Researcher Links UK-Russia Workshop

Scientific and Technical Grounds of Future Low-Carbon Propulsion

19th - 22nd November 2018, Northumbria University at Newcastle, UK

Using of heat transfer intensification by dimples at heat recovery system

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Piston Engine Department

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Since 1826
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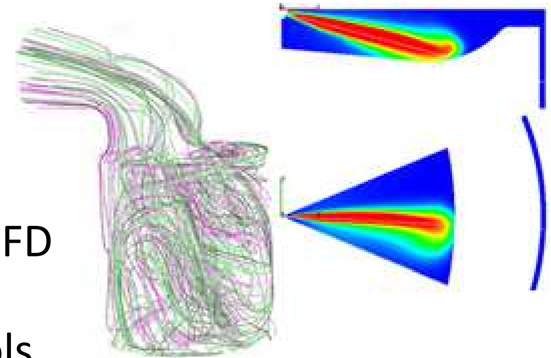
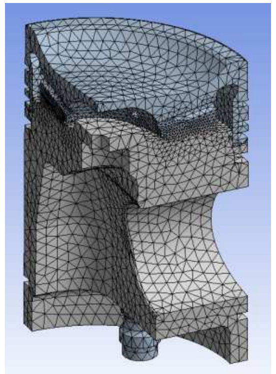
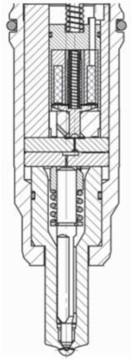




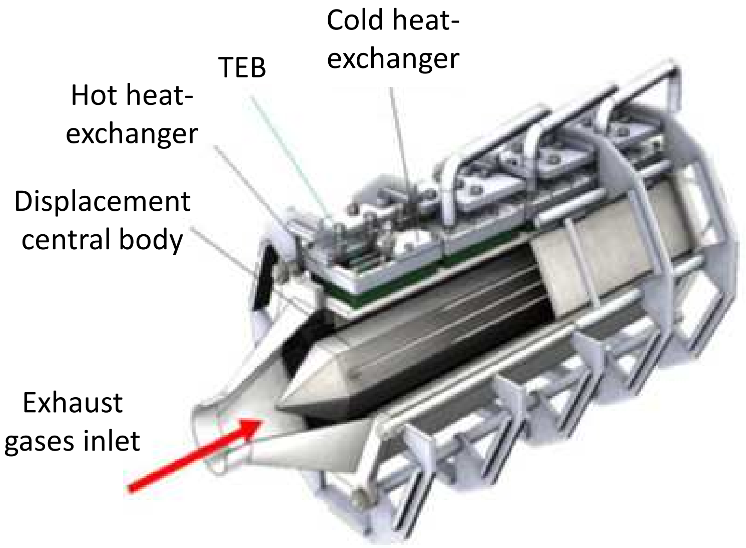
Research and commercial work
Simulation and experiment



Waste heat recovery

- Waste heat
  - Heating
  - Cooling (absorption chillers)
  - Conversion to mechanical energy
  - Direct conversion to electricity
    - Thermoelectric generator (TEG)

Designed and made at Bauman university automotive TEG



CFD of heat exchanger flow

$$\rho \frac{DW_i}{D\tau} = G_i - \frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial W_i}{\partial x_j} + \frac{\partial W_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial W_k}{\partial x_k}\right)\right],$$

$$\rho \frac{DH}{D\tau} = \frac{\partial}{\partial x_j}\left(\lambda \frac{\partial T}{\partial x_j}\right) + \frac{\partial p}{\partial \tau} + \frac{\partial}{\partial x_j}\left(\tau_{ij} W_j\right) + G_j W_j + w_r Q_r + \frac{\partial q_{Rj}}{\partial x_j},$$

$$\frac{\partial \rho}{\partial \tau} + \frac{\partial}{\partial x_j}\left(\rho \cdot W_j\right) = 0.$$

Turbulence model (k-ζ-f)

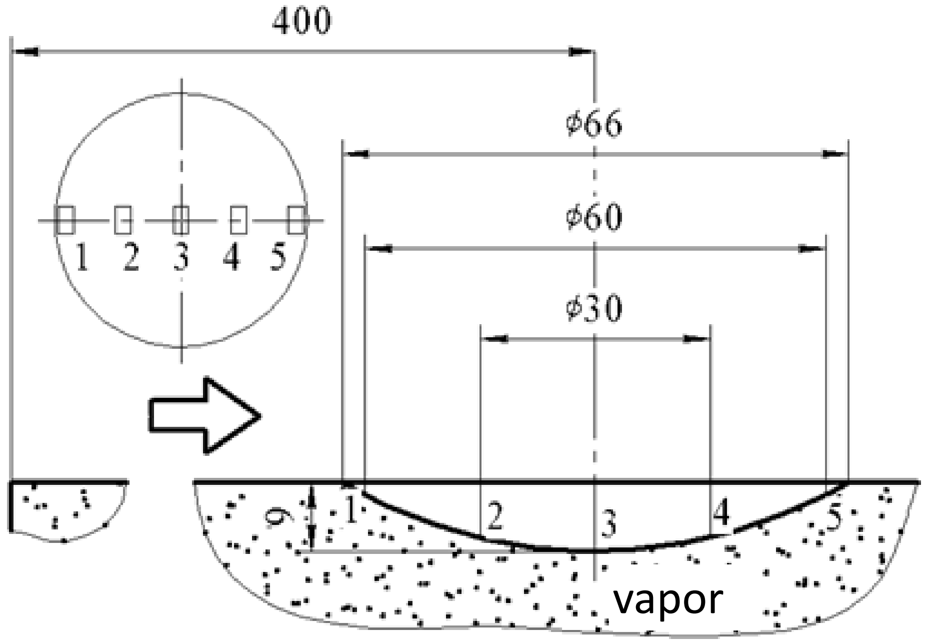
$$\rho \frac{Dk}{D\tau} = \rho(P_k - \varepsilon) + \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]$$

