SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE
FAKULTA CHEMICKEJ A POTRAVINÁRSKEJ TECHNOLÓGIE

Kompresory

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Obsah

Abstract

The aim of this paper is to describe various options for the optimalization of compressors used in industry . The consumption of energy, as well as fossil fuels, is rising, which has a significant impact on the environment. This trend is present in all of the areas of industry worldwide. By reducing the energy consumption we can not only reduce the negative impact on the environment and the production of the greenhouse effect gasses, but we can also significantly reduce the operational costs.

Keywords: optimimalization, compressor, efficiency, energy saving

1. Úvod

Rastúca spotreba energií vo svete spôsobuje zvyšovanie koncentrácie skleníkových plynov v ovzduší, nakoľko výroba energie sa stále zakladá na spaľovaní fosílnych palív. Priemyselné výroby sa na spotrebe energie podieľajú v nemalej miere, no napriek veľkým možnostiam zefektívnenia výrob, ktoré by mali nielen pozitívny dopad na životné prostredie, ale aj na zisk samotných prevádzok, tomu nie je venovaná dostatočná pozornosť. Samotné kompresory sú zodpovedné za 15 % spotreby elektrickej energie [1].

2. Spôsoby úspor

Práca kolektívu Mckane, Hasanbeigi v spolupráci s priemyslom sa zameriava na globálne možnosti šetrenia energií zlepšením účinností čerpadiel, vzduchových kompresorov a fúkacích systémov. Zozbierali údaje z USA, Kanady, Európskej únie, Thajska, Vietnamu a Brazílie, a pokúsili sa vytvoriť prehľad možností, ako znížiť spotrebu energie aj s odhadom kapitálových nákladov. Pre lepšiu prehľadnosť uvádzam tabuľku a graf z článku [2].

Table 4
Expert Input: energy efficiency measures, efficiency improvement and cost for *pumping* systems.

No.	Energy efficiency measure	Typical % improvement in energy efficiency over current *pump* system efficiency practice			Expected useful life of measure (years)	Typical capital cost (US$)				
		% Improvement over LOW eff. base case (%)	% Improvement over MED eff. base case (%)	% Improvement over HIGH eff. base case (%)		≤ 50 hp ≤ 37 kW	> 50 hp ≤ 100 hp > 37 kW ≤ 75 kW	> 100 hp ≤ 200 hp > 75 kW ≤ 150 kW	> 200 hp ≤ 500 hp > 150 kW ≤ 375 kW	> 500 hp ≤ 1000 hp > 375 kW ≤ 745 kW
1.1	**Upgrade system maintenance**									
1.1.1	Fix Leaks, damaged seals, and packing	3.5	2.5	1.0	5	$1000	$1500	$2000	$2500	$3000
1.1.2	Remove scale from components such as heat exchangers and strainers	10.0	5.0	2.0	4	$6000	$6000	$9000	$12,000	$15,000
1.1.3	Remove sediment/scale buildup from piping	12.0	7.0	3.0	4	$3500	$3500	$7000	$10,500	$14,000
1.2	**Eliminate unnecessary uses**									
1.2.1	Use pressure switches to shut down unnecessary pumps	10.0	5.0	2.0	10	$3000	$3000	$3000	$3000	[a]
1.2.2	Isolate flow paths to nonessential or non-operating equipment	20.0	10.0	5.0	15	$0	$0	$0	$0	$0
1.3	**Matching Pump System Supply to Demand**									
1.3.1	Trim or change impeller to match output to requirements	20.0	15.0	10.0	8	$5000	$10,000	$15,000	$20,000	$25,000
1.4	**Meet variable flow rate requirement w/o throttling or bypass** [b]									
1.4.1	Install variable speed drive	25.0	15.0	10.0	10	$4000	$9000	$18,000	$30,000	$65,000
1.5	**Replace pump with more energy efficient type**	25.0	15.0	5.0	20	$15,000	$30,000	$40,000	$65,000	$115,500
1.6	**Replace motor with more energy efficient type**	5.0	3.0	1.0	15	$2200	$4,500	$8000	$21,000	$37,500
1.7	**Initiate predictive maintenance program**	12.0	9.0	3.0	5	8000	$8000	$10,000	$10,000	$12,000

[a] This measure is not typical for large pumps, but it is a good practice for all pumps in parallel applications.
[b] For pumping systems dominated by static head, multiple pumps may be a more appropriate way to efficiently vary flow.

A. McKane, A. Hasanbeigi / Energy Policy 39 (2011) 6595–6607

Tabuľka 1 Príklady zlepšení energetickej účinnosti s predpokladaným dopadom a odhadom kapitálových nákladov [2].

