Gear oil jet lubrication efficiency

Oscar CUEVAS 29/10/2019

Overall plan

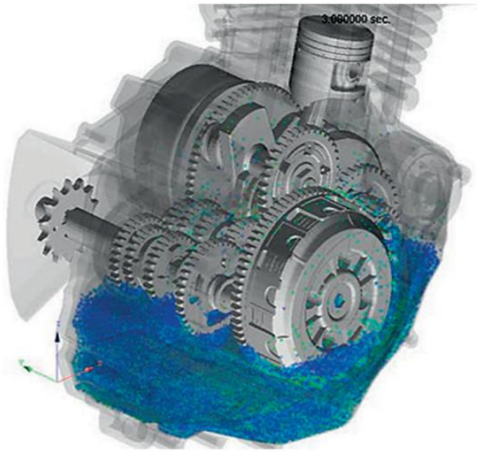
- Company’s presentation.
- Motivation.
- Problems generated by the lack of gear lubrication.
- Oil jet design.
- How to evaluate Oil jet Efficiency.
- Oil distribution on gear mesh.
- Conclusion.

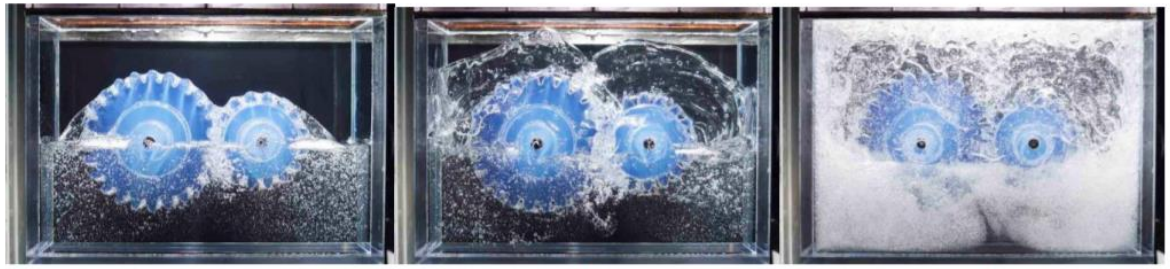
COMPANY'S PRESENTATION

- GIMA : Groupement International de Mécanique Agricole
- Located 80km north of Paris
- Design and manufacture transaxles for agricultural tractors from 70hp to 600hp
- Production : 19 500 transaxles per year
- Workforce: 800 people
- Surface: 50 000 m²

MOTIVATION

- Reduce CO2 emissions.
- Increase transmission performance.
- Eliminate churning losses using oil jet lubrication.





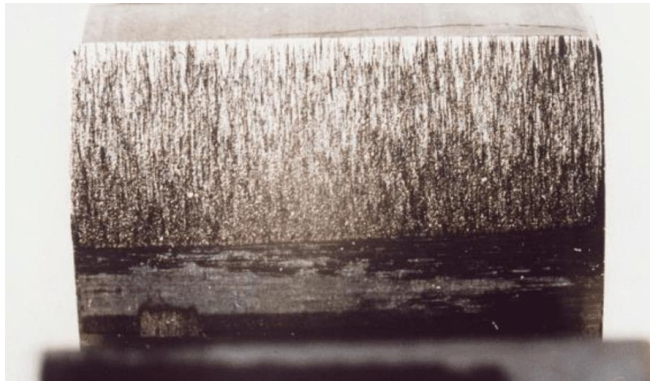
a) b) c)

Figure 1.5 The figure illustrates how the lubricant is splashed around as the gears rotate. Dimensions are the same as an FZG gear test rig .a) Wheel rotating at 145 RPM b) Wheel rotating at 290 RPM c) Wheel rotating at 580 RPM [19]

E.A. Hartono, A. Pavlenko, V. Chernoray, Stereo-PIV Study of Oil Flow Inside a Model Gearbox, (n.d.).

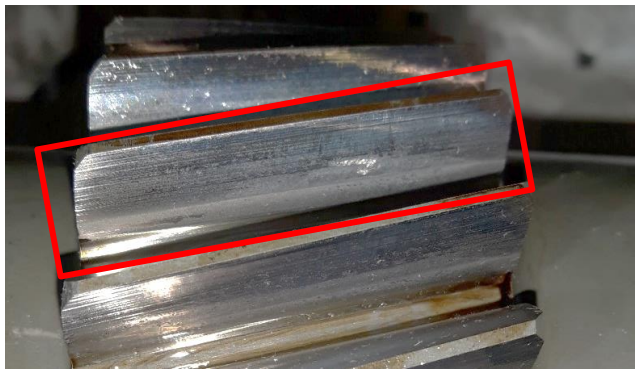
Problems generated by lack of lubrication in gears

- Gear failure related to lubrication
  - Gear Scoring



Gear scoring, Surface texture measurements of gear surfaces using stylus instruments; Wenjuan Sun 2017

- Gear Micro-Pitting
  - Noise problems
  - Generate pitting



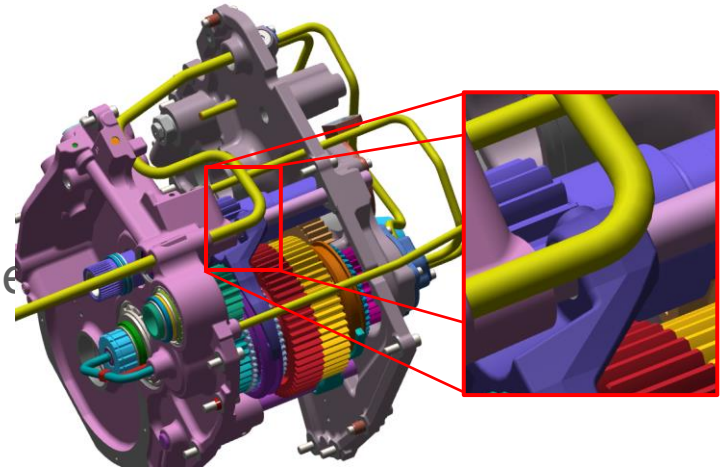
- Put the right amount of oil at the right place

