离心泵总效率的影响因素分析

黄仕元,何少华,张　宇
(南华大学建筑工程与资源环境学院,湖南 衡阳 421001)

摘要:本文对离心泵总效率的影响因素进行了详细的分析,认为离心泵总效率不但与水力效率、容积效率和机械效率有关,还与水泵液槽中的"反旋现象"有关,从而可推导出离心泵总效率的计算公式应为 $\eta=\eta_h\cdot\eta_v\cdot\eta_p\cdot\eta_m$。

关键词:离心泵;总效率;反旋现象
中图分类号:TH311　**文献标识码**:A　**文章编号**:1004 - 7948(2003)03 - 0018 - 02

1 前言

离心泵广泛应用于工农业生产和居民生活的各个领域,每年消耗在水泵机组上的电能占全国总电耗的 21 %以上,就一般城镇水厂而言,泵站消耗的电费,通常占自来水厂制水成本的 40 %～70 %,甚至更多。因此,研究离心泵的节能问题具有重要意义。而离心泵的总效率是反映离心泵耗能的主要指标。分析离心泵总效率的影响因素,具有重要的经济价值。由中国建筑工业出版社出版的国家级"九五"重点教材《水泵及水泵站》[1](简称"教材")以及《给水排水设计手册》等参考书上的离心泵总效率的影响因素均只考虑到水力效率、容积效率和机械效率,没有考虑水泵液槽中"反旋现象"的影响。笔者认为,离心泵总效率的影响因素还应考虑"反旋现象"。

2 离心泵总效率的影响因素分析

2.1 反旋现象对总效率的影响

在推导离心泵的基本方程式时,为了简化分析推理,假定液槽中液流均匀一致,叶轮同半径处液流的同名速度相等。然而,在实际应用中是有差异的。因为实际水泵的叶轮叶片一般为 2～12 片左右,在叶槽中水流具有某种程度的自由。当叶轮转动时,叶槽内水流的惯性,反抗水流本身被叶槽带着旋转,趋向于保持水流的原来位置,因而相对于液槽产生了"反旋现象"。因此,对水泵的理论扬程要进行修正,修正后的理论扬程为:

$$H_T'=\frac{H_T}{1+P} \qquad (1)$$

式中　H_T —水泵的理论扬程,mH_2O;
H_T' —修正后水泵的理论扬程,mH_2O;
P —修正系数,由经验公式确定。

下面以低比转数离心泵为例,对修正系数 P 进行分析,其计算公式[2]为:

$$P=\left(1+\frac{\beta_2}{60}\right)\cdot\frac{2\gamma_2^2}{Z(\gamma_2^2-\gamma_1^2)} \qquad (2)$$

式中　P —压水室形状引入系数,一般为 0.65～0.85;
β_2 —叶片出水角,一般为 20～30 °;
Z —叶轮中叶片数,一般为 6～8 片;
r_1、r_2 —叶轮进、出水口半径,对于正常比转数离心泵,叶轮进、出水口半径,其比值为$\frac{1}{2}$。

对于低比转数离心泵,其修正系数 P 一般为 0.29～0.57,也即,由于反旋现象的影响,离心泵的理论扬程 H_T 将下降为 $(0.64～0.78)\ H_T$,那么是否意味着反旋现象将消耗 22 %～36 %的能量呢?不是的。一方面,我们可以理解为反旋现象是叶轮中水流没有完全跟着转动,趋向于原来的位置,从而减少了对叶轮的输入功率。另一方面,由于水泵所输送的液体为实际液体,反旋现象引起叶轮内水流运动不会均匀一致,靠近叶片背水面的地方,流速提高压力降低,靠近叶片迎水面的地方,流速降低压力升高,也即在过水断面上形成了流速梯度,又由于水泵所输送的液体为实际液体,流速梯度的变化会改变流层间的切应力,从而造成能量的不断消耗,引起水泵的效率降低。其值可用反旋效率来度量:

$$\eta_p=\frac{H_T'}{H_T''} \qquad (3)$$

式中　H_T'' —反旋损失修正前水泵的理论扬程,mH_2O。

2.2 水泵内部水头损失对总效率的影响

水泵的内部水头损失包括摩阻损失和冲击损失,前者是指流体流经吸水室、叶槽和压水室时产生的损失,后者是指运行流量不同于设计流量时、在叶轮的进口导水器、蜗壳压水室的进口等处发生冲击现象而产生的损失。泵体内这两部分水力损失必然要消耗一部分能量,使水泵总效率下降。其值可用水力效率 η_h 度量,在"教材"中第 24 页表达为:

