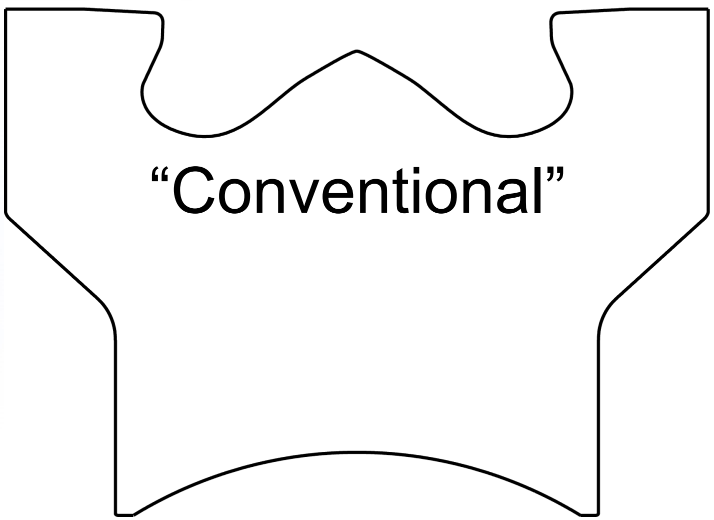
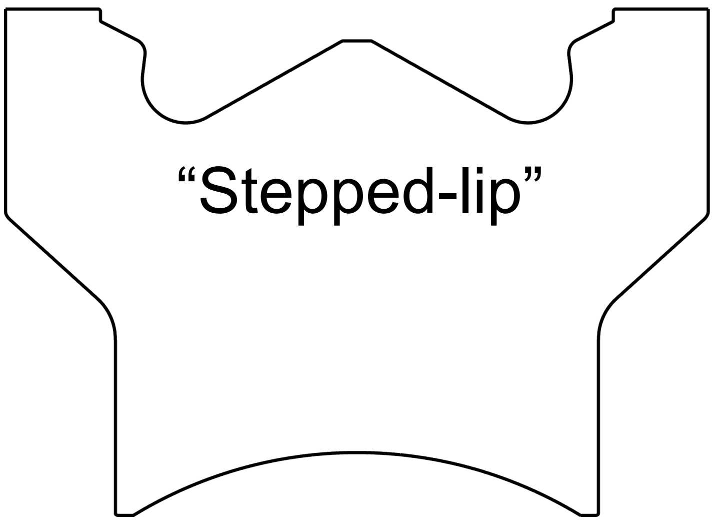
SAND2015-6870PE

Piston bowl geometry variation: status and planning

Steve Busch, Kan Zha

Wednesday, August 19, 2015





Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-AC04-94AL85000

Outline

- Status update
- Planned work: objectives and schedule
- Discussion: experimental objectives for squish and reverse squish interactions

Status update: August 19, 2015

- New titanium piston (conventional bowl, flat top)
  - Arrived this week; will be assembled in the coming weeks
  - Necessary for a fair comparison with the stepped-lip piston
- Most recent lab activity: gas temperature measurements
  - Custom-built thermocouple probe to calibrate our GT-POWER model
  - This is a DOE deliverable
  - An evaluation of the current experimental setup and a few parametric variations should take about a week
- Next up: metal piston testing
  - Dial in operating points: LTC and conventional combustion
    - No extensive parameter sweeps at this stage
  - Full characterization for both piston geometries: AHRR, exhaust emissions
    - Injection rates to support simulation efforts
- Optical pistons (conventional bowl, flat top)
  - Necessary for a fair comparison with the stepped-lip piston
  - Scheduled to arrive in mid-October

Planned work: objectives

- Metal piston testing
  - Characterize operation with two different piston geometries for both LTC and conventional operating points
  - Ensure that trends measured at SNL match with expectations
- PLIF measurements
  - Characterize mixture formation behavior for both piston geometries
  - Provide calibration data for CFD simulations with DPRF58 fuel
  - Make best use of available optical pistons and test bench time
- CFD simulations: motored operation with both piston geometries
  - Can simulations predict measured trends in temporal development of swirl ratio during the compression stroke? Are more PIV measurements necessary?
- CFD simulations: fired operation with multiple injections
  - Opportunity to put latest improvements to the test (full grid, parallel code, improved spray models)
  - Comparison with measured data – improved understanding of combustion processes with a pilot injection