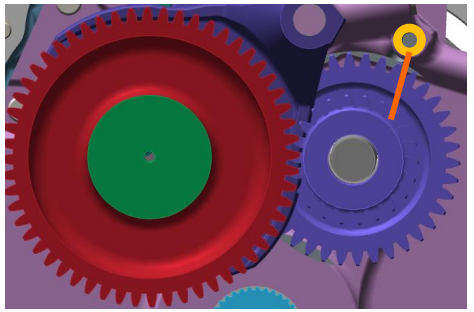
Source: Gear technology

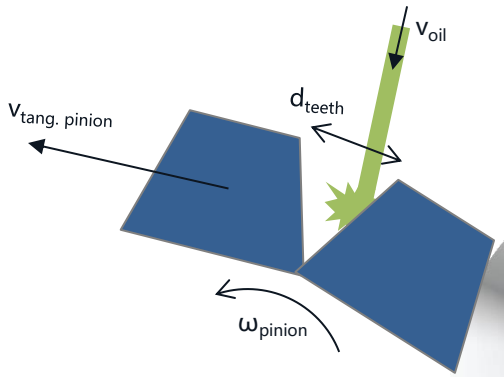
OIL JET DESIGN

Lubrication oil jet Design: Architecture constraints

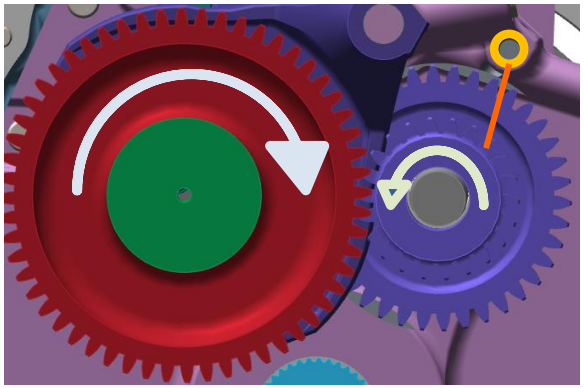
- Reduce hydraulic pressure losses.
  - Avoid too many bends.
- Manufacturing
  - Minimum radius of curvature and angle
- Gear meshes
  - Gear meshes located at different positions.
- Oil jet must avoid other components in its trajectory.
  - Shifting forks
  - Cables
  - Sensors
- Oil jet must:
  - Ensure the right flow.
  - Be correctly orientated.
  - travel at the right linear speed.



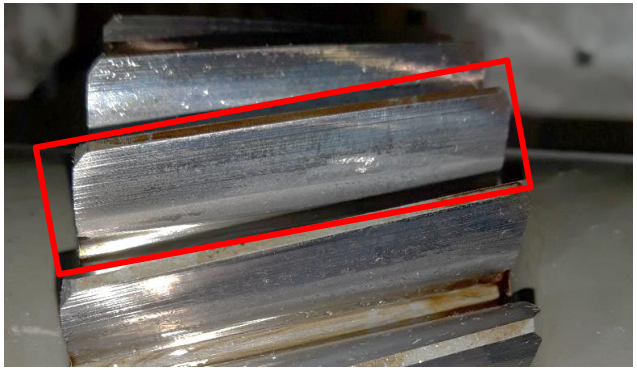


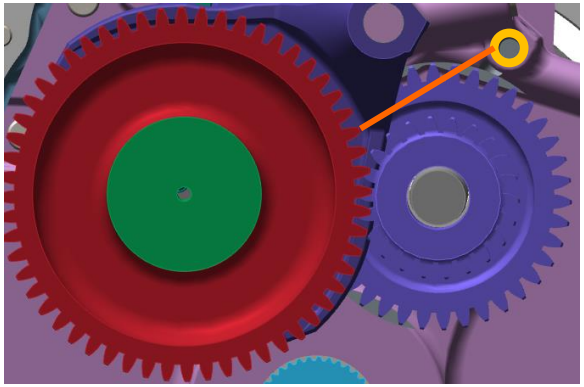


Lubrication oil jet Design: Propositions



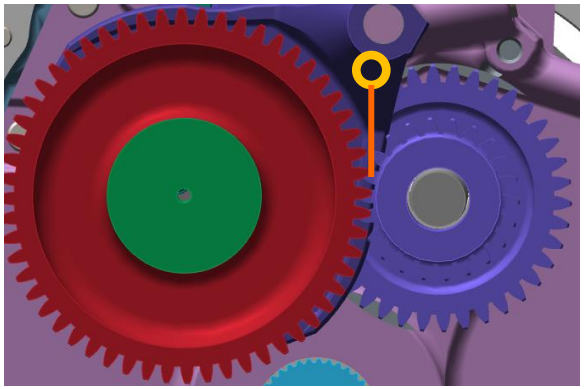
- Initial Design





- Improved

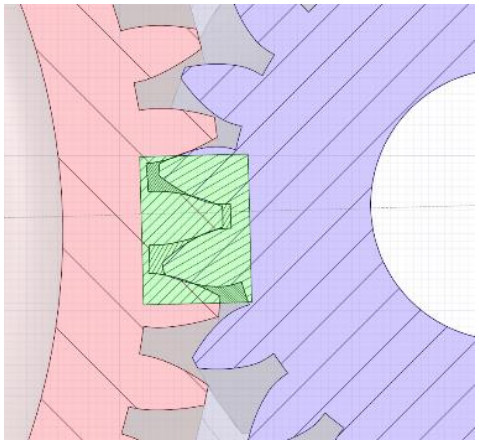
Is it a better solution?
How to prove it?

