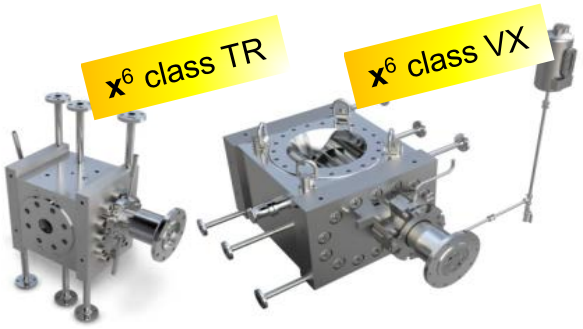
Maag x^6 class Gear Pump

Introducing the x^6 class

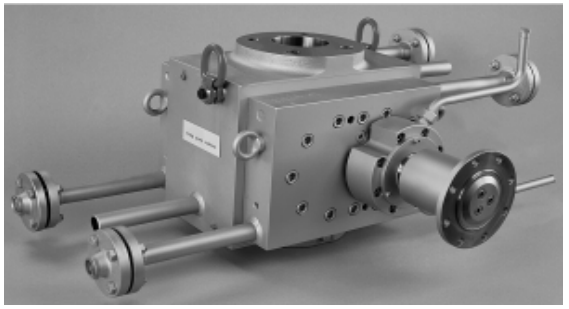
pronounced “six class”

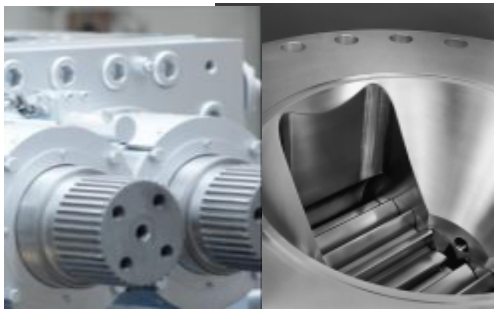


Our innovation

enables your success

Applications in Virgin Polymer Compounding





Maag x^6 class Gear Pump

1. **Introduction**

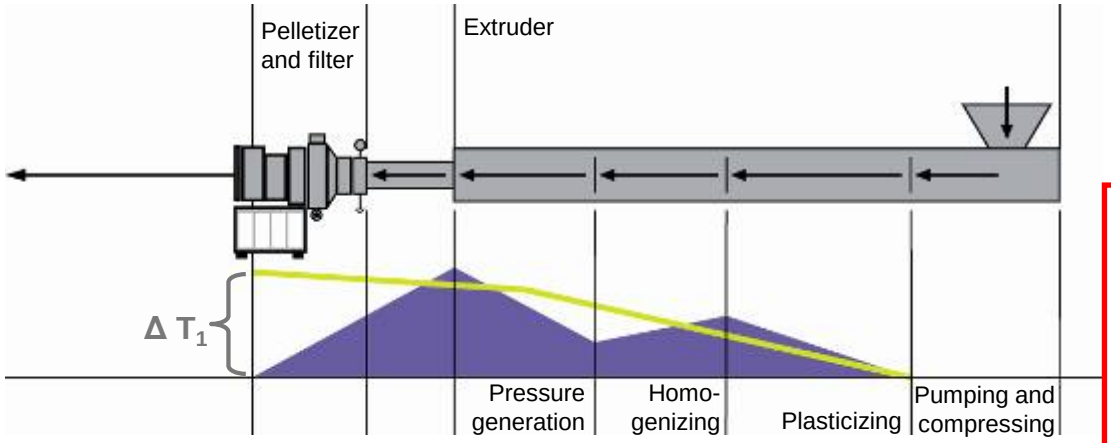
2. **Limitations of a classic gear pump and how the x^6 class pump overcomes the limits**
    1. Production Capacity
        a. Back-Flow
        b. Heat Transfer
    2. Reliability
        a. Bearing Lubrication Film
        b. Bearing Load Capability
        c. Axial Gap
    3. Size and Cost
        a. Pump Size
        b. Shaft and Bearing Cooling

3. **Examples - x^6 class Benefits Quantified**
    1. HDPE plant 60 tph
    2. PP plant 20 tph

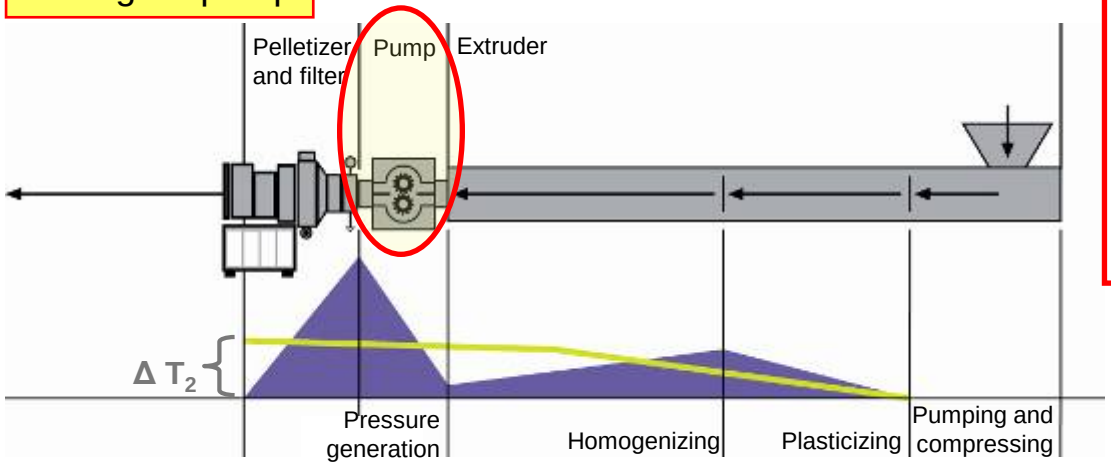
4. **Conclusion**

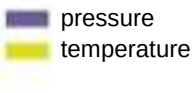
Pressure generation gear pump vs extruder

