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Koncept novog modularnog hibridnog motora s unutrašnjim izgaranjem

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International Professional Conference ME4CataLOgue

4. – 5. prosinac 2014.
Slavonski Brod

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Počeci

- 2011. Ostvarena suradnja FESB-a i CAD Automotive Engineering Munchen (BMW)
- Projekt AMICES
- Proučavanje , simulacija i modeliranje radnih karakteristika novog hibridnog motora
- Uključeni studenti prediplomskog i diplomskog studija strojarstva u projekt

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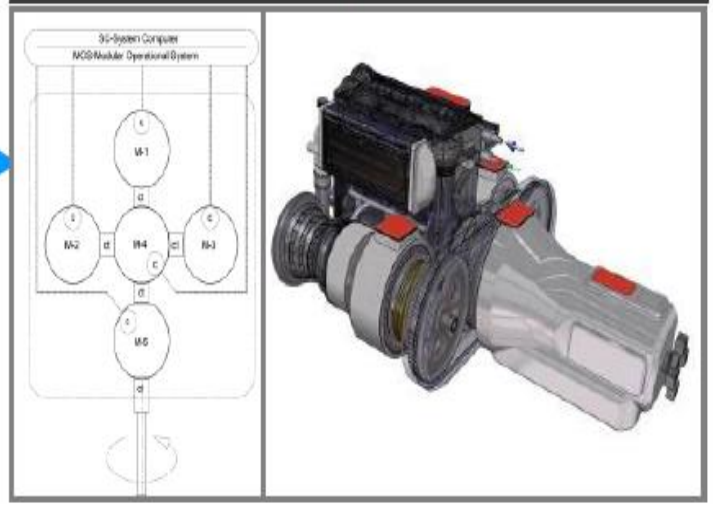
AMICES

Conventional ICE Basis: Hybrids 1st Generation

Modulation: reduction of complexity, time and investment

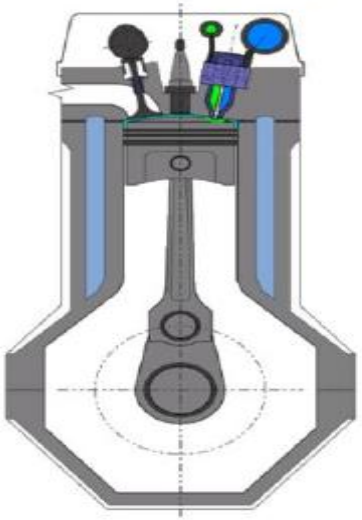
AMICES Basis: Hybrids 2nd Generation

- the power enhancement > 4X
- the efficiency enhancement > 2X
- the reduction of weight and costs

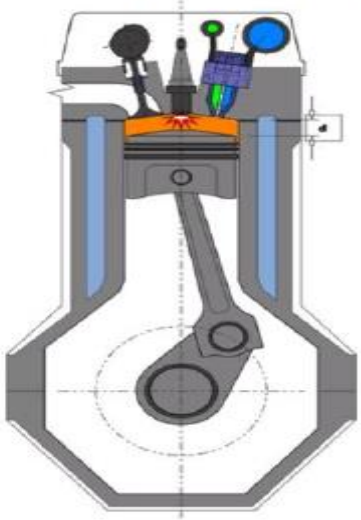


1.) Takt :

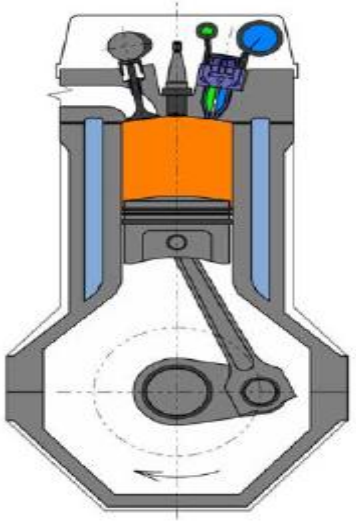
A) Ubrizgavanje (0-1)



B) Paljenje smjese (1-2)

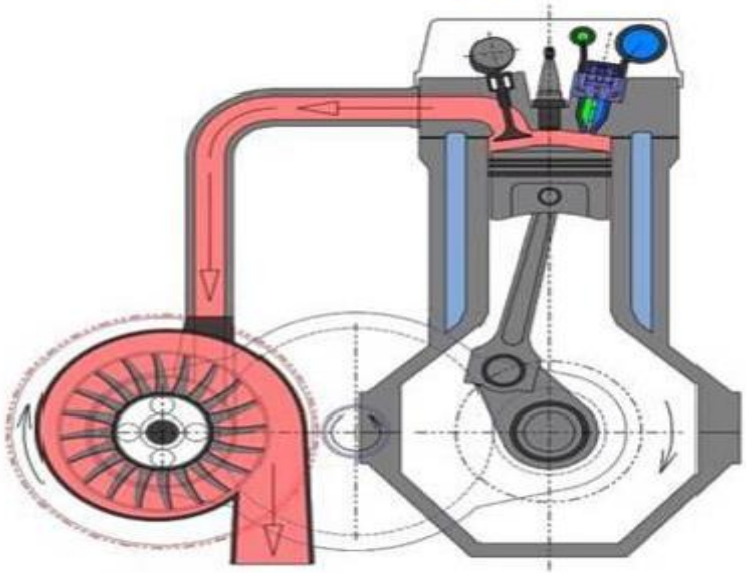


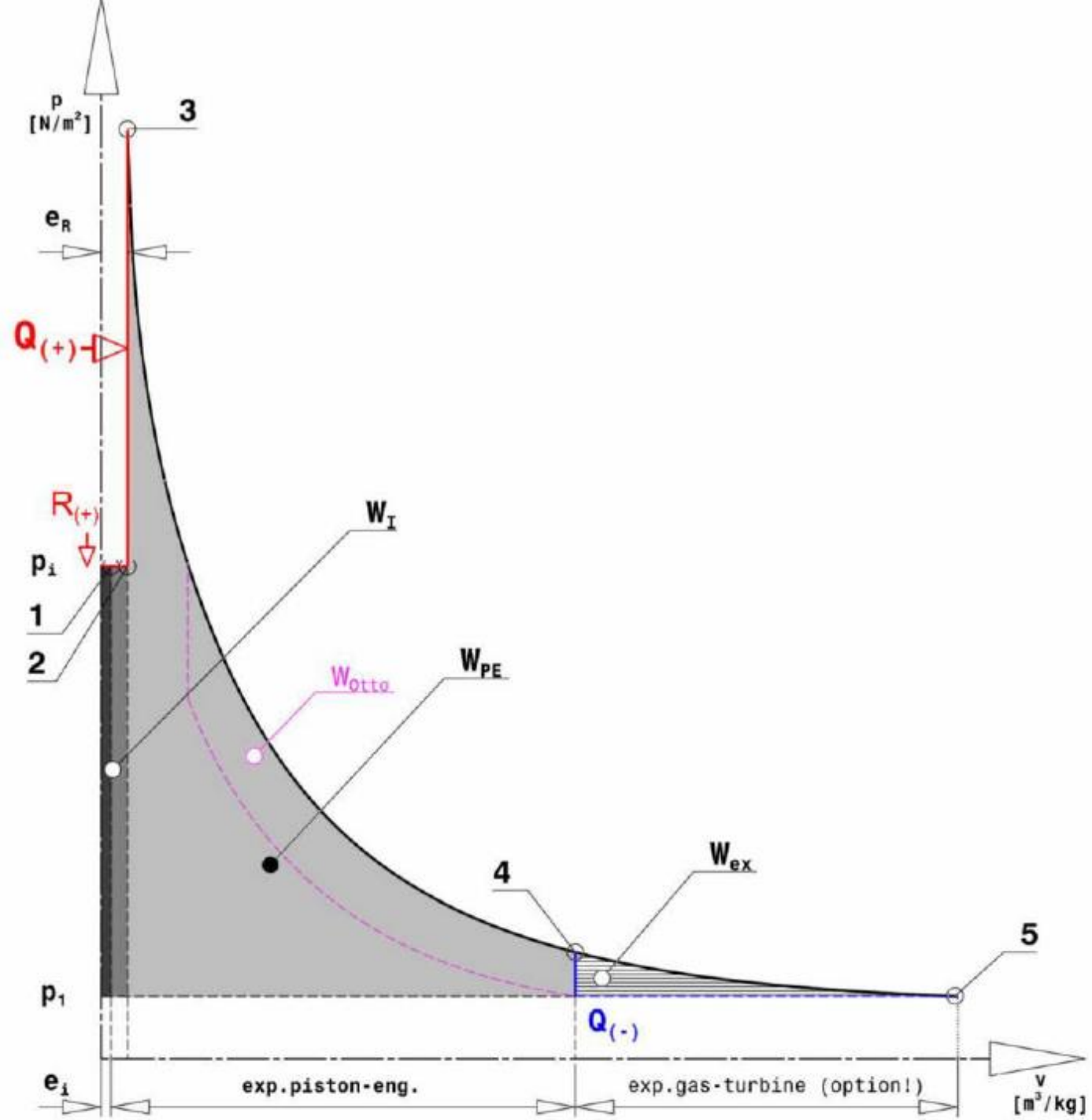
C) Ekspanzija (2-3)



2). Takt :

D) Ispuh (3-4)




p
[N/m²]
3
e_R
Q(+)
R(+)
W_I
p_i
1
2
W_Otto
W_PE
4
W_ex
5
p_1
Q(-)
e_i
exp.piston-eng.
exp.gas-turbine (option!)
v
[m³/kg]

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Performanse

PERFORMANCE : AMICES T/ BG 500 :	T– power splitter, B– regenerative breaking, G– exhaust recuperation
Engine System:	COPAG 3-cylinder active piston engine + exhaust turbine
Displacement:	0,5 liters (500 cc), Injection Air/Fuel on constant pressure 50 bar
Power output:	200 kW @ 10000 rpm
E. Motor/Gen.:	3X perm. magnet AC synchronous motor, 5-10 kW @ 10000 rpm, (integrated electromagnetic clutch on both sides!)
Battery:	(Ni-MH) or (Li-Ion) - home rechargeable (1 – 10 kWh)
Fuel:	Multi-fuels applicable! (liquid fuels - tank 30 l)
Transmission:	Power-Splitter T type / conventional transmission box
Brakes: (ABS)	Integrated regenerative braking
Compressor system:	Electric Rotary-Vane 2 stage compression with oil separation and intercooler (10/100 bar) /Structure-Tank
Recuperation Type:	Polyvalent! Regenerative Breaking end Exhaust
No engine idle mode:	Native start/stop (comp. air injection!)
EV mode:	All-electric mode 10-60 km
FEV mode:	Fuel-electric mode 1000 km / 25 l
FV mode:	All-fuel mode 1000 km / 30 l
Functionalities:	Can bee used as mobile electric power plant + compression-air unit
Accessory functions:	Managed-Pneumatically (power steering, brakes, air- condition…etc)