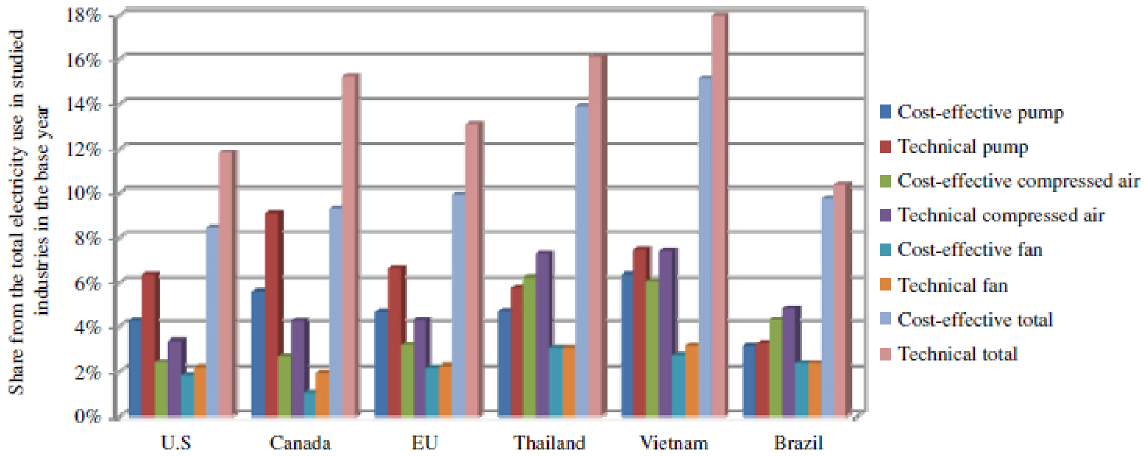


Fig. 5. Energy savings by motor system as a share of total electricity use in the base year for industries studied in the six selected countries.

Obrázok 1 Ročná miera úspory energie pre jednotlivé oblasti [2].

Každá prevádzka má svoje špecifické podmienky, a preto nie je možné prísť s jedným univerzálnym riešením. V článku kolektívu Montanes- Morantes, Jobson a Zhang bola optimalizácia zameraná na chladiace systémy. Charakteristikou chladiacich systémov je, že pracujeme pri veľmi nízkych teplotách, veľakrát sa jedná o kryogenické procesy. V prípade, že využívame chladiaci cyklus, máme vysoké nielen počiatočné investičné náklady, ale aj operačné. Minimalizovanie týchto operačných nákladov vedie k efektívnejšiemu využitiu energií a taktiež k redukcii uhlíkových emisií [3].

Pre odstredivé kompresory je kľúčovou operačnou premennou rotačná rýchlosť. Lenže jej zmena nemôže byť izolovaná a je potrebné zmeniť prevádzkové podmienky tak, aby bol chladiaci výkon zachovaný. V práci boli optimalizované podmienky pre 2 prípady, 3-stupňový chladiaci cyklus a kaskádu. Optimalizáciu vykonali vo výpočtovom programe Matlab. Len 3 % ročná úspora energie zníži náklady na prevádzku približne o 0,86 milióna libier, čo nie je zanedbateľná čiastka [3].

Článok publikovaný Viholainenom, Gronmanom a kol. sa zameral na zlepšenie efektívnosti odstredivého kompresora využívaného pri spracovaní odpadových vôd na aeráciu. Porovnali efektívnosť 3 typov difúzorov-bezlopatkového, low solidity lopatkového (LSD, scenár 2) a lopatkového (VND, scenár 3) . Bezlopatkový difúzor môže byť vylepšený pinchom (PND, scenár 1) [4].