Without gear pump



With gear pump



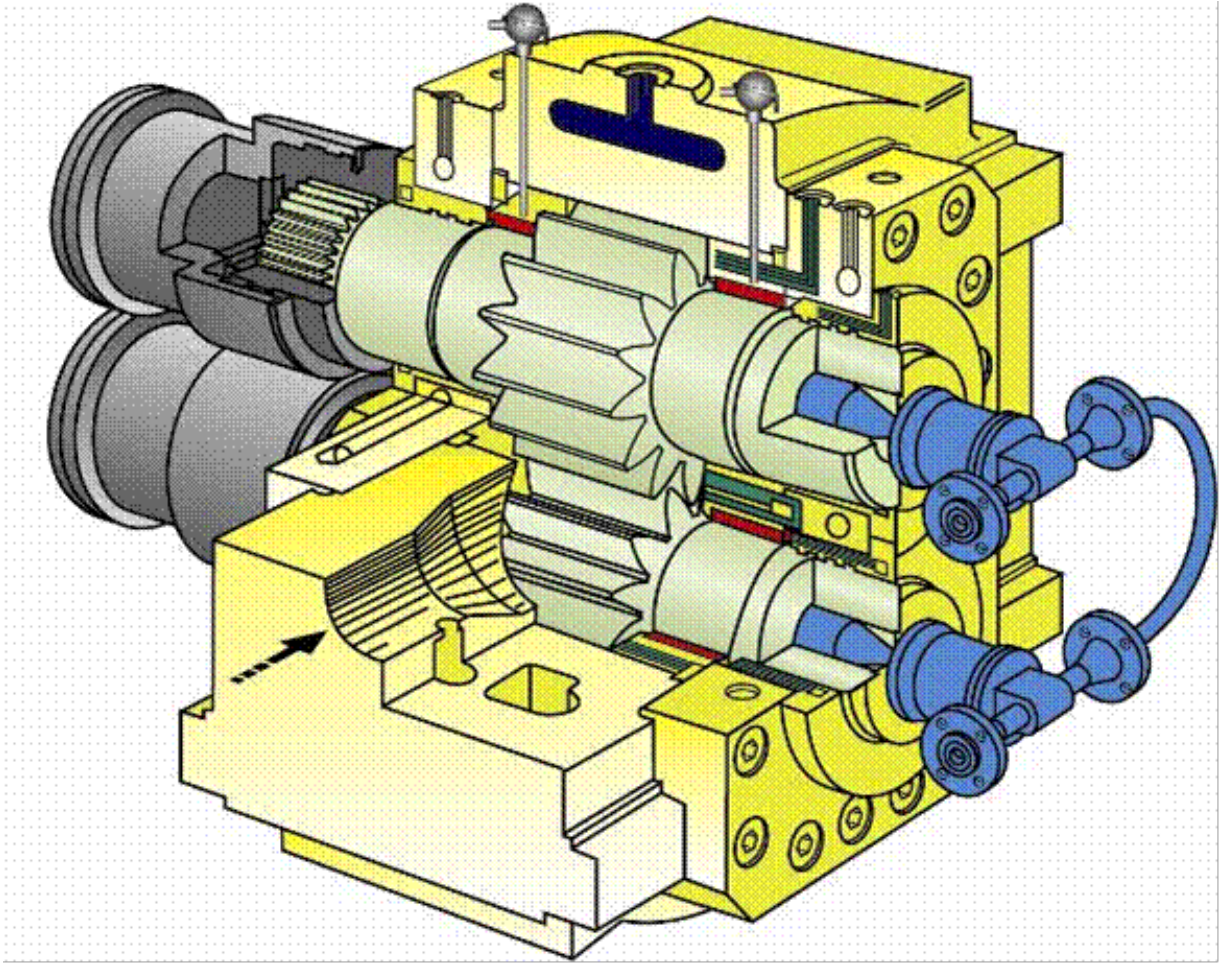


Use of a gear pump in a continuous compounding process separates the melting and mixing phase from the pressure building phase

Results:

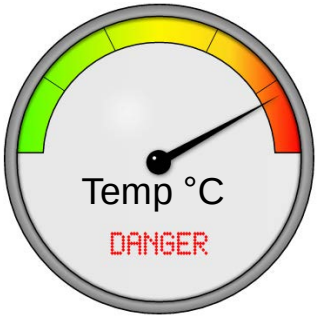
- improved mixing in the extruder
- reduced energy consumption
- increased production capacity
- lower polymer temperature
- gentle conveying
- high delivery pressure
- constant flow rate
- surge-free flow to pelletizer
- reduced screw & barrel wear

Maag Polyrex Gear Pump



Maag polyrex® gear pump

Production capacity limits



The maximum achievable flow rate of a gear pump of a given size is governed by the pump's speed limit, typically in the range of 40 to 50 rpm for polyolefin compounding applications.

The pump's speed limit is determined by the maximum allowed bearing temperature.

If a gear pump of a given size cannot reach the desired flow rate, one of the following two solutions are often employed, both of which involve a significant investment cost:

1. A larger size gear pump is installed, operating at slightly slower speed.

2. A shaft and bearing cooling system is added to reduce bearing temperature and effectively raise the pump's speed limit.