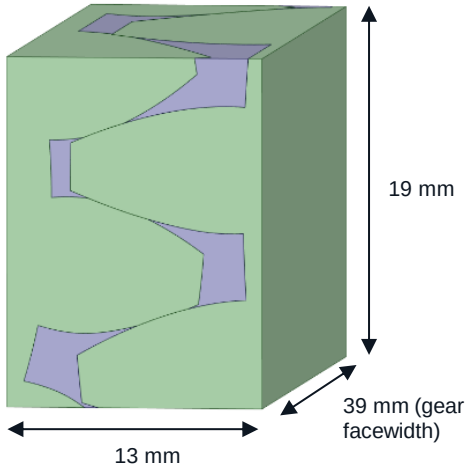


- Ideal positio
(theoretical)

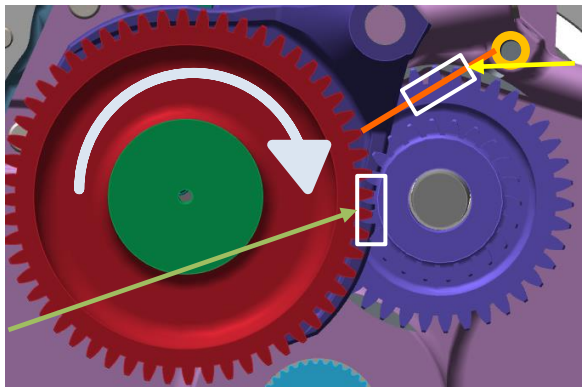
OIL JET EFFICIENCY

- Measure the input volume of oil and the oil contained in the gear mesh.





h_probe: Height is defined by the distance between gear engaging and end of gear mesh.



Oil jet Efficiency: Methods evaluation

$$E_1 = \frac{V_{oil}^{meshing}}{V_{oil}^{inflow}}$$

- → $V_{oil}^{meshing}$: Volume in the gear mesh.
- → V_{oil}^{inflow}: Input volume.

No speed dependency

$$E_2 = \frac{V_{oil}^{meshing} * \omega_{pinion}}{Q_{oil}^{inflow}}$$

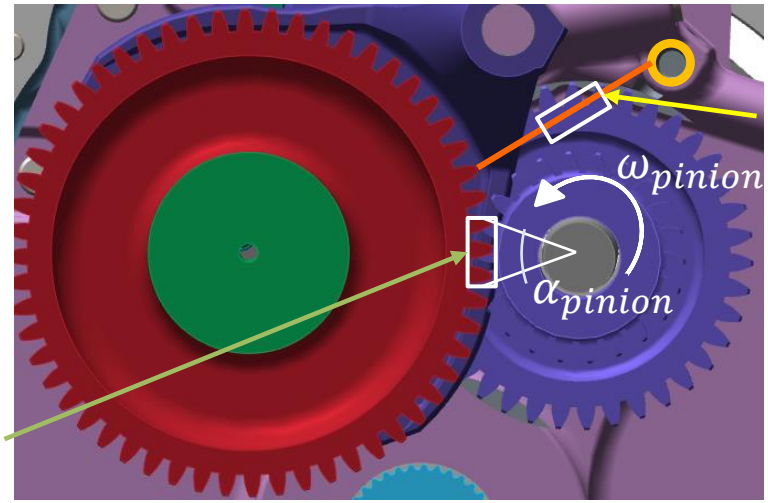
- → ω_{pinion} : Pinion rotational speed.
- → Q_{oil}^{inflow}: input flow.

Results depends on pinion or gear

$$E_3 = \frac{(V_{oil}^{meshing}/\epsilon_\alpha) \cdot (\omega_{pinion}/\alpha_{pinion})}{Q_{oil}^{inflow}}$$

- → ϵ_α : Gear contact ratio.
- → α_{pinion}: angle on pinion between centre and gear mesh

Results depends on gear macro geometry

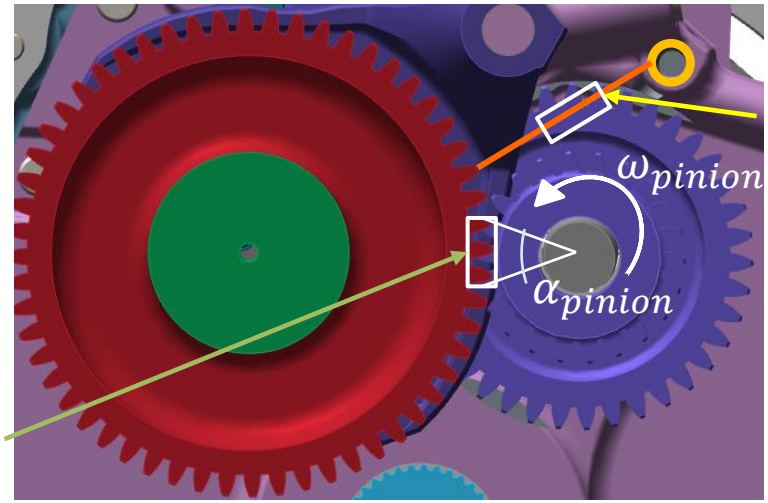


- Lubrication efficiency equal to the ratio between the oil volume contained within two control volumes.

$$E_4 = \frac{V_{oil}^{MESHING}}{V_{oil}^{INFLOW}} = \frac{V_{oil}^{MESHING}}{t_{PROBE} * Q_{INFLOW}}$$