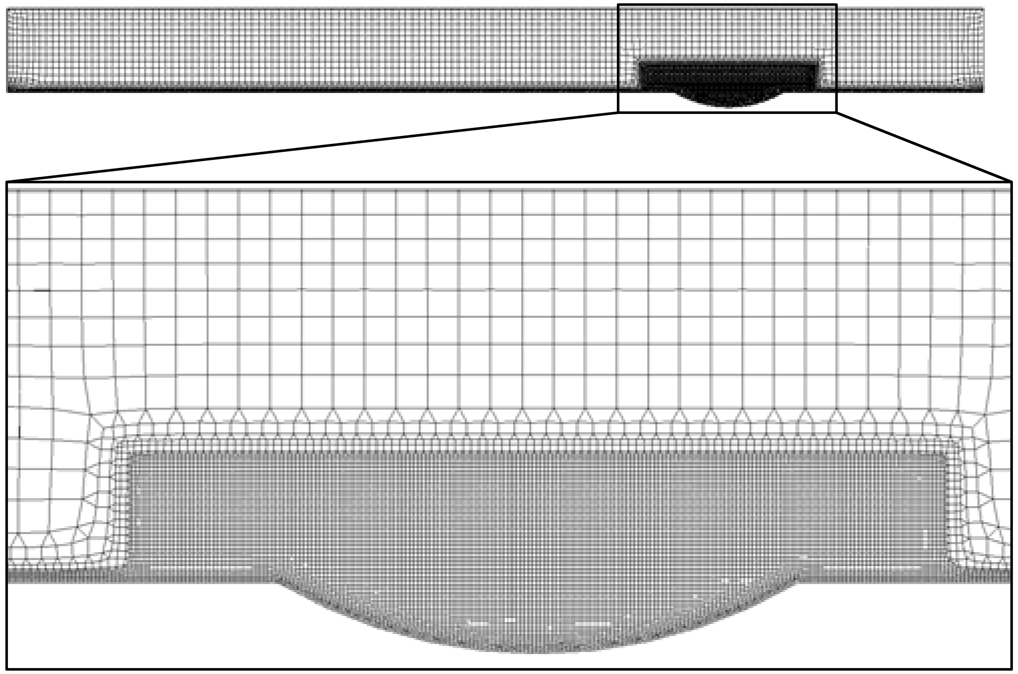
$$\rho \frac{D\varepsilon}{D\tau} = \rho \frac{C_{\varepsilon 1}^{*} P_k - C_{\varepsilon 2}\varepsilon}{\tau_t} + \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]$$

$$\rho \frac{D\zeta}{D\tau} = \rho f - \rho \frac{\zeta}{k} P_k + \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\zeta}\right)\frac{\partial \zeta}{\partial x_j}\right]$$

$$f - l^2 \frac{\partial^2 f}{\partial x_j x_i} = \left(c_1 + C'_2 \frac{P_k}{\zeta}\right)\frac{\frac{2}{3} - \zeta}{\tau_t}$$

Local Heat Fluxes on the Dimpled Surfaces Validation





Experiment by Mityakov V.Y., Mityakov A.V. and Sapozhnikov S.Z. [Local heat fluxes on the surfaces of dimples, ditches, and cavities/ Mityakov V.Y., Mityakov A.V., Sapozhnikov S.Z., Isaev S.A.// Thermal Engineering. 2007. V. 54. I. 3. P. 200–203]

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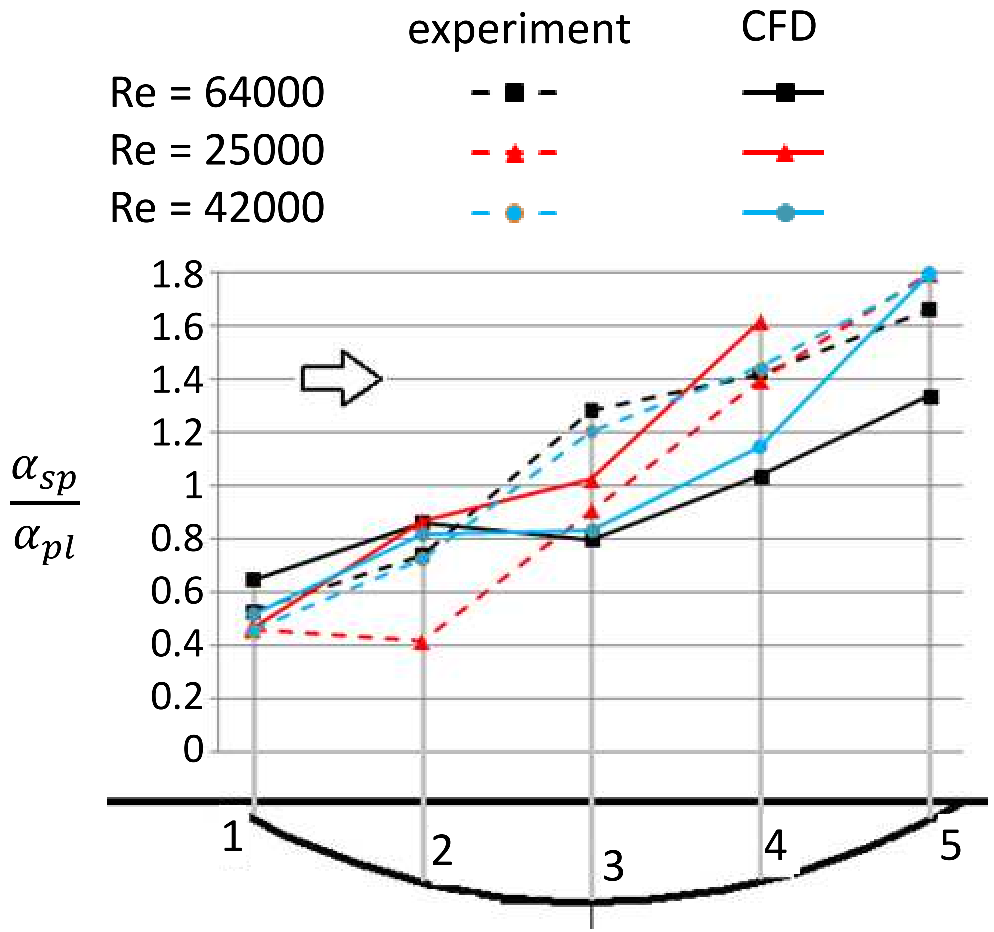