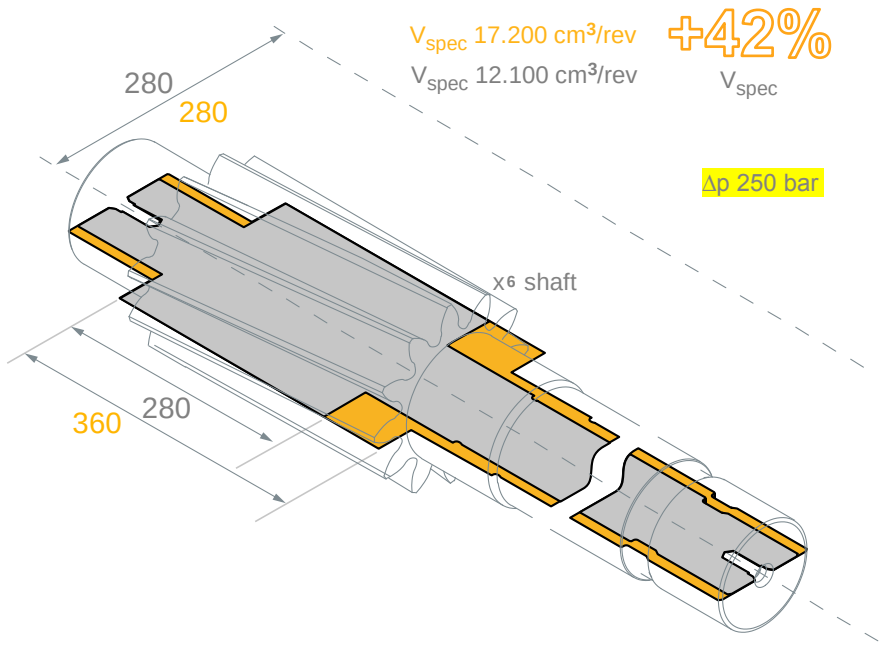
Production **Capability**^{6}

Maximized Output

Superior flow capacity
to boost your productivity

- Increase of shaft diameter permits longer gear teeth section until ending limits are reached
- Significant increase in specific volume at given shaft center distance and given pressure

Polymer Shaft Example



Pumps with same shaft center distance and tooth width provide about 50% higher flow against same differential pressure (40 - 50% bigger specific volume)

x^{6} classic

sample case: x^{6}: VX 280-6 GU classic: VX 280-M GP

Volumetric **Efficiency**[6]

Instant Flexibility

Reduced back-flow

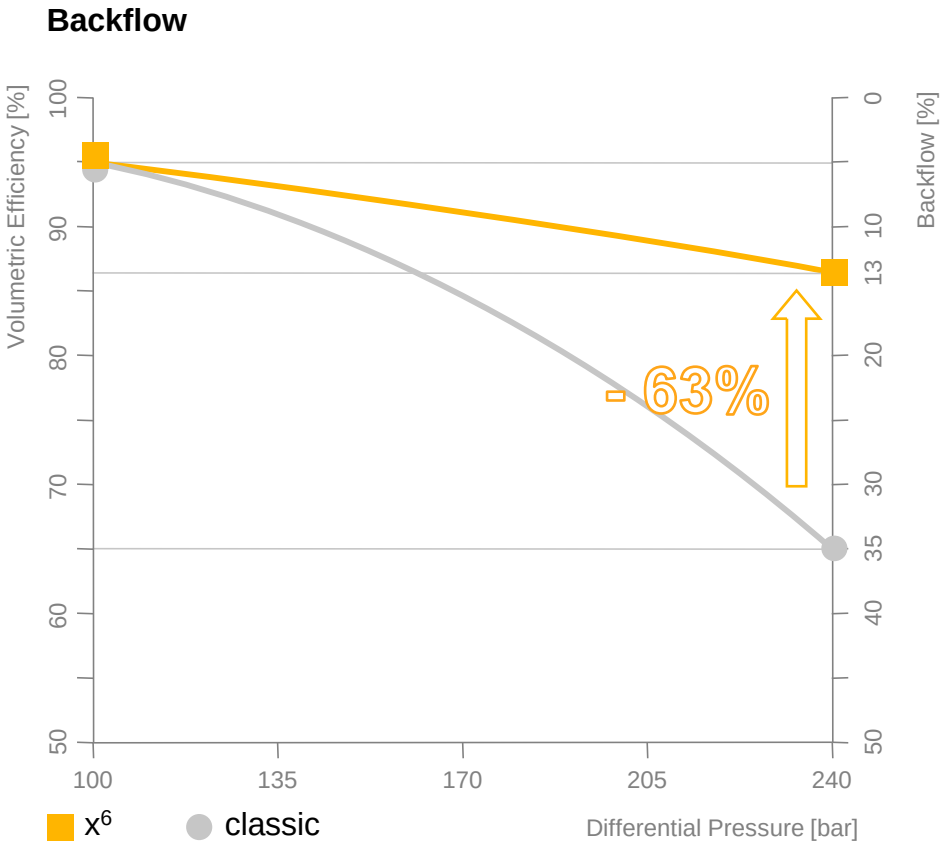
Higher production capacity

Higher pressure capability

- Redesigned seal gap geometry
- Significant increase in volumetric efficiency
- Higher pressure capability especially for high MI products
- 42% more throughput at unchanged pressure