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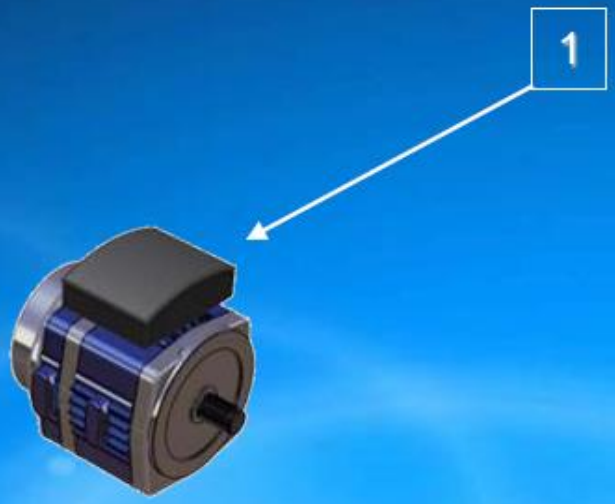
2011/12.- Provjera AMICES-a

- Teorijske pretpostavke i izračuni AMICES-a
- Od studenata uključenih u projekt zahtijevalo se dobro poznavanje principa rada motora s unutrašnjim izgaranjem, ali i obuka za rad u softverskom paketu Lotus Engine Simulation
- Prvi zadatak je bio kreirati što vjerodostojniji model kako bi se mogle usporediti brojke dobivene simulacijom na kompjuteru s teorijskim izračunima

- Dobra teorijska podloga o MUI-em – izrada potpuno novog modela
- Prilagodba zahtjevima tržišta i dokaz isplativosti za daljnje ulaganje i razvoj
- Podrška od strane BMW-a
- Dizajn motora u softverskom paketu CATIA V5

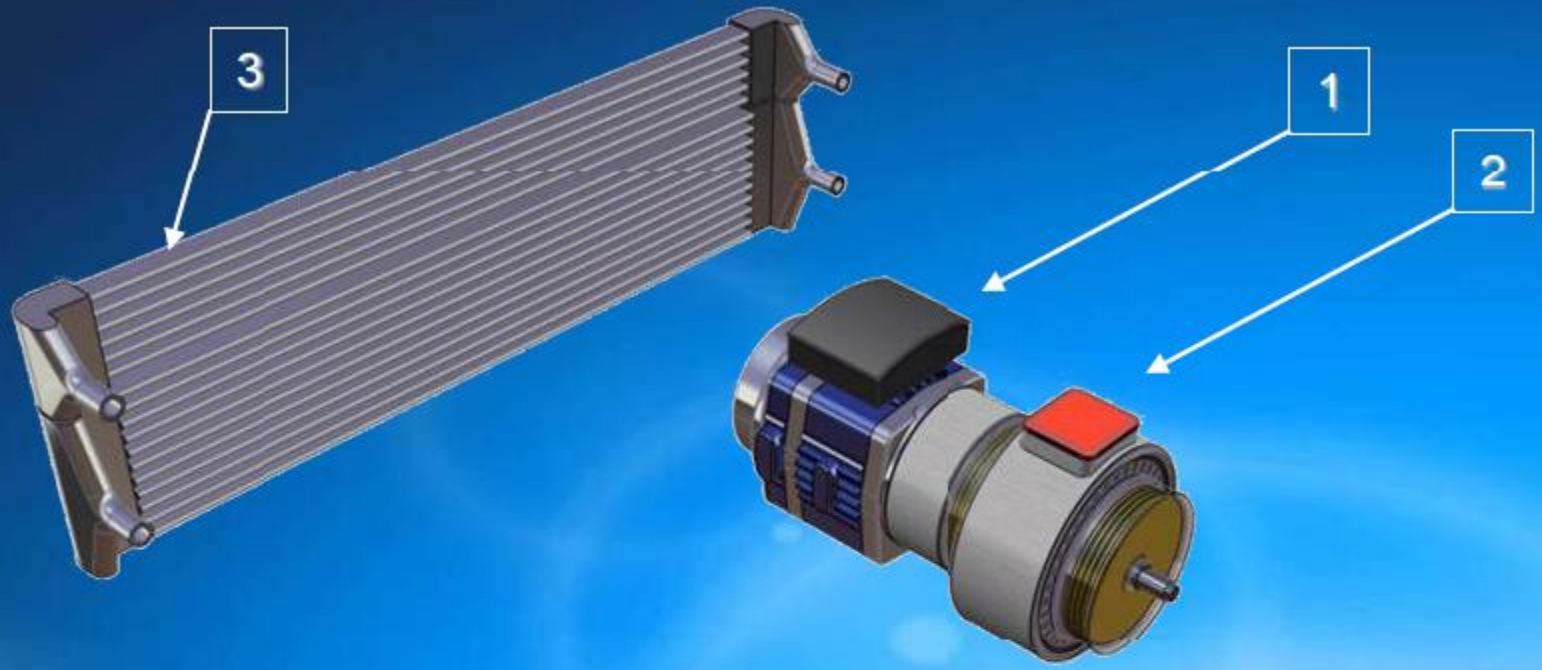


1 - rotary vane oil compressor (2 x stages-comp. + oil separation –10/100 bar)

2 – electromotor/generator (electromagnetic clutch integrated on both sides)

3 – compressed air chiller (2 x stages-cooling)

1 + 2 = 1 - M (the system air module)



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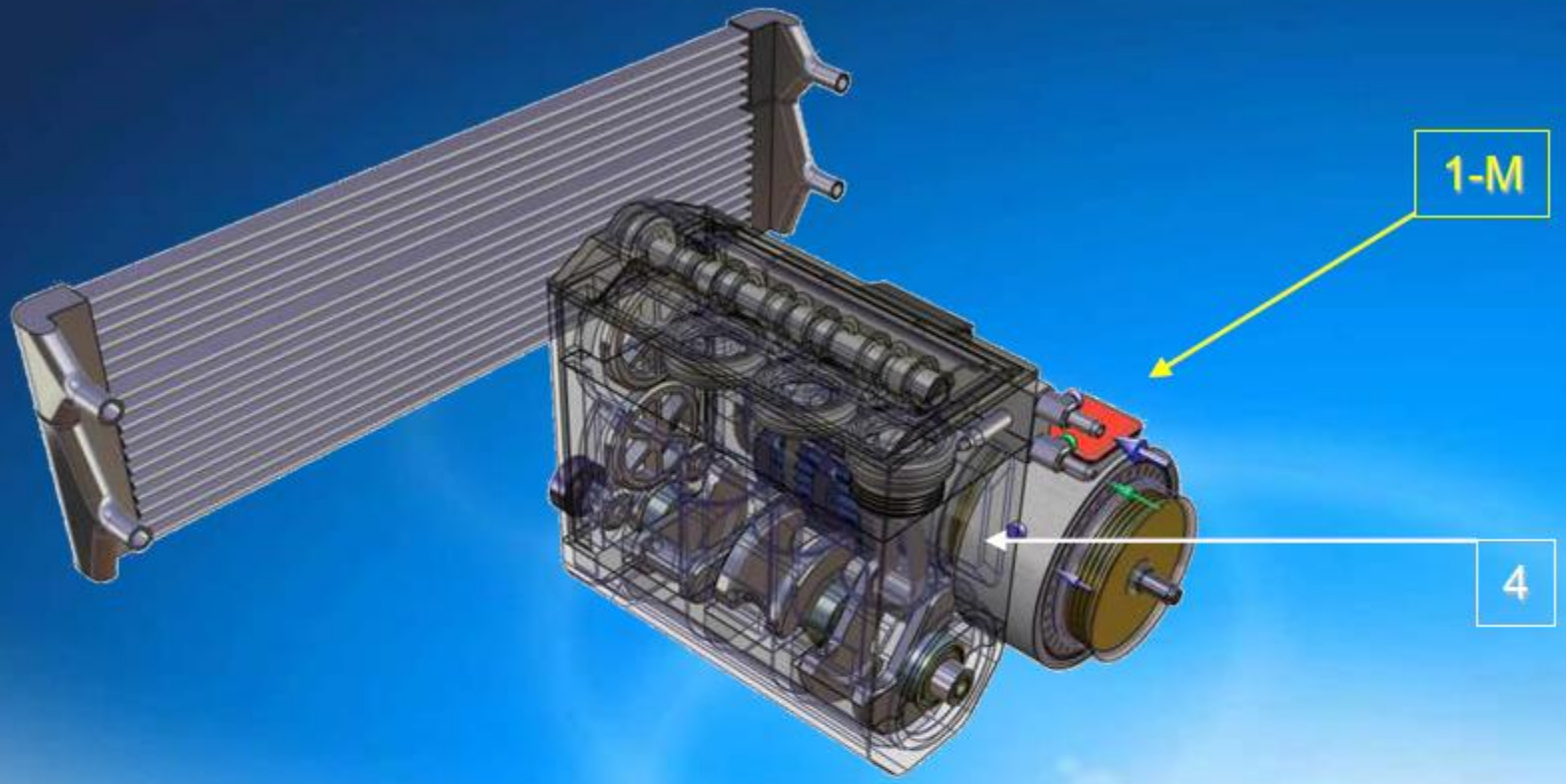


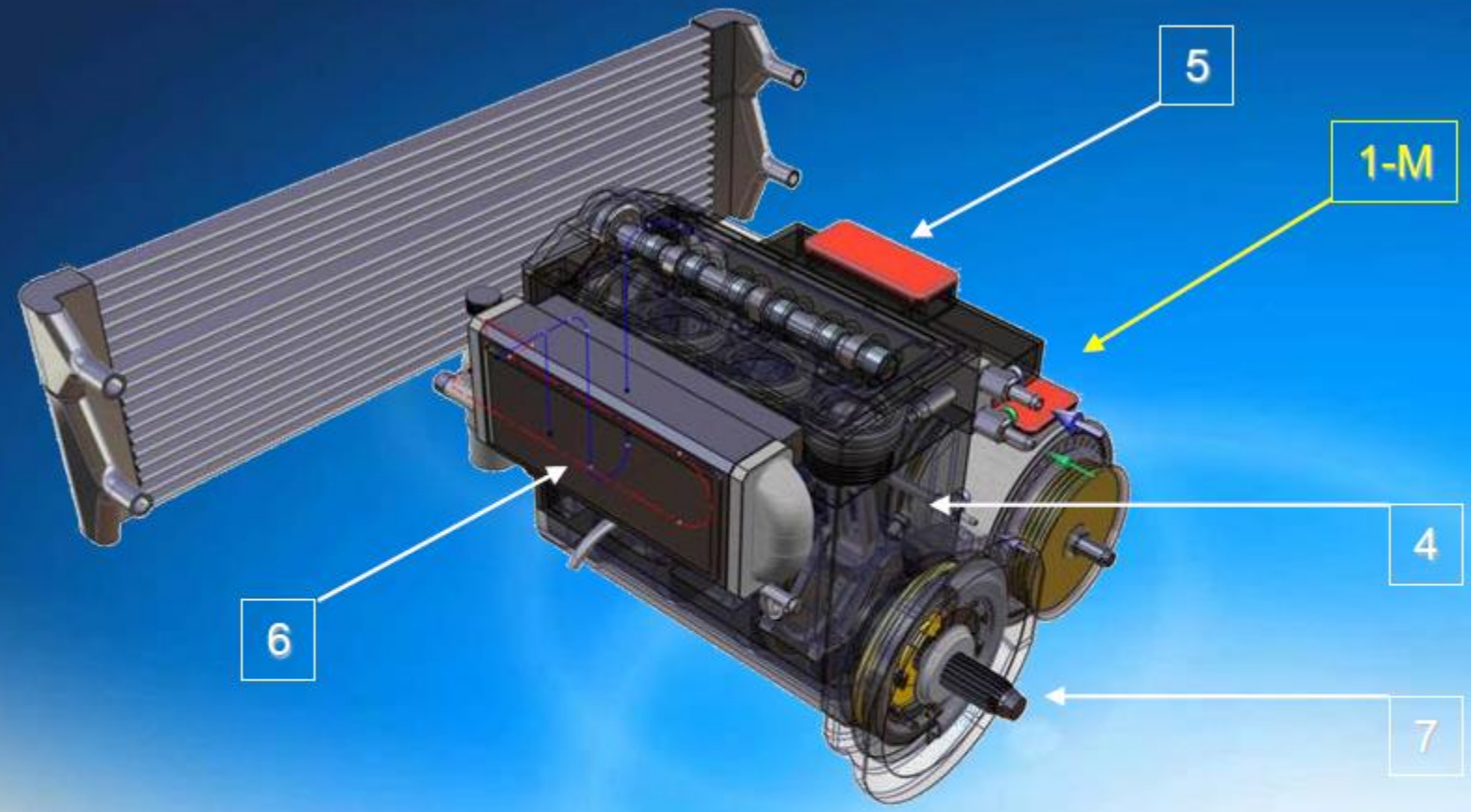
4 – active internal combustion piston engine (500ccm 3 x cylinder)

5 – MCCRS “multi component common rail system”

6 – exhaust catalytic-recuperation unit

7 – main clutch (mechanical, electro-magnetic, electro-pneumatic…etc.)

