On the centrifugal pumps performance curves estimation using empirical equations

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Abstract: - A group of empirical equations were developed in order to estimate the performance curves (H - Q, n - Q, P -Q, NPSHr -Q) of a centrifugal pump, using quite small amount of pumps geometric data. The results of the present study prove that centrifugal pumps performance curves direct estimation could be accomplished without using complex mathematical models. Furthermore more, all-basic parameters affect the pump behavior are taken into account (including the installation), resulting on very good approach to basic potential performance curves, before attempting the manufacture of the prototype. These empirical equations satisfactorily provide the ability to approximate the potential performance curves of commercial centrifugal pumps.

Key Words: - centrifugal pumps, performance curves

1 Introduction

The empirical equations used to describe typical centrifugal pump performance curves were analytical expressed in [1] to [5] (KSB Meganorm and Etanorm centrifugal pumps). Centrifugal pumps [6] to [8] have been used as reference data curves.
In the following sections a brief explanation of the empirical equations will be presented followed by the associate comparison diagrams [9].

2 Mathematical formulation

2.1 Pump total head

The pump total head depends on the impeller's velocity expressed as $u_2 = \pi \cdot D_2 \cdot n$. The coefficient *cos(ξ.π/2)* modulates the empirical equations to the real performance curves $H = f(Q)$ of the pump. The coefficient ξ, represents the division of each quantity of pumping time required to reach maximum total head and it takes values between 0 and 1. The real performance curves are better converged by adding the diameter of the discharge pipe d_p to the equation. This value never directly appears in the common theoretical equations.

Whereupon

$$Q = 0 \quad \text{for} \quad H_{\max} = 0{,}6 \cdot \left[\left(\frac{n(rpm)}{60} \cdot D_{2X} \right)^2 \right]$$

And

$$Q = Q_{\max} \quad \text{for} \quad H = 0 .$$

$$H(m) = 0{,}6 \cdot \left[\left(\frac{n(rpm)}{60} \cdot D_{2X}(m) \right)^2 \right] \cdot \left[\cos\left(\frac{\pi}{2} \cdot \xi \right) \right]^{0{,}2}$$

When Euler's theory leads to

$H = \frac{u_2^2}{g} - \frac{u_2}{\pi \cdot D_2 \cdot b_2 \cdot \tan\beta_2} \cdot Q$, see [10].

2.2 Efficiency

The dimensionless volume rate number ξ is introduced to represent the pump's operational point. The ratio D_{2x}/D_2 represents the correlation among pumps of the same category, while D_2 is the representative impeller diameter and b_2 is the width of the impeller.

$$\xi = \frac{Q(m^3/h)}{5 \cdot d_p(m) \cdot b_2(m) \cdot \frac{n(rpm)}{60} \cdot D_{2x}(m)}$$

The pump efficiency could be calculated by:

$$\eta = 3{,}6 \cdot \xi \cdot (1-\xi) \cdot \left[0{,}95 \cdot \left(\frac{D_{2X}(m)}{D(m)} \right)^{0{,}5} \right] \cdot \left(b_2(m) \cdot 10 \right)^{0{,}1}$$

2.3 Net positive suction head

The NPSH value also depends on the pump's operational point and can be defined as a function of n and Q.

$$NPSH(m) = 0{,}075 \cdot \left[\left(\frac{n(rpm)}{60 \cdot 0{,}35} \right) \cdot \left(\frac{Q(m^3/h)}{3600} \right)^{0{,}5} \right]^{1{,}3} \cdot \left(\frac{D_2(m)}{D_{2x}(m)} \right)^3$$

2.4 Pump motor power

The mathematical formula presented below determines the optimum pump motor power while a realistic NPSH value is being obtained.

$$N(Watt) = \frac{\rho(kg/m^3) \cdot g(m/s^2) \cdot Q(m^3/h) \cdot H(m)}{\eta}$$

3 Results and discussion

The impeller's basic dimensions are shown in Fig.1. In Fig.2 to Fig.5 the mathematical formulas presented above were plotted together with KSB 80-250 operating at 1450 RPM.