Classic

VX 280 M GP



sample case: LLDPE (MFI 25) against 220 bar

Thermal Mastery

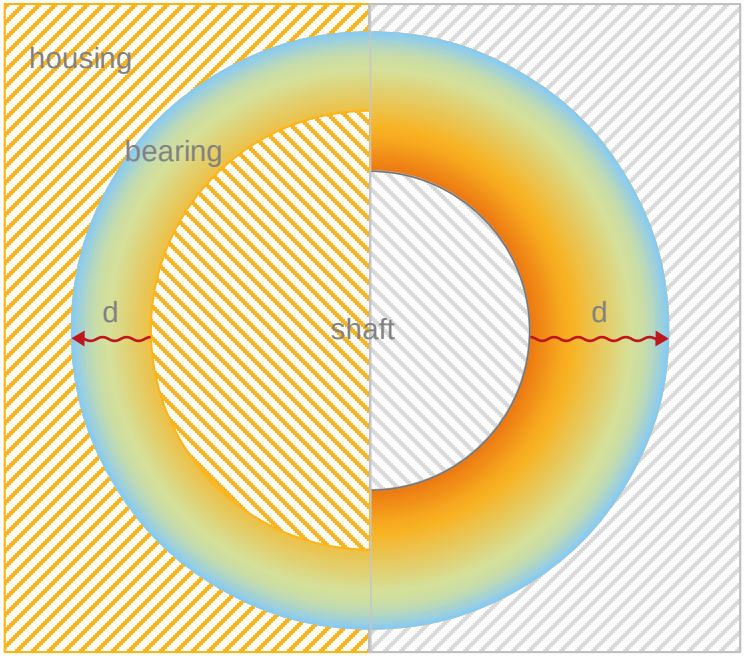
$$\dot{Q} = \lambda \cdot A \cdot \frac{T_{W_1} - T_{W_2}}{d}$$

Efficient temperature management

to enhance your process security

- Improved heat transfer
- Modified bearing geometry with larger shaft diameter and thinner bearing
- Heat accumulation in bearings is removed faster
- Faster replacement of lubrication film
- Reduced temperature in bearings
- Heat stress relief for the polymer

Smaller Bearing Section with Increased Heat Transfer



x^6 classic

Section perpendicular to shaft axis

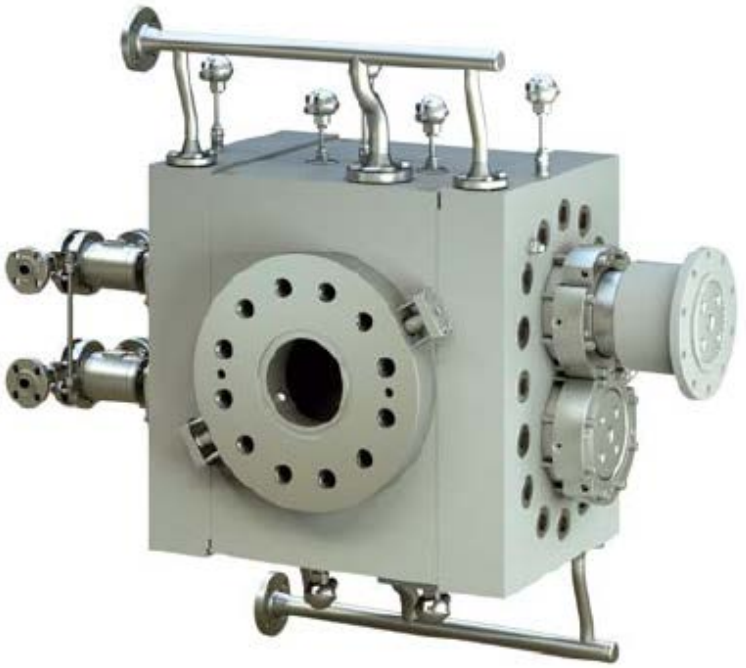
Better heat transfer through thinner bearings

Production rate limits raised with x^6 class

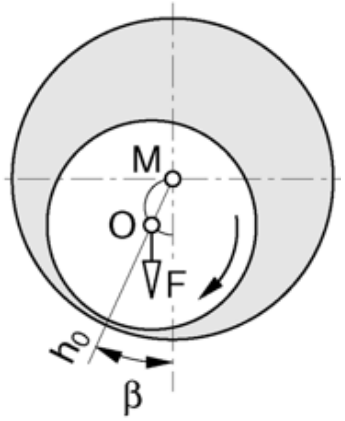
Maag x^6 class pump technology makes it possible for a gear pump of the same basic size to achieve significantly higher rates without additional investment.

1. Enhanced the transfer of heat out of the bearings to reduce the bearing temperature and thus raise the maximum allowable pump speed.

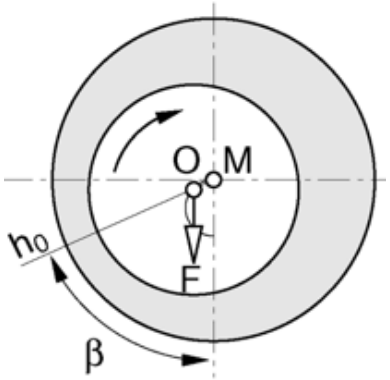
2. Increased gear pump output per revolution, increasing the flow rate even without increasing speed.



Reliability



Bearing Lubrication



Pump failures – common causes

- process upsets such as sudden changes in:
  - pressure
  - viscosity
- ingestion of foreign material

Production **Capability**^{6}

Shaft Endurance

Improved load capability

to raise your differential pressure limits

- Significant increase of bearing diameter
- More load capability
- Resistance to pressure spikes
- Higher allowed discharge pressure for given pump size