4 + 5 + 6 + 7= 2 - M (active piston engine-module)



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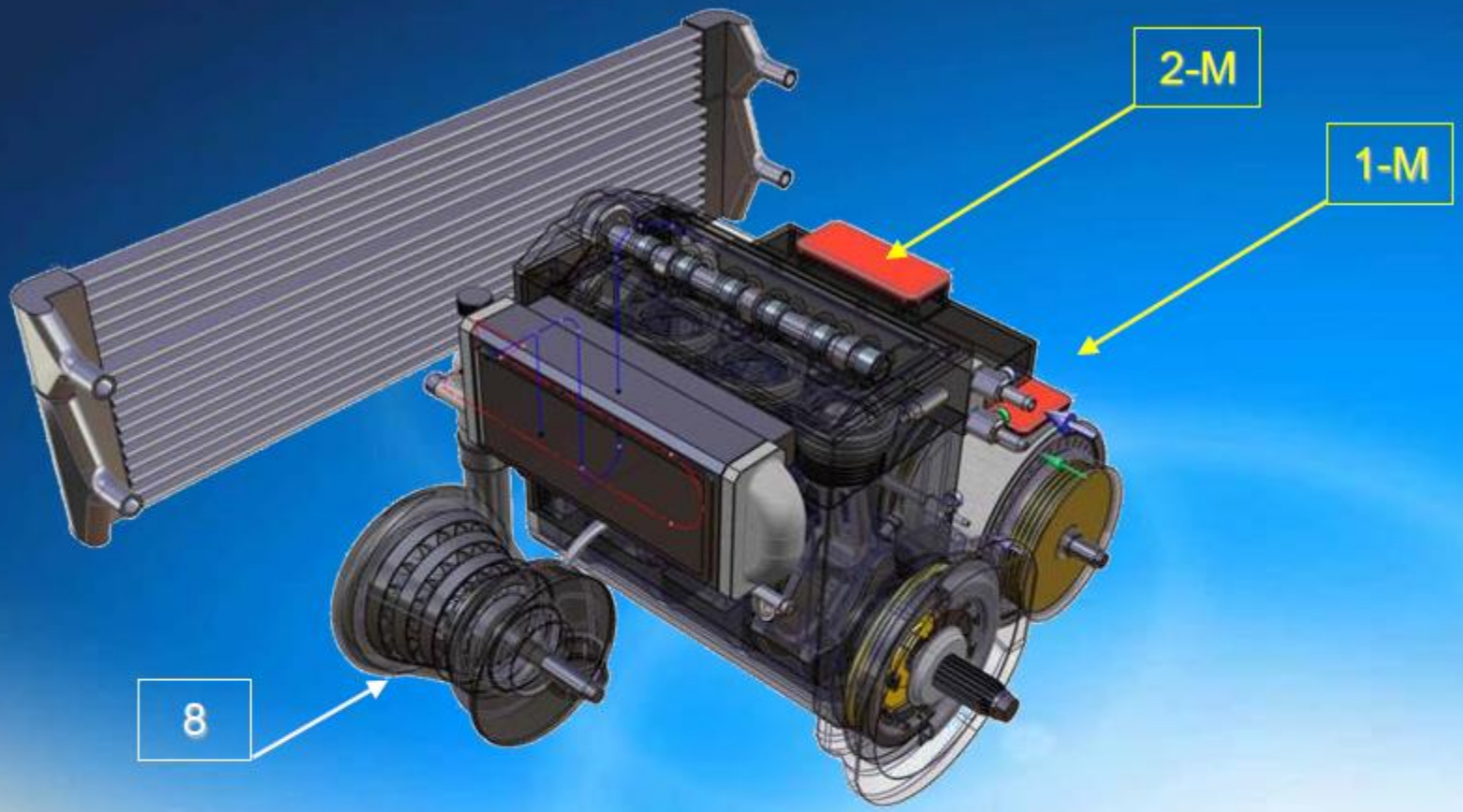
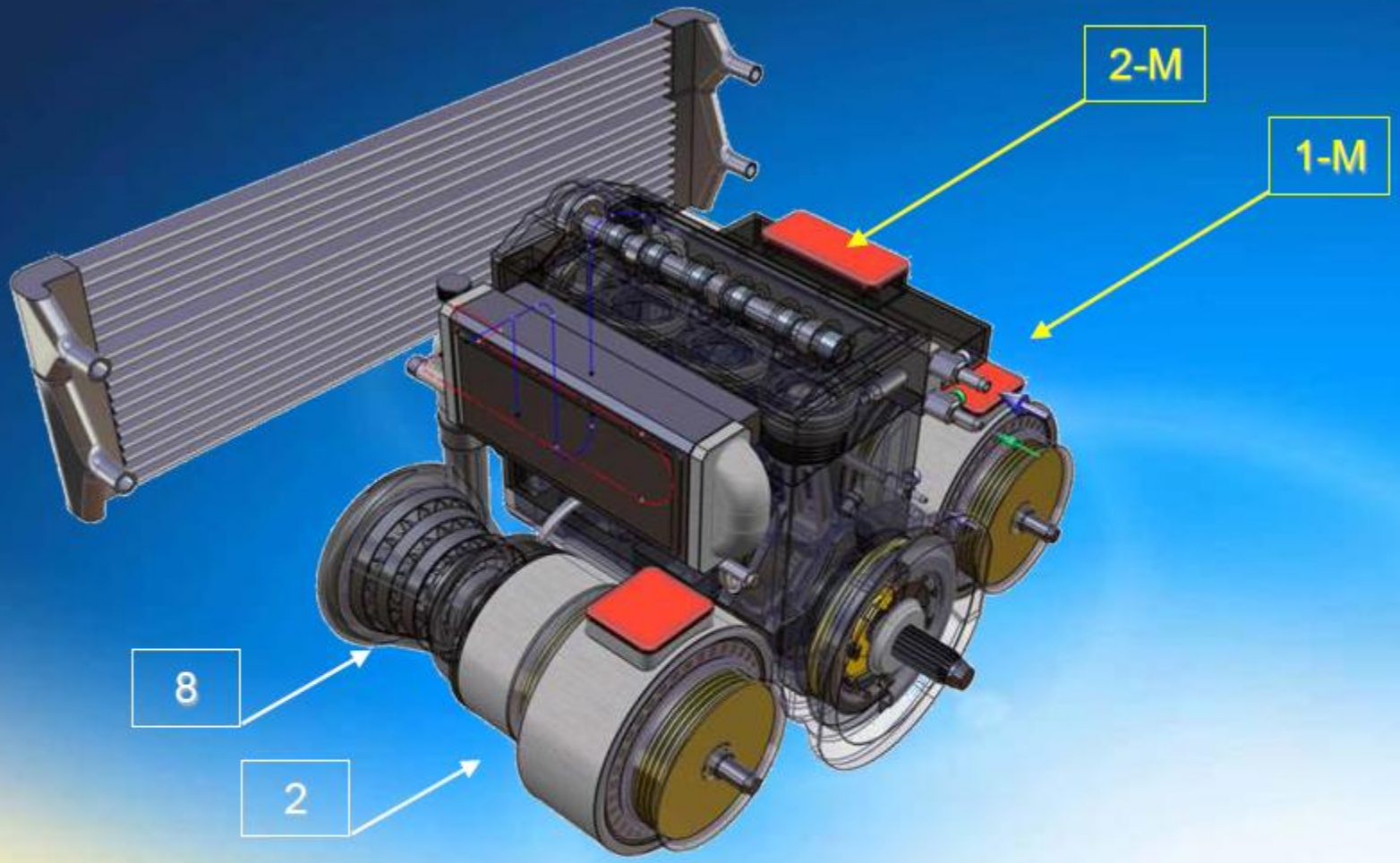


8 – exhaust gas turbine

2 – electromotor/generator (electromagnetic clutch integrated on both sides)

8 + 2 = 3- M (exhaust gas recuperation module)



