Intro: by Tom Collins

The late Gene Grant was very much involved in what was then called Predicted Log Racing and now known as Cruiser Navigation Rallying. He was a senior scientist with Hughes Research Center and brought a lot of technical analysis into our sport. Many of the formulas we use now were developed by Gene. I’ve gone back into the archival copies of our Cruiser Log to see what we might republish that is still of interest today. This one on the propeller slip curve reveals a way of finding the RPM that gives the least speed change for a change in RPM. That can reduce the criticality of accurate throttle setting.

GRANT'S CORNER

Miscellany Regarding Propellers

A curve this time instead of a table, for a curve shows the big picture when accuracy is not the main object. The idea of this is to show the general tachometer-speed relationship and note the four general regions named by me: 1) Viscous, 2) Displacement, 3) Transition, and 4) Planing. There are two lines on the graph. The straight one is of zero slip, i.e. as if the water were a solid and the propeller was screwing its way through it. I've found it more convenient to think of the propeller as a pump squirting a jet of water of speed equal to the shaft revs/second multiplied by the propeller pitch in feet. Slip is defined as 1 minus the ratio of vessel velocity divided by the propeller jet velocity. Slip is an indicator of the power efficiency of the propeller system. The engine and reduction gear deliver power to the propeller shaft and in turn to the propeller then to the water and back to the boat. It takes a certain force to drive the vessel at a given speed, dictating the required power. The power efficiency is less than 1 minus the slip. This neglects prop-water friction and bearing losses. Of course, in the larger sense all of the power goes to heating up the ocean and the vessel.

At very low velocities the dynamic forces are very small and the viscous forces dominate. The slip is determined by the geometry of the propeller and the hull. As the RPM is increased the dynamic forces of the propeller increase, reducing the slip. Somewhere in between the viscous and displacement region where the dynamic forces are still low there will be a region of very low slip. If the engines have good fuel efficiency in this region this might be near the speed for maximum range. The range might be even better on one engine. As RPM is further increased the dynamic forces of the water flowing around the hull increase and the slip increases substantially. As pointed out last time, the vessel cannot stay in the surface. It must either dive or plane. If it's truly "displacement", the slip increases until maximum power is reached in a normally designed vessel. From the point of view of a cruiser navigator an interesting phenomena is noted in the displacement region, i.e. the speed variation is insensitive to the RPM variation. For the curve shown a 4 percent RPM error will be only a 1 percent speed error. If the hull is a planing type and there is sufficient power aboard (there isn't always) the vessel planes on the surface. The resistance forces are the "uphill climb" (usually constant at about 5 percent of the vessels weight), the boundary layer friction, the turbulent drag of rudders, struts, etc., and wind resistance. As RPM is increased still further, the dynamic forces increase in such a way the slip decreases. In some of the 40 knot ocean racers the slip may be under 10 percent. Ideally, the slip must decrease from a maximum of 30 to 40 percent as the RPM is increased. Therefore, the speed sensitivity to RPM increases substantially as is noted on the graph. A one percent change in RPM may change the speed 1.3 percent.