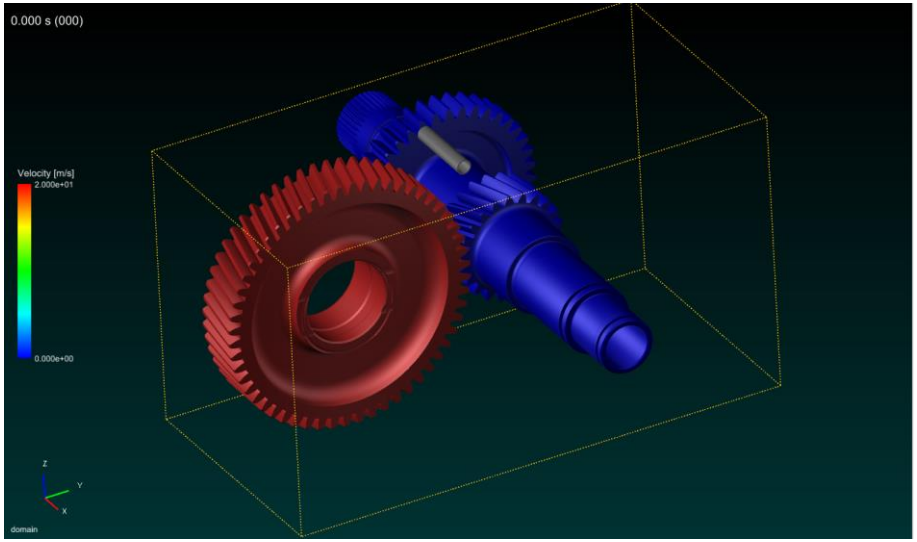
- The time to probe the input flow is derived from gear tangential speed:

$$t_{PROBE} = \frac{h_{PROBE}}{U_{pinion}} = \frac{h_{PROBE}}{\omega_{pinion} * R_{pitch\,pinion}}$$

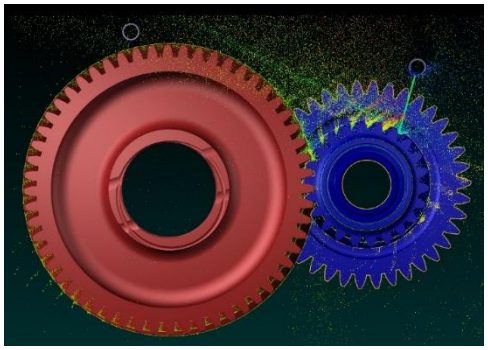


Oil jet Efficiency: Building the model

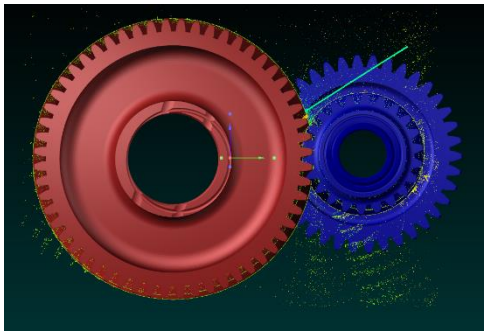
- Input data
  - Lubricant characteristics : oil viscosity, oil density, surface tension coefficient, contact angle.
  - Oil flow rate.
  - CAD (STL format)
- Working conditions: shaft speed
- Process settings: particle size, simulation time, interval time.



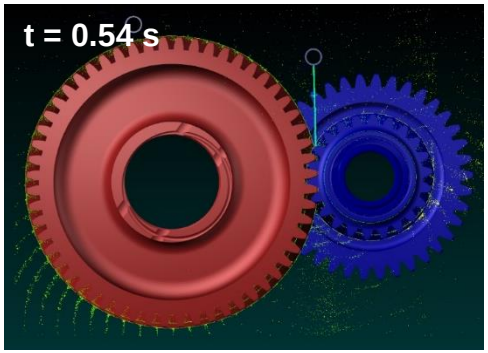
Oil jet Efficiency : Results



- Initial Geometry
  - Oil jet efficiency: 102%



- Lubrication improvement
  - Oil jet efficiency: 158%



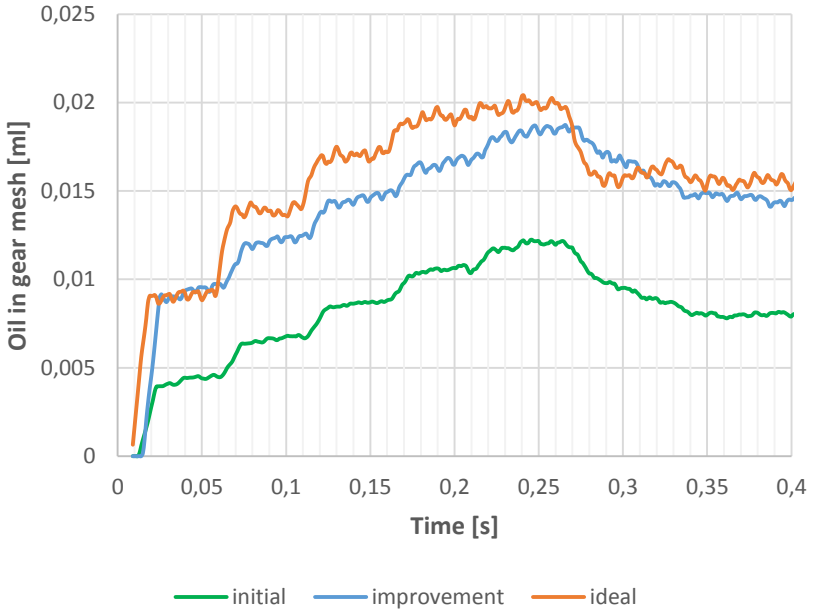
- Ideal Geometry (theoretical)
  - Oil jet efficiency: 178%

Why is there an efficiency > 100%?

