▶设计计算◀

基于遗传算法的自增压汽化器优化设计

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摘要 通过分析自增压汽化器的传热模型，应用遗传算法对自增压汽化器进行了优化设计；讨论了算法的优化步骤，并以自增压汽化器总长度最小为目标进行优化，得到1组翅片管的结构参数。实际算例结果表明，采用遗传算法进行自增压汽化器的优化设计切实可行，遗传算法寻优快捷、可靠，为同类汽化器的优化设计提供了参考。

关键词 遗传算法 自增压汽化器 优化设计

引 言

自增压汽化器在低温液体的贮运和供气系统中起着十分重要的作用，是必不可少的部件。低温液化气体如液氧、液氮、液化天然气等贮运容器普遍采用自增压来使贮运容器达到工作压力，即把一部分液体通过管路引出，经汽化器汽化后再引入贮罐的气相空间，实现增压排液的目的。为了使汽化器的产气量、生成气体的状态参数达到预定要求，必须对汽化器的结构尺寸进行合理的优化。笔者采用遗传算法进行优化。

遗传算法是一种基于自然选择和遗传变异等生物进化机制的全局性概率搜索算法。遗传算法的主要本质特征在于群体搜索策略和简单的遗传算子。群体搜索使遗传算法得以突破领域搜索的限制，可以实现整个解空间上的分布式信息探索、采集和继承；遗传算子仅仅利用适应值度量作为运算指标进行染色体的随机操作，降低了一般启发式算法在搜索过程中对人机交互的依赖。这样就使得遗传算法获得了强大的全局最优解搜索能力，成为一种具有良好普适性和可规模化的优化方法[1]。

自增压汽化器的传热模型

1. 汽化器的吸热量

对于自增压汽化器的原理和吸热量的计算在文献[2, 3]中有详细论述，吸热量可参考两文献进行计算。

2. 汽化器的换热系数计算

现在应用较多的自增压汽化器由铝翅片星形管按一定形式组合而成，见图1。低温液体在管内流动吸热汽化，管外为空气自然对流，热量由空气通过翅片及管壁传给低温液体。其传热系数K为

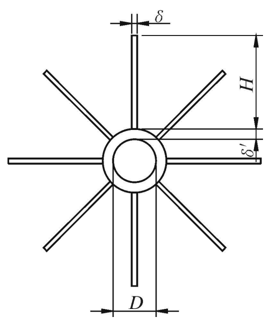

图1 星形翅片管

$$K = \frac{1}{\frac{1}{\alpha_f} + \frac{\delta'}{\lambda} + \frac{1}{\alpha_a \beta \eta}} \tag{1}$$

式中 K——总传热系数，W/(m^2·K)；

δ'——翅片管的壁厚，m；

λ——铝的导热系数，取158 W/(m·K)；

α_f——低温流体与管壁的对流换热系数，W/(m^2·K)；

α_a——空气与翅片管的自然对流换热系数，W/(m^2·K)；

β——肋化系数，$\beta = F_2/F_1$，F_1、F_2为翅片管的内外表面积，m^2；

$$\eta = \frac{\mathrm{th}(mH)}{mH} \qquad m = \sqrt{\frac{\alpha_a U}{\lambda A}}$$

式中，η为肋片效率；H为翅片高度。对于矩形直

肋, $A = L\delta$ (L为翅片长或管长, δ为翅片厚度); 因为 $L \gg \delta$, 所以 $U \approx 2L$, 则得

$$m = \sqrt{\frac{\alpha_a 2L}{\lambda L\delta}} = \sqrt{\frac{2\alpha_a}{\lambda\delta}} \quad (2)$$

