Synergy of the main technologies supported downsized engine

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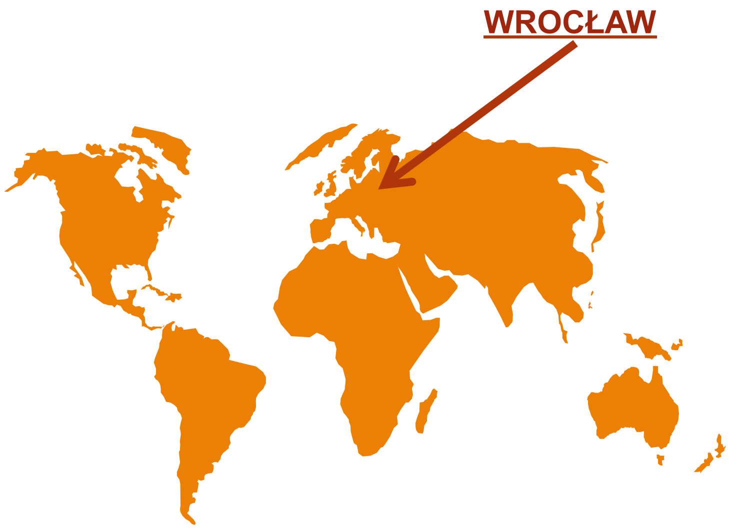
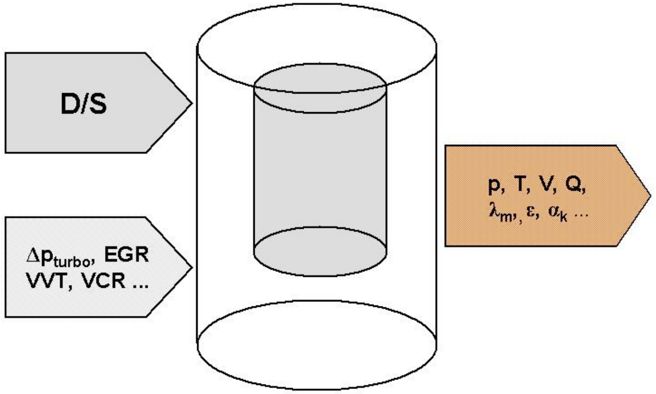
Agenda

- What is downsizing ?
- Why does downsizing use?
- How can downsizing realize ?
- Geometry and supported technologies.
- Baseline engine vs. downsized mix engine.



In global terms, transport has a significant share in the production of CO_2, approaching the level of 30%, as the combustion engine still remains the dominant source of drive power, and in principle, it is responsible for producing carbon dioxide. That indicates the presence of a real threat to the existence of transport or the necessity of its significant reduction and it has an impact on countries' economies and politics. For these reasons automotive research centers and academic institutions worldwide organize numerous projects aimed at improvements in the design of combustion engines.

Downsizing is one of the latest trends in development. It means reducing the engine displacement while maintaining or increasing its performance. The downsizing concept incorporates a reduction in fuel consumption, and hence, the decreased emission of carbon dioxide to the atmosphere.



What ?

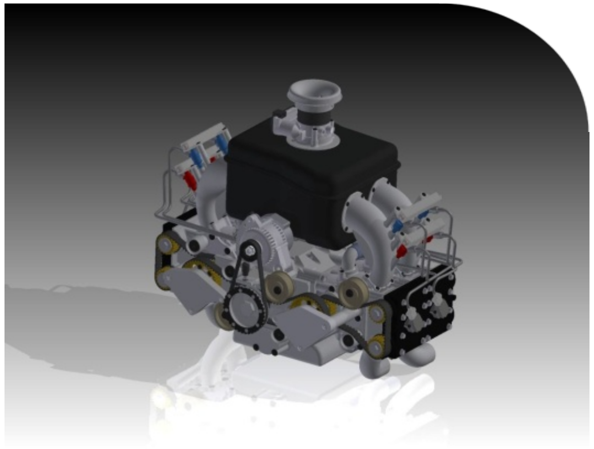
Consideration example due to author’s research

If a reduction in CO_2 at the level of 20%, resulting from the implementation of the concept of combustion engine downsizing (which corresponds to a reduction in displacement by about 30%), is adopted for all vehicles operated on the routes Wroclaw – Dresden – Prague, during one day, the ecological effect connected with the decreased emission of carbon dioxide to the atmosphere will amount up to 79 Mkg.