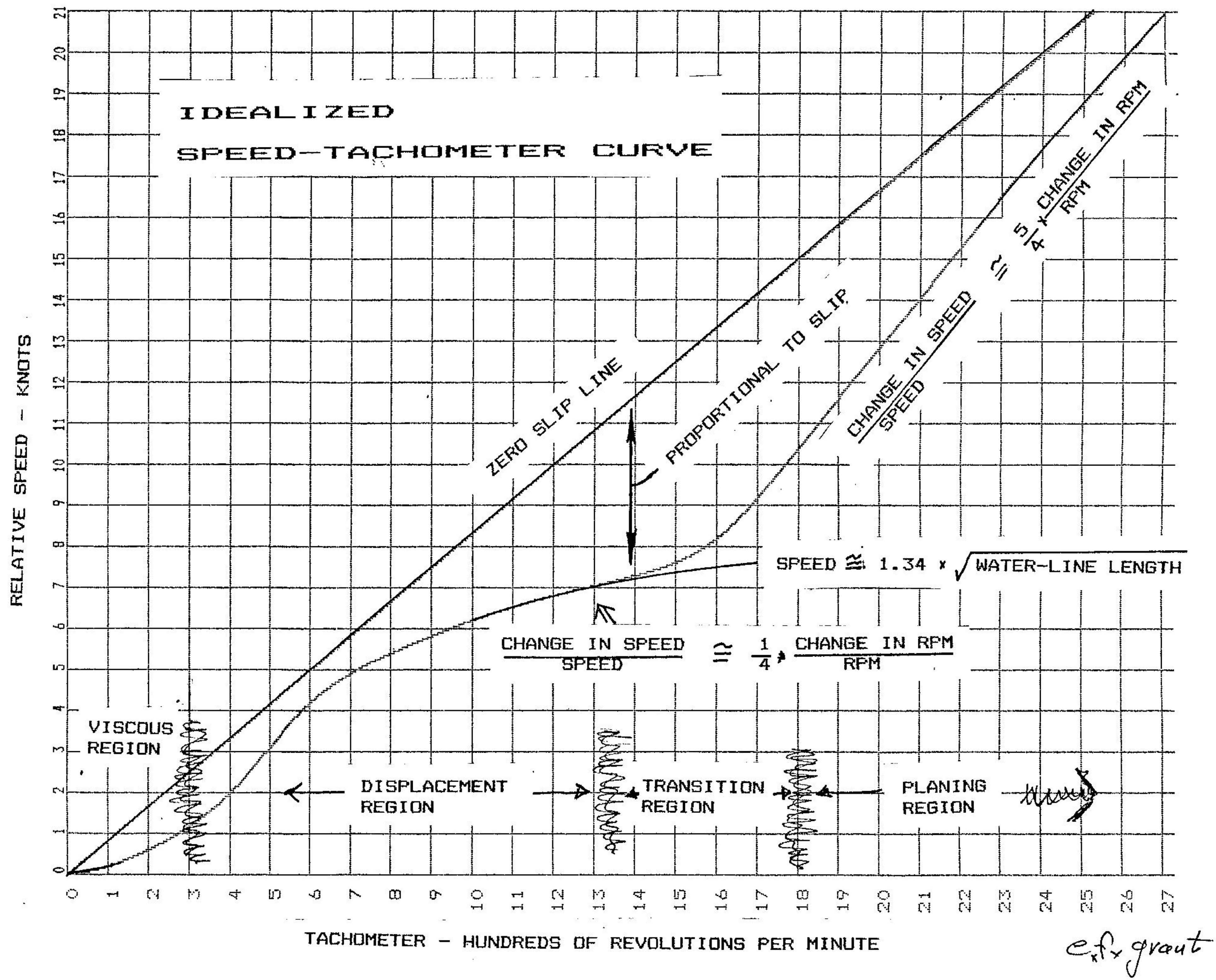
This raises an interesting point that may have been overlooked by those advocates for handicapping fast vessels. While it is true that the error in the knowledge of the current is a smaller percentage of the speed for a fast vessel, the requirement for precision in the tachometer and its usage which includes setability of the throttles is about 5 times as great as that for the displacement vessel. It may not be possible to achieve the control accuracy with the usual type of vessel instrumentation. This is particularly true with engines that surge with swell. So there is a trade between the ability to predict current versus the ability to control RPM with standard instruments and linkages.

An accurate speed-tachometer graph may not be so smooth as that shown for several reasons. The power into the wake is made of many components from various points or curves of the hull. These small wakes interfere and combine to form the larger wake. As a consequence, the driving force has many small variations as the speed is varied. If a planing vessel is not well trimmed, it may have two planing angles in the transition region. One of them is steep with increasing speed and the other small with speed decreasing. Sometimes it is manifest by not being able to find an RPM where the vessel will run consistently. This effect is noted more frequently on out of trim vessels that do not have engine governors. Gasoline engines generally do not, but some diesels do have governors whereas other diesels have only over-speed limiters.

The accompanying graph illustrates vessel performance through the regions as described by the notes on the graph.

e.f. grant 1985

*** The first rule of intelligent tinkering is to save all the parts. ***


IDEALIZED
SPEED-TACHOMETER CURVE
ZERO SLIP LINE
PROPORTIONAL TO SLIP
CHANGE IN SPEED / SPEED ≅ 5/4 × CHANGE IN RPM / RPM
SPEED ≅ 1.34 × √WATER-LINE LENGTH
CHANGE IN SPEED / SPEED ≅ 1/4 × CHANGE IN RPM / RPM
VISCOUS REGION
DISPLACEMENT REGION
TRANSITION REGION
PLANING REGION
RELATIVE SPEED - KNOTS
TACHOMETER - HUNDREDS OF REVOLUTIONS PER MINUTE
0
1
2
3
4
5
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