VX 280-6 EP

Center distance	280
Tooth length	280

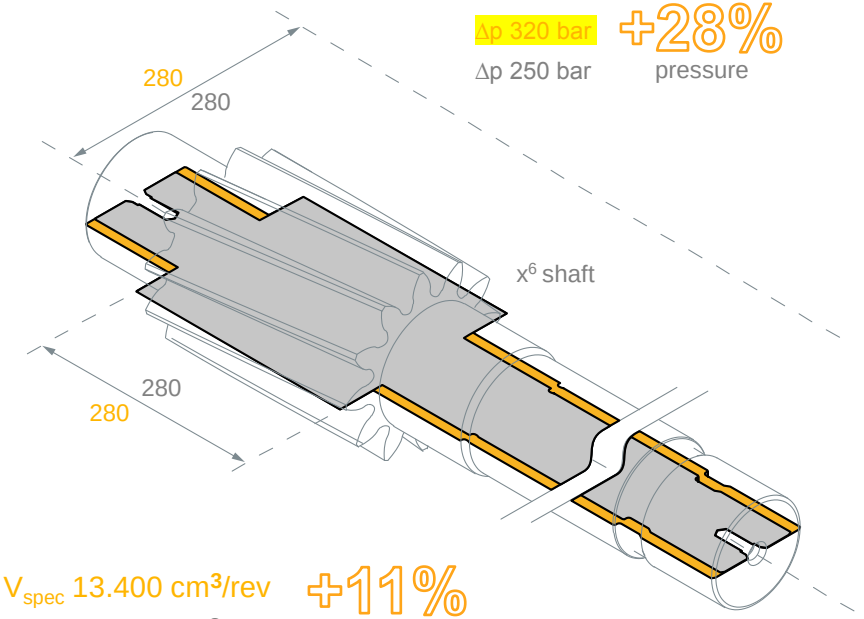
Classic

VX 280-M GP

Center distance	280
Tooth length	280

Due to the larger diameter of the shaft in the bearing section, the shaft is stronger (reduced bearing) and can take higher torque

Increased Shaft Diameter
reduces bending of shaft for Increased Pressure



sample case: x^6: VX 280-6 EP classic: VX 280-M GP

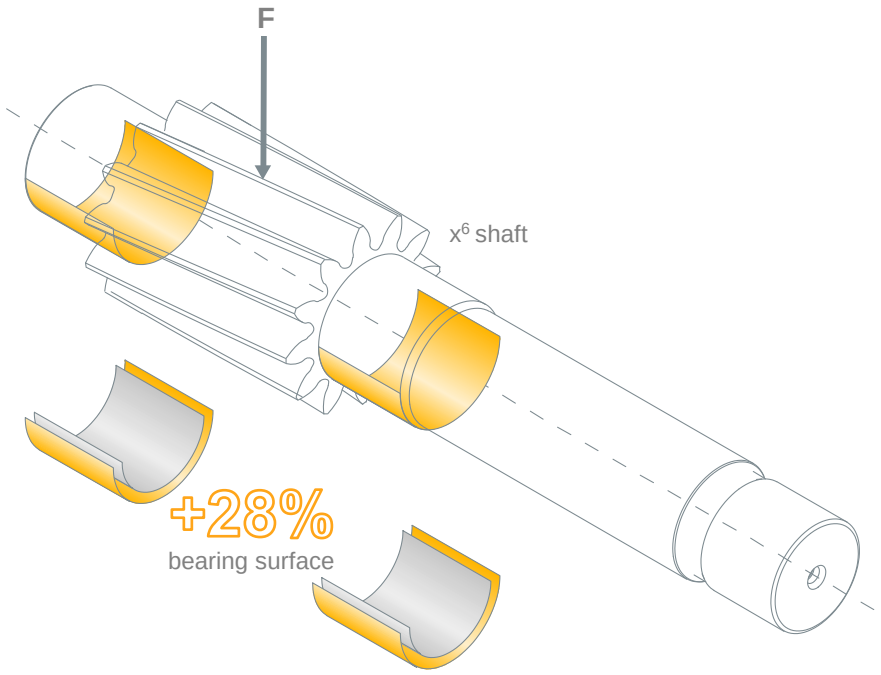
Dynamic Stability

Stronger lubrication film

to enhance your polymer grade flexibility

- Increased bearing surface
- Increased lubrication film thickness
- Massive improvement of the hydrodynamic bearing load capacity

Increased Bearing Surface



sample case: x6: VX 280-6 EP classic: VX 280-M GP

Classic

Bearing surface & Lubrication film is less pronounced

The hydrodynamic load capability is increased due to the increased bearing surface
Applicable for: Prepolymer / Polymer with high solvent content / waxes / shear thinning polymer / screen change applications
Especially for low viscose and very shear thinning products

Dynamic Lubrication

Increased impurity tolerance

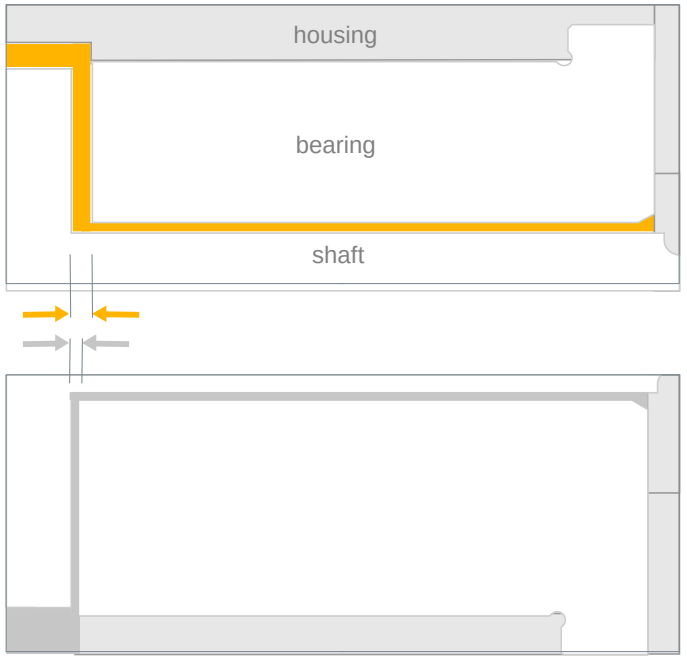
to secure your uptime & improve stability

- Larger axial gap between shaft and bearing with longer circumferential seal length
- Increased tolerance against foreign material
- Increased process security
- Improved geometry of lubrication gaps
- Faster lubrication film replacement
- Improved process stability
- Smaller backflow channel
- Reduced backflow