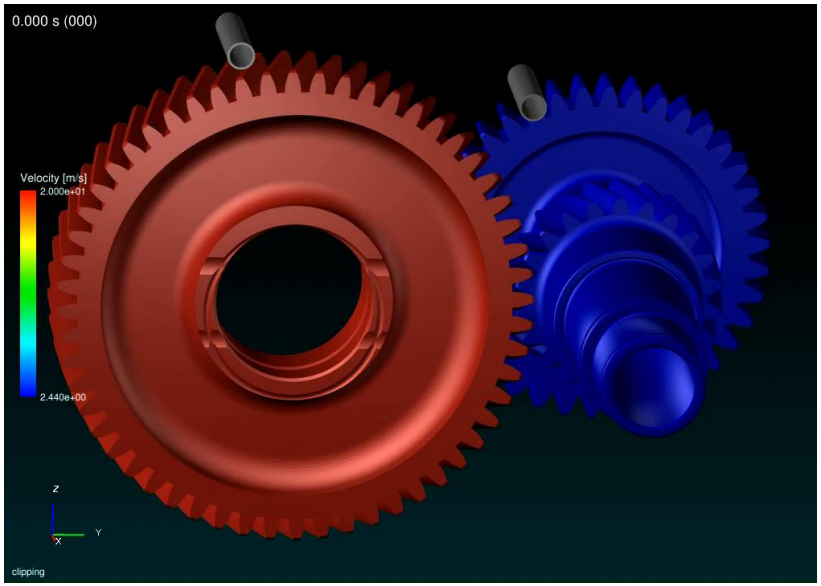
* Results for 3000rpm on pinion

Oil jet Efficiency : Results

- Curve of oil quantity vs time:

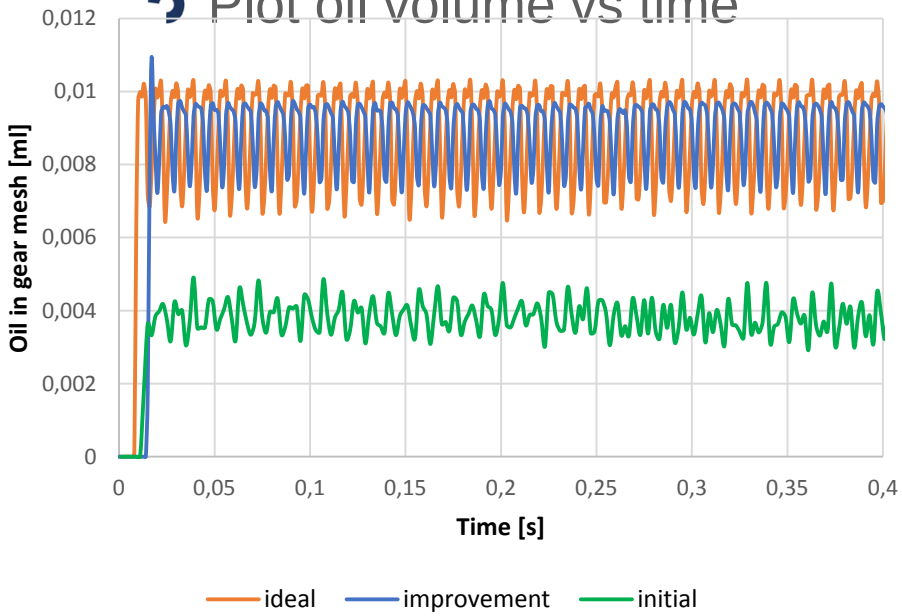


- Simulation Analysis:



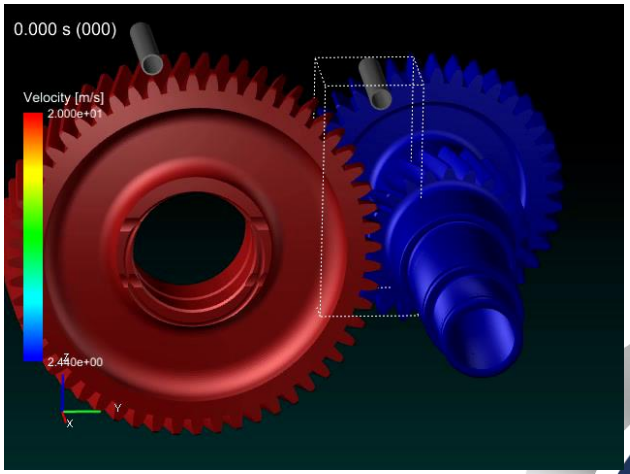
* Results for 3000rpm on pinion

- Calculation domain reduced:
  - Plot oil volume vs time



- Calculation domain reduced:
  - Results

Geometry	Efficiency [%]
Initial	40 %
Improvement	100%
ideal	100%

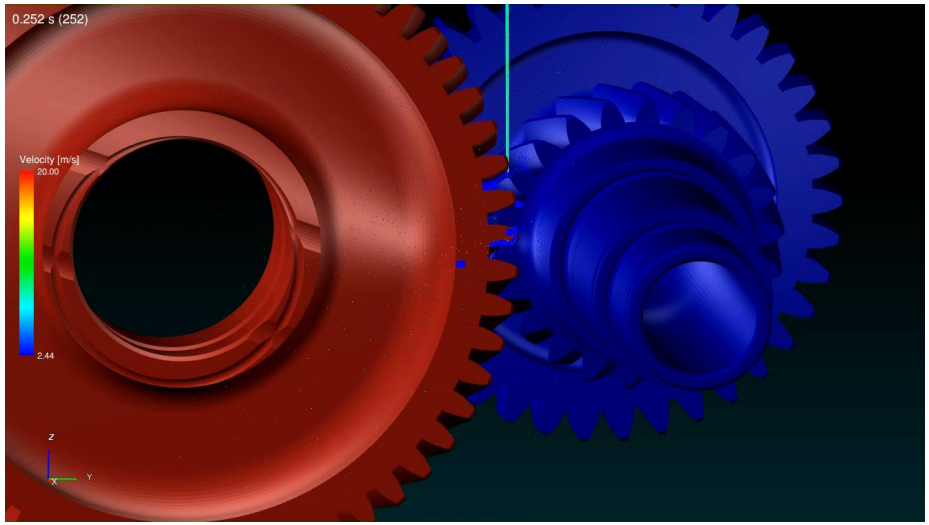


* Results for 3000rpm on pinion

Oil jet Efficiency : Speed sensitivity

- How is the evaluation method behaving against gear speed.
  - Based on the theoretical position
  - Evaluation at different speeds from slow to fast