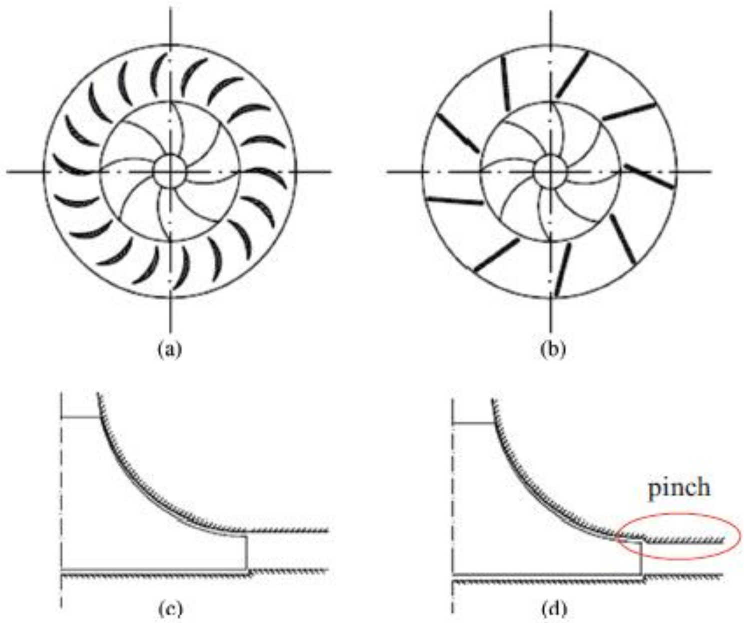
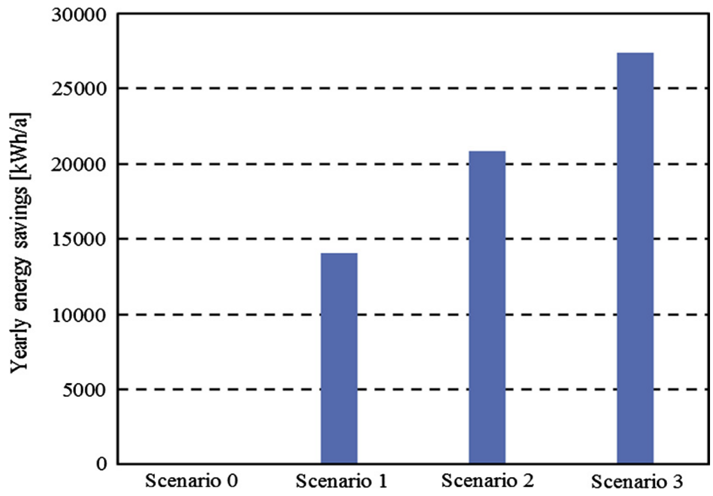
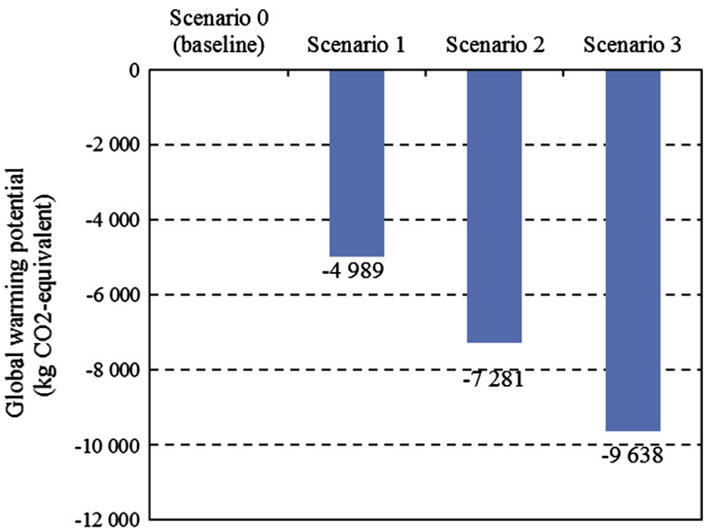


Fig. 2. A schematic view of different diffuser designs (a) vaned diffuser, (b) low solidity vaned diffuser with flat plate vanes, (c) unpinched vaneless diffuser, and (d) pinched vaneless diffuser.

Obrázok 2 Schematický pohľad na dizajn rôznych difúzorov [4].



Obrázok 3 Ušetrená energia ročne pre všetky možnosti v porovnaní s pôvodným riešením [4].



Obrázok 4 Zníženie emisií skleníkových plynov pre všetky riešenia v porovnaní s pôvodným [3].

Práce talianskeho koletívu sú zamerané na prehľad v súčasnosti využívanej technológie a možností výrazného zníženia energetickej náročnosti. Samostatne posudzujú každú zložku účinnosti kompresora (adiabatickú, mechanickú, objemovú, elektrickú). Výsledkom analýzy je zistenie, že zefektívnenie termodynamických vlastností počas kompresie jej rozdelením na dve fázy s menším kompresným pomerom, môže významným spôsobom znížiť spotrebu energie. Tiež porovnali možnosti úspor pri veľkých a malých kompresoroch. K zefektívneniu môže dôjsť aj optimalizáciou riadenia kompresorov krátkodobým (delenie záťaže), dlhodobým (plánovaním zaťaženia) prístupom. Hlbšie sa zamerali na Real Time (krátkodobý prístup). Optimalizácii činnosti kompresorov sa táto skupina venuje aj v ďalších publikovaných článkoch, niektoré z nich sú uvedené v doplnkovej literatúre [1,5].

3. Záver

V elaboráte som spracovala články venujúce sa zlepšeniu účinnosti kompresorov. Boli použité rôzne prístupy, od hľadania univerzálnejších riešení, cez zefektívnenie činnosti zameranej na konkrétne prevádzky, až po zlepšenie činnosti samotným riadením kompresorov. Priestoru na ušetrenie energií je v priemysle dostatok a je to výhodné nielen pre samotné výroby, ale aj pre spoločnosť ako takú.