On an annual basis the ecological effect of downsizing will total almost 20 Million kg.

Why ?

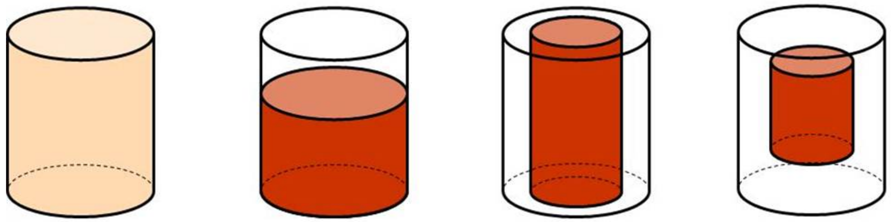
Downsizing can be done by changing:
- in stroke ($A = S_d/S$),
- in diameter ($B = D_d/D$)
- both parameters – as mix.



Downsizing ratio: $W_d = 1 - (V_d/V) \Longrightarrow W_d = 1 - A \cdot B^2$

where:
V_d – swept volume of downsized engine
V- swept volume of baseline engine
S_d – downsized stroke,
S – baseline stroke
D_d – downsized bore
D- baseline bore

		Changing B for cylinder diameter						
		1,00	0,96	0,90	0,85	0,80	0,75	0,70
Changing A for piston stroke	1,00	0,00	0,08	0,19	0,28	0,36	0,44	0,51
	0,95	0,05	0,12	0,23	0,31	0,39	0,47	0,53
	0,90	0,10	0,17	0,27	0,35	0,42	0,49	0,56
	0,85	0,15	0,22	0,31	0,39	0,46	0,52	0,58
	0,80	0,20	0,26	0,35	0,42	0,49	0,55	0,61
	0,75	0,25	0,31	0,39	0,46	0,52	0,58	0,63
	0,70	0,30	0,35	0,43	0,49	0,55	0,61	0,66



The same results in swept volume reduction

How ?

Data for baseline engine			
name	symbol	Value	unit
Geometry – some parameters			
Cylinder bore	D	84,80	mm
Piston stroke	S	88,00	mm
Ratio of cylinder bore to piston stroke	R_{BL}	0,96	
Engine swept volume	V_S	1988,04	cm^3
Clearance volume	V_C	212,62	cm^3
Working cycle – some factors			
Coefficient of pressure drop during filling stroke	C_p	0,95	
Coefficient of filling	η_v	0,87	
Compression ratio	ε	9,35	
Relative air/fuel ratio	λ	0,92	
Maximum theoretical pressure of cycle	p_{max}	7,54	MPa
Mean friction pressure	p_f	0,20	MPa
Average piston speed	S_p	17,60	m/s
Mean effective pressure	BMEP	0,94	MPa
Mechanical efficiency	η_m	82,27	%
Total efficiency	η_o	28,37	%
Specific fuel consumption	g_e	295,09	g/kWh
Engine power at 6000 rpm	P_e	93,16	kW