Speed [rpm]	Efficiency [%]
30	84 %
3000	100%
12000	100%

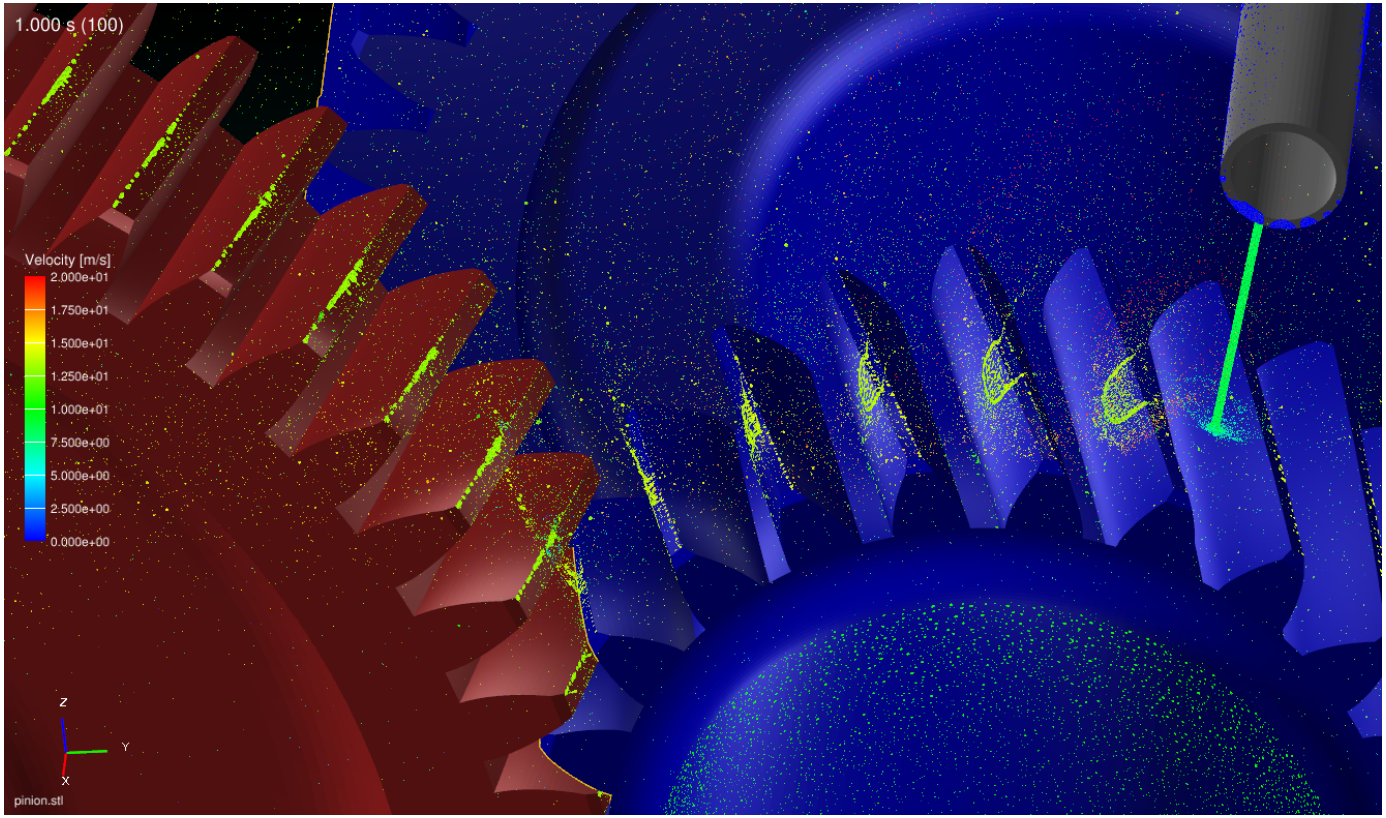


Evaluation method works for a large range of speed.

OIL DISTRIBUTION IN GEAR MESH

Distribution of oil in the gear mesh

- Is the oil well distributed in the gear mesh?



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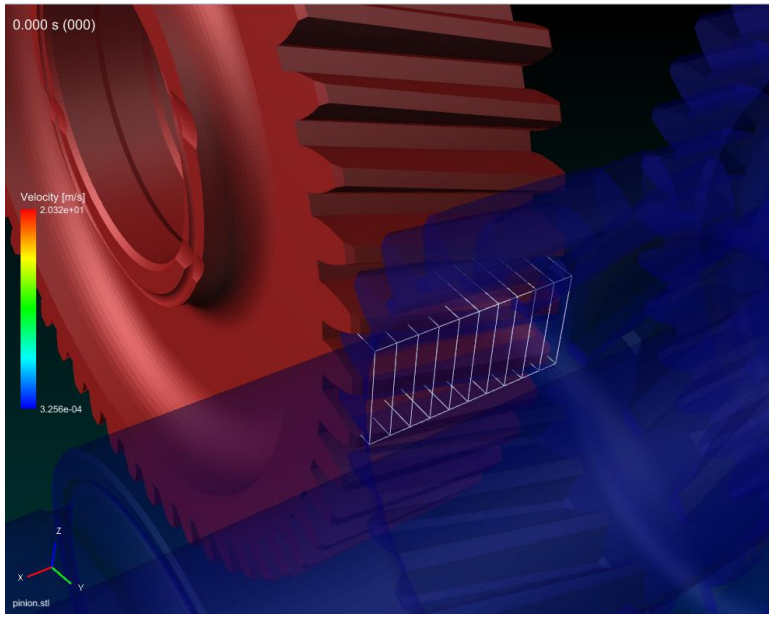