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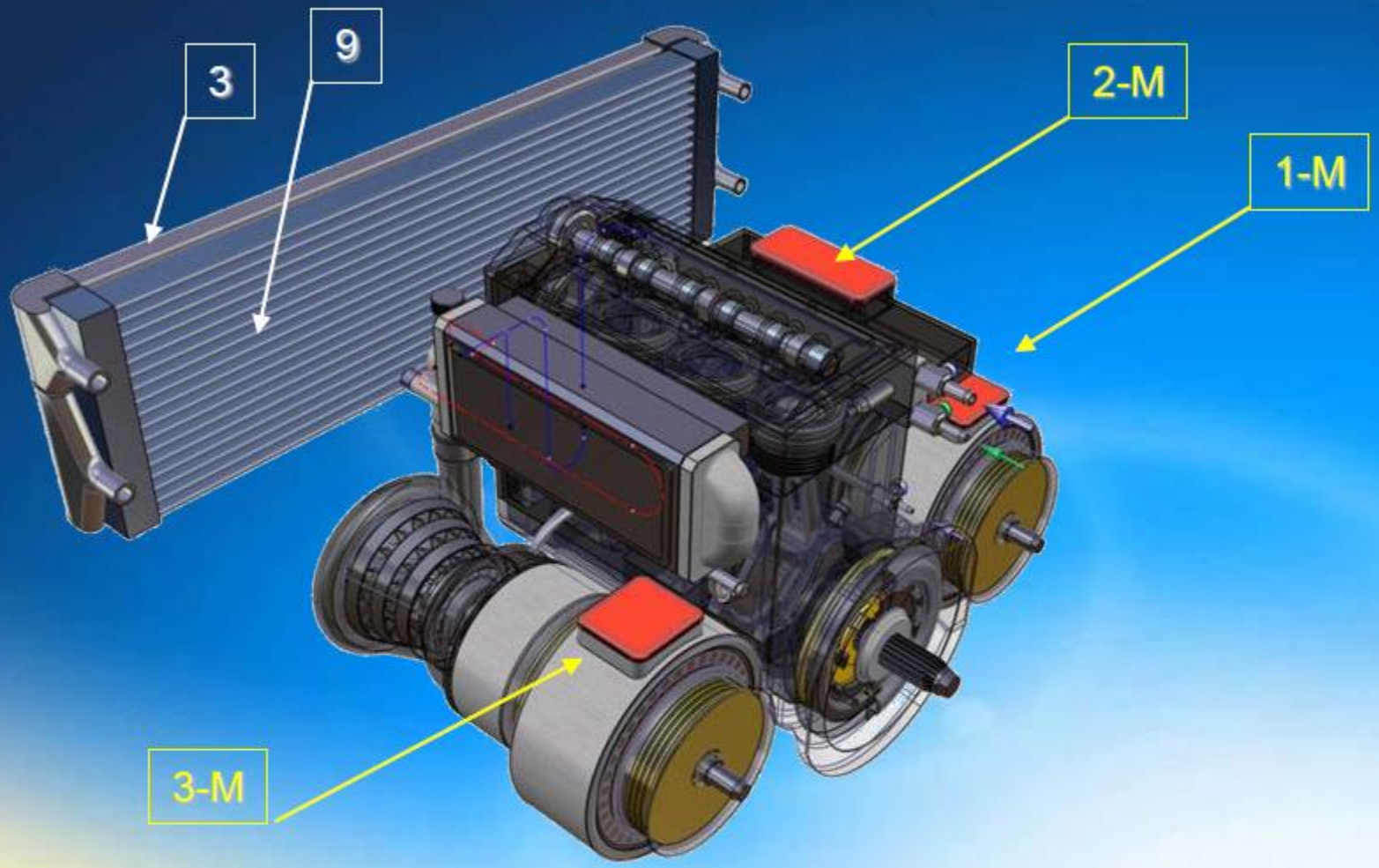
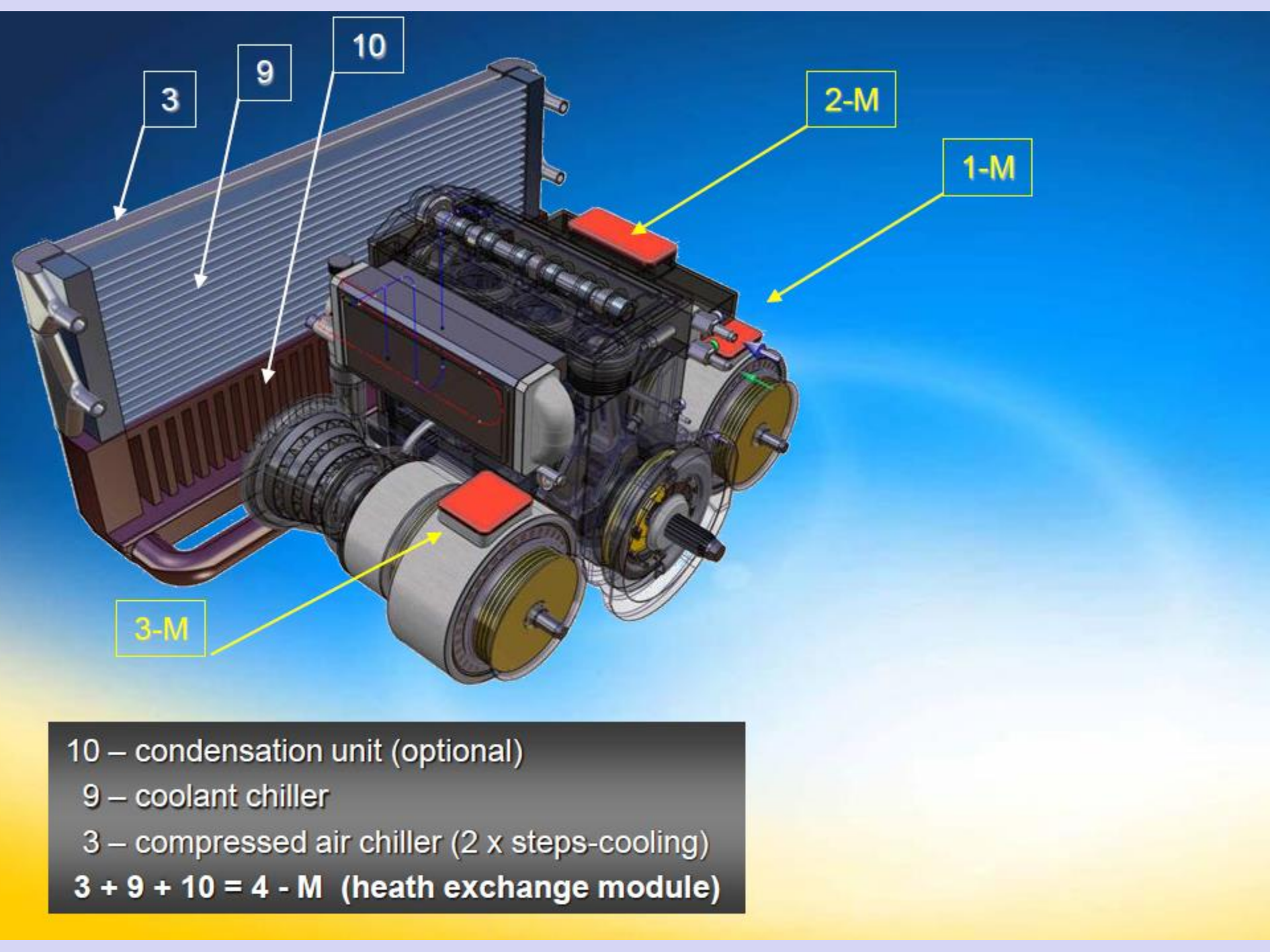


10 – condensation unit (optional)

9 – coolant chiller

3 – compressed air chiller (2 x steps-cooling)

3 + 9 + 10 = 4 - M (heath exchange module)