Classic

Increased tolerance against foreign material in radial gap

Smaller Back-Flow Channel



x^6 classic

Section parallel to shaft axis

Machine Size and Cost

Total Investment Cost

Classic Gear Pumps

- Payback time < 1 year due to energy savings and increased production rate
- Smaller extruder drive unit

Maag x^6 class Gear Pumps

- Smaller, more economical pump can achieve the same production capacity as before
- Shaft and bearing cooling may no longer be needed to reach desired production rate!
- May be driven by smaller motor and gearbox due to higher efficiency and lower speed

Performance Improvement Example x^6 class

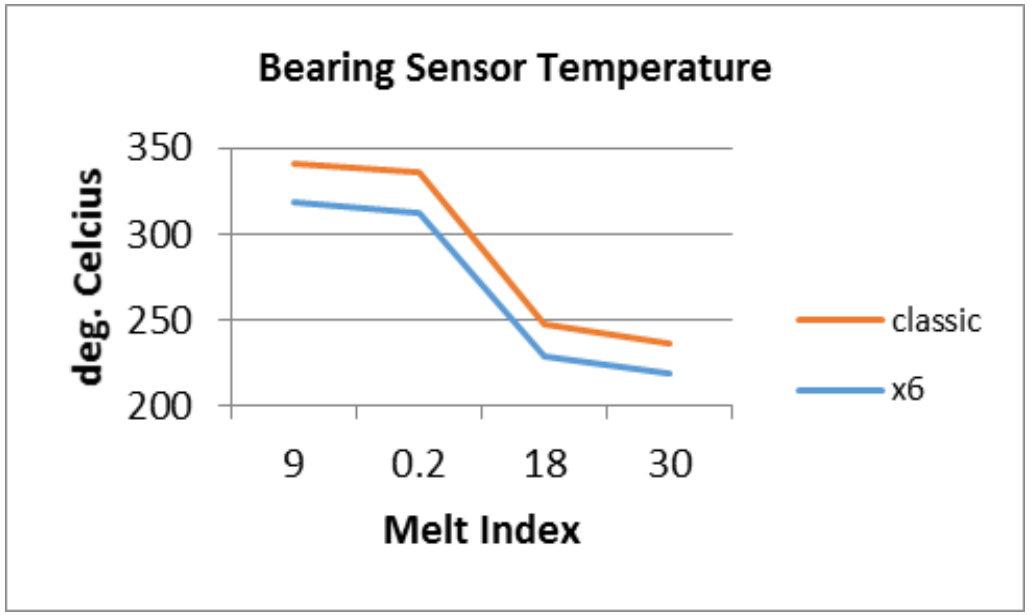
Comparable pump sizes, same flow rate

PR 50-9 classic	PR 450-6 EP 3
Classic **with** shaft & bearing cooling	**without** shaft & bearing cooling

Polymer grade		HLMI=9		MI=0.2		MI=18		MI=30		
Rate	*tph*	60								
Rate	*Mt/a*	480								
P-diff	*bar*	250				120				
T-Fluid	*C*	260		255		210		200		
Eta10	*Pas*	4'741		2'089		271		293		
Pump model		**PR 50-9**	**PR 450-6 EP**	**PR 50-9**	**PR 450-6 EP**	**PR 50-9**	**PR 450-6 EP**	**PR 50-9**	**PR 450-6 EP**	
Shaft & Bearing Cooling		yes	no	yes	no	yes	no	yes	no	
Speed	*rpm*	38.3	26.7	40.5	27.3	38.2	25.6	38.2	25.5	- 30%
Torque	*kNm*	267	337	224	289	94	124	95	125	
Power pump	*kW*	1068	938	950	827	378	333	381	333	- 10%
S&B cooling	*kW*	196	0	192	0	98	0	47	0	- 100%
Vol. Eff	*%*	88	93	83	90	85	93	85	93	

x^6 class – Quantifying the benefits
Example: HDPE 60 tons per hour

x^6 class: No shaft or bearing cooling required!



Without cooling, the classic pump would operate with > 340°C bearing temperature for low MI grades of HDPE, while the x^6 class pump maintains temperatures comfortably below the limit with no need for cooling.

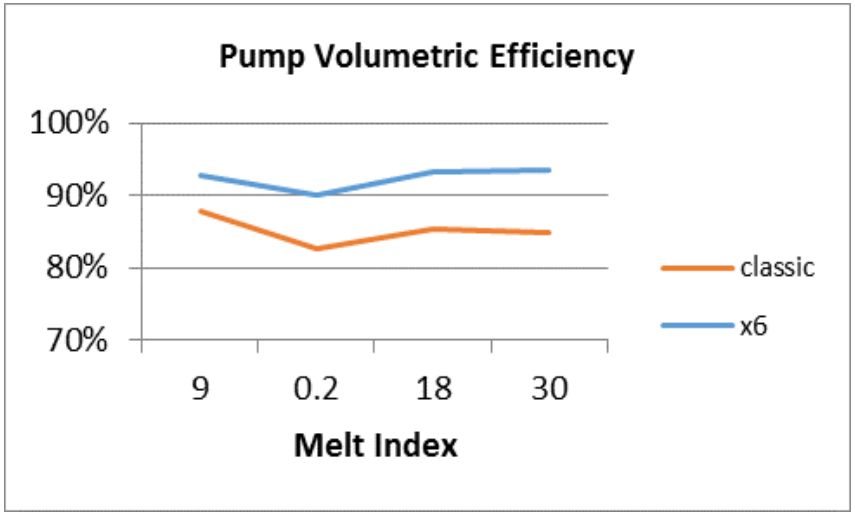
A classic pump would require the addition of a shaft and bearing cooling system to maintain the bearing temperatures below the alarm limit for the high viscosity (low MI) product grades.

An x^6 class pump of the same size would not require cooling. Removal of a cooling system from the gear pump system scope significantly reduces the investment and installation costs, and reduces energy consumption for the pump system by 10% to 15%.