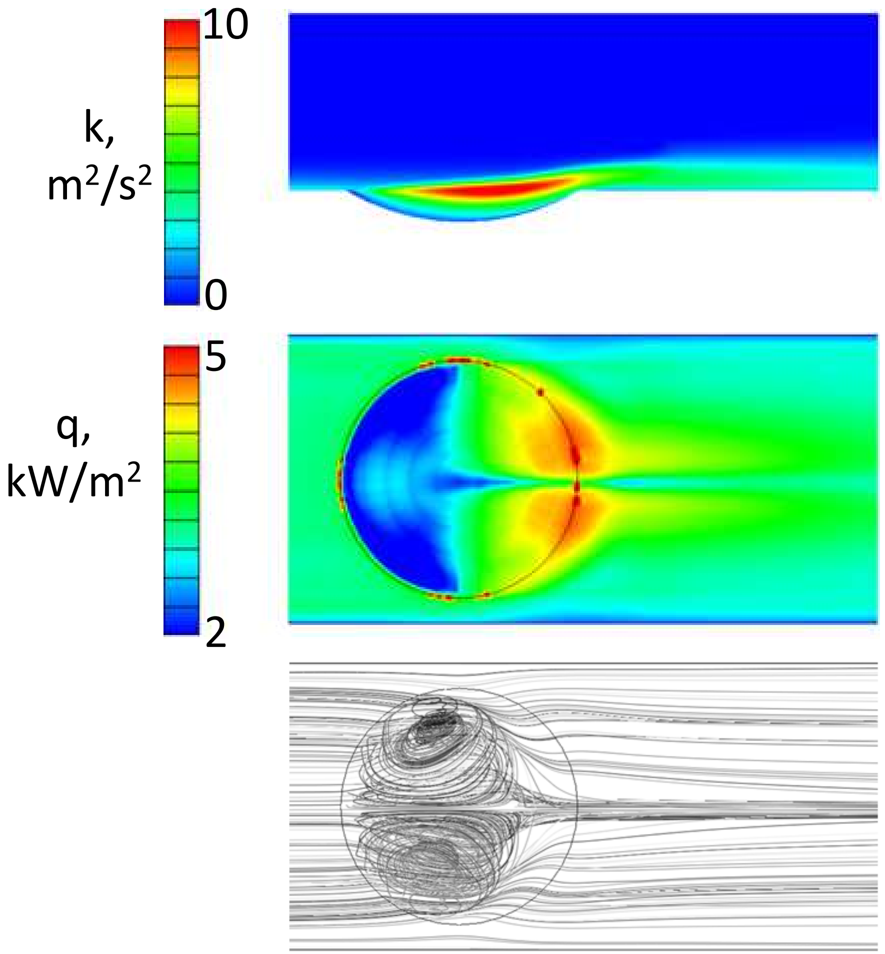

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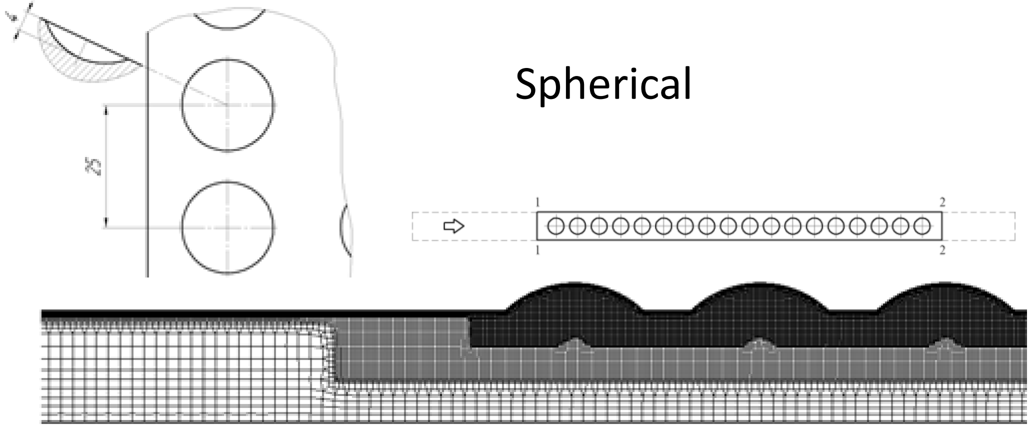
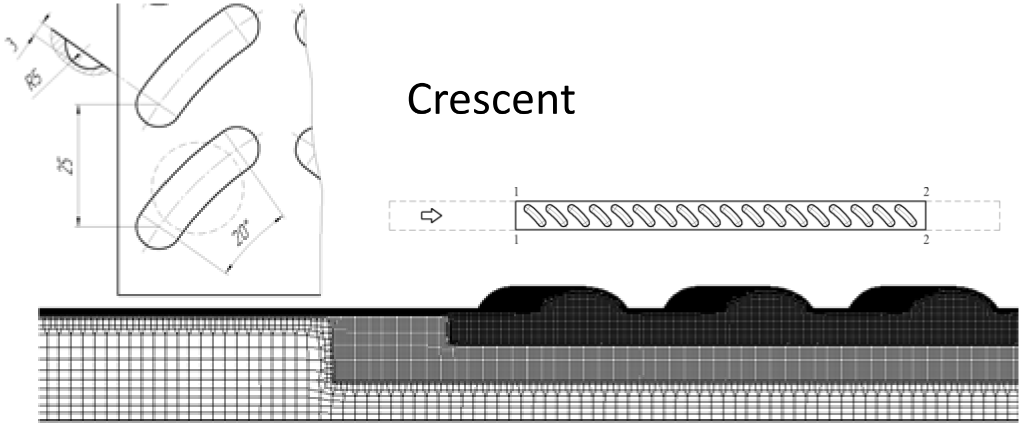
Dimple shapes