因管内汽化换热系数 α_f 及铝的导热系数 λ远大于管外的自然对流换热系数 α_a, 则在实际设计计算中可将式 (1) 中 $1/\alpha_f$ 及 δ'/λ忽略, 则式 (1) 可简化为

$$K = \alpha_a \beta\eta \quad (3)$$

α_a 可按空气对平壁的自然对流换热准则方程求得[4]。

$$\alpha_a = \lambda_a \cdot Nu/H \quad (4)$$

3. 汽化器的换热面积及长度计算

据传热关系式 $Q = KF_1\Delta T_m$ 和式 (3) 可得

$$F_1 = Q/(\alpha_a \beta\eta \Delta T_m) \quad (5)$$

对数平均温差

$$\Delta T_m = (\Delta T_1 - \Delta T_2)/\ln(\Delta T_1 - \Delta T_2) \quad (6)$$

其中 $\Delta T_1 = T_a - T_0$, $\Delta T_2 = T_a - T$

则翅片管的总长度计算式为

$$l = \frac{Q}{\alpha_a \beta\eta \Delta T_m \pi D} \quad (7)$$

遗 传 算 法

1. 适应函数的确定

适应函数是由目标函数映射而得, 在遗传算法中, 目标函数到适值函数的映射方式需要保证 2点[1]: ①映射后的适值是非负的; ②目标函数的优化方向应对应适值的增大方向。

笔者欲研究的最小化问题一般采用如下适值函数 $f(x)$ 和目标函数 $g(x)$ 的映射关系[1]:

$$f(x) = \begin{cases} c_{max} - g(x) & g(x) < c_{max} \\ 0 & \text{其它} \end{cases}$$

其中, c_{max}可以是一个输入值或理论上的最大值。也可以是到目前所有代中 $g(x)$ 的最大值, 此时 c_{max}会随着代数变化。

星形翅片管汽化器属于紧凑型换热器, 要求尺寸尽可能小, 故笔者采用式 (7) 所确定的翅片管总长度最小为目标函数, 从而就可以确定相应的适应函数进行优化, 并得出优化值。

2. 编码方式及初始群体

采用二进制编码。二进制编码将问题空间的参数表示为基于 0和 1组成的二进制代码串, 建立位串空间。串长由变量的个数、精度、上下界决定; 总串长为所有变量的串长相加; 一个变量对应的串长计算式为 $Len = \log_2^{\frac{max - min}{\text{精度}}}$。

初始群体是由计算机按随机方法从可能解中产生给定数量的二进制代码串构成的, 此过程不断重复, 直到初始群体个数达到设定的规模为止。

3. 遗传操作

遗传算法的操作算子包括复制、交叉和变异 3种基本形式。它们构成了遗传算法的核心, 是模拟自然选择以及遗传过程中发生的繁殖、杂交和突变现象的主要载体。

(1) 复制 复制即从群体中选择适应值高的个体以生成交配池的过程。采用轮盘赌方式实现, 这种方式首先计算每个个体的适应值, 然后计算出此适应值在群体适应值总和中所占的比例, 表示该个体在选择过程中被选中的概率。对于给定的规模为 n的群体 $P = \{a_1, a_2, \cdots, a_n\}$, 个体 $a_j \in P$ 的适应值为 $f(a_j)$, 其选择概率为

$$P_s(a_j) = \frac{f(a_j)}{\sum_{i=1}^{n} f(a_i)} \qquad j = 1, 2, \cdots, n$$

(2) 交叉 交叉是指随机选择 2个个体作为父代个体, 加以替换重组而生成新个体的操作, 它是提高算法搜索能力、加快算法收敛速度的关键。交叉点位置由随机选取产生, 交叉点后基因进行交换。以串长 10为例:

双亲		后代
1001101 ∣ 000	→	1001101 ∣ 011
1001011 ∣ 011	→	1001011 ∣ 000

(3) 变异 变异即随机地选取若干个体, 对选中的个体随机地选择某一位, 然后改变该位的值 (0变为 1, 1变为 0)。如 10110010→10111010。