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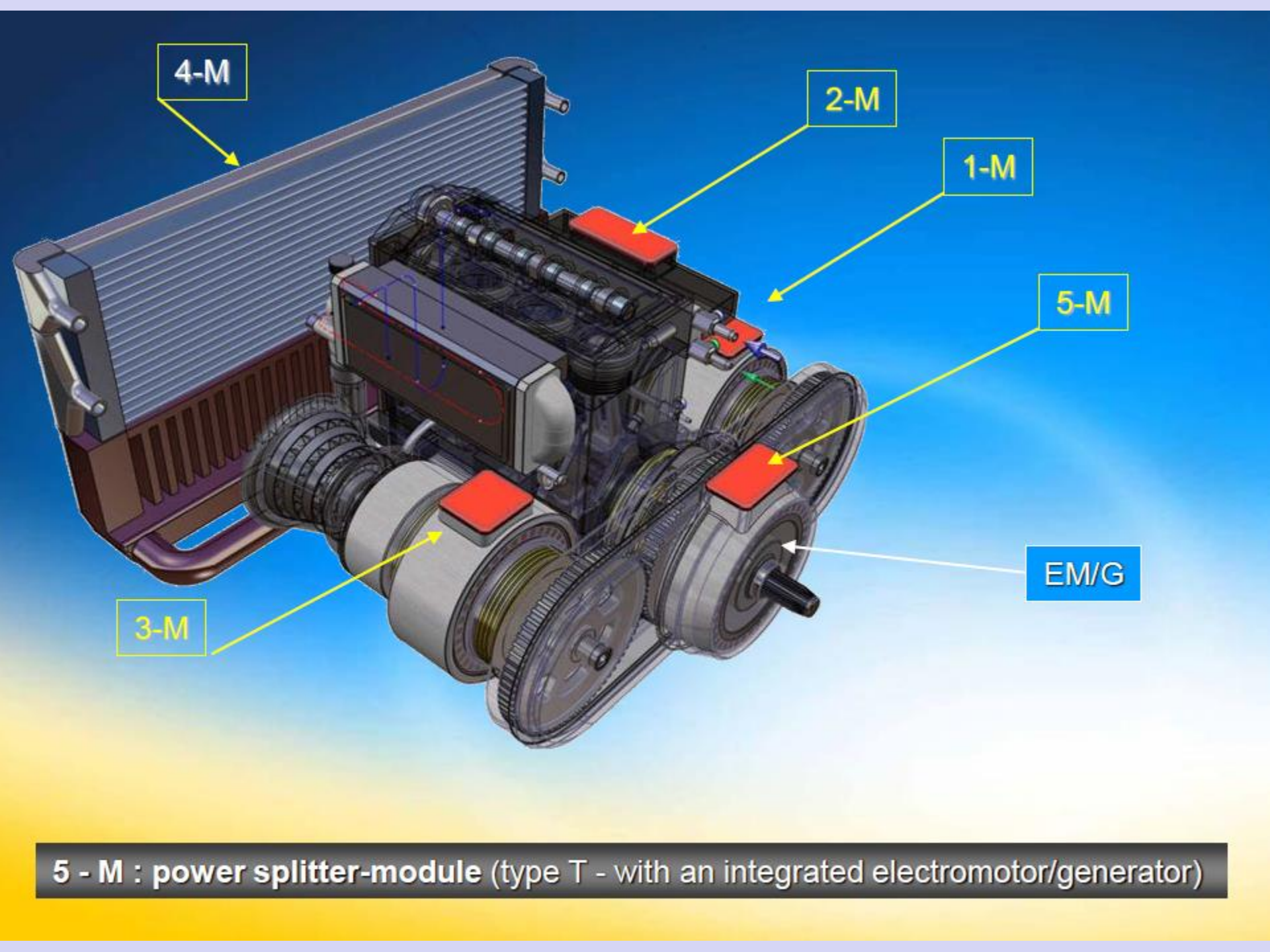
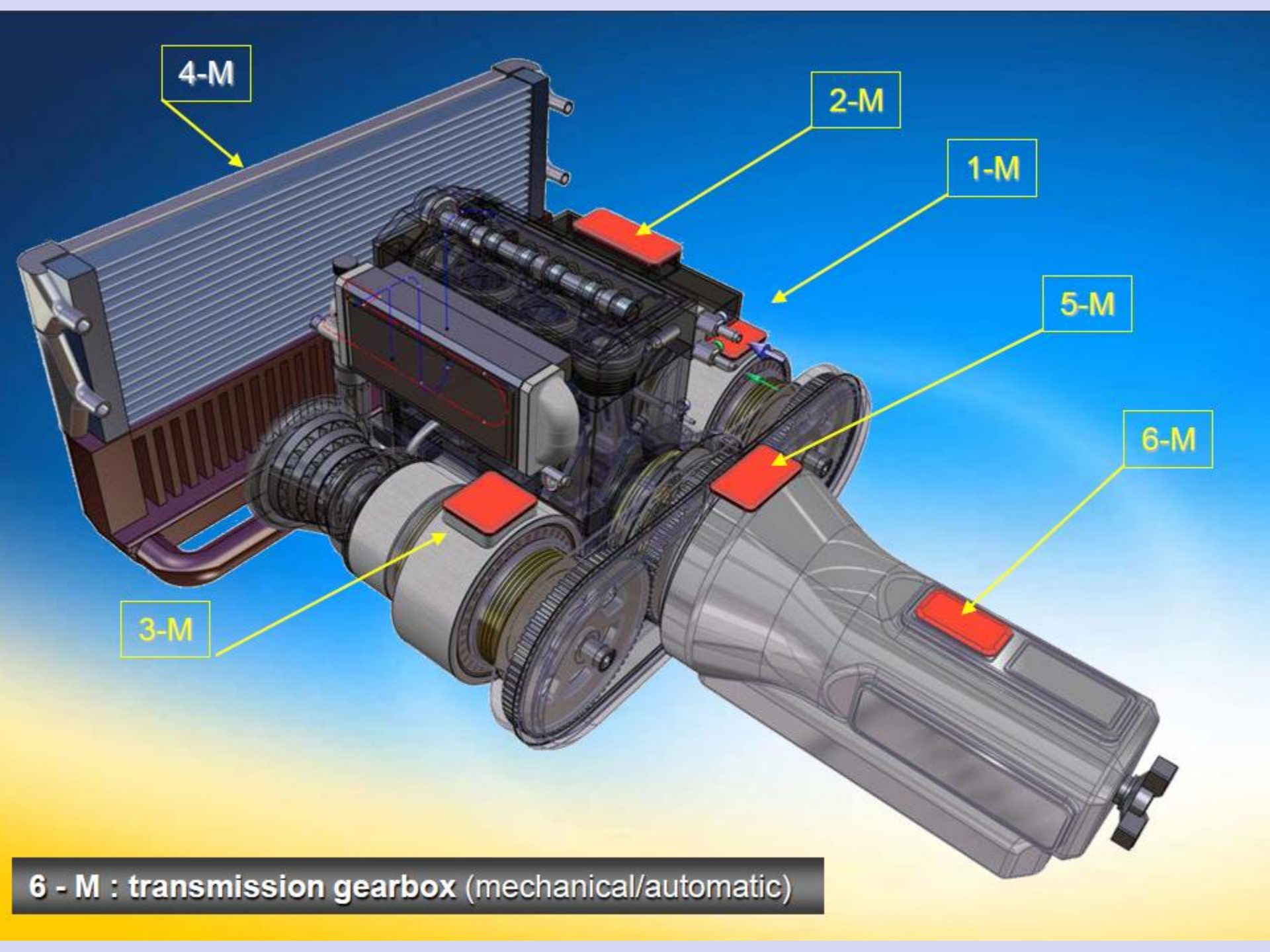
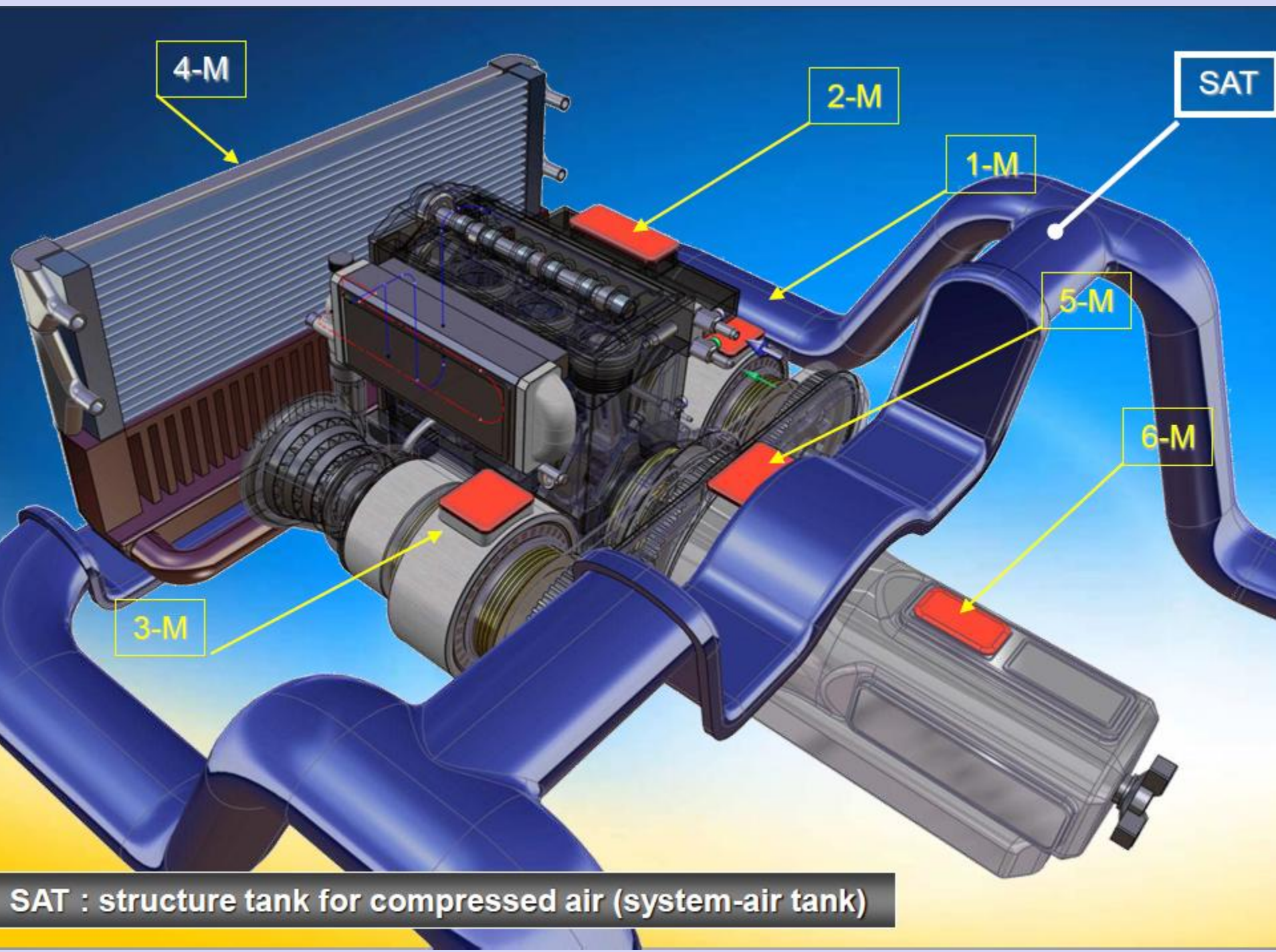


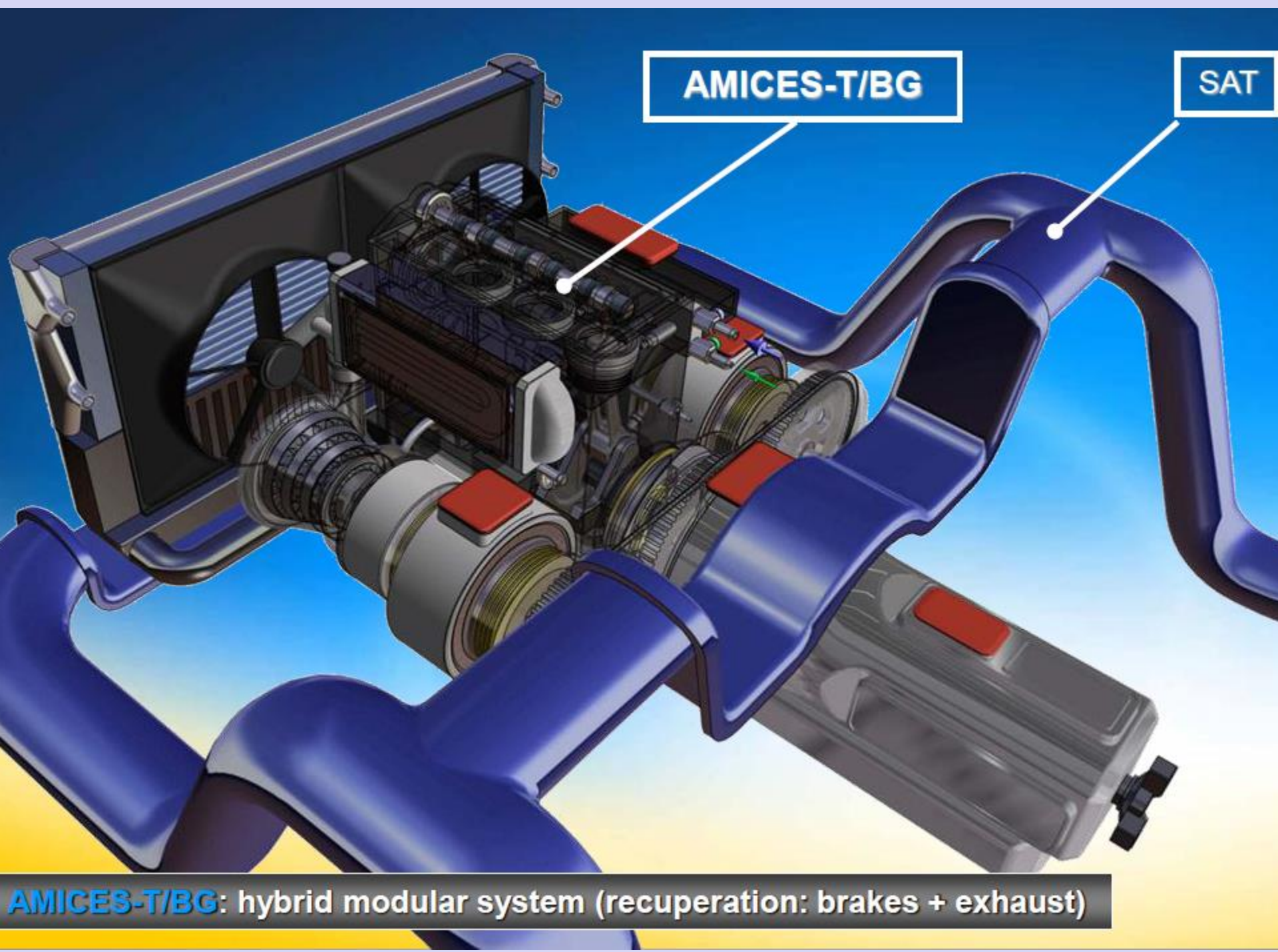
5 - M : power splitter-module (type T - with an integrated electromotor/generator)