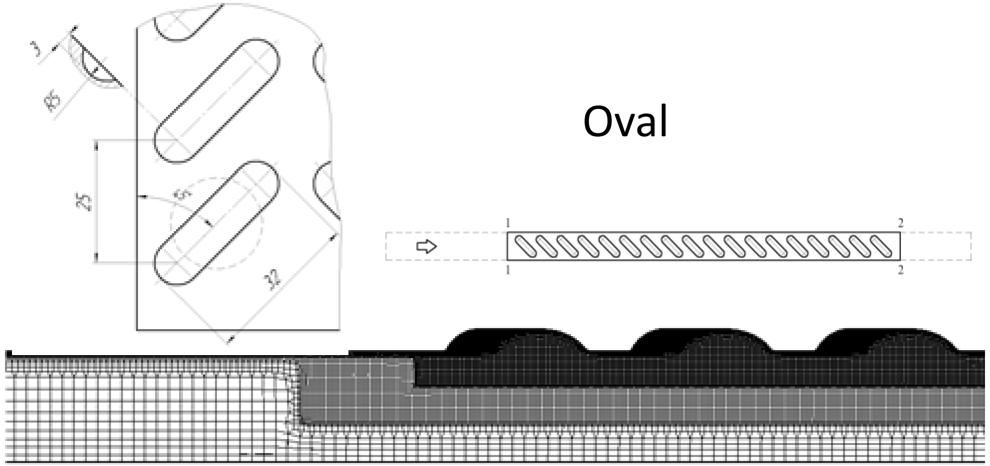
Spherical



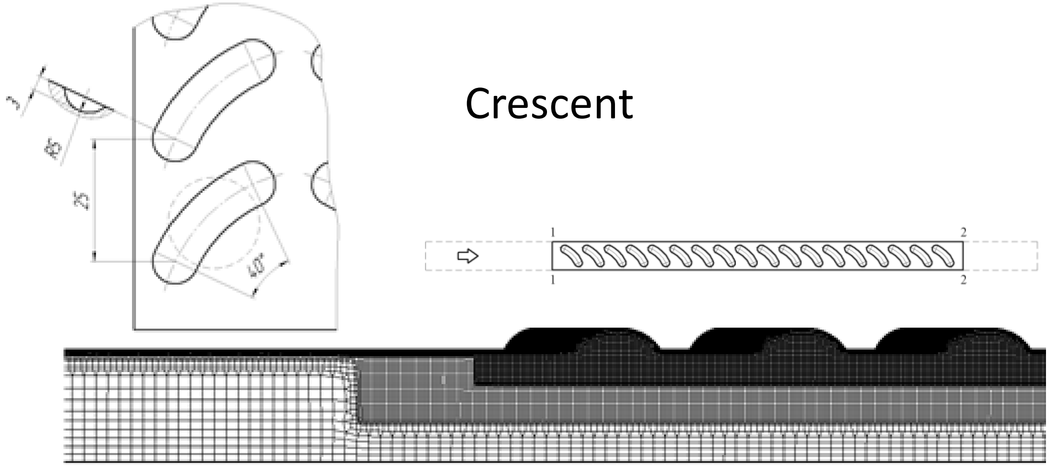
Crescent



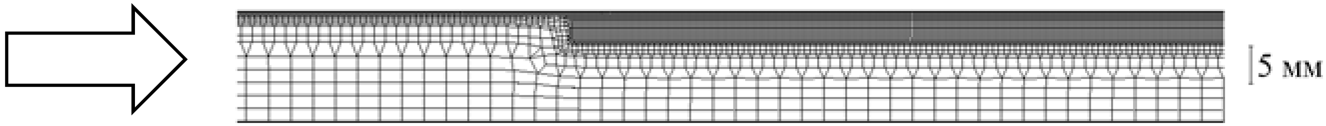
