Årsrapport Kompetenscentrum Gasväxling, CCGEx, 2014

Sammanfattning

Kompetenscentrum gasväxling, CCGEx, har 2014 gått in i sin tredje period. Finansiering från energimyndigheten, KTH , Scania, Volvo Cars och Volvo GTT som huvudpartner är avtalad för perioden 2014-2017. Centrumets tredje verksamhetsperiod innefattar en fortsättning med en inriktning av verksamheten inom tre huvudområden, ”Cold Side – Compressor off Design”, ”Integrated Hot Side – iHOT” samt ”Exhaust After Treatment”. Alla projekt, doktorander och aktiviteter är nu organiserande inom dessa områden. Fokuseringen inom områden har ökat möjligheten till samsyn mellan akademi och industri om vilka frågor som behandlas och vad respektive projekt syftar till att besvara och tillföra. Områdes fokuseringen har också underlätta för industrin och akademi att i samarbete identifiera och tillföra inkind vilken för projekten framåt och förbi möjligheterna som akademin har själva.

2014 har varit ett produktivt år med 5 disputerade doktorer från tre av centrumets fyra institutioner/ämnen. Ett tjugotal artiklar har publicerats och centrumet har varit fysiskt representerat på sju konferenser.

Budgeten för 2014 anpassades till att det vid årets början inte fanns full industriell medfinansiering säkrad för att kunna möta upp energimyndighetens och KTHs bidrag. Under årets gång har ytterligare industribidrag tillkommit genom BorgWarner, VTT och ViF. Dessutom har industrins inkind bidrag tagit fart med uppstarten av projekt och doktorander vilkas aktiviteter är väl förankrade hos industripartnerna.

Summary

With 2014 the Competence Center Gas Exchange at KTH started its third phase. Finansing from the Swedish Energy Agency, KTH and the industrial partners Scania/Volvo Cars/Volvo GTT as main partners was approved in late 2013. The funding period was decided for four years 2014-2017.

The center has in this phase set up the research to be organized within three focus areas: “cold side-compressor off design”, “integrated Hot Side” and “Exhaust After Treatmen”. All projects, PhDstudents and activities are aligned with these areas. This focus has gives a clear common understanding between academy and industry on which questions/tasks that are addressed and which question each project aims at addressing. The focus areas has enabled the academy and industry to identify and execute the inkind contribution to the projects, which drives the outcome beyond the possibility for the academy alone.

2014 has been a productive year with 5 PhDs thesis’ successfully defended at three of the four disciplines presented in the center. In total around 20 articles have been published and the center has been represented at seven conferenses.

The 2014 budget was adopted to the fact that the industry financing did not meet the full 8 MSek which was allocated from the energy agency and KTH. During the year additional industrial contribution from BorgWarner, VTT and ViF has been received. In addition to this the industry inkind from the main partners have been successful with the startup of projects which are commonly prepared between industry and academy.

Innehåll

Inledning

Energimyndigheten beslutade 2013 om en ny finansieringsperiod 2014-2017 för kompentenscentrumen samlade inom Swedish Combustion Engine Consortium (SICEC) relaterat till förbränningsmotorteknik. Denna period innebär för KTHs förbränningsmotorcentrum (CICERO 2006-2009, CCGEx 2010-2013) att det går in i sin tredje finansieringsomgång

Bakgrund

Kompetenscentrum Gasväxling (CCGEx) (tidigare CICERO) startades 2006 som ett kompletterande tredje svenskt förbränningsmotor kompetenscentrum.

Sverige har en stark motorindustri som för sin överlevnad är beroende av att kunna förnya sina produkter så att de miljö- och energimässigt ligger väl framme i internationell konkurrens. Den nuvarande trenden med allt strängare utsläppskrav, vilka lägger allt mer vikt på CO_2 utsläpp, minimering av energianvändning, ökande andel biobränslen och hybridmotorer innebär att marginalerna för de i motorn ingående komponenter, system och processer blir allt mindre.

Svensk fordonsindustri står i och med detta inför ett antal stora utmaningar i form av krav på effektivare motorer, hårdare optimeringar, minskade utsläpp samt stark internationell konkurrens.

Vägen att möta dessa utmaningar är en övergång till ett mer kunskaps- och beräkningsbaserat arbetssätt med mindre beroende av prototyptestning och lösningar byggda på praxis.

Detta skapar ett starkt tryck på att identifiera, förstå och arbeta innovativt med de bakomliggande fysikaliska processer som utnyttjas i de system och komponenter som krävs för framtida högeffektiva förbränningsmotorkoncept.

Den svenska motorindustrin har varit tidiga med överladdning och är starka inom detta område ur ett internationellt perspektiv. Betydelsen av detta område ökar med nya förbränningssystem som kräver höga EGR-halter och laddningstryck. Ventilsystem med variabla öppnings- och stängningstider och lyft kommer mer och mer. För att behålla industrins konkurrenskraft är det viktigt med kontinuerlig kompetensförsörjning inom området. Det gäller såväl sakkunskap som forskare med relevant kompetens. Området gasväxling och överladdning är specifikt för Competence Center Gas Exchange (CCGEx) och täcks inte upp av något annat svenskt kompetenscentrum.

CCGEx:s syfte är att utföra akademisk forskning med högsta kvalitet inom området förbränningsmotorers gasväxling i nära samverkan med fordonsindustrin och därmed bidra till ett effektivt, hållbart och konkurrenskraftigt transportsystem baserat på effektiva alternativbränsle anpassade motorsystem i kombination med elektrifiering. Genom att utnyttja avancerade analys-, mät- och syntesmetoder ska den fysikaliska förståelsen öka för grundläggande relevanta fenomen. Genom denna ökade förståelse kommer forskare inom CCGEx att kunna identifiera nya tekniska möjligheter och lösningar inom gasväxling, EGR-system, överladdning och efterbehandlingssystem.

Organisation (struktur och personer)

Deltagande organisationer inom CCGEx är , liksom i tidigare perioder, KTH , Energimyndigheten samt de svenska fordonsföretagen Scania CV, Volvo Cars och Volvo GTT. Från KTH involverade enheter / institutioner ingår förbränningsmotorteknik, fluidmekanik och MWL akustik. Under 2014 har också ett första närmande till energiteknik.

Genom MWLakustik har CCGEx också deltagande från Wärtsilä, BMW och ViF (Österrike).

Ett samarbete med Borg Warner Turbo System är också uppstartat och formalisering av samarbetet pågår.

Utgångspunkten för formulering av forskningsuppdrag är förhållanden på verkliga motorer. Fenomenen kan sedan renodlas vid grundläggande strömnings- och akustiska undersökningar, med användande av en kombination av simulerings- och experimentella verktyg. Att få en stabil grund för förståelsen av förloppen i motorn och finna svagheter/utvecklingsbehov hos modeller vilka möjliggör ökad simuleringsbaserad utveckling i industrin är slutmålet. Länken över simuleringsverktyg med reducerat antal dimensioner (”reduced order models”), fungerar som koppling mellan industriell tillämpning samt möjligheten att göra ansatser till fysikalisk analys för formulering av behov av detaljstudier inom såväl fluidmekanik, akustik som motorsystem.

En genomgående tanke i organisation och arbetssätt är att främja samarbete över gruppgränser samt att involvera yngre disputerade forskare i centrets ledning. Centret är organisatoriskt placerat på ITM skolan. Det löpande arbetet i centret leds av en föreståndare samt en vice föreståndare.

Som stöd för sitt arbete har föreståndare och vice föreståndare en ledningsgrupp (LG) bestående av föreståndare, vice föreståndare samt yngre disputerade forskare från de ingående ämnena.

De vetenskapliga ledarna (professorer på respektive enhet) ingår, tillsammans med föreståndare och vice föreståndare, i ett vetenskapligt råd (VR), vilket fungerar som remissinstans för ledningsgrupp och ska säkra vetenskaplig höjd och relevans inom centrumets forskningsområden och projekt.

Huvudhandledare för de lic/doktorsprojekt som drivs inom centret är docenter inom LG och professorer inom VR. Centret eftersträvar projekt som utnyttjar den breda kompetens som finns inom centret och strävar därför mot att så många projekt som möjligt involverar biträdande handledare med en annan profil än huvudhandledaren.

Huvuddelen av CCGExs forskningsverksamhet genomförs av forskarstuderande med målsättning att dessa ska avlägga licentiat- och/eller doktorsexamen. Samtidigt är det av vikt att inom respektive forskningsområde tidigt och kontinuerligt eftersträva möjligheten till arbetsfördelning där industriparter engageras inom forskningen för att utnyttja kompetens och resurs hos alla centrumets deltagare. Förutom dessa medverkar disputerade forskare samt de vetenskapliga ledarna (professorer + docenter) som är knutna till centret.

För samverkan med industrin finns arbetsgrupper (AG) kopplade till de olika forskningsområdena samt till enskilda projekt. Dessa arbetsgrupper träffas regelbundet för att diskutera arbetsfördelning och projektresultat inom pågående projekt, nya forskningsområden samt projektidéer.

Inom CCGEx olika funktioner har 2014 följande personer varit engagerade:

Programråd

Sören Udd	SICEC Ordförande
Arne Johansson	KTH
Gunilla Efraimsson	KTH
Per Lange	Scania
Lucien Koopmans	VCC
Johan Wallesten	Volvo GTT
Anders Johansson	Energimyndigheten

Föreståndare

Föreståndare	Jonas Holmborn / MFM
Vice Föreståndare	Mats Åbom / MWL

Ledningsgrupp

Jonas Holmborn	MFM
Mats Åbom	MWL
Andreas Cronhjort	MFM
Mihai Mihasecu	FlMech
Ramis Örlü	FlMech
Susann Boij	MWL
Nils Tillmark	FlMech & CICEROlab ansvarig

Vetenskapligt Råd

Jonas Holmborn	MFM
Mats Åbom	MWL
Andreas Cronhjort	MFM (tom 2014 Q2)
Anders Hultqvist	MFM(from 2014Q3)
Laszlo Fuchs	Fluid Mech
Henrik Alfredsson	Fluid Mech
Hans Boden	MWL

Forskare

Område ”Cold Side – Compressor off Design”	
Mihai Mihaescu	Områdesledare
Bertrand Kerres	Doktorand MFM
Elias Sundström	Doktorand FlMech
Raimo Kabral	Doktorand MWL
Lin Zhou	Doktorand MWL
Antti Hynninen	Doktorand MWL/VTT
Andreas Bergqvist	Doktorand FlMech/Scania – VR
Martin Söder	Doktorand FlMech/Scania FFI
Athanasia Kalpakli	Doktorand FlMech (PhD Q2)
Markus Pastuhoff	Doktorand FlMEch (PhD Q3)
Område “integrated Hot Side – iHOT”	

Mihai Mihaescu	Områdesledare
Johan Fjällman	Doktorand FlMech (PhD Q3)
Shyang Maw Lim	Doktorand FlMech
Ted Holmberg	Doktorand MFM
Marcus Winroth	Doktorand FlMech
Habib Aghaali	Doktorand MFM (PhD Q3) / SICEC FFI
Yasser El Nemr	Doktorand MWL/ViF
Område "EAT"	
Mikael Karlsson	Områdesledare

