TAKING GEAR PUMP TECHNOLOGY TO THE NEXT LEVEL

Ryan Emerick, MaagAutomatik Inc., Charlotte, NC

Abstract

Processes in the manufacture of virgin polyolefin resins require high-pressure gear pumps which build up pressure for the pelletizing units downstream. Maag Pump Systems has recently redesigned each component featured in its gear pump portfolio, from gears and shafts to bearings and seals, fine-tuning how all components interact, culminating in a new, state of the art technology. The new performance-driven geometry of Maag Pump Systems' "**x**6 class" gear pump, pronounced six class, enables higher throughput rates of high viscosity polymers and can convey low viscosity polymers where classic pump technology failed. This paper describes features of this latest design and the benefits they bring to polyolefin post reaction processing.

Introduction

The use of a gear pump in a continuous Polyethylene compounding process improves mixing performance of the twin screw extruder and reduces overall energy consumption, while in Polypropylene compounding it increases production capacity when processing high-viscosity resins. When a gear pump is installed between the outlet of a twin screw extruder and the inlet of the screen changer prior to the pelletizing die, the outlet pressure of the extruder is greatly reduced. When the gear pump takes over the task of pressure building, energy consumption of the unit is cut by one-half to two-thirds and the temperature of the polymer resin entering the pelletizer is reduced significantly. The extruder can then more effectively melt and mix the resin and at a higher production capacity.

While a gear pump brings these clear benefits to the compounding operation, it does require additional initial investment, occupies additional space on the production floor and adds to overall system complexity which add to concerns about plant reliability. The new x6 class of gear pumps were developed to minimize each of these costs while maximizing each of the benefits. The purpose of this paper is to describe the limits which classic gear pumps were facing, how they are being overcome, as well as to quantify the benefits which today's polyolefin compounding operations stand to gain from the new technology.

Redesigning to Raise the Limits

<u>Flow rate</u>

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 rpm at which the maximum allowed bearing temperature is reached. If the 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.

The x6 class pump technology makes it possible for a gear pump of the same basic size to achieve significantly higher rates without additional investment. This allows a different approach to be taken:

1. Increase gear pump output per revolution, to increase flow rate without increasing rpm.

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

The output per revolution, or specific volume capacity of a gear pump, is determined by the volume between the gear teeth. One way to increase that volume is to design the pump with longer gear teeth. There is a limit to tooth length, however, because longer teeth have always meant reduced differential pressure capability due to the resulting higher shaft deflection and bending stress. To circumvent this limitation, the shaft journal diameter of the x6 class pump is larger so that it resists deflection under load and allows the use of longer gear teeth without sacrificing pressure capability. The longer teeth add 25 to 30% in specific volume and the inlet-to-outlet width of the gear pump remains the same as classic pumps.

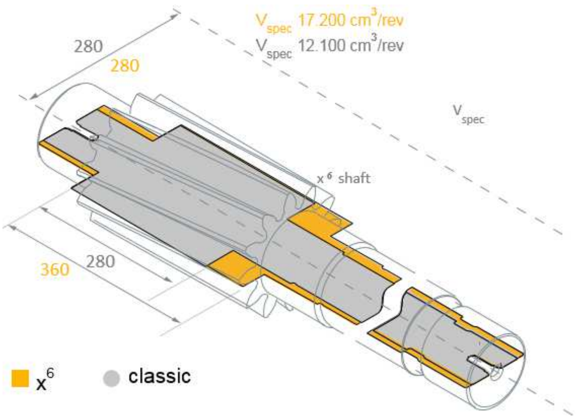

Figure 1: The larger shaft journal diameter of the x6 class pump makes it possible to have longer gear teeth for higher specific volume, without sacrificing the pump's pressure-building capability.