Planned work: schedule

	2015					2016	
	August	September	October	November	December	January	February
Experiments	AEC; Metal piston testing, TC measurements	PLIF setup	PLIF: stepped-lip piston bowl	Install new piston; PLIF: re-entrant bowl, flat top	Buffer	Characterize squish / reverse squish flow	
Simulations & analysis	Motored flow	Bowl geometry comparison: cold flow; swirl development		PLIF processing		Mutiple injections, conventional combustion	
		Verify fired operation is as desired					
Planning	Develop techniques to measure squish and reverse squish flow interactions				TBD		

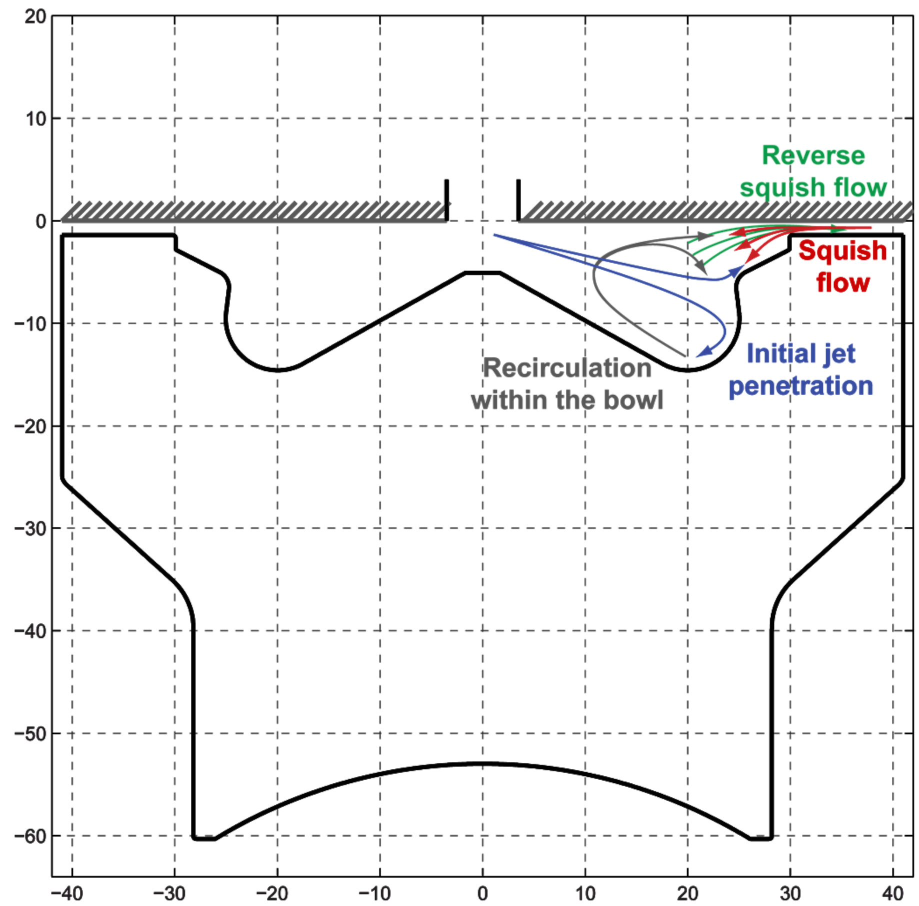
Discussion: experimental objectives for squish and reverse squish interactions

- Measuring squish flow interactions has been a goal for some time, but we have yet to succeed
- Squish flow measurements have been set as a specific EERE-VT deliverable for March 2016
- Goal of this discussion: ensure SNL (Steve and Kan) understands what interactions are of interest and what we hope to achieve with our experiments

- Next slides: cartoons to show the interactions that may be expected and challenges that measuring them presents

