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Affinity Laws for Pumping Systems (ALPS) – Part One

This new tool predicts how pumps and systems interact.

When I first discovered the affinity laws, I was impressed by their simplicity, versatility, and power. For me, they held a certain allure. I believed I could use these three simple relationships to solve any pump problem:

$$\frac{Q_1}{Q_2}=\frac{N_1}{N_2}=\frac{D_1}{D_2} \qquad \frac{H_1}{H_2}=\frac{N_1^2}{N_2^2}=\frac{D_1^2}{D_2^2} \qquad \frac{BHP_1}{BHP_2}=\frac{N_1^3}{N_2^3}=\frac{D_1^3}{D_2^3}$$

Here Q represents *flow*, N is *rotational speed*, D is *impeller diameter*, H is *pump differential head*, and BHP is *required pump brake horsepower*.

My problem was that, unknowingly, I misapplied these laws early in my pump career because of a common misunderstanding: *these simple relationships are only meant to be used on pump curve predictions or when system curves fit the general form of* $H = KQ^2$, *i.e. friction only system curves!* Using them to directly determine the effects impeller or speed changes for system curves with static head can result in serious calculation errors.

The affinity laws are primarily used to estimate the effect of speed and impeller diameter changes on pump performance. For example, let's look at Figure 1.

To use the affinity laws to determine the effect of increasing speed from 3400-rpm to 3600-rpm, we must first calculate the effect of speed on flow and head for each performance point and replot the points as seen in Figure 1.

Using the classical affinity laws, the points for the new pump curve (purple) were determined by knowing the head and flow values of the original pump curve (pink) and the change in pump speed. Once you have the two pump curve plots, you can plot your system curve on top of the pumps curves to predict how the pump and system will interact.

For the friction-controlled curve shown in Figure 1, you can see that the intersection of the pump performance