BASELINE ENGINE DOWNSIZED by 30%													
geometry changing only													
SYMBOL	UNIT	INITIAL VALUE	RESULTS										
D	mm	84,80	84,80	0%	81,30	-4%	76,50	-10%	74,50	-12%	71,10	-16%
S	mm	88,00	61,80	-30%	67,30	-24%	76,00	-14%	80,10	-9%	88,00	0%
V/W_d	cm^3	1988,04	1396,14	- 30%	1397,48	-30%	1397,29	-30%	1396,67	-30%	1397,56	-30%
η_v	-	0,87	0,87	0%	0,87	0%	0,87	0%	0,87	0%	0,87	0%
p_{max}	MPa	7,54	7,54	0%	7,54	0%	7,54	0%	7,54	0%	7,54	0%
BMEP	MPa	0,94	0,99	+5%	0,98	+4%	0,96	+3%	0,95	+2%	0,94	0%
g_e	g/kWh	295,10	279,76	-5%	282,84	-4%	287,87	-2%	290,30	-2%	295,10	0%
P_e	kW	93,16	69,01	- 26%	68,32	-27%	67,12	-28%	66,53	-29%	65,49	-30%
CO_2	kg/h	86,87	61,01	-30%	61,06	-30%	61,06	-30%	61,03	-30%	61,07	-30%

(green)	Less than initial value
(orange)	More than initial value

D- cylinder diameter
S- piston stroke
V - swept volume,
W_d- downsizing ratio,
n_v - volumetric efficiency,
p_{max} - max pressure in chamber,
BMEP - brake mean effective pressure,
g_e - specific fuel consumption,
P_e - effective power,
CO_2 - carbon monoxide

DOWNSIZED ENGINE by 30% (for D=76,50mm and S=76,00mm)													
Turbo support only													
SYMBOL	UNIT	INITIAL VALUE	RESULTS										
C_p	-		**1,00**		**1,25**		**1,50**		**1,75**		**2,00**		
η_v	-	0,87	0,92	+6%	1,18	+35%	1,43	+65%	1,69	+94%	1,95	+124%	
p_{max}	MPa	7,54	7,95	+5%	10,14	+35%	12,32	+64%	14,51	+93%	16,70	+122%	
BMEP	MPa	0,96	1,03	+7%	1,40	+45%	1,76	+84%	2,13	+122%	2,50	+160%	
g_e	g/kWh	287,87	283,54	-2%	267,73	-7%	258,50	-10%	252,45	-12%	248,17	-14%	
P_e	kW	67,12	71,95	+7%	97,58	+45%	123,21	+84%	148,85	+122%	174,48	+160%	
CO_2	kg/h	61,06	64,464	+6%	82,556	+35%	100,647	+65%	118,738	+95%	136,830	+124%	

Less than initial value (green)

More than initial value (orange)

C_p - coefficient of pressure drop during filling stroke,
n_v - volumetric efficiency,
p_{max} - max pressure in chamber,
BMEP - brake mean effective pressure,
g_e - specific fuel consumption,
P_e - effective power,
CO_2 - carbon monoxide

DOWNSIZED ENGINE by 30% (for D=76,50mm and S=76,00mm)												
Variable Compression Ratio support only												
SYMBOL	UNIT	INITIAL VALUE	RESULTS									
CR	-		**6,00**		**8,0**		**10,00**		**12,00**		**14,00**	
V_c	cm^3	149,44	232,88	+56%	174,66	+17%	139,73	-7%	116,44	-22%	99,81	-33%
η_v	-	0,87	0,87	-1%	0,87	0%	0,87	0%	0,87	0%	0,87	0%
p_{max}	MPa	7,54	4,46	-41%	6,29	-17%	8,14	+8%	10,02	+33%	11,91	+58%
BMEP	MPa	0,96	0,77	-19%	0,90	-7%	0,99	+3%	1,06	+10%	1,11	+16%
g_e	g/kWh	287,87	355,32	+23%	307,61	+7%	280,34	-3%	262,36	-9%	249,42	-13%
P_e	kW	67,12	54,06	-19%	62,71	-7%	68,96	+3%	73,80	+10%	77,70	+16%
CO_2	kg/h	61,06	60,70	-1%	60,95	0%	61,09	0%	61,18	0%	61,24	0%

Less than initial value

More than initial value

CR- compression ratio,
V_c - clearance volume,
n_v - volumetric efficiency,
p_{max} - max pressure in chamber,
BMEP - brake mean effective pressure,
g_e - specific fuel consumption,
P_e - effective power,
CO_2 - carbon monoxide