Oval



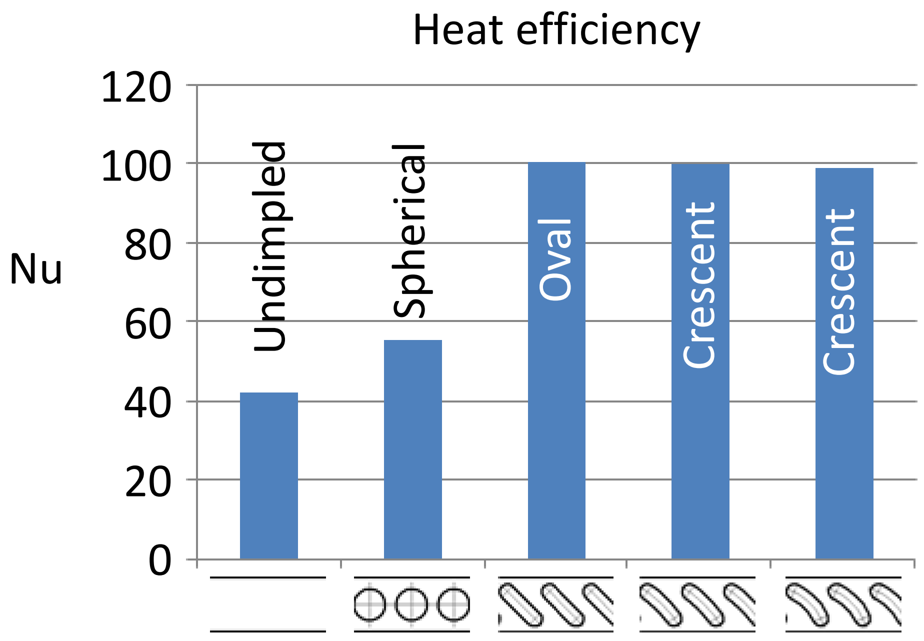
Crescent

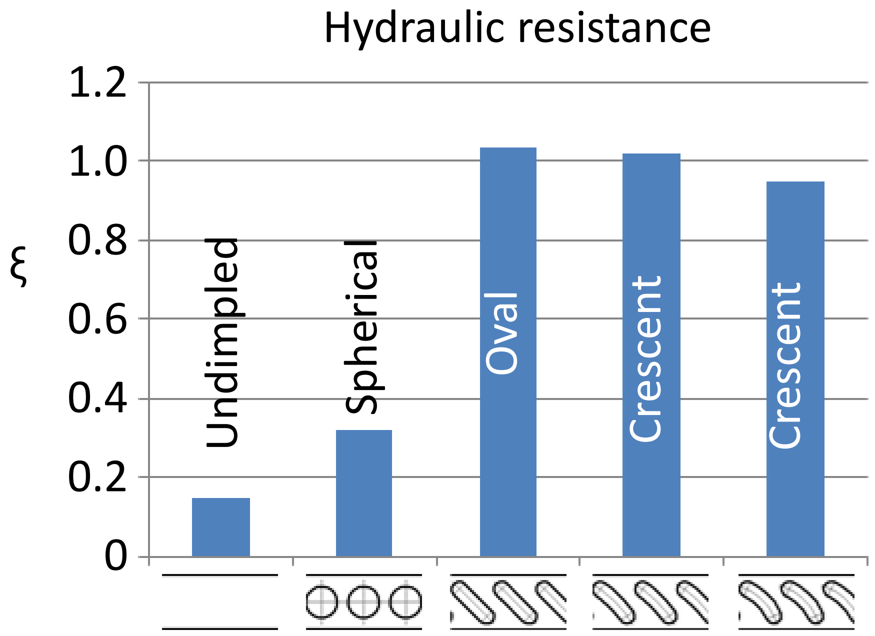


Undimpled wall



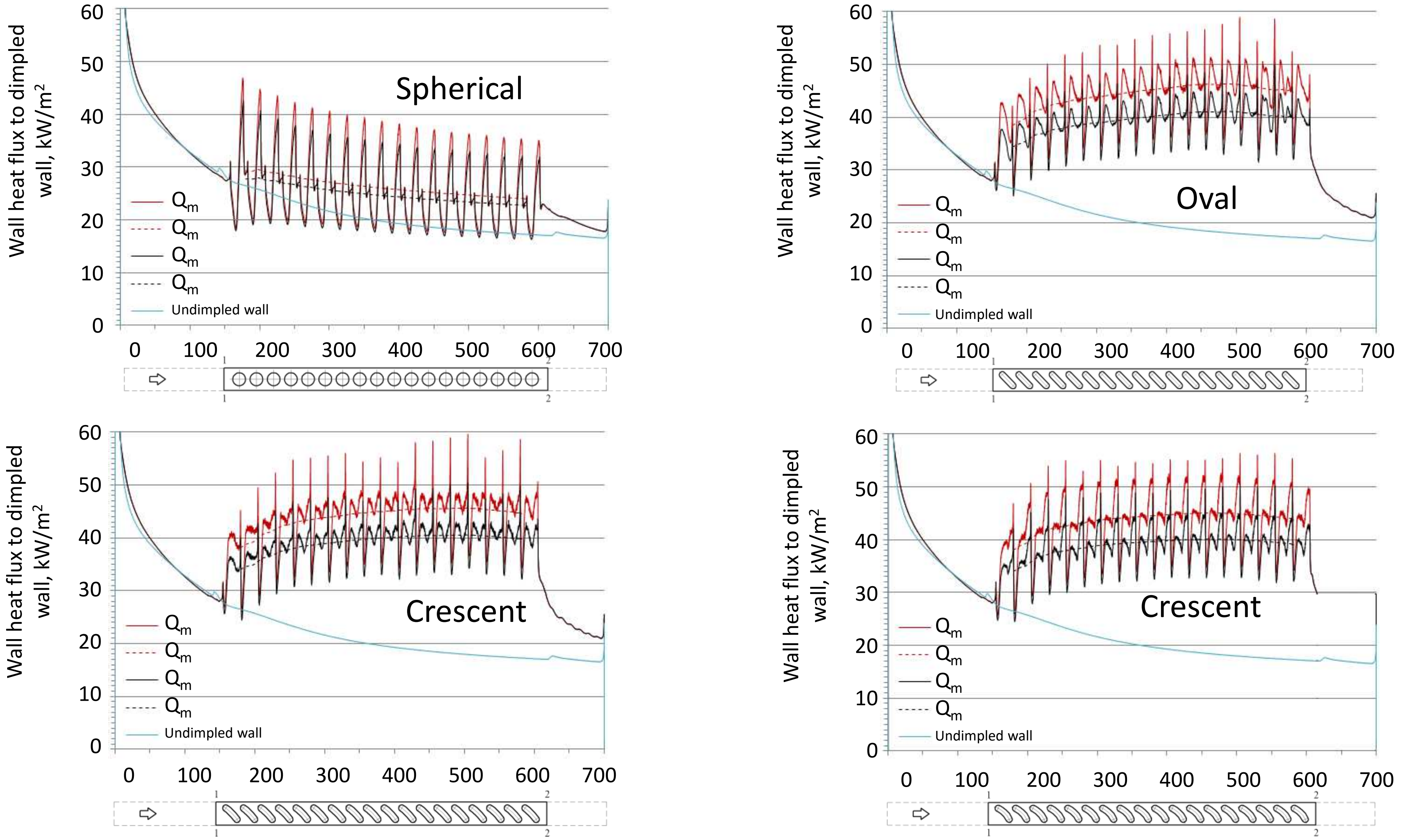