$$\eta_h = \frac{H}{H_T} \tag{4}$$

笔者认为,此公式表达不正确。因为 H 值为水泵的实际扬程,远远低于其理论扬程,其原因是由于反旋现象的影响和水泵内部水头损失共同所致。从前面分析可知,仅反旋影响导致 H_T 值下降 22 %～36 %,如果考虑水头损失将下降更多,也即水力效率 η_h 值肯定小于 0.64～0.78,这与离心泵总效率一般为 0.8 左右是相矛盾的。要正确反映 η_h 值,必须扣除反旋现象的影响,即:

$$\eta_h = \frac{H}{H_T} \Big/ (1 + P)\frac{H}{H_T} \tag{5}$$

式中 H —水泵的实际扬程,mH_2O。

2.3 容积损失对总效率的影响

在水泵工作过程中存在着泄漏和回流问题,也就是说水泵的出水量总要比通过叶轮的流量小,即 $Q = Q_T - \Delta q$,此 Δq 就是泄漏和回流流量,它仍要损失一部分能量,使水泵总效率降低,其值可用容积效率 η_v 度量:

$$\eta_v = \frac{Q}{Q_T} \tag{6}$$

式中 Q —水泵的实际流量,m^3/s;

Q_T —水泵的理论流量,m^3/s。

2.4 摩擦损失对水泵总效率的影响

水泵在运行中还存在轴承内的摩擦损失,填料轴封装置内的摩擦损失等,这些机械性的摩擦损失,同样消耗了一部分能量,使水泵的总效率下降,其值可用机械效率 η_m 来度量:

$$\eta_m = \frac{N_h}{N} \tag{7}$$

式中 N —水泵的轴功率,kW;

N_h —叶轮传给水的全部功率,$N_h = \rho Q_T H_T$,kW。

在"教材"中,叶轮传给水的全部功率表达为 $N_h = \rho Q_T H_T$,笔者也认为不妥。因反旋现象引起的理论扬程将下降,主要表现在叶轮传给水的功率下降了,而不是消耗了如此多的能量。叶轮传给水的全部功率应为 $\rho Q_T H_T$ 与反旋能耗之和,即反旋损失修正前的功率 $N_h = \rho Q_T H_T$"。

3 离心泵总效率计算公式的推导

离心泵的总效率是单位时间内流过水泵的液体从水泵那里得到的能量(ρQH)与水泵轴功率(N)的比值。即:

$$\begin{aligned}\eta &= \frac{\rho QH}{N}\\ &= \frac{\rho QH}{\rho QH_T}\cdot\frac{\rho QH_T}{\rho Q_T H_T}\cdot\frac{H_T}{H_T}\cdot\frac{\rho QH_T}{N}\\ &= \frac{H}{H_T}\cdot\frac{Q}{Q_T}\cdot\frac{H_T}{H_T}\cdot\frac{N_h}{N}\\ &= \eta_h\cdot\eta_v\cdot\eta_p\cdot\eta_m\end{aligned} \tag{8}$$

从(8)式可看出,水泵的总效率不仅与水力效率、容积效率和机械效率有关,同时还与液槽中水流的反旋现象有关。

4 结语

反旋现象产生于水泵液槽中。所以,反旋能耗与水泵压水室的形状、叶轮进、出口半径、叶片数以及叶片出水角等因素有关。要减小反旋损失,必须减小叶片出水角,尽量选用导叶式压水室,增大叶轮进、出口半径的差值。特别是与叶片数有直接关系,当叶片数相对较多时,反旋现象较弱,反旋损失较少。但此时液槽中过水断面狭窄摩阻损失较大,因此,要减小反旋损失势必增加摩阻损失。在设计制造中,必须综合考虑,二者兼顾。

本文提出的离心泵的总效率与液槽中的反旋现象、水力损失、机械损失、容积损失等四种因素有关,表明要想提高水泵的总效率,必须尽量减小机械损失和容积损失;力求改善泵壳内过水部分的设计、制造和装配,以减少水力损失;还要尽量减小修正系数 P,以减小反旋损失。只有综合考虑影响总效率的各种因素,才能设计制造出更加高效节能的水泵来,更好地为国民经济服务。

参考文献

[1]姜乃昌等. 水泵与水泵站[M]. 北京:中国建筑工业出版社,1998.

[2]丁成伟等. 离心泵与轴流泵[M]. 北京:中国机械工业出版社,1986.