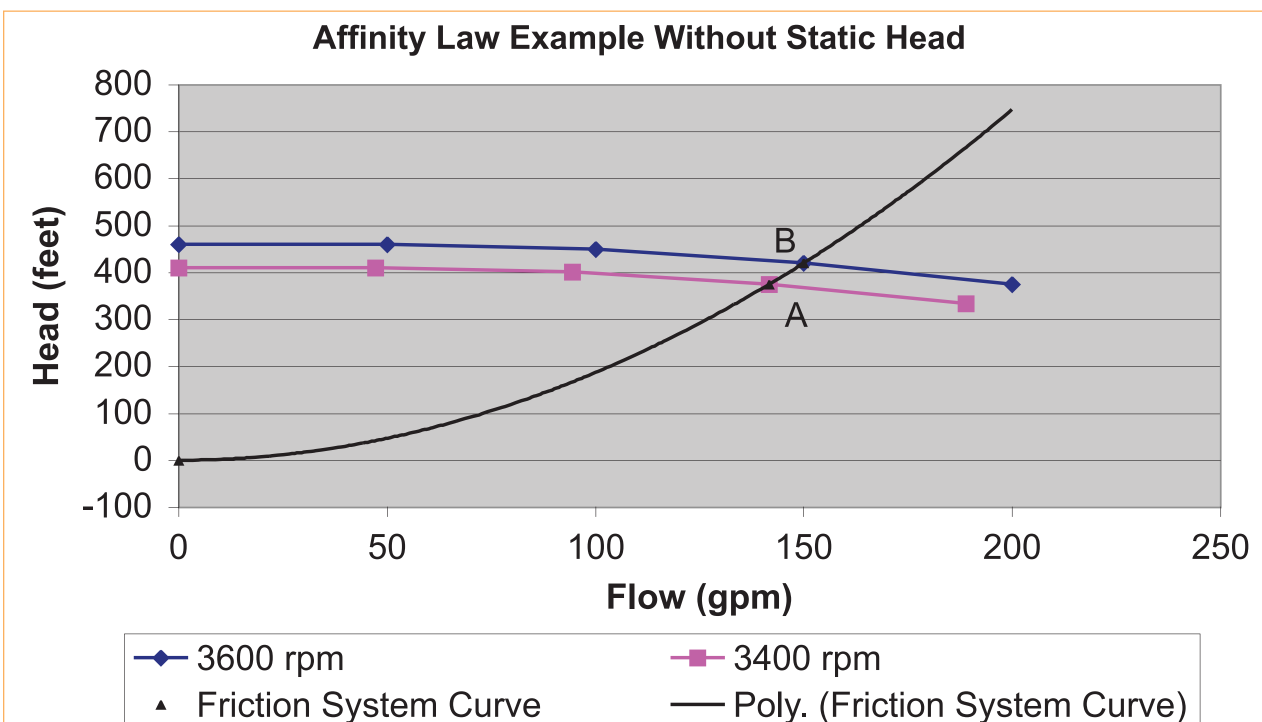

Figure 1

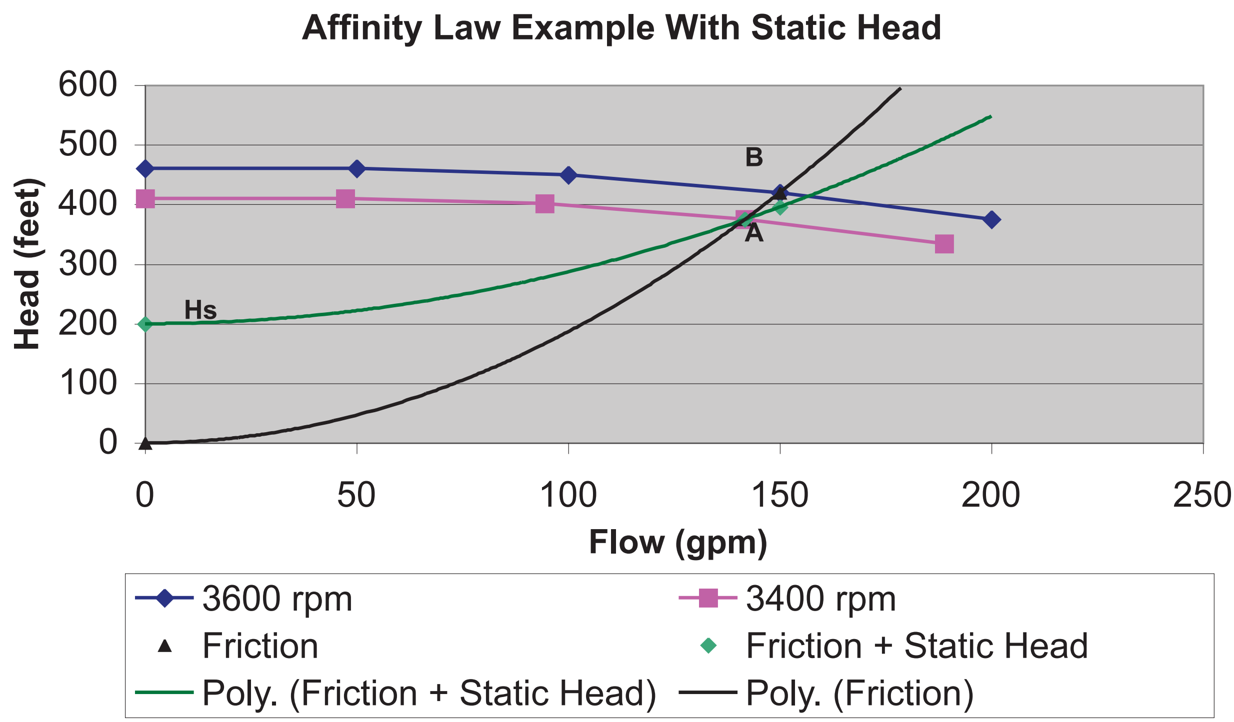

Figure 2

and the system curve points at "A" and "B" match perfectly at both speeds. This visually confirms that the affinity laws can be used to forecast where your pump and system will operate, assuming your systems follows the $H = KQ^2$ relationship.