Working against the gear pump's output per revolution is the back-flow of polymer through the pump's internal clearances from the high pressure discharge side of the gears back to the low pressure inlet side of the gears. Actual pump output per revolution in polyolefin compounding is typically 10 to 35% less than the theoretical specific capacity, depending on differential pressure and resin viscosity. By identifying the back-flow paths and reshaping the geometry of the pump's internal components, the back-flow paths which existed in classic gear pumps have been dramatically reduced. The x6 class pump operates with roughly half the amount of back-flow thereby regaining 5-15% of the gear pump's output per revolution.

In order to maintain thermal balance and to avoid excessive thermal growth of the bearings which would close off the pump's internal clearances and possibly lead to pump seizure, the temperature of the pump's bearings must not exceed a certain limit. Heat which accumulates in the bearings during operation is generated from the shearing of polymer as it flows through the gap between the rotating gear shaft journals and the stationary journal bearings. The heat is transferred out from the inner to outer diameter of the bearings and into the pump housing and covers. The geometry of the x6 class pump bearing has been redesigned to reduce the bearing temperature by:

1. Increasing the inner diameter to reduce the thickness of the bearings, so that heat is more quickly transferred out of the bearings.

2. Speeding the flow of polymer through the bearings.

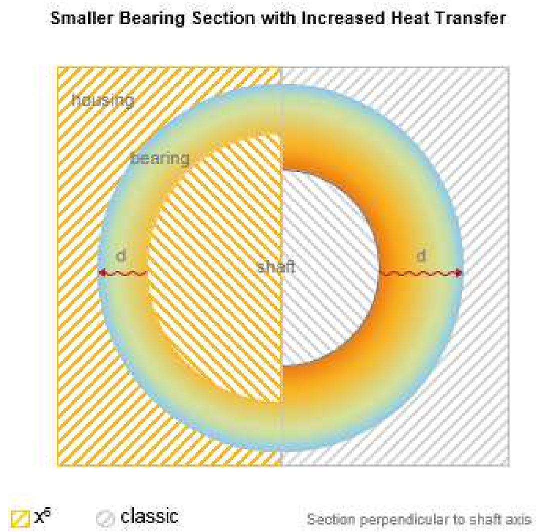

Figure 2: Modified bearing design reduces bearing temperature and effectively increases the pump speed limit to make higher flow rates possible.

Reliability

The shafts and bearings of a gear pump are lubricated by the polymer which it pumps, as 2 to 4% of the overall polymer flow is directed through internal lubrication channels into the gaps between shaft and bearing. Here it forms the thin lubricating film which lifts the rotating shaft journal away from the surface of the bearing.

Pump failures often result from process upsets such as sudden changes in pressure, viscosity or ingestion of foreign material which either disturbs the lubricating film or exerts an extreme load on the shafts, overcoming the lubricating film and resulting in metal-to-metal contact between shaft and bearing.

The redesigned shaft and bearing geometry in the x6 class pump improves reliability by reducing the likelihood of such a failure by:

1. Increasing resilience to process upsets by increasing the thickness of the lubrication film between gear shaft O.D. and bearing I.D.

2. Increasing resilience to foreign material by increasing axial gap between gear teeth side face and bearing face.

3. Increasing bearing load capability by increasing the bearing I.D. surface area.

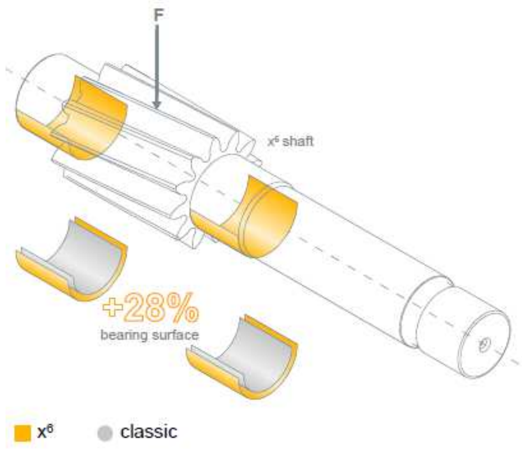

Figure 3: Increasing the bearing surface area to improve pump reliability.