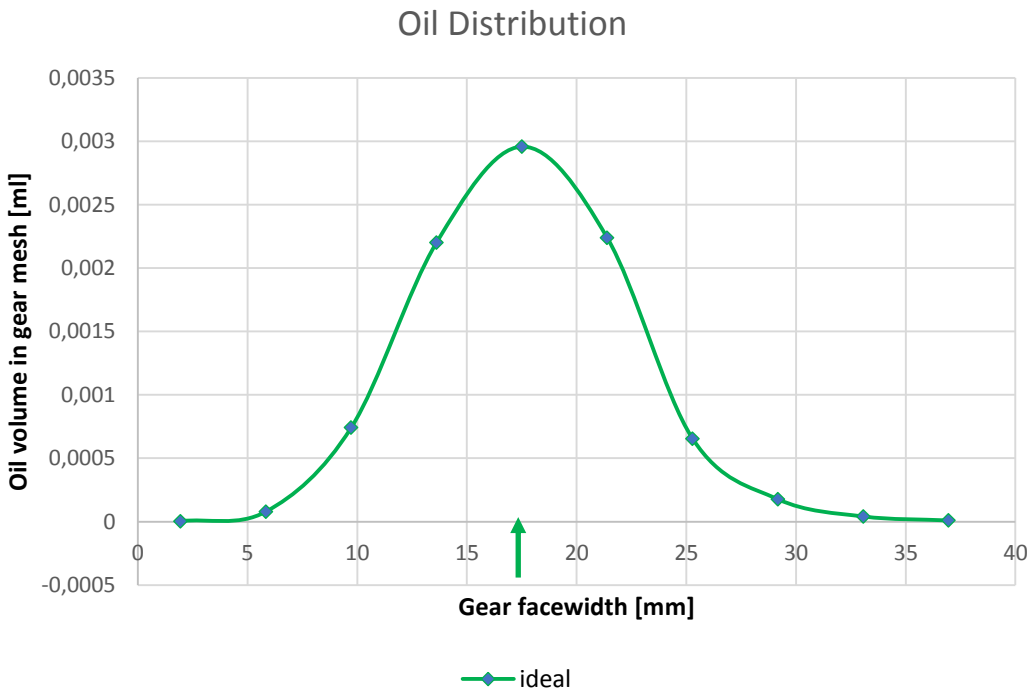

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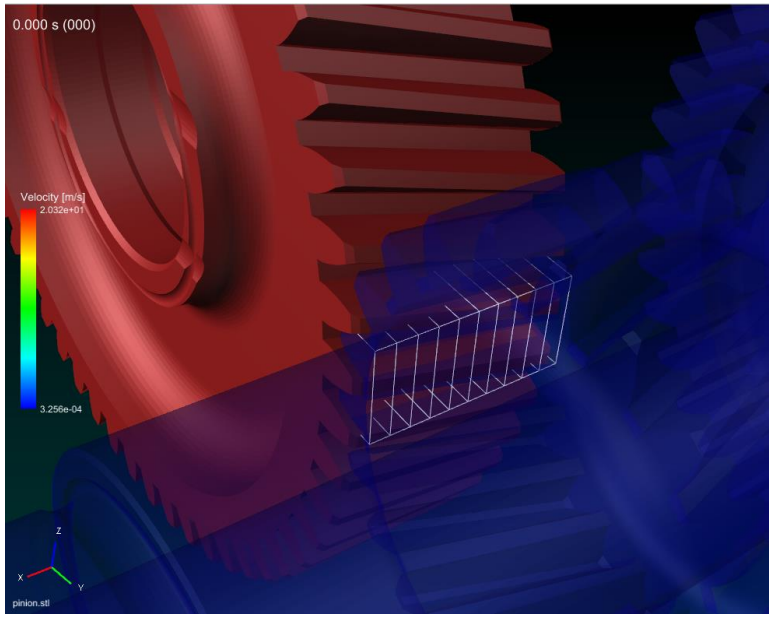