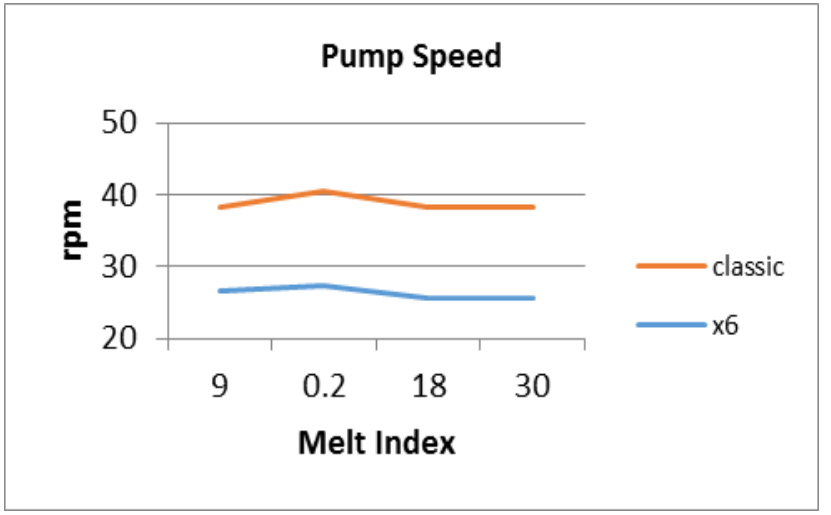
Applicable for new plants - performance depending on specific polymer properties and operating conditions

x^6 class – Quantifying the benefits
Example: HDPE 60 tons per hour

Production Rate Capabilities



A classic pump operates at 85% volumetric efficiency, while the x^6 class pump operates at 92% volumetric efficiency.

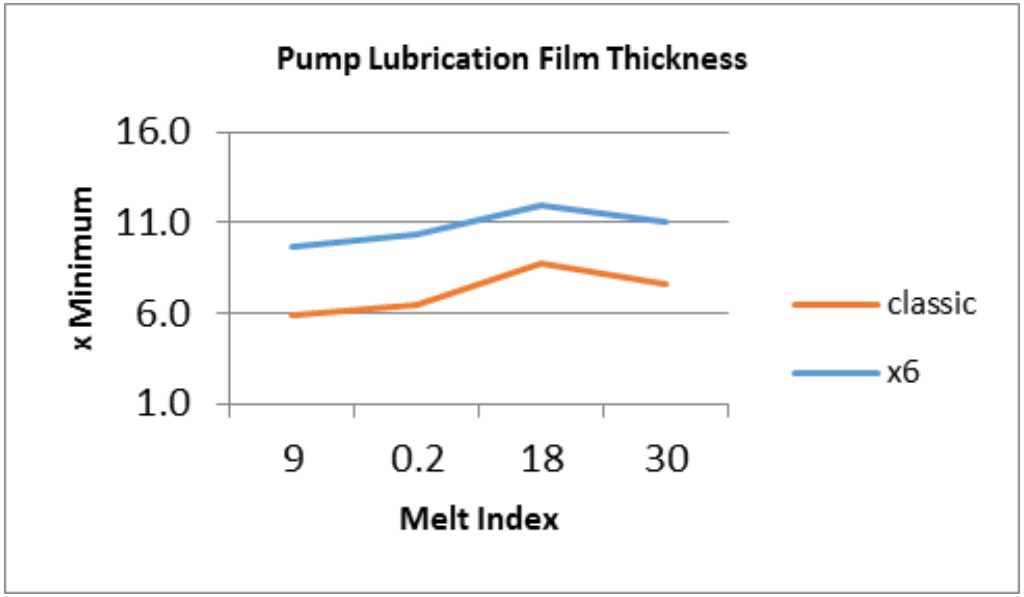


A classic pump operates at 39 rpm requiring a 1750 kW motor, while a x^6 class pump of the same size operates at 26 rpm requiring only a 1500 kW motor with higher gearbox ratio.

Applicable for new plants - performance depending on specific polymer properties and operating conditions