Huvudresultat

CCGEx leveranser och resultat tydliggörs lättas genom publikationer, konferensdeltagande och examinationer av doktorer. Till detta bör också läggas det utbyte av kunskap, erfarenheter och resurser som möjliggörs genom att delar av experimentella kampanjer, men också simuleringar, genomförs hos de industripartnerna i centrumet. I dessa kategorier har CCGEx 2014 levererat följande :

Doktorsexamina	**5st**
Reifarth, S.	*Efficiency and Mixing Analysis of EGR-Systems for Diesel Engines*. PhD thesis, KTH Internal Combustion Engines
Kalpakli Vester, A.	*Vortices in turbulent flows—rocking, rolling and pulsating motions*. PhD thesis, KTH Mechanics
Pastuhoff, M.	*Measuring with pressure sensitive paint in time-varying flows*. PhD thesis, KTH Mechanics
Fjällman, J.	*Large Eddy Simulations of Complex Flows in IC-Engine's Exhaust Manifold and Turbine*. PhD thesis
Aghaali, H.	*Exhaust Heat Utilisation and Losses in Internal Combustion Engines with Focus on the Gas Exchange System*, PhD thesis, KTH Machine Design
Publikationer	**20 st** ➢ *SAE Tech Paper* ➢ *SAE Int. J. Engines* ➢ *AIAA* ➢ *ASME J Vib* ➢ *Int J. Heat Fluid Flow* ➢ *Advances in Mech. Engineering* ➢ *Computational Fluids* ➢ *Oil Gas Science Tech.* ➢ *Applied Therm Eng* ➢ *Energy Convers. Manage* ➢ *Journal of Sounds and Vibration*
Konferensdeltagande	➢ *SAE : Italy, Detroit* ➢ *ImechE: London* ➢ *FISITA: Maastricht* ➢ *MTZ Conference: Saarbrücken* ➢ *ASME:* ➢ *ERCOFTAC: Marbella* ➢ *Progress in Turb: Italy*
Kampajer hos industripart	**4st**

Forskningsresultat

Compressor off Design (CoD)

Inom CoD genomfördes fortsatt karaktärisering och modellbygge av generering, transmittering och dämpning av akustiska vågor i turboaggregat från Garrett som funnits i centrumet sedan starten. Nya aggregat från BorgWarner som används i Volvo Cars motorer installerades och karaktäriserades också.

Inom delprojektet gällande kompakta dämpare baserat på akustiskimpedans i ”microperforated plates” genomfördes mätningar i både MWLs labb och i CICEROlabbet. Dessa data analyserades och applicerades i fysikaliskmodell bygge. Dessa modeller använders sedan för att generera förslag till omdesign för att täcka bredare frekvensområden och att ytterligare öka dämpningen. Prototyper gör ”gen2” byggdes, provning sker i början av 2015.

Kompressor prestanda , surge och choke vid varierande inströmnings villkor testades initialt i CICEROlabbet för den existerande Garret turbon. Mycket tid för att säkerställa uppställningens noggrannhet och att ansluta nya inloppsgeometrier som genererar flexibla inströmningsfält.

CFD beräkningar av ett 20 tal driftpunkter vid två varvtal och längs driftlinjen för varvtal genomfördes. Väl validerad kod och metod. Utvärdering av instabiliteter och dess koppling till strömningsfält. DMD och POD använt för att identifiera vilka frekvenser som uppstår var i geometrin och vilket strömningsfenomen. Tidigare beräkningar för att validera metoder gjorda på Heavy Duty turbo där detaljerade mätdata finns. Har under året kompletterats med Light Duty turbo. Grundorsaker, var i turbogeometrin de uppstår och kopplingen mellan geometri och strömning har identifierats för de frekvenser som identifieras i experimentella uppställningar. Surge, bladpassing frequency, harmonics har alla fångats med tillfredställande noggrannhet.

Integrated Hot Side

CFD beräkningar av strömning vid konstant- och pulserande flöde från avgasport, genom grenrör och över turbin. Analys av vilka strömningsfenomen som behandlas vid mätning i konstantflöde. Identifierat instabiliteter i strömningen även för konstantflöde och var dessa uppstår, vilka effekter har detta på turbinprestanda och hur relevanta blir turbomappar.

Litteratursökning, forsknings/hypotes formulering samt försöksplanering för avgasventils arbete.

Simuleringsstudier kring strategier för att utnyttja avgasenergin bättre genom utnyttjande av turbocompunding och alternativa ventilstrategier. Resultaten indikerar potentiell förbrukningsminskning i området 2-5 % överlastområdet genom utnyttjande av varierande kombinationer av ventilstrategier.

Genomförande

CCGEx har under 2014 bedrivit forskning inom två forskningsområden ; ”Cold Side – Compressor off Design” och ”Integrated Hot Side – iHOT”. Beredning och formulering av ett tredje forskningsområde ”Exhaust After Treatmen” har genomförts under året där resultatet och förslag till forskningsupplägg presenterats för programråd och rekommenderats till uppstart i och med programrådsmöte i december 2014.

Forskningsprojekt

De under 2014 pågående projekten listas nedan, för mer detaljerad projektpresentation se bilaga samt CCGEx hemsida, http://ccgex.kth.se

Cold Side - Compressor off Design	
Gas dynamics of in--cylinder flow	Andreas Bergqvist
Acoustic Simulation of Automotive Turbochargers	Yasser El Nemr
Pulsating flow in complex channels–experiments	Athanasia Kalpakli-Vester
Pressure sensitive paint (PSP) for rotating components	Markus Pastuhoff
Rotating Machines and Innovative Noise Control	Raimo Kabral
Compressor Maps for Engine Installations	Bertrand Kerres
Large Eddy Simulations of the 3D Flow in a Centrifugal compressor	Elias Sundström
In-cylinder flow	Martin Söder
Impedance eduction and validation	Lin Zhou
Integrated Hot Side – iHOT	
Detailed modeling of single & double turbines	Johan Fjällman
Waste Heat Recovery on Internal Combustion Engines by Using Turbines	Habib Aghaali
Interaction between ICE Exhaust Pulses and Turbine	Ted Holmberg
Exhaust noise from large diesels	Antti Hynninen
Flow and Heat Transfer Effects on the Efficiency of a Radial Turbine	Shyang Maw Lim
Gas dynamics of in--cylinder flow	Marcus Winroth

Interaktion/mötesforum

Forskningen bedrivs främst i form av doktorandprojekt där handledare och doktorand har kontakt och diskussioner på daglig/vecko basis. Forskare, doktorander och industrirepresentanter träffas inom respektive forskningsområde med en frekvens på 4-6 veckor för att presentera och diskutera de senaste resultaten inom projekten, diskutera framtida aktiviteter samt planera och säkra samarbete inom KTH institutioner och industri. Industrideltagande vid dessa möten sker främst genom telefon/web uppkoppling.

Centrumet samlades under 2014 i sin helhet med alla forskningsområden, KTH funktioner och industrirepresentanter vid två tillfällen under 2014. Under dessa träffar presentarades och diskuterades främst centrumets generella riktning och strategiska områden relaterat till industrins behov.

Programrådet har gett i uppdrag till föreståndare och vice föreståndare att leda centrumet. Detta realiseras genom en centrumledningsgrupp bestående av :

- Föreståndare
- Vice föreståndare
- Forskare (doktorer, docenter) inom CCGEx vilka representerar de tre forskningsdisciplinerna (förbränningsmotorteknik, fluidmekanik samt akustik)

Ledningsgruppen har till första uppgift upprätta och underhålla CCGEx vision/mission/strategy samt CCGEx road map vilka ligger till stöd för att formulera forskningsteman (research areas) som ska rikta till att uppfylla de centrum mål som finns i uppdragsbeskrivning och styrelsens uppdrag till CCGEx. Ledningsgruppen har fasta mötestillfällen var fjortonde dag där uppdrag distribueras till ledningsgruppen och uppföljning av uppdrag sker.

Ledningsgruppen har till stöd för att säkra forskningshöjd/relevans och tillgång till ”linjens” resurser, en kontrollfunktion i form av CCGEx Vetenskapligt Råd (center scientific board). I CCGEx VR ingår de centrum anslutna fyra professorerna för förbränningsmotorteknik, fluidmekanik och akustik, samt föreståndare. Rådet har under 2014 samlats vid tre tillfällen vilka varit behovs styrda snarare än schema lagda. Inför 2015 kommer rådets möten att sätta till en gång i kvartalet med kompletterande möten vid behov.

Ekonomi

Finansieringen, och med den tillgängliga medel inom CCGEx, utökades i den nya perioden till 8 MSEK/år i kontant bidrag från energimyndigheten. Samma bidrag i form av viss kontant del och större del natura säkrades från KTH. De tre huvudindustriparterna ökade i den nya perioden sitt åtagande till att omfatta totalt 1.7 MSEK/år och part (fördelat på kontant och natura). Vid periodens början, 2014, var emellertid inte det industriella bidraget inte säkrat upp till fulla 8 MSEK/år som energimyndigheten och KTH avdelat. Med detta i åtanke lades budgeten för 2014 att motsvara de 6.5 MSEK i medfinansiering som var säkrade.

Ett intensivt arbete har också lagts ner i beredningen och genomförandet av forskningsprojekten för att få en överenskommelse och planering för naturabidraget från de parter (KTH och industri) som har sådana åtaganden.

Ett intensifierat arbete med att knyta ytterligare industriparter till centrumet har pågått under året. Framsteg har nåtts med intresse från ett antal nya företag, men inget slutgiltigt åtagande och tilläggskontrakt har förts i hamn. Turbotillverkaren har dock utan formellt avtal tillfört hårdvara, geometrier och turbomappar till centrumets Compressor off Design projekt.

I följande tabell presenteras en sammanställning av kontantbudget och kontantflöden för 2014.