变异增加了群体基因的多样性和自然选择的空间, 有利的变异将由于自然选择的作用得以遗传与保留, 而有害的变异则将在逐代遗传中被淘汰。

算 例

设计一液氮自增压汽化器, 已知排液量为 0.96 kg/s, $p = 8$ MPa, $T = 120$ K, $\tau = 20$ min, $p_0 = 0.1$ MPa, $T_0 = 77$ K, $V_o = 12.5\ m^3$。空气的定性温度为 $T_a = 223$ K。查 $T_a = 223$ K下空气的物性参数为 $\lambda_a = 0.020\,59$ W/(m·K), $\beta = 4.51 \times 10^{-3}$ (1/K), $v = 9.55 \times 10^{-6} m^2/s$, $Pr = 0.715$。

以星形铝翅片管为对象进行优化, 式 (8) 决

定的目标函数中各变量的取值范围如下

翅片厚度 δ= 0.002, 0.003, 0.004, m

翅片高度 0.030< H < 0.080, m

翅片管内径 0.020< D < 0.050, m

以自增压汽化器的总体积 V < 0.20 m^3 为约束条件进行优化。取种群规模 50, 终止代数 50, 交叉概率 0.6, 变异概率 0.01。优化结果：图 2为目标函数值随进化代数的变化图形，曲线从上到下依次表示目标函数平均值、目标函数最小值。

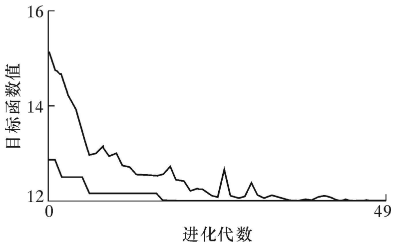

图 2　目标函数值随进化代数的变化图形

目标函数最小值随遗传代数的变化情况见表 1。

表 1　目标函数的最小值随进化代数的变化情况

进化代数	目标函数最小值	进化代数	目标函数最小值
0	12.628	12	11.957
1	12.628	13	11.957
2	11.993	14	11.957
3	11.993	15	11.957
4	11.993	16	11.957
5	11.981	17	11.957
6	11.981	20	11.957
7	11.981	25	11.957
8	11.981	30	11.957
9	11.981	35	11.957
10	11.957	40	11.957
11	11.957	49	11.957

从表 1中数据可知，随着进化代数的增加，目标函数的最小值逐渐减小，到第 11代就开始趋于稳定值。最终可返回 1组翅片管自增压器结构的优化值：δ= 0.002 m, H = 0.050 m, D = 0.039 m, 此时翅片管的长度 l = 11.957 m。该优化值与实际使用的翅片管自增压器的结构相接近，可见遗传算法用于翅片管自增压器的优化设计是快捷、可靠的。

综合以上研究，可得出结论：

通过对翅片管自增压汽化器的传热分析，应用遗传算法可对翅片管自增压汽化器的结构进行优化设计。算例表明，采用遗传算法进行自增压汽化器的优化设计切实可行，具有寻优快捷、可靠的特点，是一种理想的优化方法，为同类汽化器的优化设计提供了参考。

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收稿日期：2005-08-16

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MPa左右时接头存在滑扣脱落失效的可能性；

(3) 复合射孔枪接头出现剪切破坏，常发生在螺纹扣数少且内压和静压较大的状态下。

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收稿日期：2006-01-04

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the influence of ASP flooding on NBR fatigue life is severe, but when it is in even friction, its average friction factors is stable and reflects the lubrication performance of medium, although its cyclic fluctuation of itself is reflected in the friction process.

Key words: NBR, frictional performance, ASP flooding, ceramic coating

Tao Liang (*College of Aeronantics, Northwest Polytechnical University, Xi'an*), Yu Qingjun, Li Yulong, et al. **Numerical simulation on combined perforator joint failure.** ***CPM***, 2006, 34(4): 17~19, 22

Under the conditions of similar structure charging rate, higher pressure in the perforators can be produced in downhole operation by using combined perforation, failure would be caused in its joints. On the basis stated above, a numerical method of plastic dynamics and material failure judgment are used to analyze the causes of joint failure from the aspects of structure and internal pressure. It is found out that the shear destruction of threads has certain time sequences and order and the laws of loads and failure, thus technical support is provided for preventing the joint failures in combined perforators.

