Introduction

A 3:1 relationship between power increase and speed loss is often used to estimate power increase or fuel consumption increases from given speed loss values. The following describes the origin of the relationship and the assumptions it is based on.

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The 3:1 relationship between power increase and speed loss

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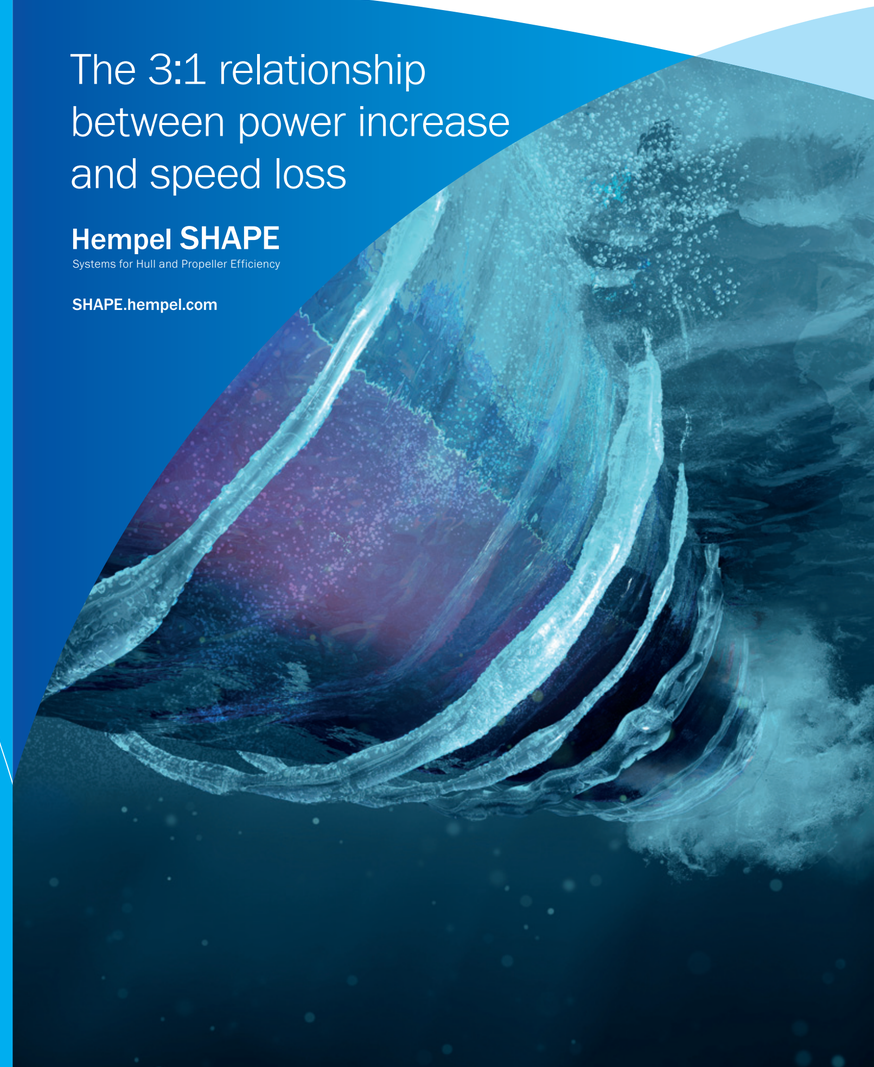

Speed-power relationship

In order to move a ship through water at a given speed, a certain power output from the engine is required. The relationship between power (P) and speed (v) depends on many factors, but for a given ship at a given draft and trim, disregarding the influence of wind and waves etc., the power is most often well described by the relationship:

$$P = constant \cdot v^3$$

The constant is ship and draft/trim specific.

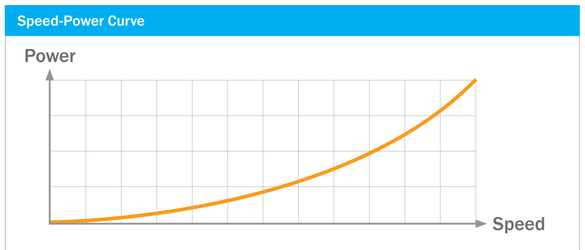

Figure 1: *Illustration of typical speed-power relation.*

A typical speed-power curve is shown in figure 1.