BUDGET draft 2014

		2014	**Uppföljning**	**DIFF**
INTÄKTER		**BELOPP, SEK**	**2014-12-31**	
IB 2013		-		
KTH medfinansiering		1 000 000	1 000 000	0
Energimyndigheten		6 650 000	8 000 000	-1 350 000
Scania		800 000	800 000	0
Volvo Car, ***avser 2014, inbet 2015***		600 000	600 000	0
Volvo Lastvagnar		800 000		800 000
Övriga intäkter		=Q16/3*1000		
SUMMA INTÄKTER		**9 850 000**	**10 400 000**	**-550 000**
KOSTNADER		**BELOPP, SEK**		
Föreståndare				
OH för Jonas H, som ej ersätts av Scania		**680 000**	**639 829**	**40 171**
Mats Åbom, 10%		200 000	200 000	0
Susann B , 10%, MWL		170 000	170 000	0
Andreas C, 10%, MFM		170 000		170 000
Mihai, Mekanik		170 000	170 000	0
Ramis, Mekanik		170 000	170 000	0
IAB		98 400	88 394	10 006
Styrelseordförande		200 000	200 000	0
Resekostnader		40 000	53 541	-13 541
Driftkostnader (repr m m)		60 000	32 359	27 641
Verksamhetsutveckling, internat		35 000	35 882	-882
Delsumma ledning		**1 993 400**	**1 760 005**	**233 395**
CICERO Lab				
Labchef Nils Tillmark, 25%		330 000	330 000	0
Lokalhyra lab		120 000	136 440	-16 440
Driftkostnader lab		30 000	48 704	-18 704
Utrustning / infrastruktur		60 000	40 355	19 645
Delsumma CICERO Lab		**540 000**	**555 499**	**-15 499**
ITM MMK				
Simon PhD januari		75 000	82 584	-7 584
Bertrand compressor off design		900 000	734 819	165 181
ny doktorand "heta sidan" (TD)		650 000	385 857	264 143
doktorand EAT		900000		
Scania ind.doktorand		**125 000**		**125 000**
Labdrift - provspecifikt		30 000		30 000
Utrustning / infrastruktur motorlabb		60 000		60 000
Delsumma MMK		**1 840 000**	**1 203 260**	**636 740**
SCI, MWL				
Marie Curie stipendiat 50%		450 000	455 300	-5 300
Lin - labbkostnad		100 000	100 000	
EAT akustik doktorand		900 000	450 000	450 000
EAT, Seniorforskare Mikael Karlsson		300 000	300 000	0
Delsumma MWL		**1 750 000**	**1 305 300**	**444 700**
SCI, MEKANIK				
Heta Sidan; seniorforskare		450 000	450 000	0
CoD; seniorforskare Mihai		450 000	450 000	0
EAT Fl.exp				
heta sidan Fl.exp		450 000	450 000	0
Sissy K: CoD PhD Q2		450 000	450 000	0
Pastuhoff : CoD PhD Q2		450 000	450 000	0
heta sidan Fl.sim - Fjällman		600 000	600 000	0
Volvo Cars ind.doktorand - Flsim		**125 000**		**125 000**
heta sidan Fl.sim		450 000	450 000	0
Volvo GTT ind.doktorand - FlSim		**125 000**		**125 000**
compressor off design Fl.sim		900 000	900 000	0
EAT fl.sim ?				
Delsumma Mekanik		**4 450 000**	**4 200 000**	**250 000**
SUMMA KOSTNADER		**10 573 400**	**9 024 064**	**1 549 336**
PREL RESULTAT		**-723 400**	**1 375 936**	**-2 099 336**

Fördelat på forskningsområden ser utfallet ut som nedan.

	Budget 2014 (nov 2013)	Status 140831	burnrate	Q4 2014	burnrate Q1-Q4	Summering 2014	
ledning							
löner	1 560 000	757 749	49%	802 251	100%	1 314 747	
IAB	98 400	0	0%	98 400	100%	0	
Styrelseordförande	200 000	150 000	75%	50 000	100%	200 000	
Resekostnader	40 000	27 439	69%	12 561	100%	45 167	
Driftkostnader (repr m m)	60 000	27 144	45%	32 856	100%	30 476	
Verksamhetsutveckling, internat	35 000	35 882	103%	0	103%	41 385	
Sum ledning	**1 993 400**	**998 214**	50%	**996 068**	50%	**1 631 775**	**82%**
labb							
ICE							
Labdrift - provspecifikt	30 000	0	0%	30 000	100%	0	
Utrustning / infrastruktur motorlabb	60 000	0	0%	60 000	100%	0	
Sum ICElab	**90 000**	**0**	0%	**90 000**	100%	0	**0%**
CICERO							
Labchef Nils Tillmark, 25%	330 000	165 000	50%	165 000	100%	330 000	
Lokalhyra lab	120 000	90 960	76%	29 040	100%	125 070	
Driftkostnader lab	30 000	24 745	82%	5 255	100%	16 993	
Utrustning / infrastruktur	60 000	17 315	29%	42 685	100%	37 610	
Sum CICERO	**540 000**	**298 020**	55%	**241 980**	100%	**509 673**	**94%**
Research Areas							
EGR&Exhaust manif							
Simon Reifarth - ICE	75 000	82 584	110%	-7 584	100%	75 000	
Sum EGR	**75 000**	82 584	110%	**75 000**	100%	**75 000**	**100%**
Compressor off design							
Kerres - ICE	900 000	450 000	50%	450 000	100%	720 000	
Lin - MWL Post Doc	900 000	450 000	50%	-450000	0%	450 000	
Senior forskare - Mihai	450 000	0	0%	450000	100%	450 000	
Sissy K - Fl.exp	450 000	450 000	100%	0	100%	450 000	
Marcus P - Fl.exp	450 000	450 000	100%	0	100%	450 000	
Raimo Kabral - MWL	450 000	0	0%	450000	100%	450 000	
Lin Zhou - MWL	100 000	0	0%	100000	100%	100 000	
Elias Sundström - Fl.sim	900 000	450 000	50%	450000	100%	900 000	
Sum CoD	**4 600 000**	**2 250 000**	49%	**1 450 000**	80%	**3 970 000**	**86%**
iHOT							
Ted Holmborn - ICE	650 000	0	0%	450000	69%	375 000	
Scania ind.doktorand	125 000	**0**	0%	0	0%	0	
iHOT; seniorforskare Mihai	450 000	225 000	50%	225000	100%	450 000	
Markus Winroth- Fl.exp	450 000	0	0%	450000	100%	450 000	
Shuang Maw Lim - Fl.sim	450 000	0	0%	450000	100%	450 000	
Fjällman - Fl.sim	600 000	450 000	75%	150000	100%	600 000	
Volvo GTT ind.doktorand - FlSim	125 000	**0**	0%	0	0%	0	
Sum iHOT	**2 850 000**	**675 000**	24%	**1 725 000**	84%	**2 325 000**	**82%**
EAT							
EAT, Seniorforskare Mikael Karlsson	300 000	150 000	50%	150000	100%	300 000	
Volvo VCCind.doktorand - exp.akustik	125 000	**0**	0%	0	0%	0	
Sum EAT	**425 000**	**150 000**	35%	**150 000**	71%	**300 000**	**71%**
SUM	**10 573 400**			**9 099 282**		**8 811 448**	
Balance						**1 505 219**	

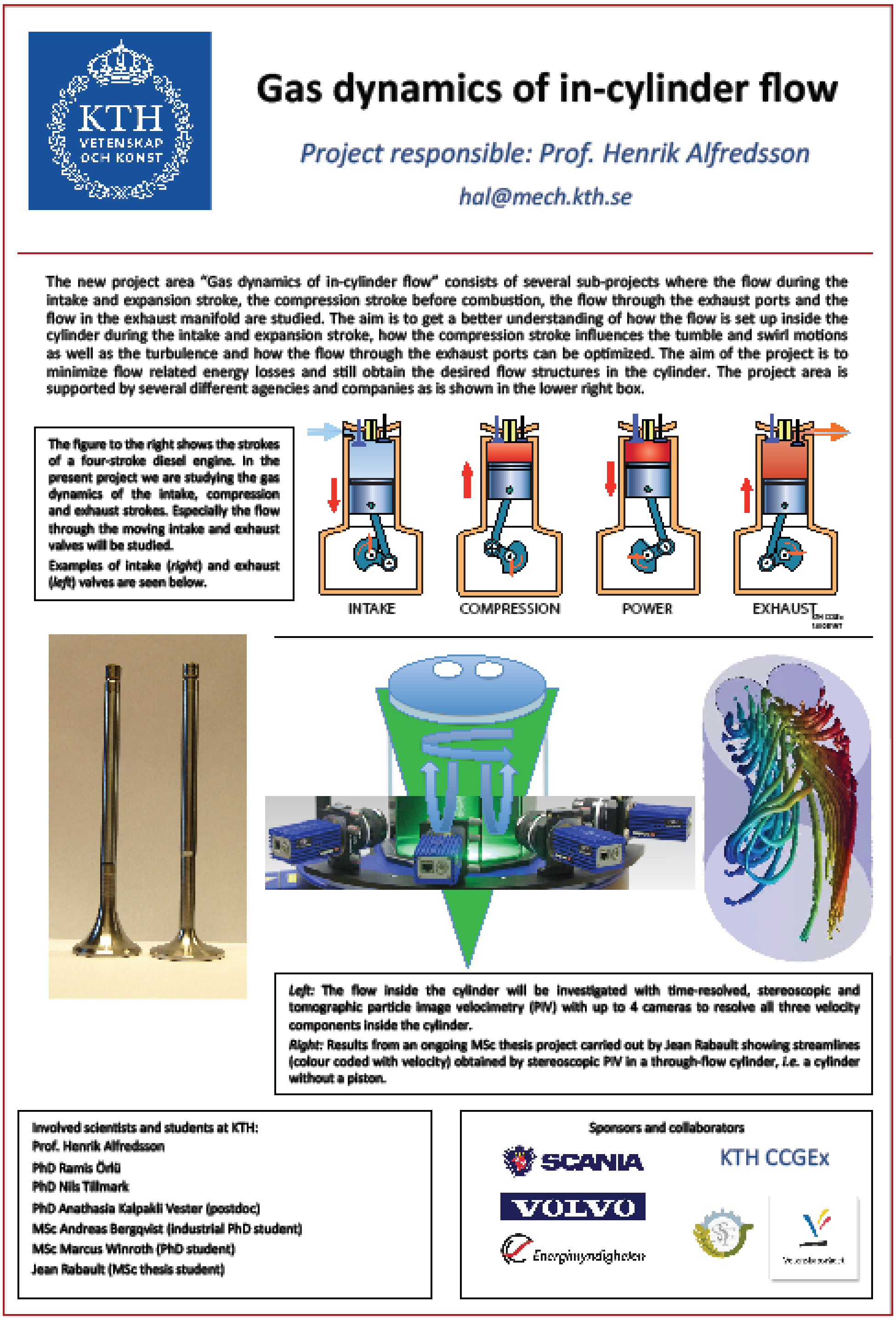
Avstämning av kontant och natura/in-kind bidrag för 2014 presenteras nedan.

		2014	2015	2016	2017
Kontant					
KTH	kr	1000000			
Energimyndigheten	kr	8000000			
Scania	kr	800000			
Volvo Cars	kr	600000			
Volvo GTT	kr				
BW	kr				
VTT	kr				
ViF	kr				
Inkind					
KTH	kr	8211227			
Energimyndigheten	kr	-			
Scania	kr	3384419			
Volvo Cars	kr	1548477			
Volvo GTT	kr				
BW	kr	274400			
VTT	kr	200000			
ViF	kr	900000			

Fördelning		**2014**	**2015**	**2016**	**2017**
KTH	kkr	9211			
Energimyndighet	kkr	8000			
Industri	kkr	7707			

Värt att notera är att KTHs medfinansiering väl täcker upp dess åtaganden, även mot en fullt utnyttjad energimyndighetsram om 8Msek. Industrin ligger några hundratusen kort mot 8MSek, men detta är orsakat av administrativa svårigheter med att få inköpsorder från några partner på plats och uppstart av överrenskomna industridoktorandprojekt. Detta ska vara korrigerat under första halvan av 2015.

Projektposters



Gas dynamics of in-cylinder flow

Project responsible: Prof. Henrik Alfredsson

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The new project area "Gas dynamics of in-cylinder flow" consists of several sub-projects where the flow during the intake and expansion stroke, the compression stroke before combustion, the flow through the exhaust ports and the flow in the exhaust manifold are studied. The aim is to get a better understanding of how the flow is set up inside the cylinder during the intake and expansion stroke, how the compression stroke influences the tumble and swirl motions as well as the turbulence and how the flow through the exhaust ports can be optimized. The aim of the project is to minimize flow related energy losses and still obtain the desired flow structures in the cylinder. The project area is supported by several different agencies and companies as is shown in the lower right box.