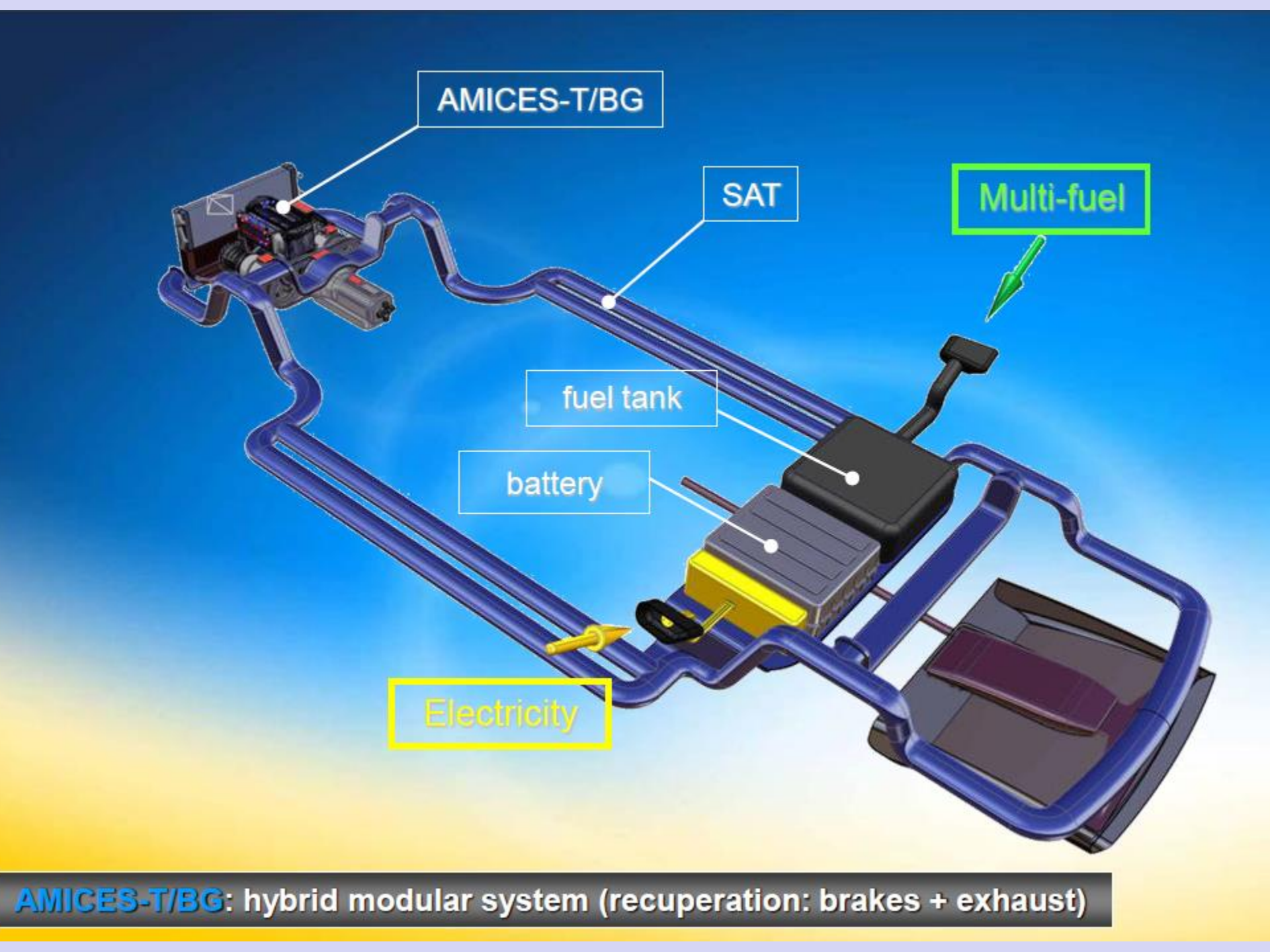
6 - M : transmission gearbox (mechanical/automatic)



SAT : structure tank for compressed air (system-air tank)



AMICES-T/BG: hybrid modular system (recuperation: brakes + exhaust)



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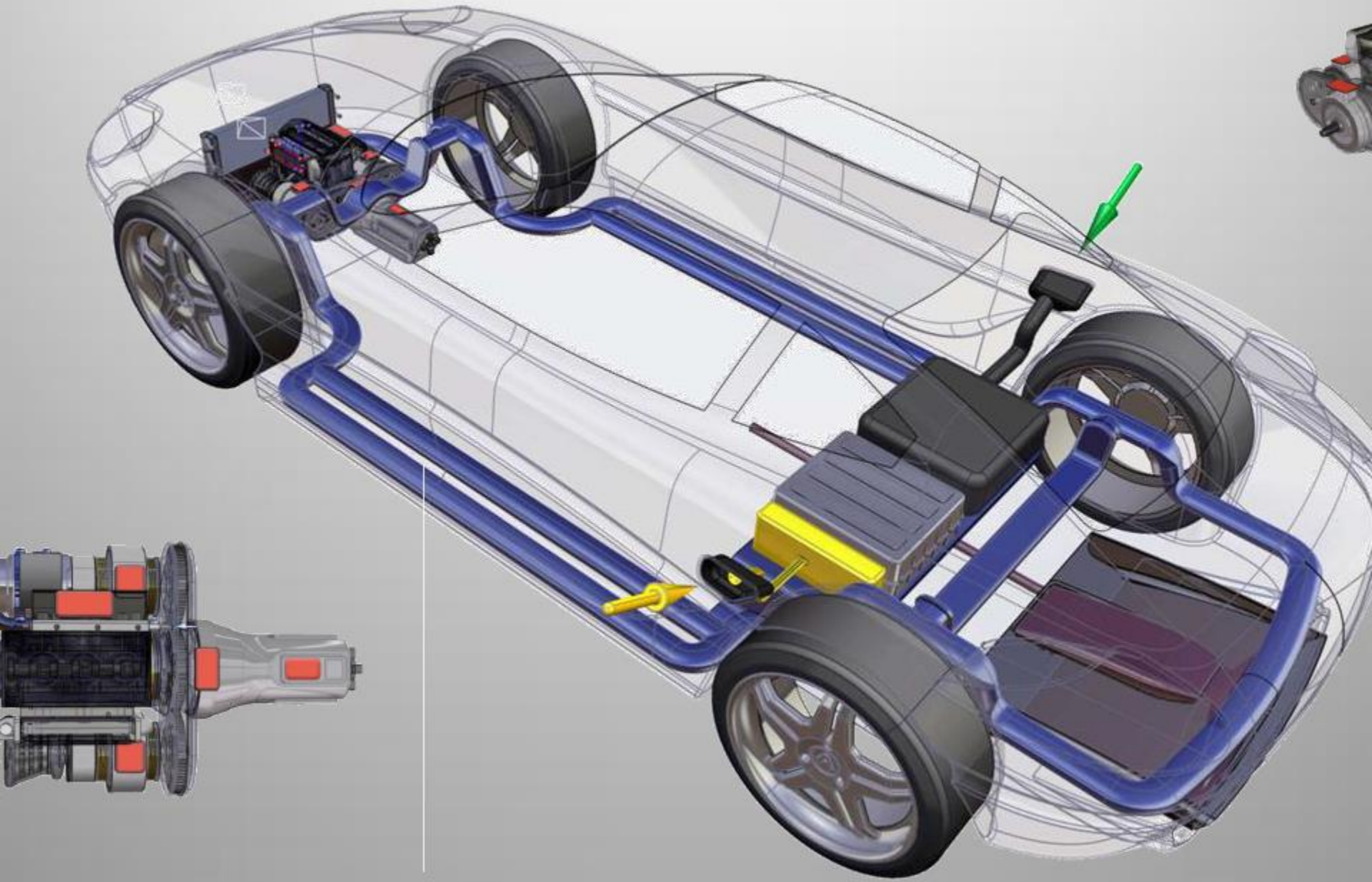

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2012/13. – Model AMICES

- Uspješno kreiran model – simulacija – potvrda teorijskih pretpostavki – problemi
- Visoke temperature i tlakovi u cilindru – upotreba nestandardnih materijala i legura
- Pulsacije unutar cilindra
- Jak ekspanzijski takt – uravnoteženje
- Laser tehnologija
- Dvostupanjski kompresor od 50 bara

- Prvi diplomski radovi s temom AMICES-a
- Uključivanje novih studenata - prenošenje znanja sa starijih studenata na mlađe
- Upoznavanje s novim softverskim paketima i rješavanje stvarnih problema vezanih uz MUI
- Neprocjenjivo iskustvo
- Završeni diplomanti nalaze posao u poduzećima vezanim uz autoindustriju (AVL, BMW, RIMAC,…)

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Radni proces AMICES-a

- Usporedba Otto motora sa Amices-om
- Određivanje mase smjese i protoka ispušnih plinova
- Rad turbine i potreban rad nesinkroniziranog krilnog kompresora
- Snaga turbine i kompresora, maseni protoci i specifična potrošnja
- Problem hlađenja komprimiranog zraka
- Strujanje i vrijeme trajanja ubrizgavanja
- Usporedba snage i efikasnosti

2013/14.

- Dokaz isplativosti AMICES-a – usporedba s najprodavanijim hibridima
- Moguća promjena konstrukcije – Doppelwelle – ispitivanje
- Daljnje ispitivanje modela u softverskom paketu Ricardo – realniji i točniji prikaz karakteristika motora
- Ideja o korištenju više kompresijskim tankova s manjim tlakom – stabilniji rad motora i manje vibracije
- Pojava novih materijala u autoindustriji – karbon
- Projekt AMICES izlazi u javnost – 4.MTSM simpozij – velik interes

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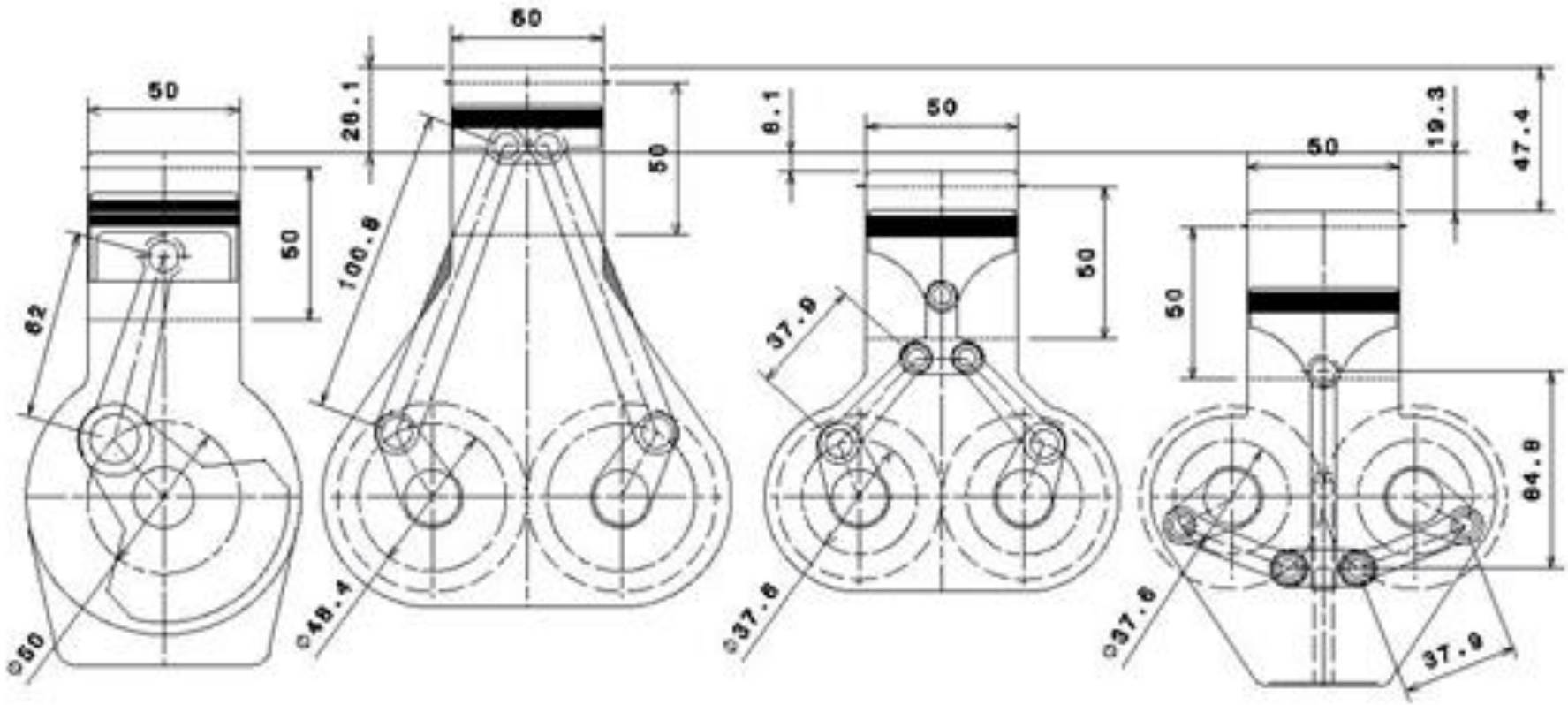
Mogući konstrukcijski koncepti