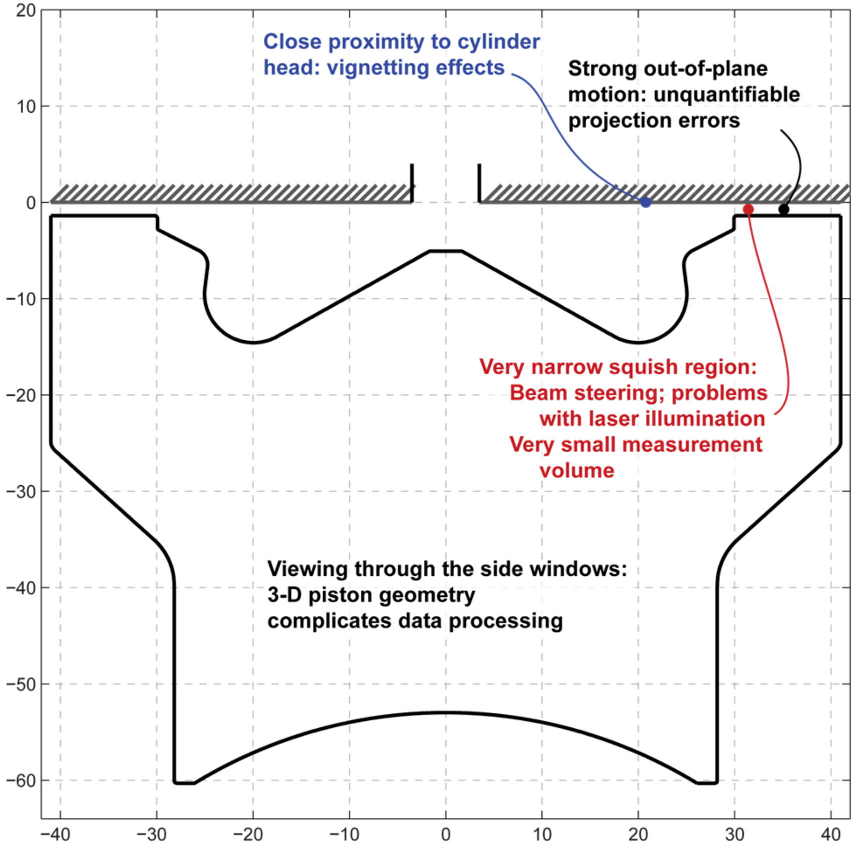
Discussion: squish/reverse squish flow interactions

- In-cylinder flows:
  - Bulk swirl flow
  - Squish flow induced by upward piston motion
  - Flow driven by the fuel injection
  - Recirculation and mixing within the bowl
  - Reverse squish induced by downward piston motion
- Are these the processes of interest?