The figure to the right shows the strokes of a four-stroke diesel engine. In the present project we are studying the gas dynamics of the intake, compression and exhaust strokes. Especially the flow through the moving intake and exhaust valves will be studied.

Examples of intake (*right*) and exhaust (*left*) valves are seen below.

Left: The flow inside the cylinder will be investigated with time-resolved, stereoscopic and tomographic particle image velocimetry (PIV) with up to 4 cameras to resolve all three velocity components inside the cylinder.

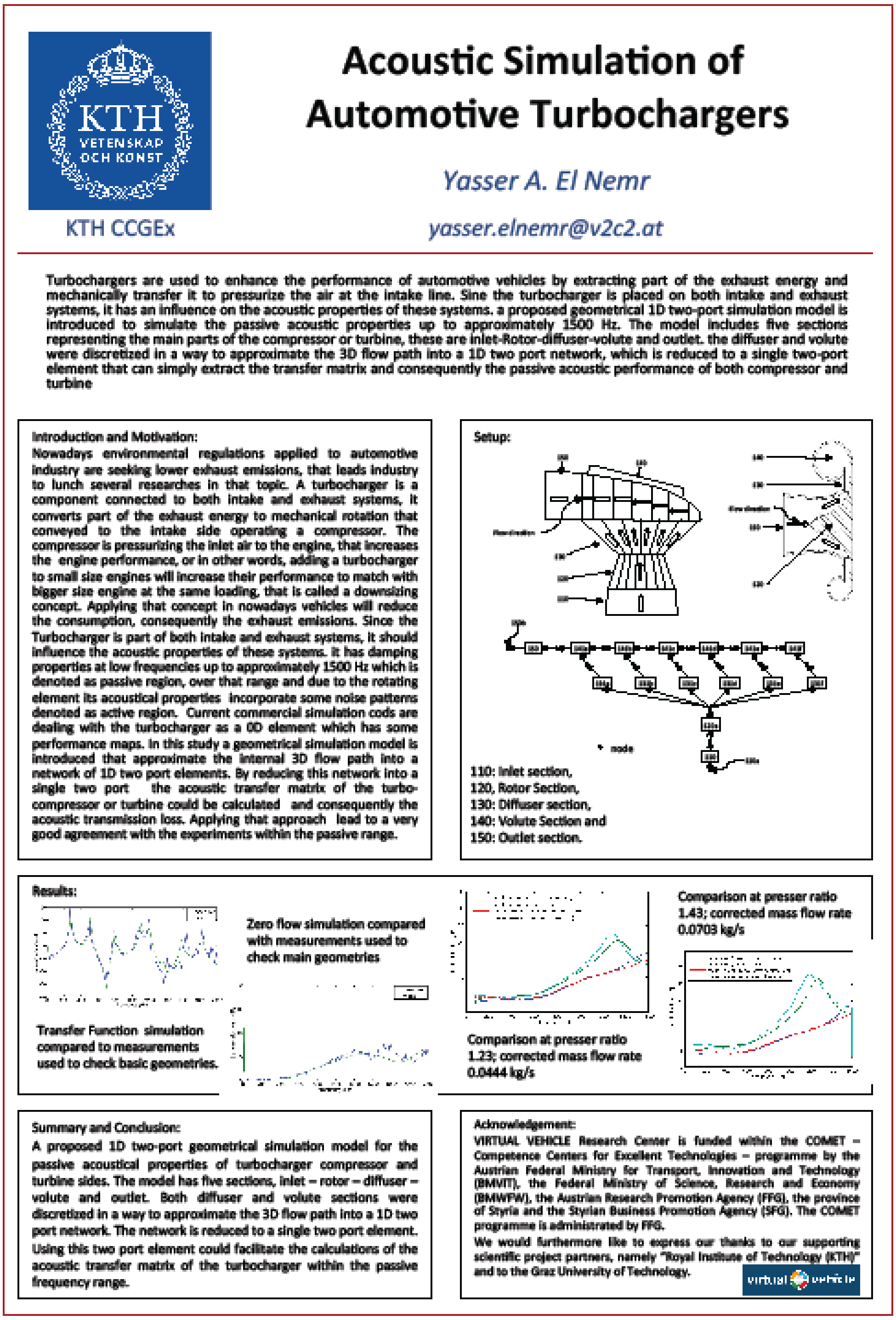
Right: Results from an ongoing MSc thesis project carried out by Jean Rabault showing streamlines (colour coded with velocity) obtained by stereoscopic PIV in a through-flow cylinder, *i.e.* a cylinder without a piston.

Involved scientists and students at KTH:
Prof. Henrik Alfredsson
PhD Ramis Örlü
PhD Nils Tillmark
PhD Anathasia Kalpakli Vester (postdoc)
MSc Andreas Bergqvist (industrial PhD student)
MSc Marcus Winroth (PhD student)
Jean Rabault (MSc thesis student)

Sponsors and collaborators

SCANIA
KTH CCGEx
VOLVO
Energimyndigheten

Bilaga 1



Acoustic Simulation of Automotive Turbochargers

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Turbochargers are used to enhance the performance of automotive vehicles by extracting part of the exhaust energy and mechanically transfer it to pressurize the air at the intake line. Sine the turbocharger is placed on both intake and exhaust systems, it has an influence on the acoustic properties of these systems. a proposed geometrical 1D two-port simulation model is introduced to simulate the passive acoustic properties up to approximately 1500 Hz. The model includes five sections representing the main parts of the compressor or turbine, these are inlet-Rotor-diffuser-volute and outlet. the diffuser and volute were discretized in a way to approximate the 3D flow path into a 1D two port network, which is reduced to a single two-port element that can simply extract the transfer matrix and consequently the passive acoustic performance of both compressor and turbine

Introduction and Motivation:

Nowadays environmental regulations applied to automotive industry are seeking lower exhaust emissions, that leads industry to lunch several researches in that topic. A turbocharger is a component connected to both intake and exhaust systems, it converts part of the exhaust energy to mechanical rotation that conveyed to the intake side operating a compressor. The compressor is pressurizing the inlet air to the engine, that increases the engine performance, or in other words, adding a turbocharger to small size engines will increase their performance to match with bigger size engine at the same loading, that is called a downsizing concept. Applying that concept in nowadays vehicles will reduce the consumption, consequently the exhaust emissions. Since the Turbocharger is part of both intake and exhaust systems, it should influence the acoustic properties of these systems. It has damping properties at low frequencies up to approximately 1500 Hz which is denoted as passive region, over that range and due to the rotating element its acoustical properties incorporate some noise patterns denoted as active region. Current commercial simulation cods are dealing with the turbocharger as a 0D element which has some performance maps. In this study a geometrical simulation model is introduced that approximate the internal 3D flow path into a network of 1D two port elements. By reducing this network into a single two port the acoustic transfer matrix of the turbo-compressor or turbine could be calculated and consequently the acoustic transmission loss. Applying that approach lead to a very good agreement with the experiments within the passive range.

Setup:

110: Inlet section,
120, Rotor Section,
130: Diffuser section,
140: Volute Section and
150: Outlet section.

Results:

Zero flow simulation compared with measurements used to check main geometries

Transfer Function simulation compared to measurements used to check basic geometries.

Comparison at presser ratio 1.43; corrected mass flow rate 0.0703 kg/s

Comparison at presser ratio 1.23; corrected mass flow rate 0.0444 kg/s

Summary and Conclusion:

A proposed 1D two-port geometrical simulation model for the passive acoustical properties of turbocharger compressor and turbine sides. The model has five sections, inlet – rotor – diffuser – volute and outlet. Both diffuser and volute sections were discretized in a way to approximate the 3D flow path into a 1D two port network. The network is reduced to a single two port element. Using this two port element could facilitate the calculations of the acoustic transfer matrix of the turbocharger within the passive frequency range.

Acknowledgement:

VIRTUAL VEHICLE Research Center is funded within the COMET – Competence Centers for Excellent Technologies – programme by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT), the Federal Ministry of Science, Research and Economy (BMWFW), the Austrian Research Promotion Agency (FFG), the province of Styria and the Styrian Business Promotion Agency (SFG). The COMET programme is administrated by FFG.

We would furthermore like to express our thanks to our supporting scientific project partners, namely "Royal Institute of Technology (KTH)" and to the Graz University of Technology.

Bilaga 1

Bilaga 1

KTH CCGEx

Pulsating flow in complex channels– experiments

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Abstract

The air flowing through the exhaust manifold of the internal combustion engine to the inlet of the turbocharger is highly pulsating and turbulent. Travelling through curved pipe sections the air enters the turbine under the effect of centrifugal (from the acute curvature), inertia and viscous forces resulting in a three-dimensional, non-symmetric flow field. Additionally, vortical structures are being formed due to the co-existence of these forces which change shape and behaviour under a pulse period. Although this complex flow field is directly connected to the inflow conditions to the turbocharger and modelling of such flows could improve the efficiency of the engine, it is yet far from being understood.

Background

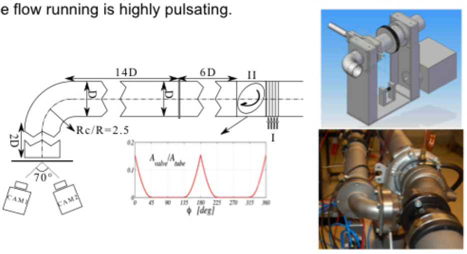
The gas flow in the exhaust system of an internal combustion engine is quite complex due to several complications such as complex geometry (bends, junctions), pulsating flow, compressibility, high temperatures, partly transonic flow etc. In order to understand how the flow to the turbine should be modelled a good model of the flow into and in the exhaust manifold, as well as to the turbine needs to be established. Numerical studies of such flow systems are/have been studied within KTH CCGEx.

Experimental Techniques

Due to the high complexity of the flow field under study, different experimental techniques need to be employed and tested in order to fully understand the different flow phenomena under highly pulsatile and turbulent conditions.

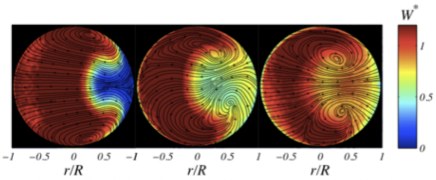
Hot- and cold-wire anemometry (HWA/CWA) have been employed in order to obtain information on the statistics of the flow with high time resolution. For this purpose an in-house automatic traversing mechanism (depicted to the right). Laser Doppler Velocimetry (LDV) measurements have been supplemented for validation purposes, while Stereoscopic Particle Image Velocimetry (S-PIV) measurements have been performed in order to obtain simultaneously the three velocity components and capture the secondary motions in a cross-sectional field.

Additional measurements using the vortex mass flow meter, developed by Laurantzon et al. [Meas Sci Technol **21**:123001 (2010)], were performed in order to determine the phase-resolved turbine maps when a sharp bend is mounted at the inlet of the turbine and the flow running is highly pulsating.

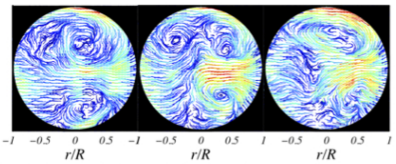


(Left) Geometrical configuration and camera set up for the S-PIV and LDV measurements. D=40.5mm, R_c=51mm. I) smoke injection inlet, II) rotating valve. (Right, Top) Automatic traversing mechanism for the rotation of the HW/CW measurements. (Right, Bottom) Pipe bend (D=40.5mm, Rc=51mm) mounted at the inlet of the turbocharger (Garrett) for the pressure ratio measurements.