Engine speed	rpm	1000	2000	3000	3999	5000	6000	7000	8000
Case	-	1	2	3	4	5	6	7	8
Subcase	-	0	0	0	0	0	0	0	0
Trapped A/F	-	14.7001	14.7002	14.7004	14.7003	14.7001	14.7	14.7	14.7
Mass Airflow	kg/hr	26.3336	48.093	68.2809	85.4221	91.0628	117.92	136.209	172.21
Pseudo-volumetric efficiency	kg/hr/rpm	0.0263336	0.0240465	0.0227603	0.0213555	0.0182126	0.0196533	0.0194584	0.0215262
Auxiliary Power	kW	0	0	0	0	0	0	0	0
BMEP	bar	8.76696	8.81555	8.46856	7.93134	6.45871	7.24613	7.20118	8.05037
Brake Power	kW	7.08524	14.249	20.5322	25.6396	26.0989	35.1368	40.7387	52.0488
Brake specific CO emissions	g/kW/hr	0	0	0	0	0	0	0	0
BSFC	kg/kW/hr	0.252836	0.229604	0.226228	0.226642	0.237357	0.2283	0.227448	0.225076
Brake specific unburned fuel emission	g/kW/hr	1.13892	0.44916	0.266537	0.194892	0.186307	0.153553	0.150422	0.131954
Brake specific NO2 emissions	g/kW/hr	0	0	0	0	0	0	0	0
Charging efficiency	-	0.0521479	0.0478785	0.0457406	0.0433881	0.0356598	0.0272696	0.0263804	0.0345093
Delivered efficiency	-	0.0523572	0.0479479	0.0457709	0.0434031	0.0356701	0.0272743	0.0263847	0.0345129
Total delivered efficiency	-	0.0522795	0.0479617	0.0457735	0.0434056	0.0356852	0.0272789	0.0263888	0.0345262
Brake thermal engine efficiency	%	32.9748	36.3112	36.8531	36.7857	35.1251	36.5186	36.6554	37.0416
EGR	-	-0.00148658	0.000286792	5.74274e-005	5.83234e-005	0.000421384	0.000168236	0.000155291	0.000385634
FMEP	bar	0.849708	0.969027	1.09464	1.21725	1.32671	1.47943	1.61547	1.77169
Friction Energy Loss	%	3.19597	3.99141	4.76362	5.64562	7.21518	7.45593	8.22304	8.15194
Friction torque	N*m	6.55765	7.47849	8.44795	9.39415	10.2389	11.4175	12.4674	13.673
Fuel mass flow	kg/hr	1.7914	3.27163	4.64496	5.81102	6.19475	8.02174	9.26592	11.7149
Fuel volume flow	L/hr	2.61996	4.78483	6.79336	8.49876	9.05996	11.732	13.5516	17.1334
Engine out CO mass flow	g/s	0	0	0	0	0	0	0	0
GMEP	bar	9.61666	9.78458	9.5632	9.14859	7.78542	8.72556	8.81665	9.82205
GMEP from crossing point	bar	9.61666	9.78458	9.5632	9.14859	7.78542	8.72556	8.81665	9.82205
Engine out unburned fuel flow	g/s	0.00224153	0.0017778	0.00152017	0.00138805	0.00135066	0.00149872	0.00170222	0.00190779
Engine out NO2 mass flow	g/s	0	0	0	0	0	0	0	0
Heat Transfer Rate	W	8439.55	10940.8	12842.7	14273.3	14636.1	17667.4	19145.6	21908
Heat Transfer Loss	%	39.2777	27.8809	23.0512	20.4783	19.698	18.3622	17.2266	15.5913
Indicated Power	hp	10.4224	21.2087	31.0932	39.6602	42.1884	56.7395	66.8872	85.1595
IMEP	bar	9.61666	9.78458	9.5632	9.14859	7.78542	8.72556	8.81665	9.82205
ISAC	kg/kW/hr	3.38828	3.04091	2.94489	2.88836	2.89457	2.78699	2.73086	2.71182
ISFC	kg/kW/hr	0.230495	0.206865	0.200333	0.196487	0.196909	0.189591	0.185773	0.184477
Indicated Torque	N*m	74.2169	75.5128	73.8043	70.6045	60.0842	67.3398	68.0427	75.802
Lambda	-	1.00984	1.00985	1.00986	1.00986	1.00984	1.00983	1.00983	1.00983
Reference pressure	bar	1	1	1	1	1	1	1	1
Exhaust port static pressure	bar	1.00294	1.00943	1.01968	1.03579	1.06969	1.08353	1.08355	1.09178
Trapped equivalence ratio	-	0.990254	0.990251	0.990237	0.990239	0.990257	0.990262	0.990263	0.990262
Intake port static pressure	bar	16.0031	16.0029	16.0052	16.0031	17.0005	23.0326	24.034	21.9886
PMEP	bar	0	0	0	0	0	0	0	0
PMEP from crossing point	bar	0	0	0	0	0	0	0	0
CO	ppm	0	0	0	0	0	0	0	0
HC	ppm	596.907	259.702	157.378	115.135	105.265	89.0354	88.2043	80.3556
NOx	ppm	0	0	0	0	0	0	0	0
Pumping torque	N*m	0	0	0	0	0	0	0	0
Residual gas fraction	%	3.81986	5.41914	7.8602	9.32105	12.4768	14.4119	14.3804	11.6551
Scavenging efficiency	-	0.961801	0.945809	0.921398	0.906789	0.875232	0.855881	0.856196	0.883449
Scavenging ratio	-	0.964229	0.947453	0.922059	0.907155	0.875853	0.856174	0.856471	0.883882
Ambient reference temperature	K	298	298	298	298	298	298	298	298
Exhaust gas temperature	K	880.862	1038.69	1112.12	1149.27	1173.08	1171.31	1172.05	1191.1
Intake port gas temperature	K	300.757	301.622	304.241	307.439	314.731	302.14	308.046	333.239
Brake Torque	N*m	67.6592	68.0343	65.3564	61.2103	49.8453	55.9222	55.5753	62.1289
Trapping ratio	-	0.996002	0.998551	0.99934	0.999655	0.999712	0.999826	0.999834	0.999896
Trapped air volumetric efficiency	-	0.774209	0.70878	0.6714	0.630159	0.537447	0.580027	0.574281	0.635348
Total volumetric efficiency	-	0.777317	0.709808	0.671842	0.630375	0.537601	0.580128	0.574377	0.635414