Dimples comparison



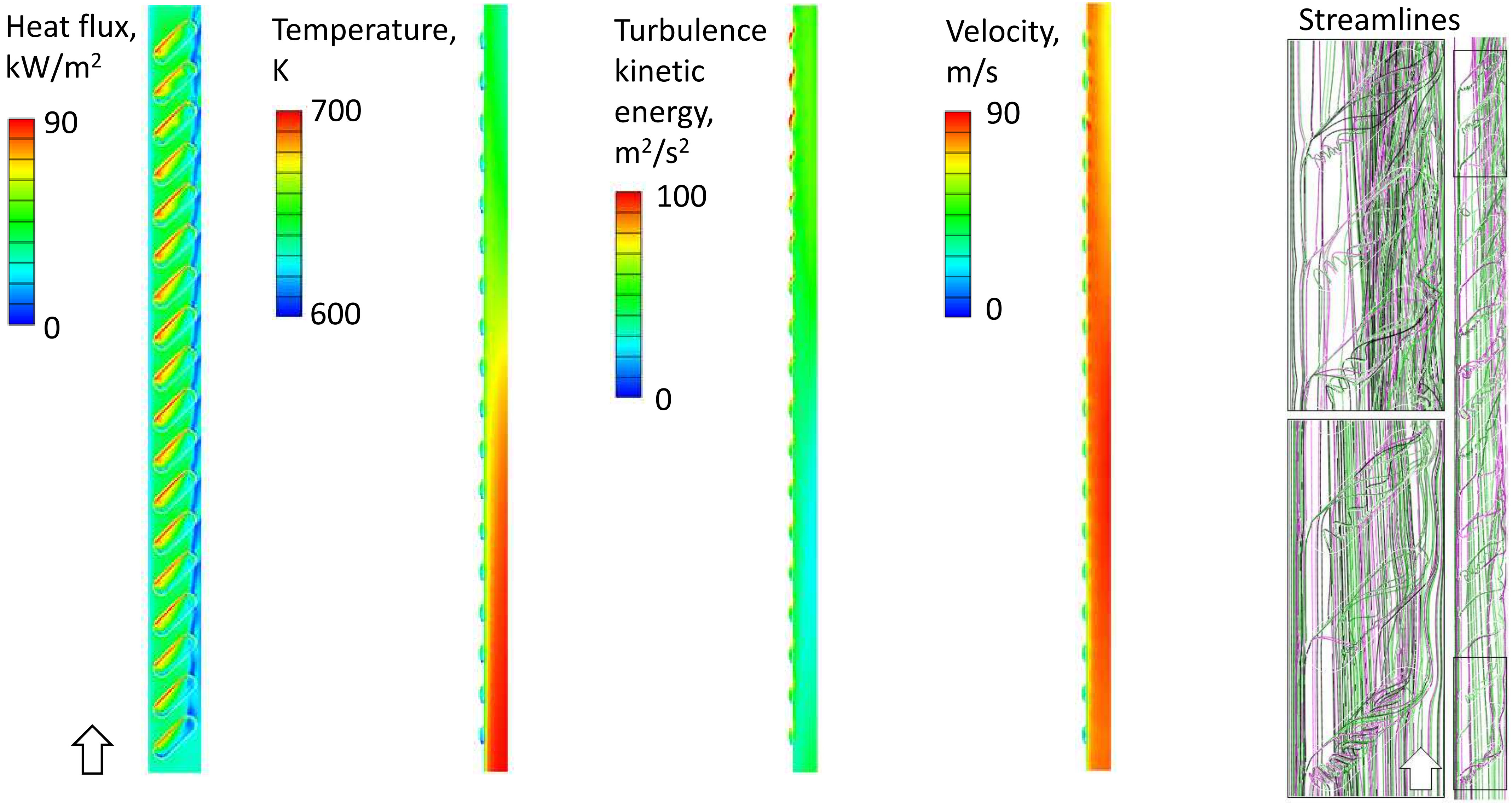


Best heat efficiency: oval dimples (2.3x heat transfer increasing).