As it could be observed, the approximation between performance curves estimated via experiments test or via empirical mathematical formulas is quite good. In this way the performance of a typical centrifugal pump could be mathematically provided without the need of the expensive experimental procedure.

It should be noted that it is quite impossible for a typical commercial centrifugal pump to match the performance curves obtained by EULER's theory. That's why operational areas on the right side of the optimum point presents curves inclined deviations.

References:

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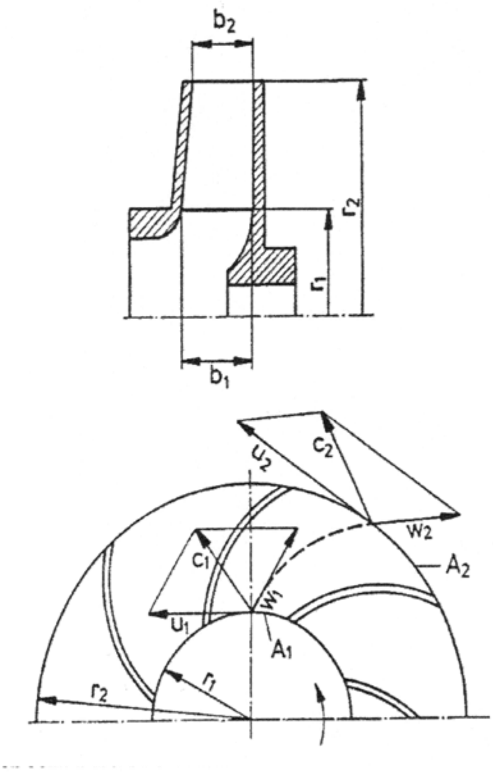

Fig. 1 Impeller's basic dimensions

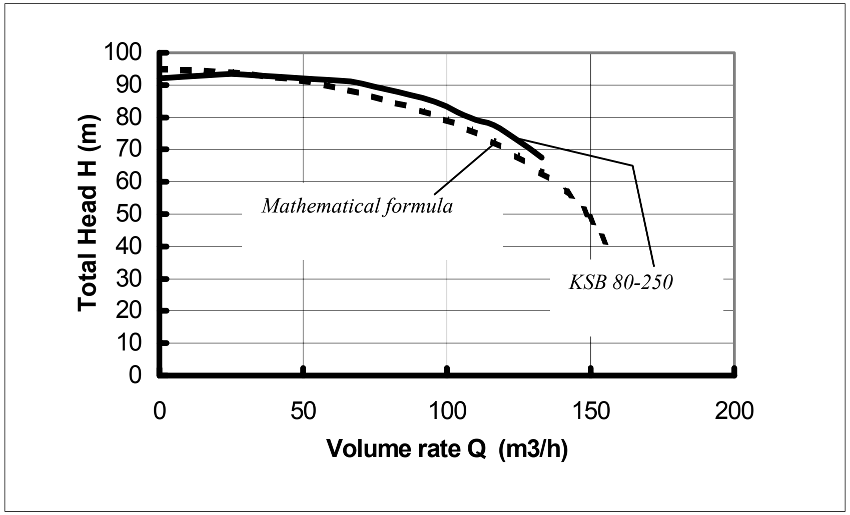

Fig.2 Volume rate vs Total head (1450 RPM)