Key words: combined perforator, joint, shear failure, slipping failure, numerical simulation

Chang Kun (*College of Petrochemical Engineering, Lanzhou University of Science and Technology*), Chen Shuping, Liu Zhenquan, et al. **Optimized design of self-pressured vaporizer based on genetic algorithm.** CPM, 2006, 34(4): 20~22

A genetic algorithm is used to make an optimized design of self-pressured vaporizer by analyzing a heat transfer model of the vaporizer. The optimized procedures of algorithm are discussed, it is optimized by using the minimum total length as the aim of study, by which a group of structural parameter are obtained for fin tubes. It is feasible for the optimized design of self-pressured vaporizer by using genetic algorithm. The result shows that the genetic algorithm is prompt and reliable for optimization, thus reference is provided for its optimized design.

Key words: genetic algorithm, self-pressure vaporizer, optimized design

Yuan Jianmin (*Huanghe Drilling Company, Shengli Petroleum Administration Bureau, Dongying City, Shandong Province*), Zhao Baozhong. **Design of automatic vertical pipe rack for oilfield tubing string.** ***CPM***, 2006, 34(4): 23~25

At present tubings used in workover operations are horizontally placed with great number of manual operations, thus automation is hard to be realized. In consideration of the problems stated above, an automatic tubing rack is developed for oilfield use. Preliminary test indicates that the automatic tubing rack is of new design, simple control and low manufacturing cost, can be matched with workover equipment and help simplify the moving trajectory of tubing and realize the automation of tubing trips. Labor intensity will be greatly reduced, the efficiency of workovers will be raised by introducing the device, also the tubing thread failure can be reduced for preventing accident occurred in workover operation; it is of great significance for improving overall efficiency in workover operations in oilfields.

Key words: well servicing, tubing, automatic tubing rack, design

Wu Taiping (*Research Institute of Petroleum Engineering and Technology, Henan Oilfield Company, Nanyang City, Henan Province*), Qiu Yong, Chen Fengying, et al. **Development and application of combined downhole gas-liquid separator.** ***CPM***, 2006, 34(4): 26~27

In order to reduce the influence of gas on pumps and improve the pumping efficiency, a combined downhole gas-liquid separator is developed. In the separator, gravity separation is combined with cyclone separation, by which blending, steering and immediate increase of velocity would induce in the oil stream containing dissolved gas, help extract the free gas and realize high efficient separation of oil and gas to greatly reduce the influence of gas on pumps. Field application indicates that the combined gas-liquid separator can be used to separate the free gas in oil stream before it comes into the pumps, and discharges it to surface through the annular space between tubing and casing, thus to reduce the influence of gas on oil pumps, better result of gas-liquid separation would be obtained especially for high gas content wells.

Key words: gas-liquid separator, pump efficiency, development, application

Chen Guanliang (*No.4 Oil Production Plant, Zhongyuan Oil and Gas High-Tech Co. Ltd, Puyang City, Henan Province*), Wang Fei, Cheng Yanhui, et al. **Research and design of tubing strings for well flushing and formation damage prevention.** ***CPM***, 2006, 34(4): 28~29

In consideration of the problems of the influence of formation damage caused by conventional dosage and cyclical thermal well flushing on the production output in "three lows" and paraffin-troubled wells, a tubing string is designed for high efficient well flushing and preventing formation damage. It is composed of Y441 hydraulic packer, sideway bypass compensator and a fixed overpressure valve. It is used in 15 wells in No.4 and No.5 Oil Production Plants of Zhongyuan Oilfield. The field application shows that the success rate and qualification rate of the field test are 100%. It can be used to solve the problem of formation damage caused by cyclic thermal well flushing, also the period of liquid discharging after thermal flushing is obtained 3 d ahead of schedule. 72 thousand Yuan RMB of average single well cost is saved yearly.

Key words: thermal well flushing, formation damage, oil pumping tubing string, application

Wang Fei (*No.4 Oil Production Plant, Zhongyuan Oil and Gas High-Tech Co. Ltd, Puyang City, Henan Province*), Chen Jiandang, Cui Weiguan, et al. **Development and application of**