Size and Cost of the Pump System

Controlling total investment cost is important to polyolefin plant design. The addition of a gear pump involves additional initial investment, but the payback time of a gear pump is typically less than one year due to energy savings and increased production rate. Furthermore, its investment cost may be partially offset by the use of a smaller drive unit for the twin screw extruder, since the pump reduces the power requirement of the extruder. The x6 class pump technology can further offset the investment cost in the following ways:

1. A smaller and therefore more economical x6 class gear pump can achieve the same production rate as a larger classic pump.

2. A production rate for which a classic pump requires a shaft and bearing cooling unit may be achievable with an x6 class pump without shaft and bearing cooling.

3. An x6 class pump can often be driven with a smaller drive unit than a classic gear pump would require, due to higher efficiency and lower pump speed requirement.

Quantifying the Benefits

To illustrate the benefits to be gained from x6 class pump technology and to make a side-by-side comparison to classic pump technology, two compounding processes were considered for this paper:

Plant 1: High Density Polyethylene

Product: High density Polyethylene
Capacity: 60 tons per hour
Grades: HLMI=9, MI=0.2, MI=18, MI=30
Pressure: 120 bar for MI 18 and MI 30
250 bar for MI 0.2 and HLMI 9
Temp: 200 – 260°C
Classic: PR 50 (450/450) with shaft & bearing cooling
x6 class: PR 450-6EP (450/450) with no cooling

In this HDPE plant, a classic pump would require the addition of a shaft and bearing cooling system to maintain the bearing temperatures below the 320°C alarm limit for the high viscosity grades HLMI=9 and MI=0.2 at a flow rate of 60 tons/hr. Removal of a cooling system from the gear pump system scope can amount to 10% to 15% lower investment cost, as well as 10 to 15% lower energy consumption for the pump system.

Using a higher gear ratio in the gearbox, a 1500 kW motor would be sufficient to power the x6 class pump, while the classic pump would require a larger 1750 kW motor. This is another way in which the new pump design is reducing investment cost and energy usage.

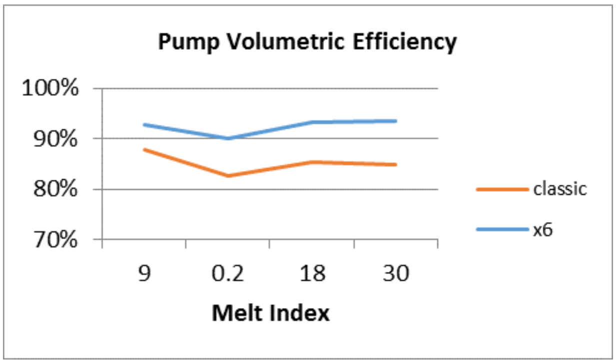

Figure 4: In the 60 tph HDPE plant, a classic pump operates at 85% volumetric efficiency, while the x6 class pump operates at 92% volumetric efficiency.

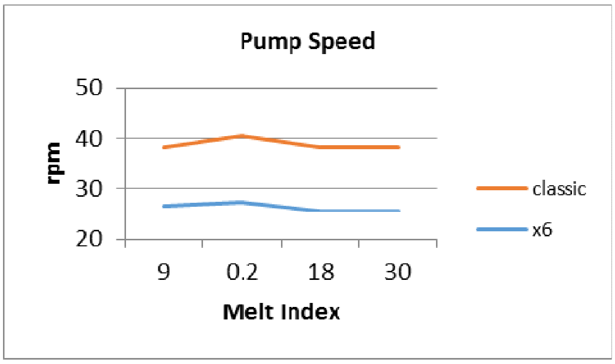

Figure 5: In the 60 tph HDPE plant, a classic pump operates at 39 rpm, while a x6 class pump of the same size operates at 26 rpm.