This convenient relationship *does not* hold true for pumping systems with static head, as seen in Figure 2.

While the revised pump curve is still valid, the affinity laws cannot predict how the pump and system will interact under the new conditions when static head is added to the mix. Notice that at point "A" both system curves converge on the 3400-rpm equation, while at point "B" the curve for "friction + 200 feet of static head" no longer matches the static-only system curve points at the higher pump speed.

This mismatch worsens with higher values of static head (H_S). (Please note that the green and black curves in Figure 2 are quite different. The black "affinity law" curve is defined by the relationship $H = K_1Q^2$ that exactly intersects points "A" and "B" in Figure 2. An "affinity law" curve was used to define all the new points on the blue 3600-rpm curve. The green curve is the pumping system curve defined by the relationship $H = H_S + K_2Q^2$, where H_S is the static head present in the system and K_2 is the constant required to allow the system curve to intersect the 3400-rpm pump curve at point "A." At speeds higher and lower than 3400-rpm, the "affinity law" curve and pumping system curve diverge from one another.)

I want to stress that there is nothing wrong with using the affinity laws. They are perfectly capable of helping you create modified pump curves at different speeds and impeller diameters. What I am saying here is that to draw valid conclusions about how changes in speed or impeller diameters will change system flows or pressures, you must pursue the problem graphically.

You must plot your "before" and "after" pump curves along with your system curve to estimate where your system will operate. Simply stated: the affinity laws predict pump performance changes – not changes in pump/system interactions.

Next month we will conclude this discussion by looking at affinity laws for pumping systems, an ALPS example involving diameter change and another with changing speed.

P & S

References

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2. Lobanoff, Val, Ross, Robert, *Centrifugal Pump – Design and Application*, Houston, Gulf Publishing, 1992, pp 12-14.

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IN THE PIPELINE

BIOFUEL PROJECTS IN FRANCE AND GERMANY GO WITH THE RENEWABLE FUELS FLOW . . .

wheat and corn-based bioethanol plant projects motivated by players in the agri-industry are underway in France and Germany, according to *Industrial Info Resources*. In France, five corn cooperatives in the Aquitaine region have formed a company OCEOL, holding a 36 percent interest in AB Bioenergy France, to partner with Spain's Abengoa Bioenergia SA (64 percent) (Seville, Spain) in a project to produce 200,000-tpa of bioethanol.

AB Bioenergy France is building the $215 million project on a section of the depleting Lacq gas field which was sold to the project by Total (France). The development, construction and exploitation investment are being financed by a loan arranged by Baywerische Hypo-und Vereinsbank, a German based member of Italy's Unicredit banking group. The project has received all the required permitting and is scheduled to come into operation in October 2008. It will receive benefits from the reduction of the internal tax on oil products which is granted to all biofuel production in France.

In Germany, Cargill (Minneapolis, MN) plans to expand its wheat processing operations in Barby, where it already processes wheat into starches and sweeteners for food, pharmaceutical, board and paper customers. The new project will develop a production capacity of one million hectoliters of bioethanol per annum (about 90,000 tons). Construction will start in the second half of 2007. Production should begin by the second quarter of 2009.

By integrating the bioethanol plant into a starch processing facility, Cargill will gain significant flexibility, become able to maximize bioethanol production through optimal use of its feedstock, and benefit from economies of scale and leverage existing synergies at the location.

Barby, on the River Elbe in a fertile farming region with competitive raw material sources, has a position to supply refineries throughout Germany and in central and northern Europe. The bioethanol project will give farmers in the region a new market for local wheat.

Germany now has compulsory rates for incorporation of biofuels into petrol and diesel and renewable fuel blends that are sold at gas stations across the EU. Cargill has been investing in biofuels in Germany and Europe since 2000 and sees the industry as an extension of its expertise in trading, origination, processing and transport of raw materials and finished products.

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