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Letting the gears pump

Today is your first day at your company's polymers division, and you are amazed at how small everything seems. You were just transferred from a world-scale ethylene plant as some manager up the food chain wants to diversify your career. Inside, you are a little disappointed because you feel you will miss the love/hate relationship that you had with the big gas turbines and "cracked gas" compressors. You always knew that the ethylene plant provided product for the polymer plant, but you never really focused on what the downstream plants did with it.

At the start of the morning meeting, someone started talking about the polymer gear pump that fed the pelletizer. From what you could tell, it sounded like a piece of "farm equipment" that someone put in the middle of the process. Your ears perked up as you heard that the bearings in this pump were polymer lubricated. Furthermore, you understood at this meeting that the bearing operated at 650 F. You then observed the production supervisor's stress level go up when the production engineer reported a rise in bearing temperature despite running the same Melt Index and turning at the same rpm.

As the new reliability engineer at the plant, the production supervisor told you to investigate. You wondered to yourself what all of the "big hurrah" was about. Then your buddy told you that all of the product generated at the ethylene plant is fed to this plant, which then uses it to make double the profit. The plant has four trains and this one was in jeopardy with the higher temperatures. The bearings have failed three times over the past year. The company is now being adversely affected with customer relations and with losses in profit.

When a world-class polymers plant goes down due to an unplanned outage from a polymer gear pump, a production facility can lose millions of dollars. As it turns out, that "farm equipment" is one of the most complex pieces of equipment to analyze. Polymer lubricated bearings are non-Newtonian. In other words, the viscosity will vary as a function of pump speed and bearing temperature for a given polymer. Most gear pumps and other rotating equipment do not have a high variance of viscosity except by temperature.

To further complicate things, the bearing load is affected by the discharge pressure and the discharge pressure is affected by the speed of the gear pump, which in turn affects the viscosity, which affects the load carrying capability. Oh yes, everything is tied together. This problem is a fully coupled heat and mass transport balance with viscous dissipation. To make matters even worse, the load distribution across the bearing is also affected by shaft deflection.

To fully model a polymer bearing requires an iterative methodology between structural and fluid/thermal analysis. A general procedure is as follows:

1. Establish acceptance criteria for the gear pump bearing design.
2. Develop a fluid/thermal model of the bearing to determine the response.
3. Perform a finite element analysis of the pump case and shaft to evaluate deflections.
4. Iterate the solution until the correct force balance is obtained and the energy balance is satisfied.

Based on the results, the bearing design can be modified or changed to meet the design constraints for the bearing and polymer. Many production facilities desire to increase production to meet demand requirements. Typically the gear pump output limits the plant production and profitability of the unit. Depending on the gear pump design, small design internals can be changed to increase the output of these units. In addition to an increase in output, reliability can also be increased.

Historically, the gear pumps have been under designed for the applications and have led to rate limitations at production facilities. With the advancements in numerical technology and algorithms to address the physics involved with these pumps, design and reliability issues can be properly addressed. These pumps typically affect the profitability of a facility as much as a large gas turbine or a compressor. These units are driven by complex physics and must be designed and addressed using advanced numerical technology to yield the best results. As always have a professional engineer competent in gear pump design involved with any modifications or failure analysis.

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