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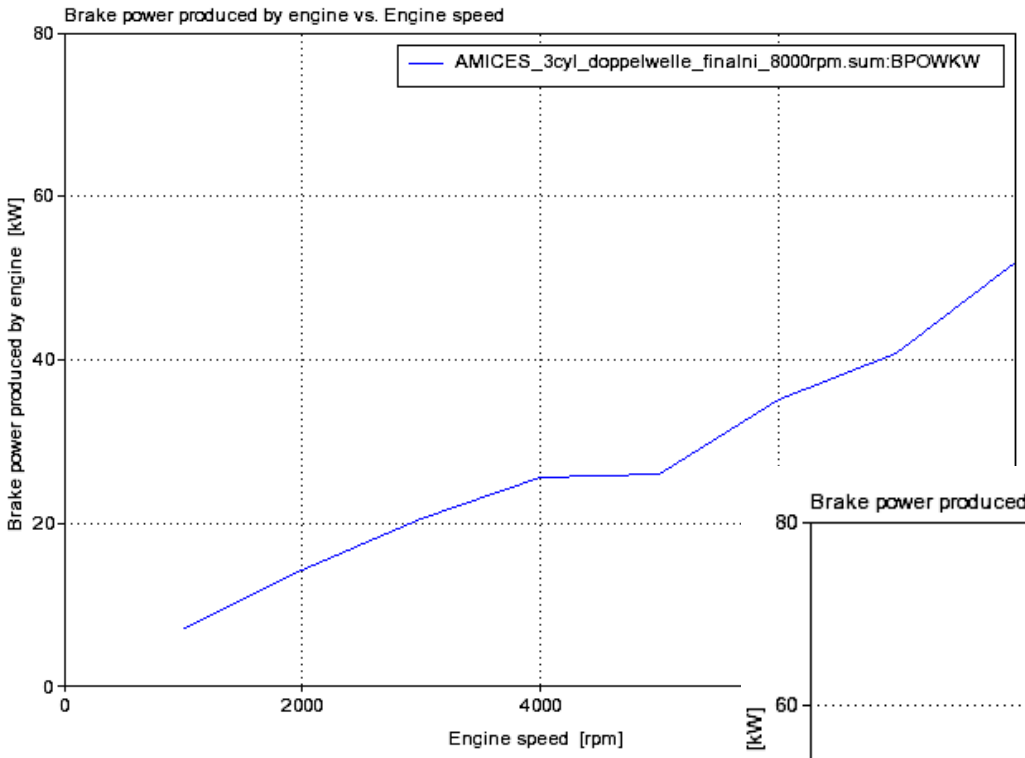
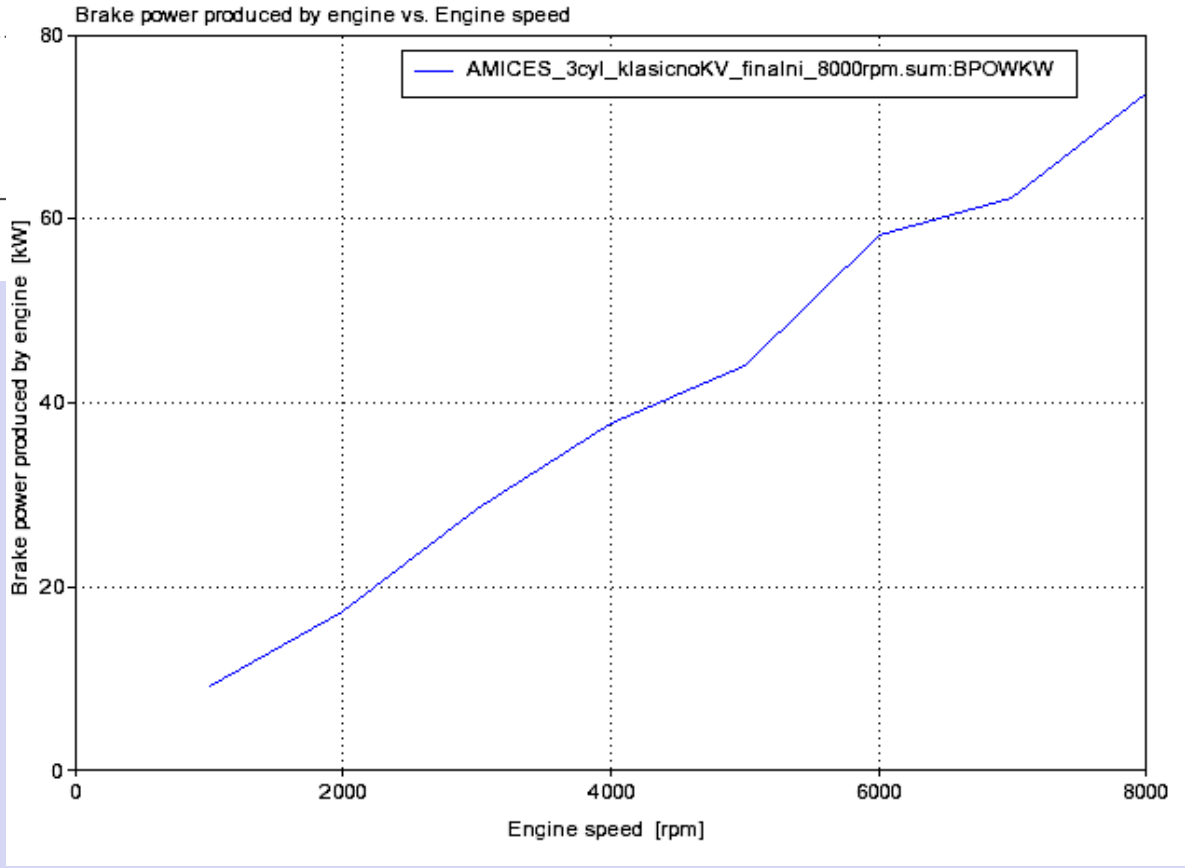
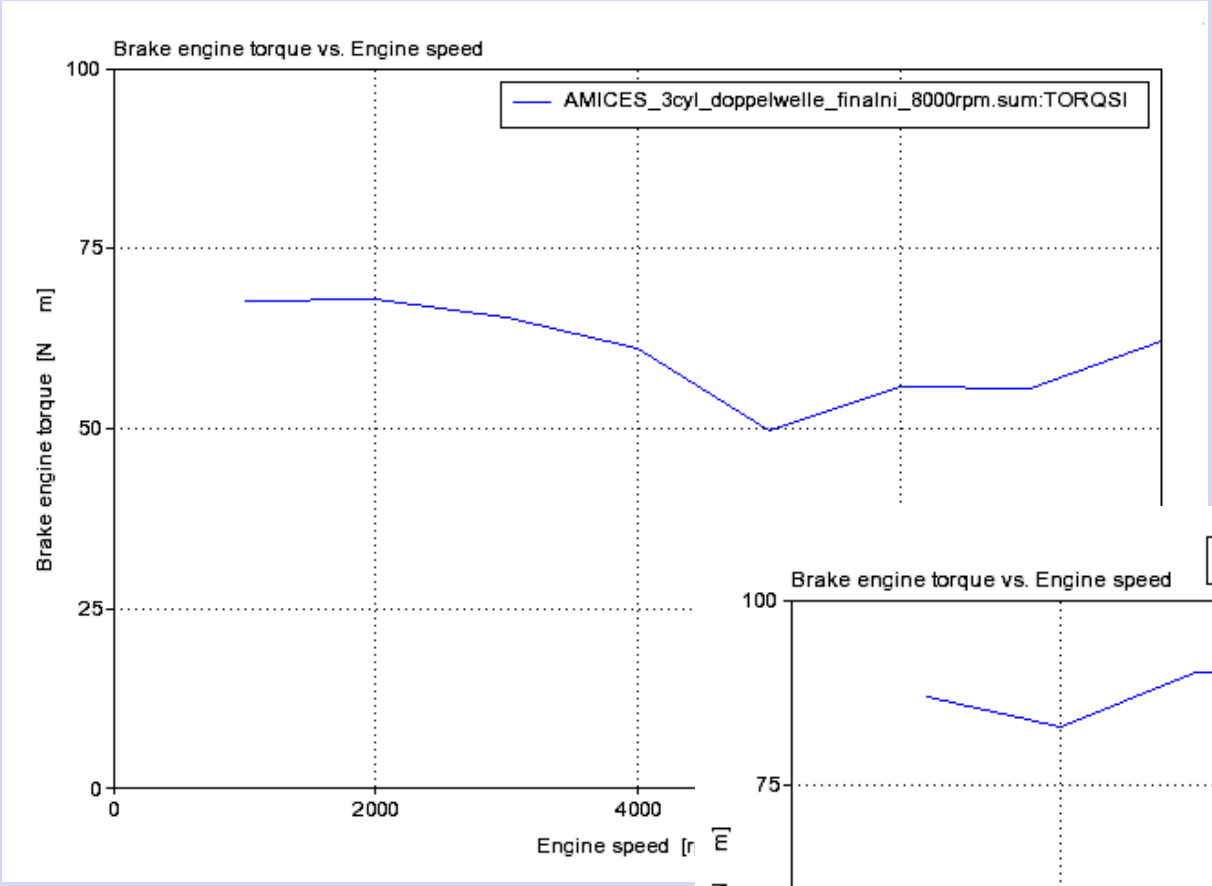
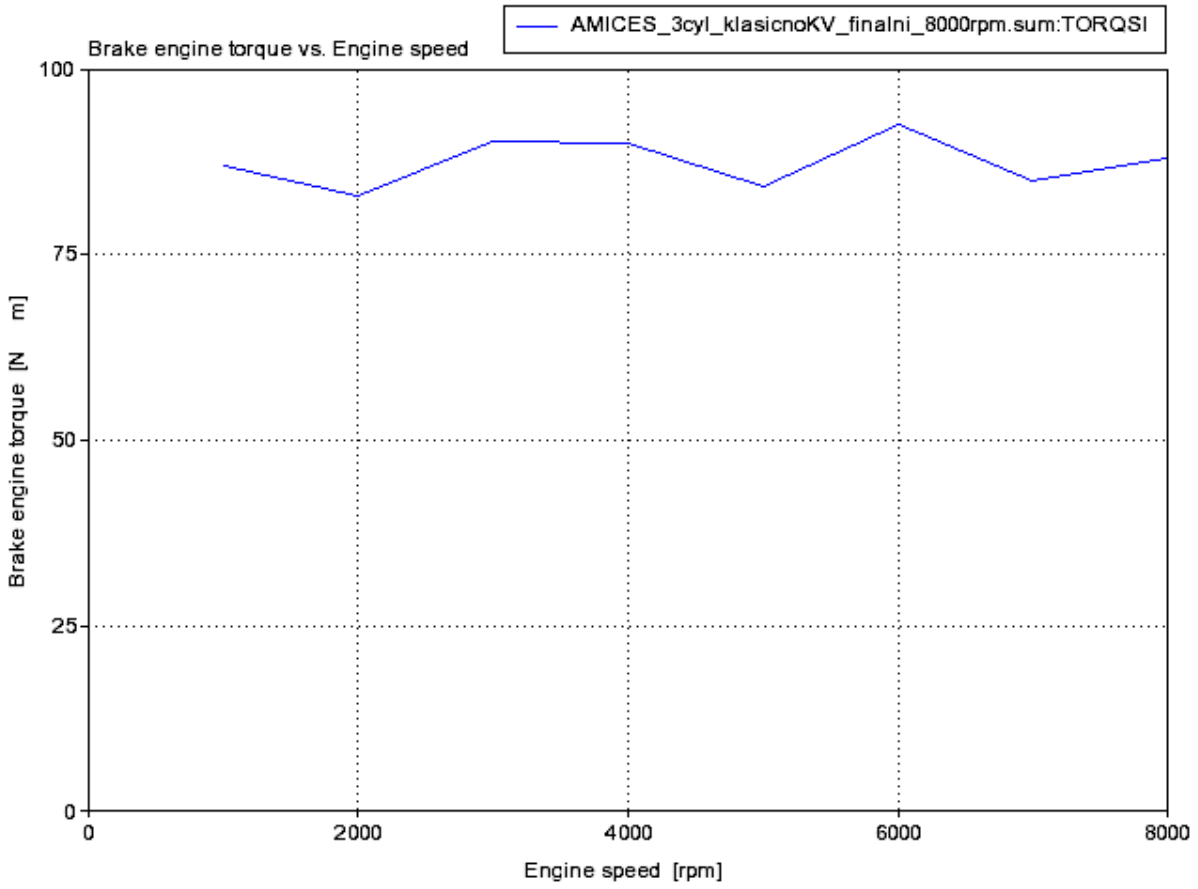
Doppelwelle






Brake engine torque vs. Engine speed
AMICES_3cyl_doppelwelle_finalni_8000rpm.sum:TORQSI
Brake engine torque [N m]
100
75
50
25
0
0
2000
4000
Engine speed [r


AMICES_3cyl_klasicnoKV_finalni_8000rpm.sum:TORQSI
Brake engine torque vs. Engine speed
Brake engine torque [N m]
100
75
50
25
0
0
2000
4000
6000
8000
Engine speed [rpm]


A
B
C

Europska unija
Projekt je sufinancirala Europska unija iz Europskog socijalnog fonda.
Ulaganje u budućnost
ESF Razvoj ljudskih potencijala

Prednosti

- Manja masa klipova i do 30 %
- Bolje performanse motora (manje vibracija, potrošnja goriva manja i do 5 %)
- Toplinska i mehanička postojanost pri velikim temperaturama
- Stabilnost
- Vrlo malo toplinsko širenje klipa
- Manje emisije štetnih plinova i to 20 % HC, 30 % CO, 3 % NOx
- Smanjenje potrošnje ulja za podmazivanje i to za 56 %. Rad motora je čak moguć i u uvjetima kada nestane ulja
- Konstantna tvrdoća od 90-120 HRB pri svim temperaturama
- Otpornost na oksidaciju, sve do 600 °C
- Izvrsna tribološka svojstva
- Jednaka raspodjela topline unutar cilindra
- Ne trebamo kompliciran sustav hlađenja

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Ulaganje u budućnost
ESF Razvoj ljudskih potencijala

Budući zadaci – 2015.

- Bolje istraživanje Doppelwelle sistema
- Uključivanje novih studenata u rad
- Moguće smanjenje snage motora, više kompresijskih tankova – bolja stabilnost sustava
- CFD analiza ubrizgavanja zraka unutar cilindra
- Ostvarivanje suradnje s AVL-om
- Daljnje ispitivanje modela u softverskom paketu Ricardo Vectis
- Posjet i prezentacija u BMW Munchen

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Ulaganje u budućnost
Europska unija
RAZVOJ LJUDSKIH POTENCIJALA

Prednosti AMICES projekta !!!

- Ostvaren kontakt sa inženjerima iz BMW-a Munchen, zadobiveno njihovo povjerenje za nastavak suradnje na ovom i budućim projektima
- 3 generacije studenata obrađuju temu AMICES-a u svojim završnim i diplomskim radovima
- Mogućnost stručne prakse i daljnjeg usavršavanja u BWM Munchen
- Usporedba znanja , kvalitete i sposobnosti studenata s FESB-a sa studentima iz drugih država EU (Mechanical Engineering at Vienna University of Technology)
- Uključivanje studenata u projekte gdje mogu primjeniti stečeno teorijsko znanje
- Rad u softverskim paketima CATIA V5, Lotus Engine Simulation, Ricardo , SOLIDWORKS i sl.
- Izvrsna referenca za buduće projekte ili zaposlenje u velikim tvrtkama u području autoindustrije

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Ulaganje u budućnost
ESF RAZVOJ LJUDSKIH POTENCIJALA

Hvala na pozornosti !