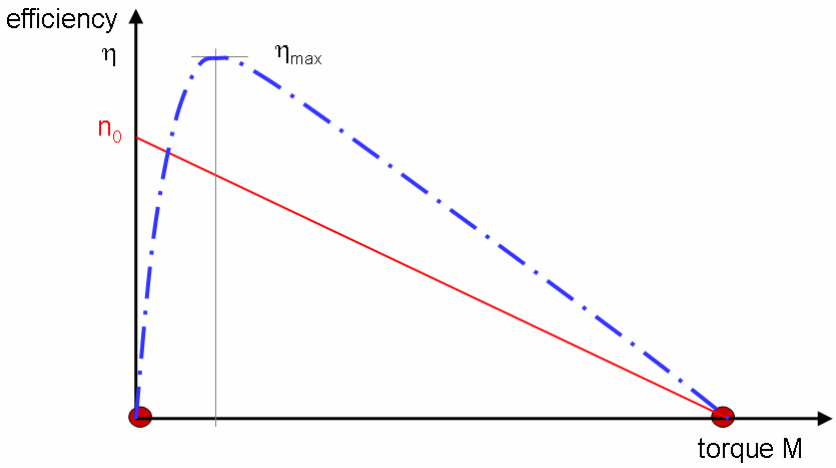
Motor Efficiency

The last number of the values at nominal voltage is the maximum efficiency.
Efficiency is the ratio of output power per input power. The input power of a DC motor is made of the current I times the applied voltage U. The output power essentially is the motor speed n times the produced torque M minus the torque losses M_R.

General equation

$$\eta = \frac{\pi}{30} \cdot \frac{n \cdot (M - M_R)}{U \cdot I}$$

The shape of the efficiency curve can be quite easily understood. At no-load all the power is consumed in the motor, no useful torque is produced. Hence efficiency is zero. At stall nothing moves and efficiency is zero as well. In between there must be some maximum.



At high motor torques near stall we can neglect the small friction torque in a first approximation. An analysis of the equation shows that efficiency must increase with speed since the applied voltage is constant as well as the ratio of M/I which is nothing but the torque constant k_M.

Near stall:

$$\eta = \frac{\pi}{30} \cdot \frac{n \cdot M}{U \cdot I} = \text{const.} \cdot n$$

Therefore, with increasing motor speed efficiency goes up. At the same time the produced torque gets smaller and friction becomes more important reducing the efficiency at small torques.

Maximum efficiency

The maximum efficiency (as given in line 9 in the catalog data) can be calculated from the starting current and no-load current. The maximum efficiency depends on the applied motor voltage. It increases with increasing voltage and it is strongly reduced at lower voltages. Therefore the maximum efficiency is not a useful selection parameter. Usually it is better to verify that the current draw is small in applications where low power consumption is a critical issue.

Maximum efficiency:

$$\eta_{max} = \left(1 - \sqrt{\frac{I_0}{I_A}}\right)^2 = \left(1 - \sqrt{\frac{M_R}{M_H}}\right)^2$$

The maximum efficiency of DC motors usually lies in the continuous operating range.