x^6 class – Quantifying the benefits
Example: HDPE 60 tons per hour

High Reliability

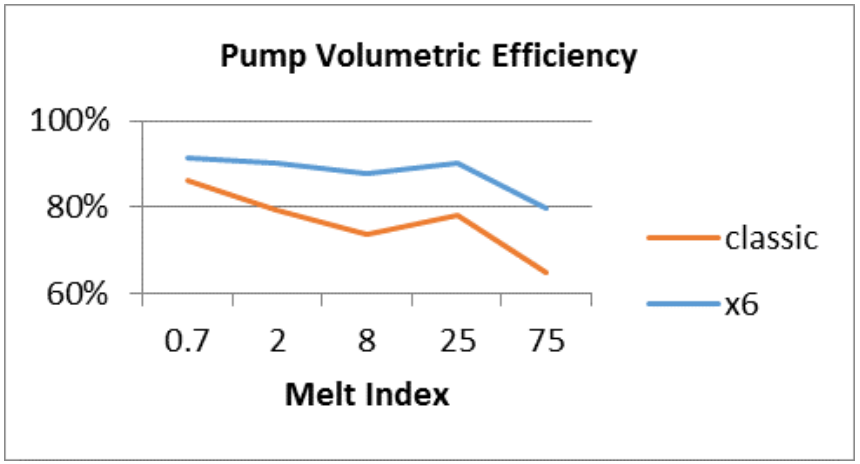


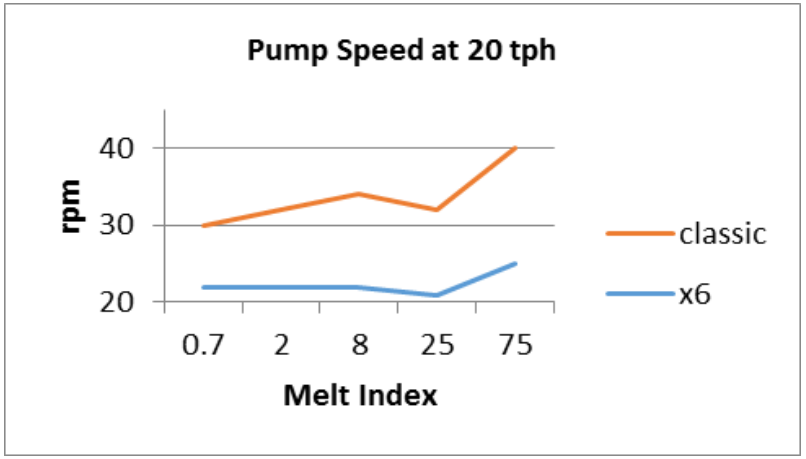
The x^6 class pump operates with approximately 1.5 times the lubrication film thickness of a classic pump.

Applicable for new plants - performance depending on specific polymer properties and operating conditions

x^6 class – Quantifying the benefits
Example: PP 20 tons per hour

x^6 class: No shaft or bearing cooling required!





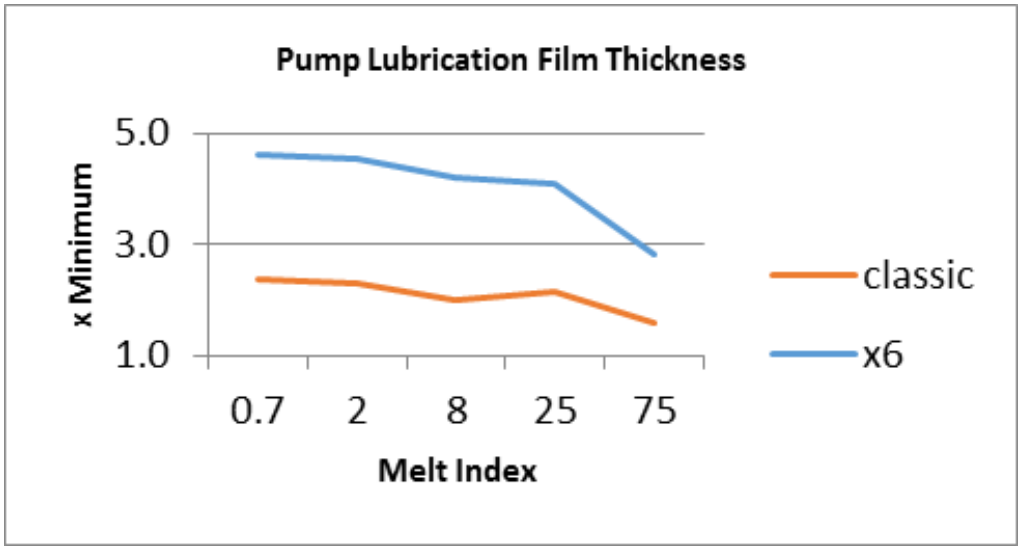
a classic pump, with shaft and bearing cooling required for MI=0.7 grade, operates at 76% volumetric efficiency, while the x^6 class pump operates at 88% volumetric efficiency and does not require cooling.

a classic pump operates at 34 rpm, while an x^6 class pump of the same size operates at 22 rpm.

Applicable for new plants - performance depending on specific polymer properties and operating conditions

x^6 class – Quantifying the benefits
Example: PP 20 tons per hour

High Reliability



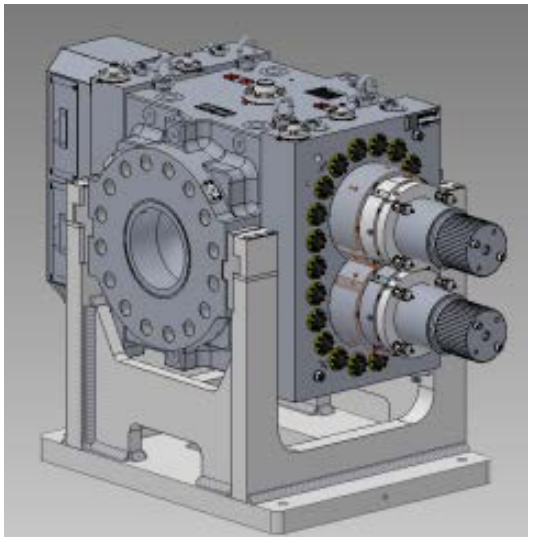
the x^6 class pump operates with approximately 2 times the lubrication film thickness of a classic pump.

Applicable for new plants - performance depending on specific polymer properties and operating conditions

Retrofitting a classic pump with **x**^{6} class pump

Your request: Retrofit Classic Pump with x^6 class Pump

Your benefit:
25% lower energy consumption
increased reliability in bearing lubrication film
increased pressure capability
Reduced system complexity and footprint
Increase production rate,
even when using the existing drive unit



Your advantage:
Increased process reliability
Higher production capacity
Reduced investment and operating costs

Maag x^6 class Gear Pump - Conclusions

Conclusions

1. Higher Production Capacity with same machine size
   a. Specific Capacity
   b. Back-Flow
   c. Heat Transfer

2. Higher Reliability
   a. Bearing Lubrication Film
   b. Bearing Load Capability
   c. Axial Gap

3. Size and Cost
   a. Same Production Capacity achievable with smaller Pump Size
   b. Same Production Capacity achievable without Shaft Cooling

Thank you

We believe in challenging the status quo, in thinking differently. We challenge the status quo by designing and building products with cutting-edge technology and high craftsmanship, for outstanding capability and superior reliability and we support them with expert knowledge backed by 100 years of research and experience. We just happen to make great gear pumps.