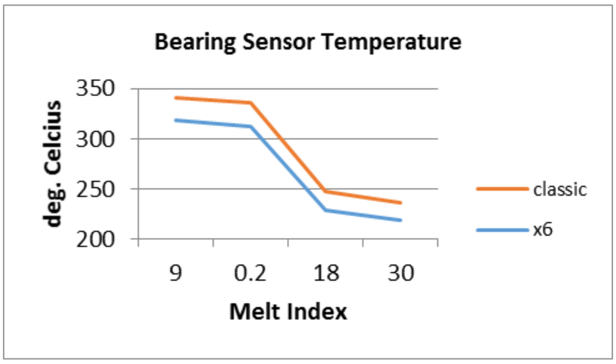

Figure 6: Without cooling, the classic pump would operate with > 340°C bearing temperature for low MI grades of HDPE, while the x6 class pump maintains temperatures comfortably below the 320°C limit with no need for cooling.

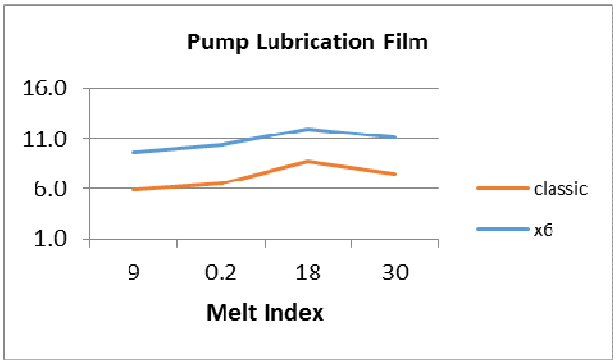

Figure 7: In the 60 tph HDPE plant, the x6 class pump operates with approximately 1.5 times the lubrication film thickness of a classic pump.

<u>Plant 2: Polypropylene</u>

Product: Polypropylene
Capacity: 20 tons per hour
Grades: MI=0.7, MI=2, MI=8, MI=25, MI=75
Pressure: MI=0.7 to MI=8 at 195 bar
MI=25 and MI=75 at 150 bar
Temp: 195 – 265°C
Classic: PR 25 (360/250) with shaft & bearing cooling
x6 class: PR 360-6SP (360/280) with no cooling

In this example, a classic pump would require the addition of a shaft cooling system to maintain the bearing temperatures below the 320°C alarm limit for the high viscosity grade MI=0.7 at a flow rate of 20 tons/hr.

The increase in volumetric efficiency makes it possible to operate at further reduced RPM, shear rates and temperatures, and consequently a narrower polymer residence time distribution. This favorably impacts production rate, polymer quality, pump reliability and lifetime, while reducing energy consumption, as losses are reduced by 50%.

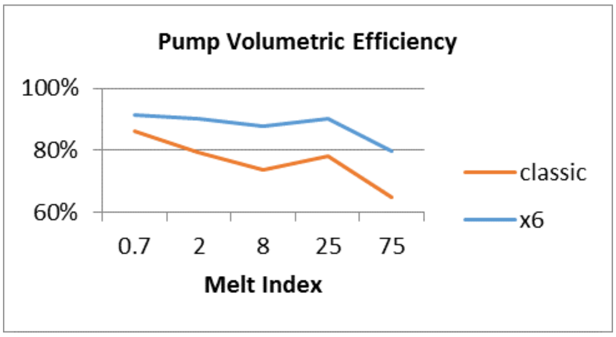

Figure 8: In the 20 tph PP plant, a classic pump operates at 76% volumetric efficiency, while the x6 class pump operates at 88% volumetric efficiency.

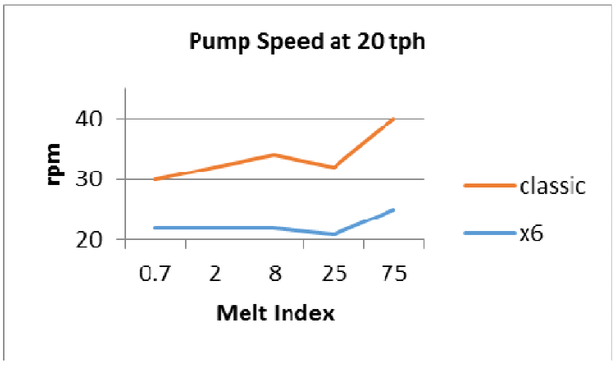

Figure 9: In the 20 tph PP plant, a classic pump operates at 34 rpm, while an x6 class pump of the same size operates at 22 rpm.

