
- Mean measures were used from 50ft on both sides of sled
- The sled was operated at 35 mph

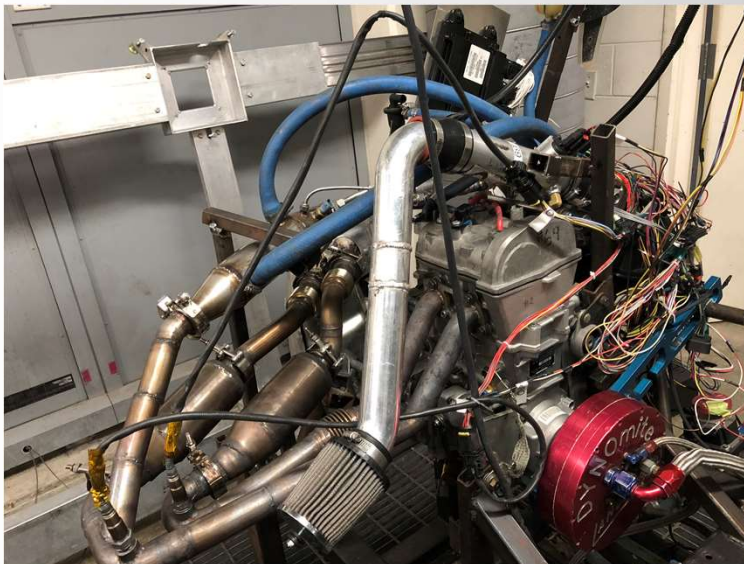


# Fuel Economy Increase

- Increased thermal efficiency from the increase in CR
- Rode 100 miles and found a new fuel economy of 18.8 mpg
  - This is an increase from 18.5 mpg both numbers were obtained running E85

# Dyno and Vehicle Testing

- Calibration done using a Dynamite water brake
- Used Vector CAN data logger in snowmobile



# WRACE 674 Summary

- Low MSRP of \$10,420.69
- Increased peak torque from 52 to 59 N-m and power from 35 to 38 kW
- E-Score improved from 190 to 206
- Quiet sound of 66.2 dBa







# Acknowledgements

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# References

- [1] MTU KRC. *2018 Snow Challenge Logo*. 2018. [Online] Available: [http://www.mtukrc.org/images/SnowChall\\_Logo18\\_blueglow\\_sm.jpg](http://www.mtukrc.org/images/SnowChall_Logo18_blueglow_sm.jpg) [Accessed 23 02 2018].
- [2] J. Heywood, *Internal Combustion Engine Fundamentals*. New York: McGraw Hill, 1988.