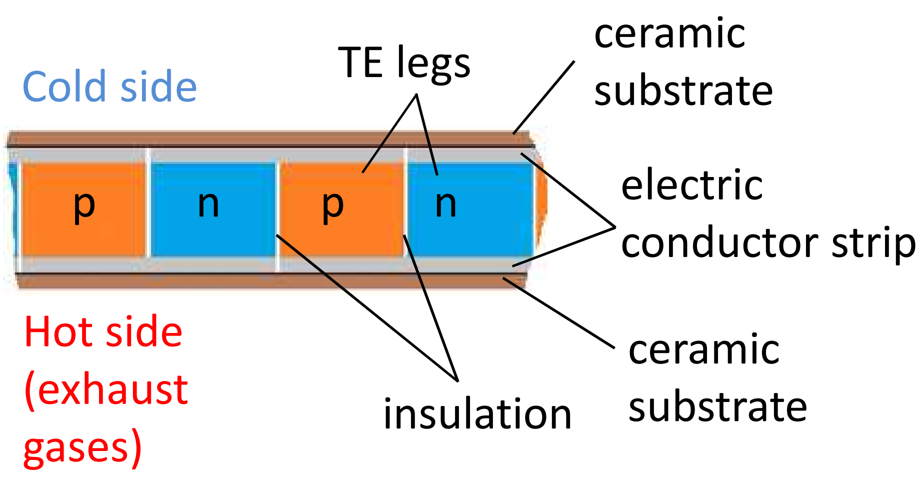
Dimples comparison

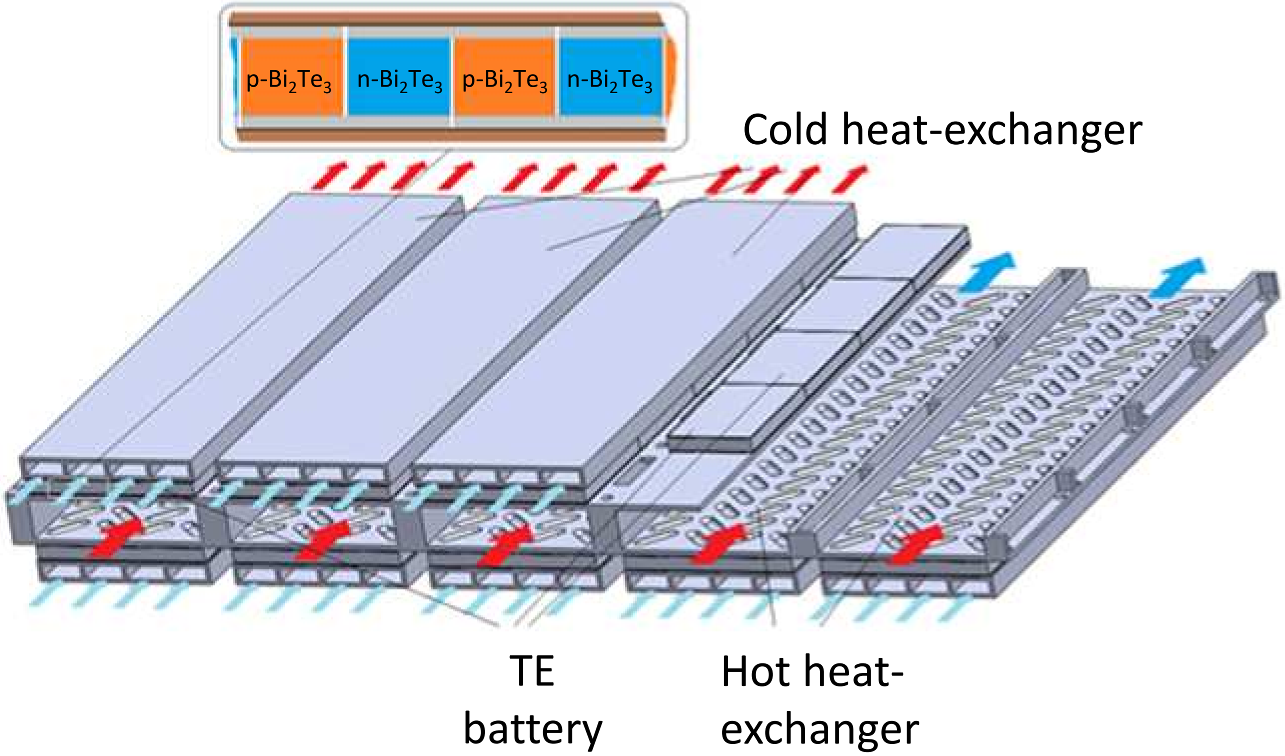


Flow at dimpled channel modeling



Thermoelectric generator



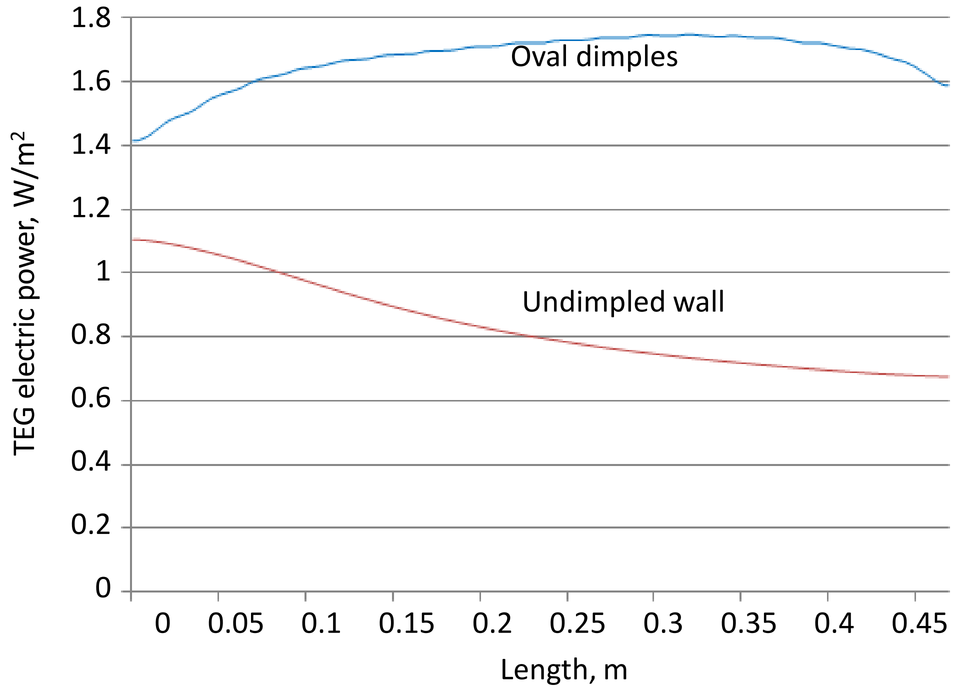


TEG heat-transfer modeling

$$\nabla(\lambda \nabla T) + q_v = 0$$

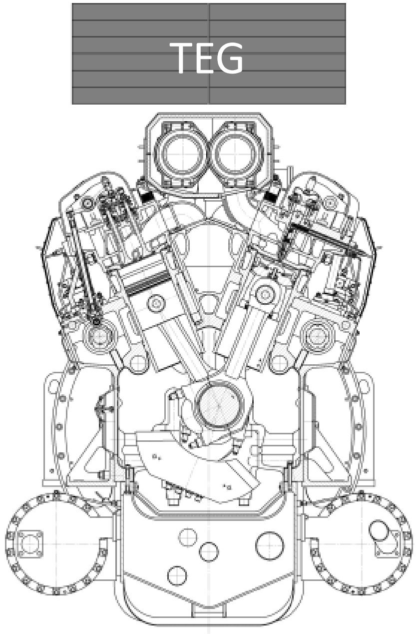
$$q_v = -\frac{\eta_{TEG} Q_{TE}}{V}$$

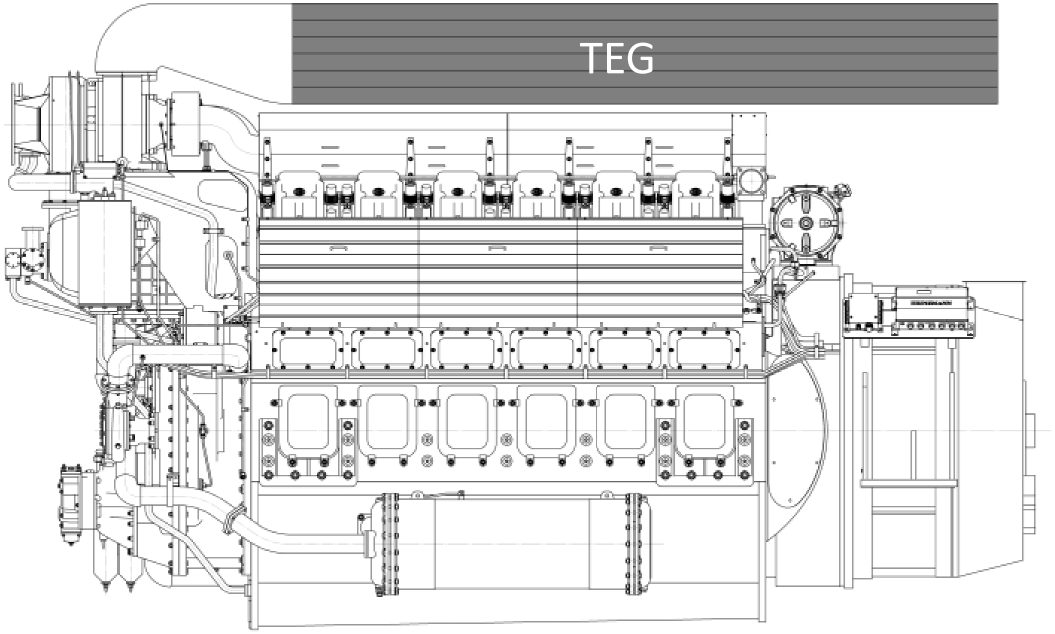
$$a_{i,j,k}T_{i,j,k} = a_{i+1,j,k}T_{i+1,j,k} + a_{i-1,j,k}T_{i-1,j,k} + a_{i,j+1,k}T_{i,j+1,k} + a_{i,j-1,k}T_{i,j-1,k} + a_{i,j1,k+1}T_{i,j,k+1} + a_{i,j,k-1}T_{i,j,k-1} + b_{i,j,k}$$



Dimple type	Heat flow to TEG, kW/cylinder	TEG electric power, kW/cylinder	TEG efficiency
Undimpled wall	13.14	0.53	4.01
Spherical	15.26	0.67	4.4
Oval	**19.91**	**1.01**	**5.08**
Crescent 1	19.87	1.01	5.08
Crescent 2	19.83	1.01	5.08

Thermoelectric generator mounted on middle-speed diesel engine





Thermoelectric generator can increasing middle-speed diesel D500 engine power at 4 kW/cylinder (48 kW for V12) and decrease fuel consumption at 2.5 $g \cdot kW^{-1} h^{-1}$.

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Thank you for your attention
Ready to answer your questions

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