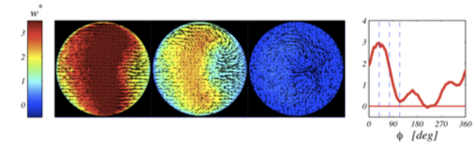
Impressions



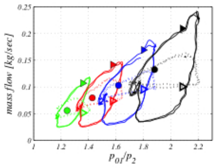
Time-averaged velocity flow field at 0.2 D (left), 1 D (middle) and 2 D (right) downstream the 90 ° pipe bend at a Dean number De=1.5x10^4. The streamwise component is shown as the background contour map while the in-plane components as streamlines. Quantities with asterisk indicate scaling by the bulk speed.



Snapshots at various time instances of the in-plane velocity vector field 2 D downstream the pipe bend for De=1.5x10^4.



Phase averaged flow field at a Womersley number of α=30 and De=1.5x10^4 for the 2 D downstream station from the pipe bend. Right: Phase averaged streamwise velocity (red line) at the centerline of the pipe. The phase angle corresponding to the shown phase averages is indicated through the dashed lines.



Turbine map for 55 (green), 80 (red), 105 (blue) & 130 g/sec (black) at 40 Hz pulsation frequency. Solid lines: inflow, dashed lines: outflow. Circles indicate average values

Presentations and Publications:

[1] Kalpakli, A., Örlü, R., Tillmark, N. & Alfredsson, P.H. 2010 *Experimental investigation on the effect of pulsations on turbulent flow through a 90 degrees pipe bend*, ICJWSF, Sept 27-30 2010, Cincinnati, USA.
[2] Kalpakli, A., Örlü, R., Tillmark, N. & Alfredsson, P.H. 2011 *Pulsatile turbulent flow through pipe bends at high Dean and Womersley numbers*, ETC13, 12-15 Sept 2011, Warsaw, Poland.
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[4] Kalpakli, A., Örlü, R. & Alfredsson, P.H. 2011 *Reynolds and swirl number effects on turbulent pipe flow in a 90 degree pipe bend,* APS 20-22 Nov 2011, Baltimore, USA
[5] Kalpakli, A., Örlü, R. & Alfredsson, P.H. 2011 *Dancing in the pipe*, selected to appear on the online gallery of fluid dynamics (APS virtual pressroom)
[6] Kalpakli, A., Örlü, R., Tillmark, N. & Alfredsson, P.H. 2012 *Experimental investigation on the effect of pulsations on exhaust–manifold related flows aiming at improved efficiency*, (submitted) 10th Int. Conf. Turbochargers and Turbocharging (ImechE), May 15-16 2012, London, England

Bilaga 1

KTH CCGEx

Pressure sensitive paint (PSP) for rotating components

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Abstract

This project aims at solving the problem of measuring pressure in high-speed rotational components (i.e. IC-engine turbo-chargers). The measurement technique chosen is a fast type pressure sensitive paint (PSP), an optical technique measuring pressure through luminescent quenching by oxygen. It has been shown that fast PSP is a promising technique that can produce fast, spatial resolved and accurate pressure measurements in unsteady flows.

Background

The pressure distribution on rotating surfaces, as for instance the turbo-charger compressor blades, is in practice impossible to measure using conventional pressure transducers. A new method is needed in order to be able to map the pressure distribution in these applications in order to make detailed investigations of rotational stall and surge phenomena.

Fast types of pressure sensitive paint (PSP) show promise in providing a solution to this issue, as well as a way of analyzing other engine related internal flows, such as pulsating flow in complex pipe systems.

Method

PSP is an optical technique to measure surface pressure in aerodynamic applications. It is composed of sensor molecules, or luminophores, embedded in an oxygen permeable binder. The luminophores are excited by light of appropriate wavelengths and through the mechanics of photoluminescence, light is emitted at lower energies. The presence of oxygen reduces the quantum yield of the system, relating air pressure and luminescent intensity. The basic experimental setup is illustrated in figure 1.

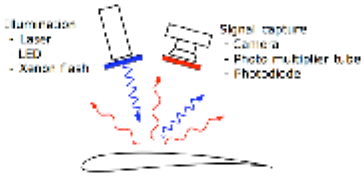

Figure 1. Basic experimental setup of PSP.

Due to the relatively slow diffusion rate of oxygen in the binder, traditional PSP is only able to resolve pressure fluctuations in the sub-Hz range. One method of overcoming this issue is by adding ceramic particles to the mix, effectively decreasing the binder thickness while maintaining the surface density of the luminophores. This mixture is a fast type PSP called polymer/ceramic pressure sensitive paint (PC-PSP) and is illustrated in figure 2.

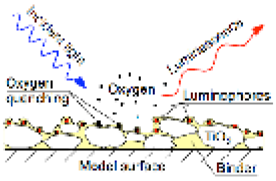

Figure 2. Schematic of conventional PSP.

Results

A combined pressure and temperature computer controlled chamber for calibration of PSP has been designed. The chamber has been tested with respect to temperature and pressure control. The temperature can be set to an accuracy better than 0.3°C.

A formula of fast responding PSP has first been statically calibrated in the chamber and thereafter run in a shock tube in order to find out the dynamic pressure response of the paint. The response time (illustrated in figure 3) was found to be about 0.3 ms. A method to evaluate the dynamic pressure response of the paint has been developed and has been presented at ICFD 2010 and at a workshop at JAXA in November 2010 (both in Japan).

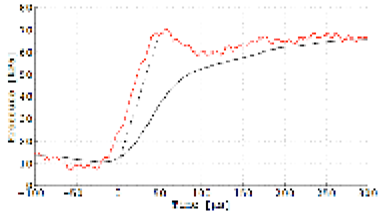

Figure 3. Ramp response from PC-PSP in shock tube showing estimated pressure (–), measured pressure (–) and corrected pressure(–).

The above-mentioned formula has been used to measure wall pressure inside a y-junction at periodic pressure fluctuations of between 40 and 80 Hz. An averaging phase locking technique has been used to increase the signal to noise ratio of the fast paint formulation and the results has been presented at Svenska mekanikdagar in June 2011 and at ISAIF10 in July 2011. An image showing a pressure pulse entering the y-junction (from the 45° branch) is shown in figure 4.

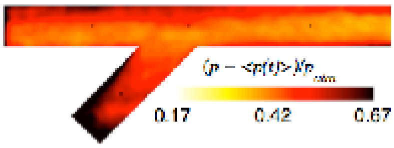

Figure 4. A pressure pulse entering the y-junction from the 45° branch.

Additional information

TeknL is planned to 2011/2012.
This project is supported by the Swedish Energy Agency.

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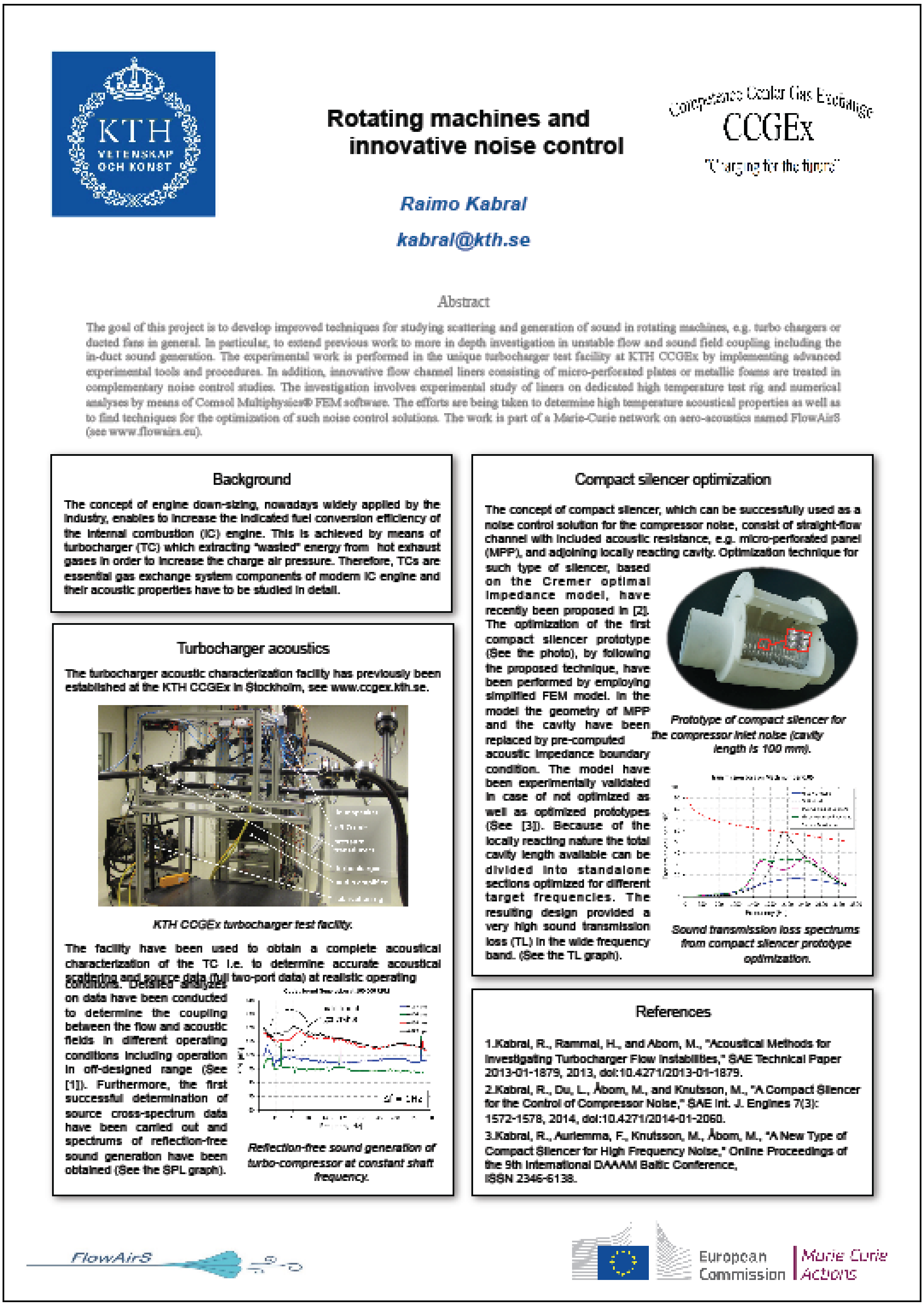

Rotating machines and innovative noise control

Raimo Kabral

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Abstract

The goal of this project is to develop improved techniques for studying scattering and generation of sound in rotating machines, e.g. turbo chargers or ducted fans in general. In particular, to extend previous work to more in depth investigation in unstable flow and sound field coupling including the in-duct sound generation. The experimental work is performed in the unique turbocharger test facility at KTH CCGEx by implementing advanced experimental tools and procedures. In addition, innovative flow channel liners consisting of micro-perforated plates or metallic foams are treated in complementary noise control studies. The investigation involves experimental study of liners on dedicated high temperature test rig and numerical analyses by means of Comsol Multiphysics® FEM software. The efforts are being taken to determine high temperature acoustical properties as well as to find techniques for the optimization of such noise control solutions. The work is part of a Marie-Curie network on aero-acoustics named FlowAirS (see www.flowairs.eu).