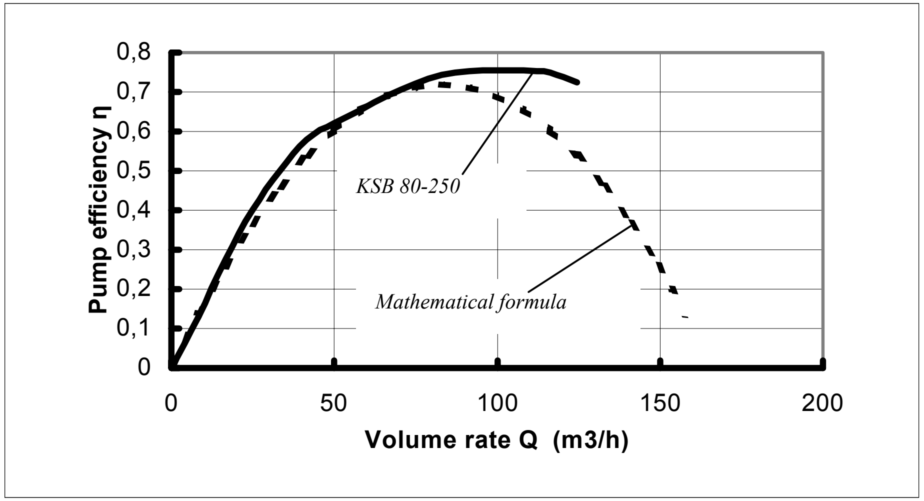

Fig.3 Volume rate vs Pump efficiency (1450 RPM)

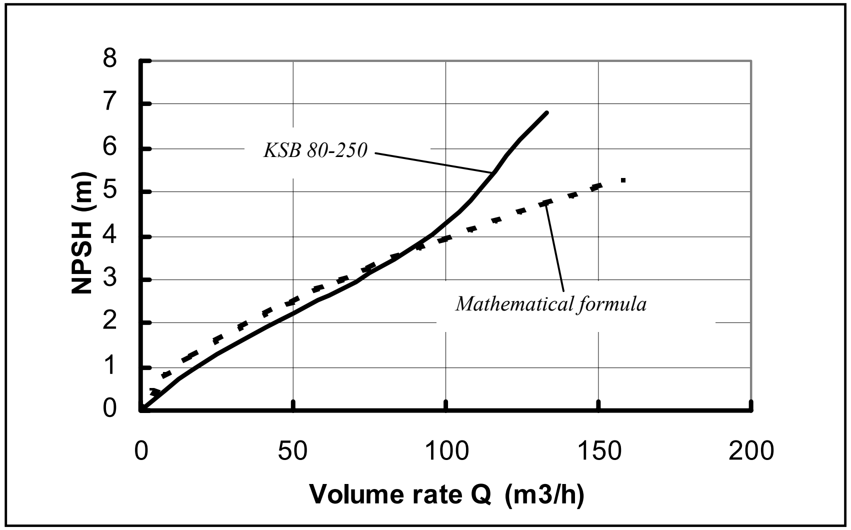

Fig.4 Volume rate vs NPSH (1450 RPM)

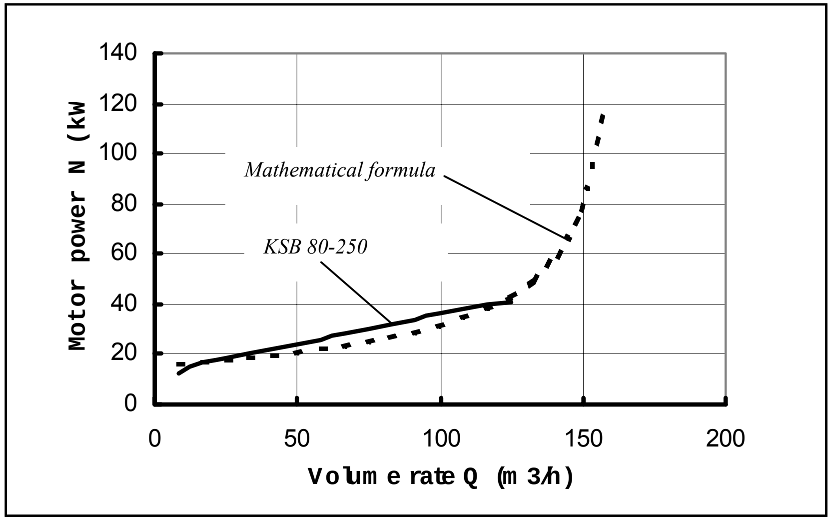

Fig.5 Volume rate vs Motor power (1450 RPM)