DOWNSIZED ENGINE by 30% (for D=76,50mm and S=76,00mm)												
Variable Valve Timing in Intake support only												
SYMBOL	UNIT	INITIAL VALUE	RESULTS									
N1	-		**1,10**		**1,25**		**1,40**		**1,55**		**1,70**	
η_v	-	0,87	0,87	0%	0,87	0%	0,87	0%	0,87	0%	0,87	0%
p_{max}	MPa	7,54	7,13	-5%	7,40	-2%	7,80	+3%	8,41	+12%	9,36	+24%
BMEP	MPa	0,96	0,95	-1%	0,96	0%	0,97	+1%	1,01	+5%	1,10	+14%
g_e	g/kWh	287,87	290,53	1%	289,25	0%	284,32	-1%	273,13	-5%	251,93	-12%
P_e	kW	67,12	66,50	-1%	66,80	0%	67,96	+1%	70,74	+5%	76,69	+14%
CO_2	kg/h	61,06	61,06	0%	61,06	0%	61,06	0%	61,06	0%	61,06	0%

Less than initial value

More than initial value

N1- polytrophic exponent for compression,
n_v - volumetric efficiency,
p_{max} - max pressure in chamber,
BMEP - brake mean effective pressure,
g_e - specific fuel consumption,
P_e - effective power,
CO_2 - carbon monoxide

DOWNSIZED ENGINE by 30% (for D=76,50mm and S=76,00mm)												
Variable Valve Timing in Exhaust support only												
SYMBOL	UNIT	INITIAL VALUE	RESULTS									
N2	-		**1,10**		**1,25**		**1,40**		**1,55**		**1,70**	
η_v	-	0,87	0,87	0%	0,87	0%	0,87	0%	0,87	0%	0,87	0%
p_{max}	MPa	7,54	7,54	0%	7,54	0%	7,54	0%	7,54	0%	7,54	0%
BMEP	MPa	0,96	1,16	+21%	0,92	-5%	0,72	-25%	0,56	-41%	0,43	-55%
g_e	g/kWh	287,87	238,85	-17%	301,75	+5%	383,34	+33%	491,49	+71%	639,28	+122%
P_e	kW	67,12	80,89	+21%	64,03	-5%	50,40	-25%	39,31	-41%	30,22	-55%
CO_2	kg/h	61,06	61,06	0%	61,06	0%	61,06	0%	61,06	0%	61,06	0%