A deterioration of the hull and propeller will lead to a decrease in the obtainable speed at a certain power, and similarly, an increase in power in order to obtain a certain speed.
In other words, the speed-power curve will be shifted upwards. The speed loss (V_{loss}) and power increase ($P_{increase}$) are often expressed as the relative change in speed and power compared to the initial speed or power:

$$P_{increase} = \frac{\Delta P}{P} \qquad V_{loss} = \frac{\Delta V}{V}$$

Δ means difference. Note that a speed loss is a negative value.

It can be shown mathematically, that for small speed losses, the corresponding power increase will be approximately three times the magnitude of the speed loss but with opposite sign. For large speed loss values, this approximation underestimates the corresponding power increase.

The 3:1 relationship holds whenever the power is a function of v^3, and the factor of 3 comes from the exponent. While the relationship between speed and power can often be described by this formula, in reality, the exponent is found to vary somewhat with speed, and may be higher than 4 for some ships. In that case, the relationship will be 4:1. Traditionally though, a value of 3 is most often used as a general rule of thumb since the actual value is typically not known.

An example of a 3:1 relation

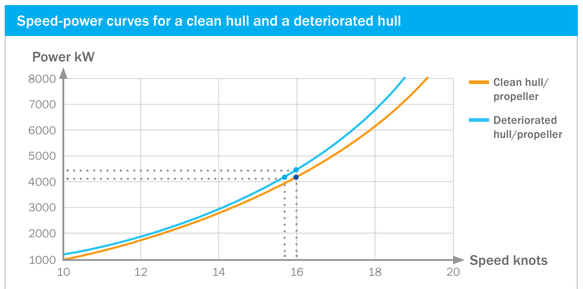

Figure 2: *Illustration of changes in the speed-power relationship between a clean hull and a deteriorated hull.*

Figure 2 shows speed power curves for a fictive vessel in the case of a clean hull (orange) and a deteriorated hull (blue) for the same draft and trim. Looking at a reference speed and power of for instance 16 knots and 4100 kW for the clean hull (illustrated by the dark dot in the figure), the obtained speed at the same power is 15.7 knots while the required power at same speed is 4350 kW for the deteriorated hull.
The relative changes are hence:

$$P_{increase} = \frac{4350kW - 4100kW}{4100kW} \approx 6\% \qquad V_{loss} = \frac{15.7\ knots - 16\ knots}{16\ knots} \approx -2\%$$

Hence:

$$P_{increase} \approx -3 \cdot V_{loss}$$

Example of actual performance data

Consider below example (figure 3) of actual performance data for a 9300 TEU container vessel. The figure shows calculated speed loss and power increase values for a set of measured data points. The data consists of noon reports, and the analysis is done following the procedure of the ISO 19030 standard on performance monitoring.
The speed loss has an average value of 3.4 per cent while the power increase is 10.5 per cent on average. This hence fits the 3:1 approximation.

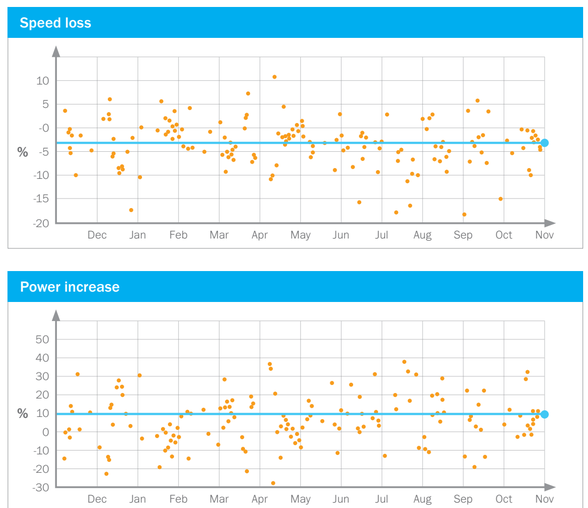

Figure 3: *Actual speed loss values (upper) and power increase values (upper) for a 9300 TEU container vessel during a one-year period. Orange dots are data points while blue lines show average values during the period.*