Energy Conservation (Monthly)
Sponsor: Liaoning Provincial Institute of Science and Technology Information
Publisher: 《Energy Conservation》Magazine Publishing House
Chief Editor: ZHANG Wei-hua
Address: No. 274 Qingnian Boulevard Shenyang City Liaoning Province China
Post Code: 110016

ABSTRACTS

March 2003 No. 3 Total Issue No. 248

The developments of HCs as refrigerants

WANG Mei-xia, LIU Cun-fang

Advantages and problems of using hydrocarbon as working fluids in refrigerating equipment are discussed. Study on cycle characteristics, heat transfer and safety precautions of different hydrocarbon alternatives must be strengthened. In addition safety standards of high flammability fluids must be revised.

Key words: hydrocarbon; working fluids; refrigerant; safety standard 6

Experimental study of evaporative condenser used in the domestic and light air conditioner unit

WANG Shao-wei, YU Li-qiang

In this paper, evaporative condenser used in air conditioner unit has been studied. It is found that evaporative condenser not only improves the performance of air conditioner(COP), but decreases the possibility of leaking refrigerant because the fluid flowing into indoor unit is cooling water instead of refrigerant. Moreover, by experimental study, the influence of the initial wet – bulb temperature of the inlet air, the air velocity passing the smallest cross area and spray water on the process of heat and mass transfer for the evaporative condenser has been discussed. As a result, the least density of spray water and the best scope of air velocity has been given, which can be applied to the engineering design.

Key words: evaporative condenser; heat and mass transfer; least spray water density; air velocity passing the smallest cross area 9

The application of neural network in model for speed regulation by frequency conversion of pumps

JIN Ming-shan, MA Gui-mei

This paper expounds a kind of more effective method for speed regulation by frequency conversion, in this method it is necessary to gain data about capacity and head at first, they can be gained through experiment or traditional calculation for water distribution network, then neural network will be utilized. At last, we can educe formula for speed regulation by frequency conversion(model) through training. The model which educed by this method and reality are more resemble.

Key words: neural network; speed regulation by frequency conversion; water distribution network 16

The calculate formula of the total efficient of a centrifugal pump

HUANG Shi-yuan, HE Shao-hua, ZHANG Yu

The influence factor of total efficient of a centrifugal pump has been analyzed in details in this article, and it is considered that the influence factor of total efficient of a centrifugal pump is not only related to the hydraulic power efficient, the capacity efficient and the mechanical efficient but also to the anti – rotary phenomenon of the pump liquid trough, that is to say the calculate formula of the total efficient of a centrifugal pump should be expressed by $\eta = \eta_s \cdot \eta_v \cdot \eta_p \cdot \eta_m$.

Key words: a centrifugal pump; total efficient; the anti – rotary phenomenon 18

The application of the input – output theory in the petrochemical corporation

LUO Xiang-long, ZHAO Liang, YIN Hong-chao

The input – output theory is a very effective method for energy analysis. In this article the basic principle of this method is introduced, and based on this mathematic model the manufacture configuration and system analysis for a famed petrifaction corporation is given. It is easier to predict the demanding amounts of all sorts of material and energy by means of this method.

Key words: input – output; system analysis; energy prediction 20

Recovering steam evaporation latent heat from exhaust gas and improving thermal efficiency of oil – fired and gas – fried boilers

HE Bei-qi, LIN Ri-yi, WANG Mi-kang

The thermal efficiency of boiler depends on heat loss of exhaust gas in a large extent. Lowered the temperature of exhaust gas below dew point of water, not only can its sensible heat of uncondensible gases be decreased, but the steam evaporation latent heat can be recovered, so the heat loss of exhaust gas will be decreased and the thermal efficiency of boiler will be improved in quantities. The steam content in exhaust gas of oil – fired and gas – fired boilers is more than that of coal – fired boilers, the thermal efficiency of oil – fired and gas – fired boilers will be increased more obviously. But the corresponding measures should be taken to keep low – temperature heated surface from acid corrosion due to condensed sulfuric acid and sulfurous acid.

Key words: thermal efficiency; evaporation latent heat; oil – fired and gas – fired boiler; acid corrosion 23

The way of energy saving in thermoeletric plant

YANG Jun-hui

Several energy saving measures in thermoeletric plant are listed here from the designing angle. The aims is from the designing angle to grasp energy saving the link, improve plant efficiency, increase economy efficiency

Key words: thermoelectric planti; thermoeletric efficiency; energy saving 26