Less than initial value

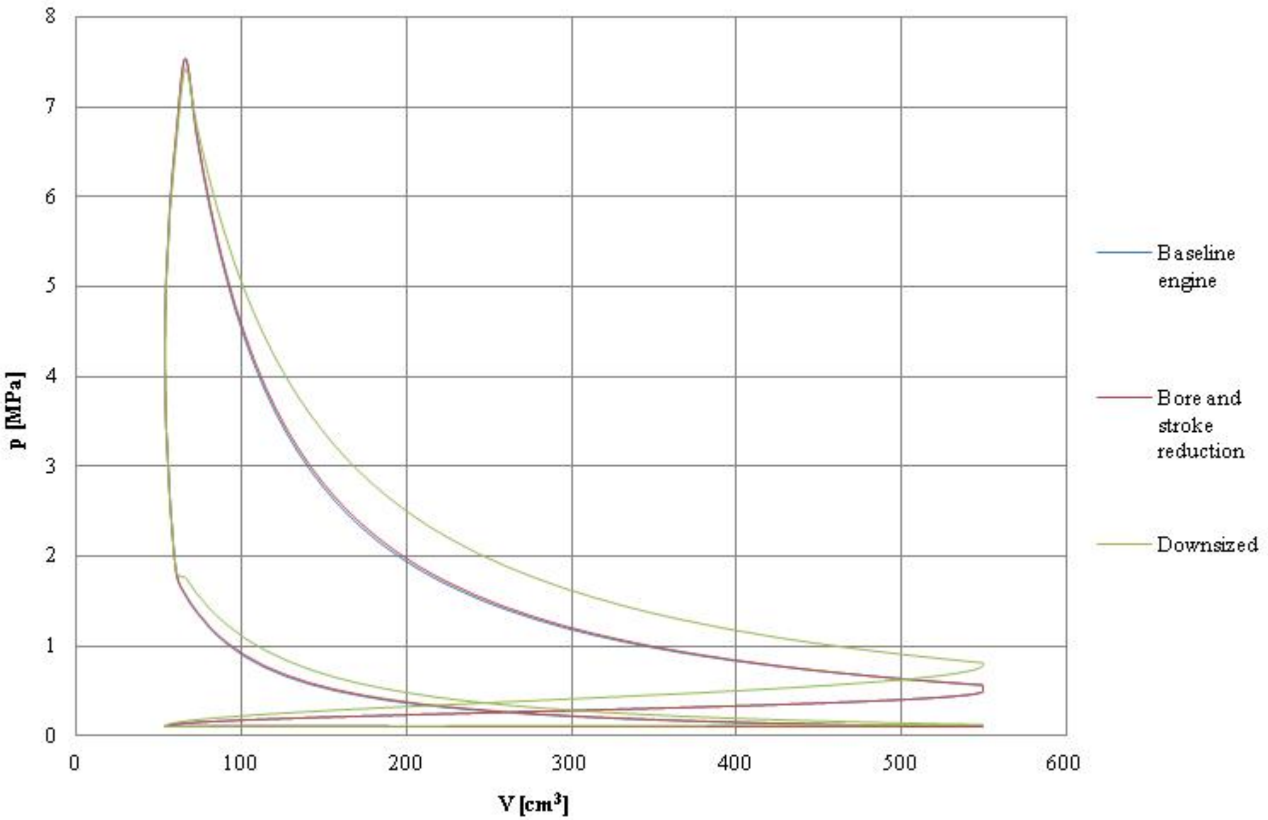
More than initial value

N1- polytrophic exponent for decompression,
n_v - volumetric efficiency,
p_{max} - max pressure in chamber,
BMEP - brake mean effective pressure,
g_e - specific fuel consumption,
P_e - effective power,
CO_2 - carbon monoxide

BASELINE ENGINE vs. DOWNSIZED ONE by 30%						
SYMBOL	UNIT	INITIAL VALUE	RESULTS			
			Downsized by geometry only		Downsized with all technologies	
D	mm	84,80	76,50	-10%	76,50	-10%
S	mm	88,00	76,00	-14%	76,00	-14%
V_s	-	1988,04	1397,29	-30%	1397,29	-30%
η_v	-	0,87	0,87	0%	1,19	+36%
p_{max}	MPa	7,54	7,54	0%	7,42	-2%
BMEP	MPa	0,94	0,96	+3%	1,38	+47%
g_e	g/kWh	295,10	287,87	-2%	273,69	-7%
P_e	kW	93,16	67,12	-28%	96,26	+3%
CO_2	kg/h	86,87	61,06	-30%	83,25	-4%

Legend	
(green)	Less than initial value
(orange)	More than initial value

D- cylinder diameter
S- piston stroke
V - swept volume,
n_v - volumetric efficiency,
p_{max} - max pressure in chamber,
BMEP - brake mean effective pressure,
g_e - specific fuel consumption,
P_e - effective power,
CO_2 - carbon monoxide


p [MPa]
V [cm³]
Baseline engine
Bore and stroke reduction
Downsized
0
1
2
3
4
5
6
7
8
0
100
200
300
400
500
600

Study of effects of downsizing technologies shows possibility developing engine with reduced swept volume, with higher performance parameters and lower fuel consumption than in standard engine. Simple bore and stroke reduction causes reduction of engines performance but using modern technologies like charging, VCR and VVT allows to increase efficiency of combustion process but without synergy.

Thank for your attention

During goal realization, completely new, downsized engine was developed with 3% more power and fuel consumption decrease by 7% as well as giving possibility to CO_2 reduction by 4%.