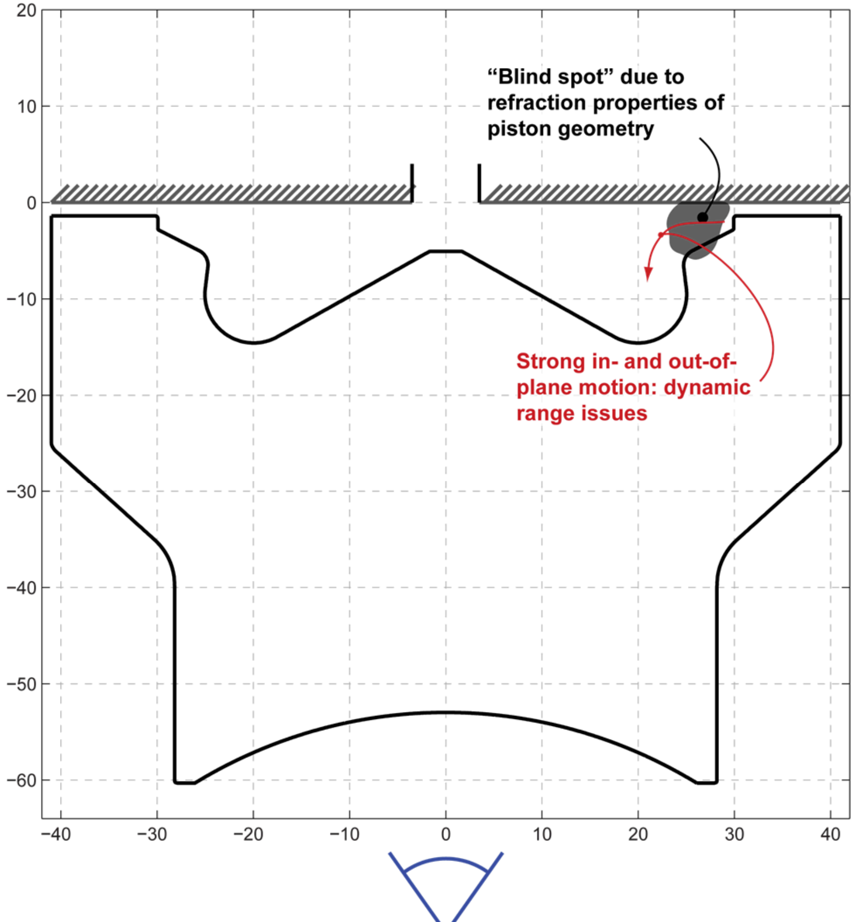


Experimental challenges

Viewing through the side



Viewing through the bottom



THANK YOU FOR YOUR SUPPORT!

Questions?

Project overview

	Hardware	**Swirl plane PIV:** characterization of swirl and flow asymmetries	**Metal piston testing:** LTC and conventional compare combustion, emissions, etc.	**Fuel tracer PLIF:** comparison of mixture formation processes; simulation validation data	**Reverse squish flow** characterization: comparison of reverse squish flow behavior
Optical pistons	Conventional bowl w/ valve cutouts CR 16.7 : 1	Large dataset; processing mostly finished	N/A	Not currently planned	Measurement technique and specific experimental objectives not yet defined
	Conventional bowl no valve cutouts CR 15.8 : 1	New pistons expected in early Oct. 2015; expected duration: 4 weeks experiments, 4 weeks processing		Experiment design depends on metal engine testing results; new pistons expected in early Oct. 2015; expected duration: 6 weeks experiments, 4 weeks processing	
	Stepped-lip bowl no valve cutouts CR 15.8:1	Large dataset; processing in progress			
Metal pistons	Conventional bowl no valve cutouts CR 15.8 : 1	N/A	New titanium piston expected in late July 2015	N/A	N/A
	Stepped-lip bowl no valve cutouts CR 15.8:1		Piston available; expected durationfor both geometries: 6 weeks experiments, 2 weeks processing		

Operating conditions: LTC

- Pistons have no valve cut-outs
  - Squish height is necessarily increased
  - Compression ratio: 15.8:1
- Intake charge flow rates & temperature will have to be adjusted to maintain TDC temperature and density
  - Use of GT-Power model to verify motored TDC conditions
- Fuel quantity will be adjusted to maintain load at the given injection timing

Engine speed	1500 rpm
Intake charge mole fractions	O_2: 10% CO_2: 9% N_2: 81%
Intake temperature	TBD
Intake pressure	TBD
$IMEP_g$	3.0 bar
Injected fuel	8.8 mg
Injection pressure	860 (500, 1000) bar
Global equivalence ratio	TBD
SSE	-26.6 CAD ATDC
SOI	-23.1 CAD ATDC
Injection duration	~6.4 CAD
Swirl ratio (Ricardo)	2.2 (1.5, 3.5, 4.5)
TDC density	20.9
TDC temperature	909

Operating conditions: conventional

- Intake charge flow rates & temperature will have to be adjusted to maintain TDC temperature and density
- Main injection quantity will be adjusted to maintain load at the given injection timing

Engine speed	1500 rpm
Intake charge mole fractions	O_2: 19.7% CO_2: 1.1% N_2: 79.2%
Intake temperature	TBD
Intake pressure	TBD
$IMEP_g$	9.0 bar
Injected fuel (P/M)	1.4 / ~22 mg
Injection pressure	800 bar
Global equivalence ratio	TBD
SSE (pilot/main)	-15 / -1.5 CAD ATDC
SOI(pilot/main)	-12.3 / 1.3 CAD ATDC
Main inj. duration	~10.3 CAD
Swirl ratio (Ricardo)	2.2
TDC density	21.8
TDC temperature	925

Fuel Injector

- Bosch CRI 2.2
  - 7 evenly spaced holes
  - Outlet diameter: 139 μm
  - ks: 1.5 / 86
  - 149° included angle
  - Flow rate: 440 cm^3/30s @100 bar