Background

The concept of engine down-sizing, nowadays widely applied by the industry, enables to increase the indicated fuel conversion efficiency of the internal combustion (IC) engine. This is achieved by means of turbocharger (TC) which extracting "wasted" energy from hot exhaust gases in order to increase the charge air pressure. Therefore, TCs are essential gas exchange system components of modern IC engine and their acoustic properties have to be studied in detail.

Turbocharger acoustics

The turbocharger acoustic characterization facility has previously been established at the KTH CCGEx in Stockholm, see www.ccgex.kth.se.

KTH CCGEx turbocharger test facility.

The facility have been used to obtain a complete acoustical characterization of the TC i.e. to determine accurate acoustical scattering and source data (full two-port data) at realistic operating conditions. Detailed analyzes on data have been conducted to determine the coupling between the flow and acoustic fields in different operating conditions including operation in off-designed range (See [1]). Furthermore, the first successful determination of source cross-spectrum data have been carried out and spectrums of reflection-free sound generation have been obtained (See the SPL graph).

Reflection-free sound generation of turbo-compressor at constant shaft frequency.

Compact silencer optimization

The concept of compact silencer, which can be successfully used as a noise control solution for the compressor noise, consist of straight-flow channel with included acoustic resistance, e.g. micro-perforated panel (MPP), and adjoining locally reacting cavity. Optimization technique for such type of silencer, based on the Cremer optimal impedance model, have recently been proposed in [2]. The optimization of the first compact silencer prototype (See the photo), by following the proposed technique, have been performed by employing simplified FEM model. In the model the geometry of MPP and the cavity have been replaced by pre-computed acoustic impedance boundary condition. The model have been experimentally validated in case of not optimized as well as optimized prototypes (See [3]). Because of the locally reacting nature the total cavity length available can be divided into standalone sections optimized for different target frequencies. The resulting design provided a very high sound transmission loss (TL) in the wide frequency band. (See the TL graph).

Prototype of compact silencer for the compressor inlet noise (cavity length is 100 mm).

Sound transmission loss spectrums from compact silencer prototype optimization.

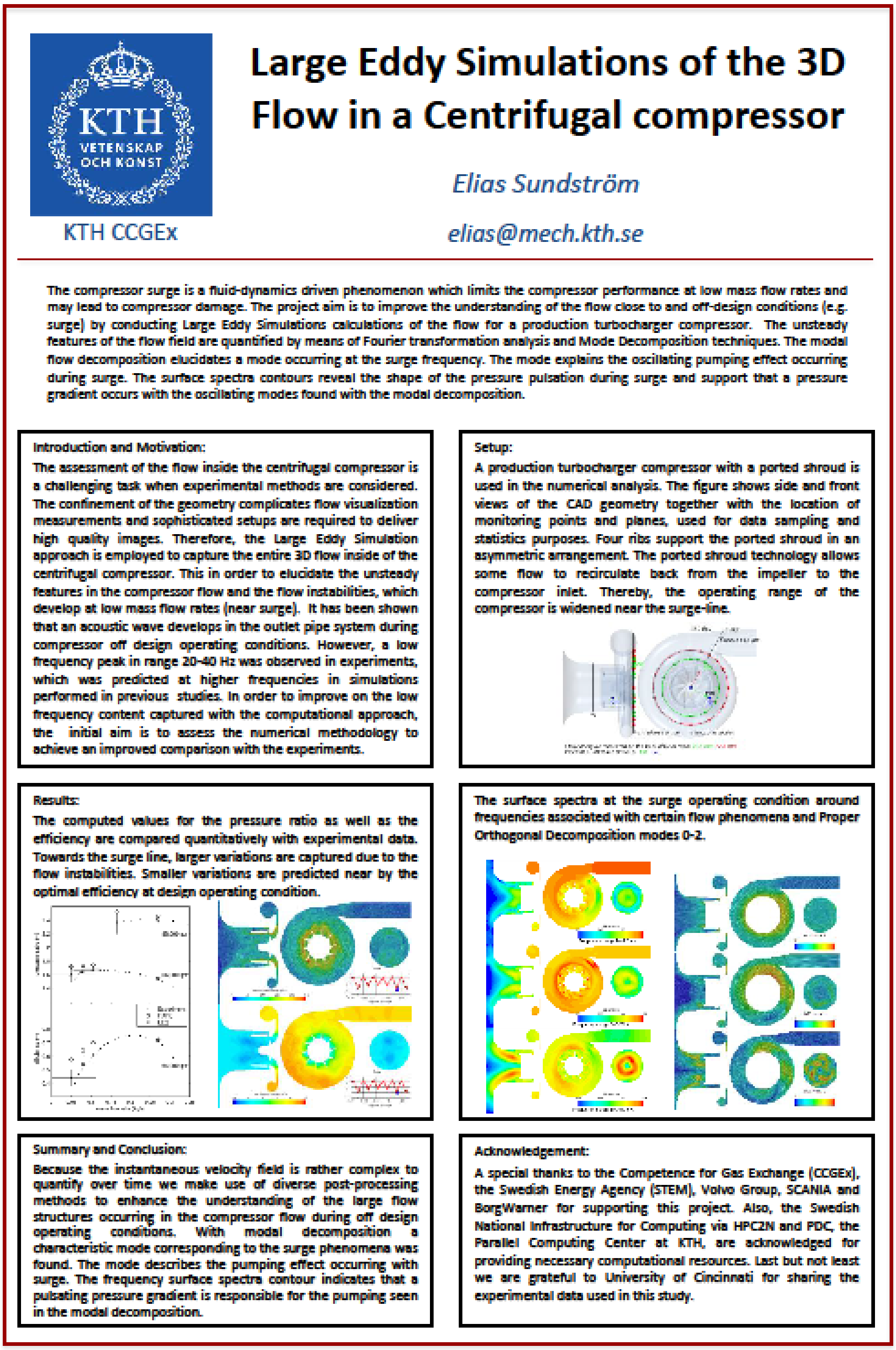
References

1.Kabral, R., Rammal, H., and Abom, M., "Acoustical Methods for Investigating Turbocharger Flow Instabilities," SAE Technical Paper 2013-01-1879, 2013, doi:10.4271/2013-01-1879.

2.Kabral, R., Du, L., Åbom, M., and Knutsson, M., "A Compact Silencer for the Control of Compressor Noise," SAE Int. J. Engines 7(3): 1572-1578, 2014, doi:10.4271/2014-01-2060.

3.Kabral, R., Auriemma, F., Knutsson, M., Åbom, M., "A New Type of Compact Silencer for High Frequency Noise," Online Proceedings of the 9th International DAAAM Baltic Conference, ISSN 2346-6138.

Bilaga 1



Large Eddy Simulations of the 3D Flow in a Centrifugal compressor

KTH CCGEx

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The compressor surge is a fluid-dynamics driven phenomenon which limits the compressor performance at low mass flow rates and may lead to compressor damage. The project aim is to improve the understanding of the flow close to and off-design conditions (e.g. surge) by conducting Large Eddy Simulations calculations of the flow for a production turbocharger compressor. The unsteady features of the flow field are quantified by means of Fourier transformation analysis and Mode Decomposition techniques. The modal flow decomposition elucidates a mode occurring at the surge frequency. The mode explains the oscillating pumping effect occurring during surge. The surface spectra contours reveal the shape of the pressure pulsation during surge and support that a pressure gradient occurs with the oscillating modes found with the modal decomposition.

Introduction and Motivation:

The assessment of the flow inside the centrifugal compressor is a challenging task when experimental methods are considered. The confinement of the geometry complicates flow visualization measurements and sophisticated setups are required to deliver high quality images. Therefore, the Large Eddy Simulation approach is employed to capture the entire 3D flow inside of the centrifugal compressor. This in order to elucidate the unsteady features in the compressor flow and the flow instabilities, which develop at low mass flow rates (near surge). It has been shown that an acoustic wave develops in the outlet pipe system during compressor off design operating conditions. However, a low frequency peak in range 20-40 Hz was observed in experiments, which was predicted at higher frequencies in simulations performed in previous studies. In order to improve on the low frequency content captured with the computational approach, the initial aim is to assess the numerical methodology to achieve an improved comparison with the experiments.

Results:

The computed values for the pressure ratio as well as the efficiency are compared quantitatively with experimental data. Towards the surge line, larger variations are captured due to the flow instabilities. Smaller variations are predicted near by the optimal efficiency at design operating condition.

Summary and Conclusion:

Because the instantaneous velocity field is rather complex to quantify over time we make use of diverse post-processing methods to enhance the understanding of the large flow structures occurring in the compressor flow during off design operating conditions. With modal decomposition a characteristic mode corresponding to the surge phenomena was found. The mode describes the pumping effect occurring with surge. The frequency surface spectra contour indicates that a pulsating pressure gradient is responsible for the pumping seen in the modal decomposition.

Setup:

A production turbocharger compressor with a ported shroud is used in the numerical analysis. The figure shows side and front views of the CAD geometry together with the location of monitoring points and planes, used for data sampling and statistics purposes. Four ribs support the ported shroud in an asymmetric arrangement. The ported shroud technology allows some flow to recirculate back from the impeller to the compressor inlet. Thereby, the operating range of the compressor is widened near the surge-line.

The surface spectra at the surge operating condition around frequencies associated with certain flow phenomena and Proper Orthogonal Decomposition modes 0-2.

Acknowledgement:

A special thanks to the Competence for Gas Exchange (CCGEx), the Swedish Energy Agency (STEM), Volvo Group, SCANIA and BorgWarner for supporting this project. Also, the Swedish National Infrastructure for Computing via HPC2N and PDC, the Parallel Computing Center at KTH, are acknowledged for providing necessary computational resources. Last but not least we are grateful to University of Cincinnati for sharing the experimental data used in this study.

Bilaga 1

In-cylinder flow

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KTH CCGEx

Abstract

As the emission legislation is getting tougher and tougher for car manufacturers in Europe and in other parts of the world the need for newer and more efficient engines has risen. In-cylinder flow involves different scales and structures as well as moving geometries and unstationary boundary conditions. Additionally, in-cylinder flow has a profound effect on engine emissions and fuel consumption. Therefore, understanding generation of these structures and the effect of compression is essential for reducing engine emissions.

Background

In-cylinder flow can be divided into several distinct phases. The flow enters the cylinder during the intake phase, forming an unsteady hollow jet around the valves. The unsteady jet creates a very turbulent in-cylinder flow field effectively mixing residual gases with fresh air. The incoming jet is also responsible for creating the large scale structures, swirl and tumble. During late part of intake and early compression the small scale turbulence settles while large scale structures remain.

During the second half of the compression any remaining turbulence will be amplified. In addition, swirl and tumble are affect by the changing geometry. Generally, swirl angular momentum is assumed to survive compression while tumble momentum is know to breakdown. If the piston and cylinder head is designed to produce squish (Pressing flow inwards by a rapid reduction of volume close to the cylinder walls), this will produce an organized motion creating turbulence and have dynamical effect on swirl and tumble. During combustion (and definitely from a Diesel spray) turbulence will increase and affect the large scale motions. During the power stroke turbulence is sharply suppressed and at Bottom Dead Center (BDC) most of it has settled.

Focus of this project is to understand the creation and evolution of large scale structures and turbulence from the intake up to start of injection. In addition, identify which parameters can be adjusted to obtain desired flow field.