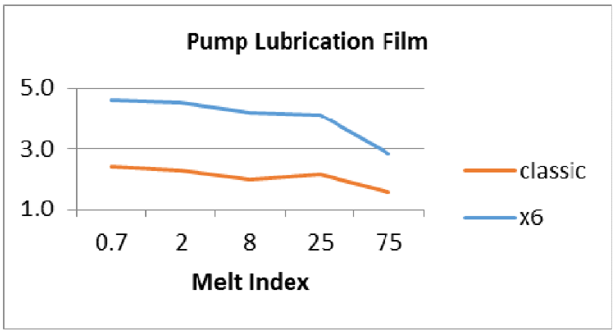

Figure 10: In the 20 tph PP plant, the x6 class pump operates with approximately 2 times the lubrication film thickness of a classic pump.

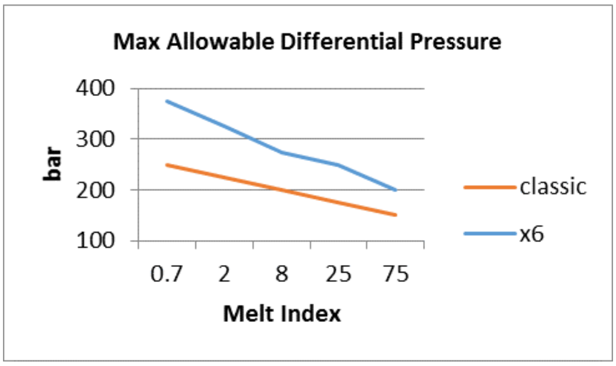

Figure 11: In the 20 tph PP plant, the x6 class pump gives the user the possibility to operate with 1.5x higher differential pressure than a classic pump.

Conclusions

Gear pumps based on classic technology face limitations in flow rate and differential pressure. Those limitations have made it necessary to use larger, more expensive, less efficient machines to deliver the polymer at flow rates and pressures required in polyolefin post reaction processing.

Maag's x6 class pump technology raises the limits of flow rate and differential pressure. The same machine size as before is now capable of higher flow rates, thanks to optimized shaft and bearing geometry which give the pump a higher specific volume capacity and higher volumetric efficiency. Furthermore, improved heat transfer reduces bearing temperature and makes it possible to operate the pump at higher speeds.

Being a critical component of a polyolefin plant, a gear pump must be a highly reliable machine in order to avoid costly unexpected plant down time. The pump is expected to operate with minimal maintenance for years between scheduled plant turn-arounds, but it can reliably do so only if operated safely within its process limits. The process limits that exist for classic pumps being relatively narrow, a small deviation from the expected operating parameters can threaten a pump's reliability.

The process limits have been widened for the x6 class pump. Thicker bearing lubrication film and increased bearing surface area give the x6 class pump a larger operating window and make it more resilient to process upsets or deviations from typical operating conditions. A larger axial gap between shafts and bearings make it less susceptible to damage, should foreign materials ever make their way into the pump.

For debottlenecking existing plants, Maag offers housing designs with matching interfaces to classic pumps, making it possible in some cases to increase flow rate by 30% with a drop-in replacement pump and using the existing drive unit.

For new plants, x6 class pump technology will give users more choices in selecting the best pump to suit their needs, whether the situation calls for a smaller, more economical pump or for a machine size comparable to a classic pump but with higher capabilities for future rate expansions and greater flexibility to process new polymer grades. Compared to gear pumps based on classic technology, x6 class pumps give polyolefin manufacturers the possibility to reduce investment cost through machine size, reduce operating cost through energy savings and increase productivity through higher reliability.