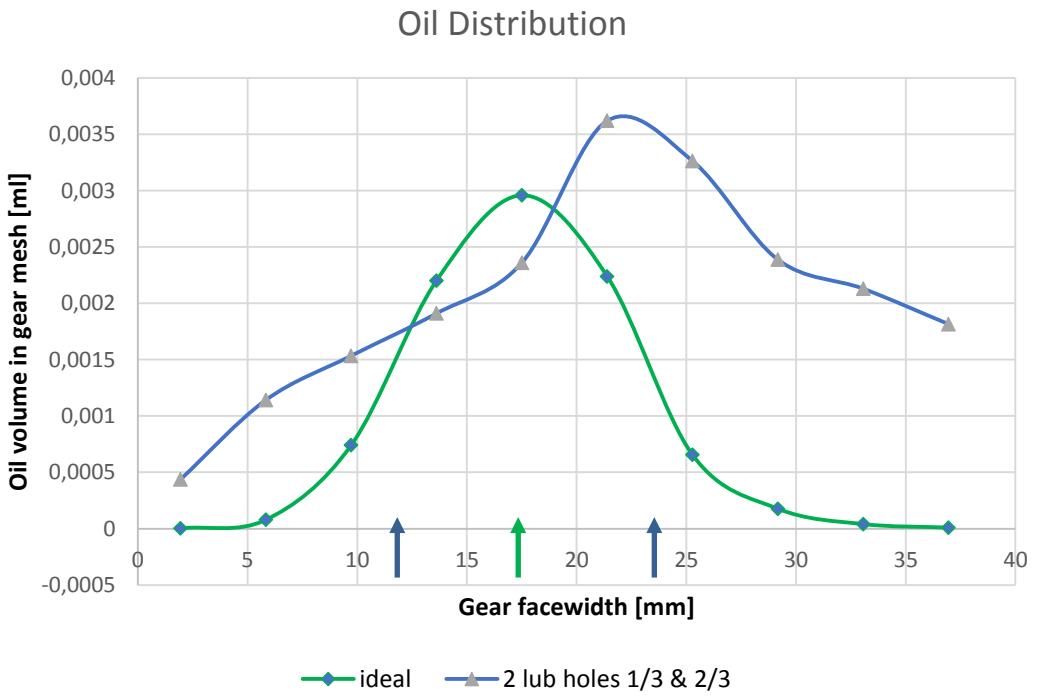

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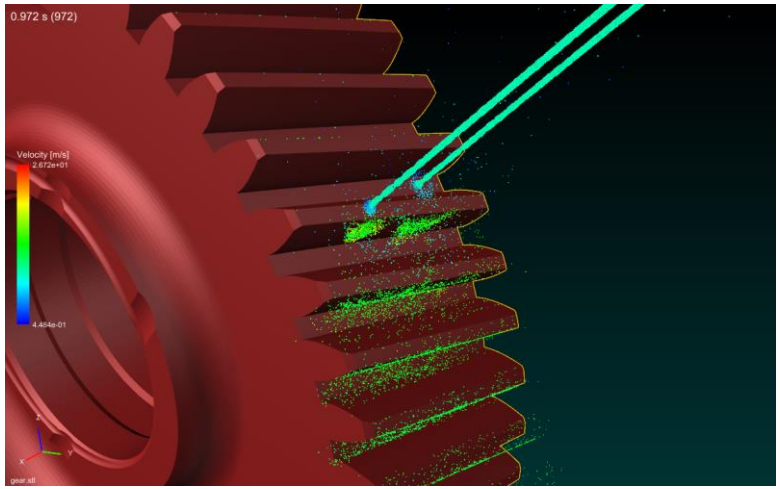

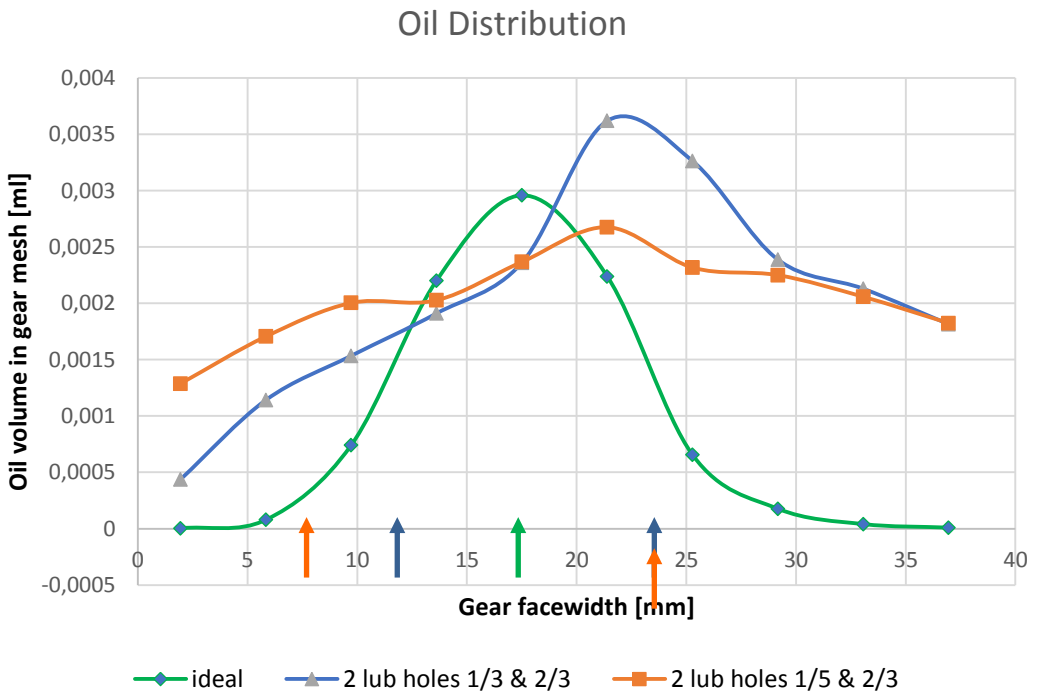

CONCLUSION

Conclusion

- Different oil jet geometries were evaluated.
- Research for a convenient method to evaluate the oil jet efficiency.
- Simulation helped to find the right geometry and the right amount of oil in the gear mesh.
- Simulation helps to improve the development timing.
- Simulation helped to visualize oil jet. This is impossible on a closed gearbox housing.

- Future Works:
  - Parts were manufactured and endurance test will start on W45.
  - Evaluate the dissipated energy by the oil in the gear mesh.

- Computer characteristics
  - 10 cores of 3GHz
  - 1 GPU (Tesla K40M)
  - 256GB RAM (model uses 10GB)
- Model characteristics
  - 320 000 particles of 0.1mm size
  - Calculation time: 12 hours

- GIMA wants to warmly thar Particleworks eWorks team for their support.

THANK YOU

Q&A