Method

In-cylinder measurements are very difficult due to a number of reasons as well as the difficulty to change the geometry and extract the effect on specific parameters. Therefore, Large Eddy Simulations (LES) has been chosen as the main method in this project.

Initially, flow structures created during intake were studied using LES coupled with Particle Image Velocimetry (PIV) in a steady swirl test rig. Thereafter, the effect of compression on a swirling/tumbling flow has been studied in a simplified engine.

Swirl Test rig

Simplified engine and initial flow field

Results, Swirl test rig

Comparison between LES simulations and PIV experiments show qualitatively good agreement. It is shown that at low valve lifts the fluctuations in swirl is greater than the mean swirl number. In-cylinder turbulence created during intake is axisymmeteric with one dominant direction.

Comparison PIV LES

Fluctuation in swirl number, 5 mm valve lift (PIV)

Results, Compression swirling/tumbling flow

It is found that vorticity-dilatation is responsible for redirecting flow kinetic energy introduced by the piston into small scale turbulence. The conversion is most rapid around the time of maximum dilatation.

Mid plane vorticity magnitude, at different crank angles

Bilaga 1

Impedance eduction and validation

KTH CCGEx

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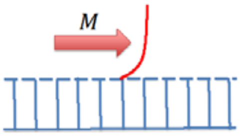
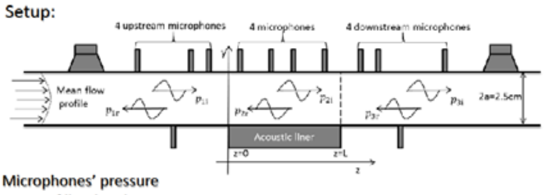
Various liner structures are commonly used in noise control devices for duct systems. Typical applications include wall treatments for vehicle intake or exhaust system. The presence of a grazing flow in such systems makes the acoustic behavior much more complex due to the interaction between sound and flow in thin turbulent boundary layer over the lined wall. Either the systematic acoustic prediction or liner optimization necessities the progress in impedance measurement method by including the effect of the grazing flow.

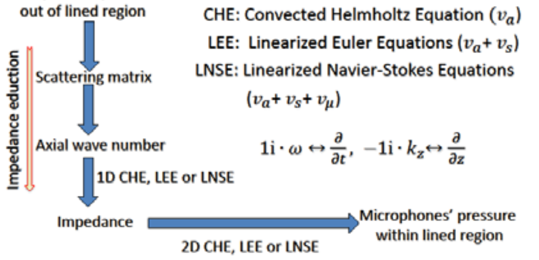
Introduction and Motivation:

Impedance($Z=p/v$) in frequency domain is a very important description for boundary conditions in acoustic/unsteady flow simulation, where p and v are the pressure and normal unsteady flow velocity over the 'soft' wall, which here is a lined wall as shown below. The unsteady flow velocity comes from three contribution sources: the acoustic part v_a, which can propagate far away; the first hydrodynamic part v_s because of the mean shear flow and the second hydrodynamic part v_μ because of acoustic shear flow near the non-slip boundary condition for the reason of viscosity. Our project is to qualify and compare their contributions to impedance based on experimental and numerical analysis.



Setup:





Microphones' pressure out of lined region

Impedance eduction

Scattering matrix

Axial wave number

1D CHE, LEE or LNSE

Impedance

2D CHE, LEE or LNSE

Microphones' pressure within lined region

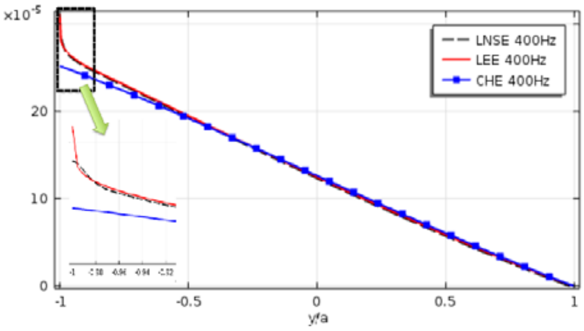
CHE: Convected Helmholtz Equation (v_a)

LEE: Linearized Euler Equations ($v_a + v_s$)

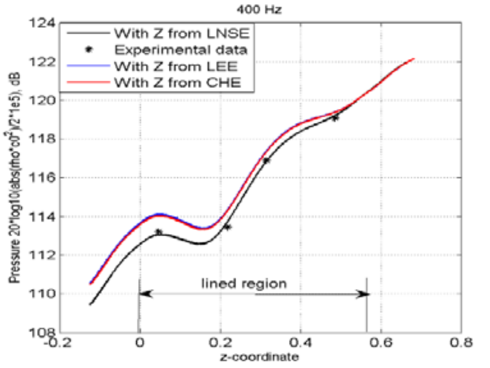
LNSE: Linearized Navier-Stokes Equations ($v_a + v_s + v_\mu$)

$$1\mathrm{i}\cdot\omega \leftrightarrow \frac{\partial}{\partial t},\quad -1\mathrm{i}\cdot k_z \leftrightarrow \frac{\partial}{\partial z}$$

Results:



Unsteady flow velocity along the tube cross section



Pressure levels from 2D LNSE with different impedance results

Summary and Conclusion:

Acoustic impedance can be influenced by the shear flow and viscosity within the thin boundary layer. Variation of normal velocity or displacement is frequency dependent, which means neither velocity continuity nor displacement continuity sustains within the boundary layer. The results highlight that the assumption for impedance eduction should be consistent with that in the propagation code, for example LNSE code should couple with impedance results including viscosity.

Acknowledgement:

Supervisor: Prof. Hans Bodén, Prof. Mats Åbom

Funding: KTH-CSC Programme

Detailed modeling of single & double turbines

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KTH CCGEx

Abstract

As the emission legislation is getting tougher and tougher for car manufacturers in Europe and in other parts of the world the need for newer and more efficient engines has risen. One way of dealing with the emission problem is downsizing the engine; a smaller engine has less geometrical losses i.e. frictional losses. One effective way of downsizing an engine is to give it a turbocharger. A turbocharger increases the engine efficiency and power output without increasing the fuel consumption or emissions as much.

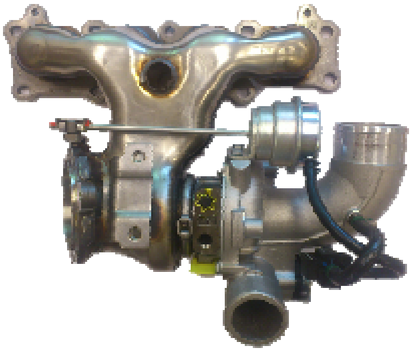
Background

Turbo-charging (TC) is essential for enabling down-sizing and for enabling emission reduction while maintaining or enhancing combustion efficiency. The energy in the hot exhaust gases can be utilized in order to compress the air that is provided to the cylinders and thereby the utilization of the combustion chamber volume is enhanced. For faster response and for better operation over a wider range of engine load one has proposed using 2 staged TC (for example in tandem). This project shall explore some issues that can be related to such systems.

When doing calculations on turbochargers in the industry today one is often restricted to 1D simulation tools in which the turbochargers are implemented as maps. These maps are commonly from the manufacturer and measured at constant massflow and low temperatures. This is very far from the environment the turbochargers are in, where the flow is highly pulsatile and the temperatures are much higher. Part of this project is aimed at looking at the differences between steady flow and pulsating flow and how much the turbine performance is changed by this.

Method

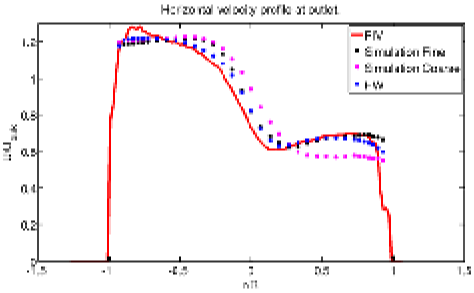
For this project Unsteady RANS and Large Eddy Simulations are being performed on a single stage turbine. Both steady and pulsating flow is being simulated and different inflow conditions are being applied.
For the steady cases experiments have been performed at the Saab Gas-stand in Trollhättan where a wide range of flow conditions were measured extensively, both in hot and cold conditions. For pulsating flow no measurements are currently available for the same geometry.



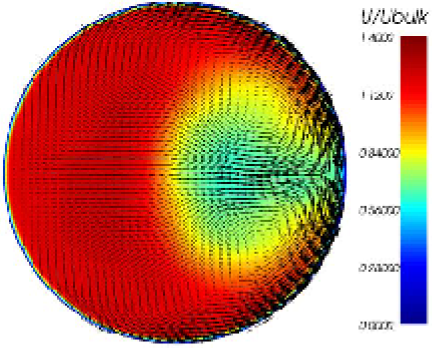
To validate the simulation software an easier case has been setup where flow in a bended pipe is being studied. Within the center measurements of the same case has been performed so the data available for validation is good and easily accessible.

Results

For the bended pipe flow simulations comparisons have been made between LES and experiments (PIV and HWA).



When comparing the simulations (2 grids shown) with both PIV and HWA good agreement is seen. HWA-data courtesy of Sohrab Sattarzadeh, PIV-data courtesy of Athanasia Kalpakli.



Mean velocity divided by bulk velocity at the outlet after the pipe bend. Both dean vortices can be seen and scalar levels are quantitatively similar to those of the PIV.

Conclusions

For the bended pipe good agreement between measurements and simulations can be shown for the outlet velocity profile.
For the bended pipe simulations the software is predicting the flow accurately compared to experiments.

Bilaga 1

KTH-CCGEx

Waste Heat Recovery on Internal Combustion Engines by Using Turbines

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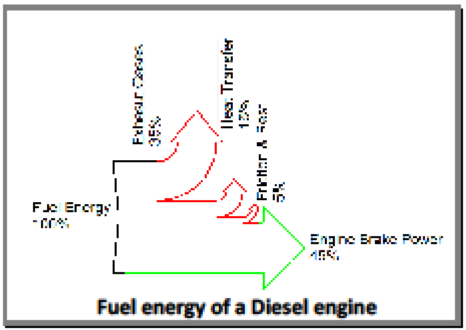
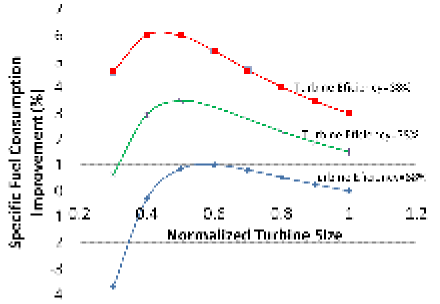
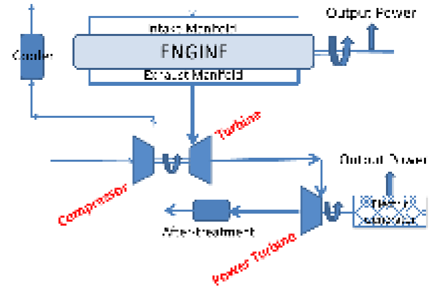
Nowadays turbomachines are widely used on internal combustion engines. However, turbomachines and reciprocating engines are different in nature and it is often a challenge to match a turbomachine with an internal combustion engine with high efficiency in a wide range of operation. Reducing fuel consumption of engines is one of the main issues in research and development of internal combustion engines. Almost one-third of fuel energy in internal combustion engines is wasted through the exhaust flow. One way to recover this otherwise wasted heat is to apply turbines on the exhaust system; however this makes a back-pressure for the engine which has a negative impact on the engine fuel consumption. The aim of this research is to show the potential of using turbines as a waste heat recovery system on internal combustion engines in combination of advanced technologies.



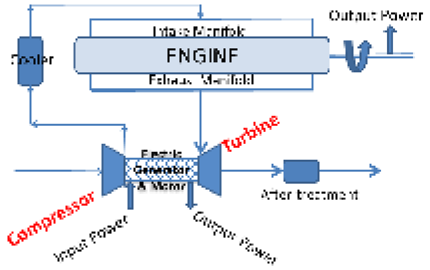
Fuel energy of a Diesel engine



Fuel consumption of a turbocompound engine vs. turbine size and efficiency



Two-stage turbocompounding



Single-stage turbocompounding

Bilaga 1

Interaction between ICE Exhaust Pulses and Turbine

KTH CCGEX

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The fuel efficiency of the turbocharged internal combustion engine depends on low pumping losses and high turbine efficiency. The aim of this project is to improve the understanding of how the pulsating exhaust flow from the internal combustion engine interacts with the exhaust turbine. The interaction will be studied with the help of 1-D simulation software. The engine model will be developed from experiments on steady-state and dynamic flow benches, and a single-cylinder engine equipped with a variable valve train.

Introduction and Motivation:

To simulate the performance of an internal combustion engine it is important to model the gas exchange accurately. The problem is that it is hard to replicate the operating conditions in the cylinder of a running engine. In industry standard 1-D engine simulation software, the flow through the exhaust valves are extrapolated from measurements done in a steady-state air flow bench at low pressure ratios. This is far from the real conditions in an engine and will likely introduce an error of unknown size. To improve the modelling of exhaust gas mass flow, measurements and flow characterization will be done on a cylinder head in cooperation another PhD student, Marcus Winroth, at the department of mechanics at KTH.

Despite the exhaust gas flow from the internal combustion engine being pulsatile the majority of turbine development are done under the assumption of constant flow. This suggests that it is possible to improve the turbine efficiency if the engine and turbocharger were developed together.

Setup:

- Steady-state air flow bench
- Dynamic air flow bench (Pressurized chamber mounted to a single-cylinder head)
- Heavy-duty single-cylinder engine with a variable hydraulic valve train.

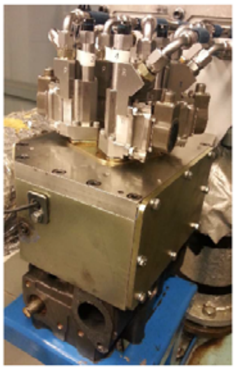


Fig 1. Hydraulic valve train mounted on cylinder head.

Method (draft):

Estimate mass flow rate through exhaust valves either through direct flow measurement or indirect from cylinder pressure

1. Steady-state air flow bench
   - Reference case: Low pressure ratios over the valves (standard industry practice).
   - High pressure ratio over the valves (Pressure ratio depending on compressor capacity)

2. Dynamic air flow bench (Pressurized chamber mounted to a single-cylinder head)
   - Vary the valve opening speed, valve lift heights, number of active valves

3. Single-cylinder engine tests
   - Motored (no combustion) – evaluate the effect of moving piston and in-cylinder flow
   - Combustion – realistic conditions at exhaust valve opening

4. Multi-cylinder engine tests
   - Estimate influence of cylinder interaction

Summary and Conclusion:

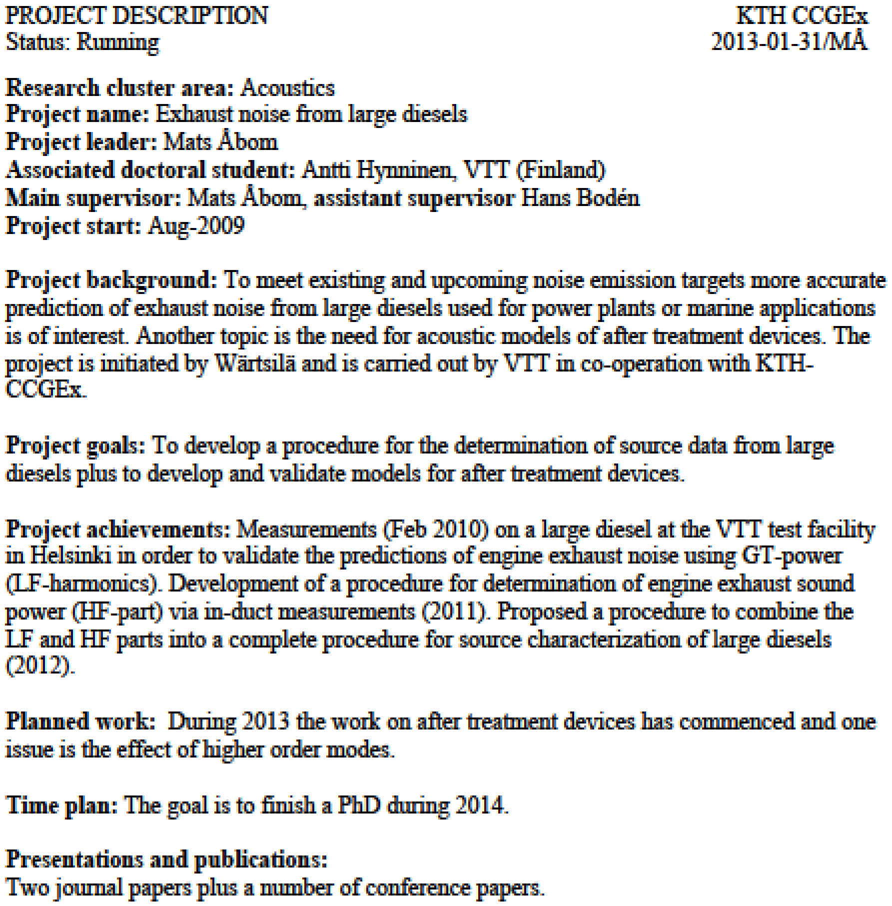
Not available (new project)

Acknowledgement:

Supervisor: Andreas Cronhjort

Swedish Energy Agency SCANIA VOLVO

Bilaga 1



PROJECT DESCRIPTION
Status: Running

KTH CCGEx
2013-01-31/MÅ

Research cluster area: Acoustics
Project name: Exhaust noise from large diesels
Project leader: Mats Åbom
Associated doctoral student: Antti Hynninen, VTT (Finland)
Main supervisor: Mats Åbom, **assistant supervisor** Hans Bodén
Project start: Aug-2009

Project background: To meet existing and upcoming noise emission targets more accurate prediction of exhaust noise from large diesels used for power plants or marine applications is of interest. Another topic is the need for acoustic models of after treatment devices. The project is initiated by Wärtsilä and is carried out by VTT in co-operation with KTH-CCGEx.

Project goals: To develop a procedure for the determination of source data from large diesels plus to develop and validate models for after treatment devices.

Project achievements: Measurements (Feb 2010) on a large diesel at the VTT test facility in Helsinki in order to validate the predictions of engine exhaust noise using GT-power (LF-harmonics). Development of a procedure for determination of engine exhaust sound power (HF-part) via in-duct measurements (2011). Proposed a procedure to combine the LF and HF parts into a complete procedure for source characterization of large diesels (2012).

Planned work: During 2013 the work on after treatment devices has commenced and one issue is the effect of higher order modes.

Time plan: The goal is to finish a PhD during 2014.

Presentations and publications:
Two journal papers plus a number of conference papers.

Bilaga 1

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KTH CCGEx

Flow and Heat Transfer Effects on the Efficiency of a Radial Turbine

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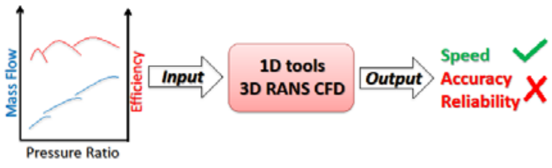
The project aims to investigate by Large Eddy Simulations (LES) the pulsatile flow effects on the efficiency of a radial turbine of an ICE turbocharging system. The complex exhaust manifold will be integrated with the turbine and the heat transfer problem will be considered. The study targets to: 1) enhance the understanding of the pulsatile exhaust flow and its interaction with the turbine for a better usage of the exhaust flow energy available to be used (exergy), 2) provide assessment of the exhaust system in an integrated manner for a realistic quantification of turbine's performance and implications on engine efficiency, and 3) provide fundamental knowledge on how the heat transfer in the exhaust manifold and turbine is affected by the flow complexity. The outcomes of the study will serve as guidelines for developing more efficient turbocharging systems (with extended operating range) for improved engine efficiency.

Introduction and Motivation:

The common practice in evaluating the turbocharger's turbine in Internal Combustion Engines (ICE) is done by performing 1D estimations of performance parameters or 3D RANS simulations. Both methods are based on the steady-state assumption. However, the flow in the exhaust manifold is highly pulsating and literature showed that such conditions have significant effects on the turbine performance [Hellström & Fuchs 2010]. *Moreover, the heat transfer problem is not considered and the effects are unknown.*



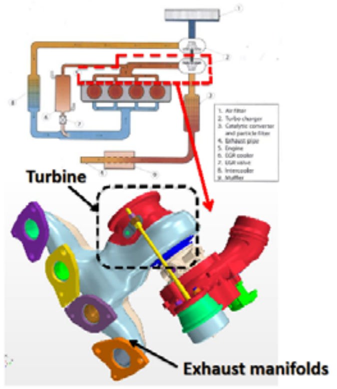
Common practice in evaluation of turbocharging system

Goals:

- **Phase 1** Improve understanding of the pulsating flow in complex manifolds and the effect on heat transfer
- **Phase 2** Characterization of the pulsating exhaust flow effects (different valve strategies) on turbocharger's efficiency
- **Phase 3** Understanding the reason for the failure of 1D and steady-state based tools for off-design operating conditions
- **Phase 4** Assessment of heat transfer and related looses for unsteady, pulsating, non-isothermal flows in the exhaust manifold and turbine of an ICE

Research activities:

1. Target device- Borg Warner turbocharger



2. Research Strategy

Phase 1
- Quantify the exhaust flow characteristics in the exhaust manifold under steady and pulsating (different amplitudes, frequencies and pulse shapes) specific engine-like conditions
- Characterize the flow structures in the exhaust flow field by using mode decomposition techniques

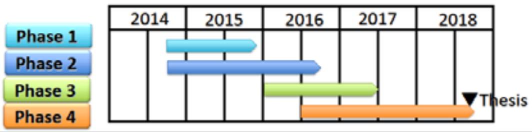
Phase 2
- Assess turbine's flow characteristics and performance under stable and unstable off-design conditions
- Characterize the turbine flow by using LES and mode decomposition techniques (selective points on performance map)

Phase 3
- Characterize the system using 1D modelling and steady-state flow solvers
- Provide models for flow losses in turbine & volute

Phase 4
- Assessment of heat transfer effects computationally.

Expected Outcomes:

The different working packages are expected to be completed according to the time line bellow. It is expected that the project will provide directions for design of exhaust port/manifold and guidelines for exhaust valve strategies that will enable maximization of exhaust flow's exergy.



Energimyndigheten
VOLVO
SCANIA
BorgWarner

Bilaga 1

Bilaga 1