4. Zoznam použitej literatúry

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5. Abstracts

1. Optimization of a network of compressors in parallel: Real Time Optimization (RTO) of compressors in chemical plants – An industrial case study

The aim of this paper is to present a methodology for optimizing the operation of compressors in parallel in process industries. Compressors in parallel can be found in many applications for example in compressor stations conveying gas through long pipelines and in chemical plants in which compressors supply raw or processed materials to downstream processes. The current work presents an optimization framework for compressor stations which describe integration of a short term and a long term optimization approach. The short-term part of the framework suggests the best distribution of the load of the compressors (where the time scale is minutes) and the long-term optimization provides the scheduling of the compressors for large time periods (where the time scale is days). The paper focuses on the short-term optimization and presents a Real Time Optimization (RTO) framework which exploits process data in steady-state operation to develop regression models of compressors. An optimization model employs the updated steady-state models to estimate the best distribution of the load of the compressors to reduce power consumption and therefore operational costs. The paper demonstrates the application of the RTO to a network of parallel industrial multi-stage centrifugal compressors, part of a chemical process in BASF SE, Germany. The results from the RTO application showed a reduction in power consumption compared to operation with equal load split strategy.

Keywords: Real time optimization, Industrials compressors, Optimal load sharing, Mathematical programming, Regression models, Energy savings

2. Energy saving potential in existing industrial compressors

The Compressed Air Sector accounts for a mean 10% worldwide electricity consumption, which ensures about its importance, when energy saving and CO2 emissions reduction are in question. Since the compressors alone account for 15% overall industry electricity consumption, it appears vital to pay attention to machine performances.

The paper presents an overview of present compressor technology and focuses on saving directions for screw and sliding vanes machines, according to data provided by the Compressed Air and Gas Institute and PNEUROP. Data were processed to obtain consistency with fixed reference pressures and organized as a function of main operating parameters. Each sub-term, contributing to the overall efficiency (adiabatic, volumetric, mechanical, electric, organic), was considered separately: the analysis showed that the thermodynamic improvement during compression achievable by splitting the compression in two stages, with a lower compression ratio, opens the way to significantly reduce the energy specific consumption.

Keywords: Compression, Efficiency, Energy saving

3. Centrifugal compressor efficiency improvement and its environmental impact in waste water treatment

Energy costs typically dominate the life-cycle costs of centrifugal compressors used in various industrial and municipal processes, making the compressor an attractive target for energy efficiency improvements. This study considers the achievable energy savings of using three different diffuser types in a centrifugal compressor supporting a typical end-use process in a waste water treatment plant. The effect of the energy efficiency improvements on the annual energy use and the environmental impacts are demonstrated with energy calculations and life-cycle assessment considering the selected compressor task in the waste water aeration. Besides the achievable energy saving benefits in the wastewater aeration process, the presented study shows the influence of the additional material needed in the diffuser manufacturing on the total greenhouse gas emissions of the compressor life-cycle. According to the calculations and assessment results, the studied diffuser types have a significant effect on the compressor energy use and environmental impacts when the compressor is operated in the aeration task. The achievable annual energy savings in this case were 2.5–4.9% in comparison with the baseline scenario. Also, the influence of the additional material and energy use for manufacturing the diffuser are insignificant compared with the avoided greenhouse gas reduction potential.

Keywords: Centrifugal compressor, Energy efficiency, Life-cycle assessment, Waste water treatment

4. Operational optimisation of centrifugal compressors in multilevel refrigeration cycles

Low-temperature energy systems are processes that require cooling at temperatures below ambient, which are accomplished using refrigeration cycles. Little research has addressed the operational optimisation of refrigeration cycles considering the performance of existing equipment. This work develops a methodology for operational optimisation of refrigerated processes, taking into account existing centrifugal compressors. For the optimisation of multilevel cycles, the evaporation temperatures of each level are varied to find a set of operating conditions that minimise shaft work demand. The optimisation takes into account equipment constraints, including compressors on a common shaft, minimum and maximum allowable inlet flow rates, etc. Two examples are presented; the first represents a three-level refrigeration cycle and the second a cascade cycle. For the two examples, the conditions of the base case are optimised, identifying improvements of around 3% in shaft work demand. In addition, both cycles were also optimised for a range of process cooling demands.

Keywords: Refrigeration cycles, Propane precooled C3-MR cycle, LNG

5. Motor systems energy efficiency supply curves: A methodology for assessing the energy efficiency potential of industrial motor systems

Motor-driven equipment accounts for approximately 60% of manufacturing final electricity use worldwide. A major barrier to effective policy making, and to more global acceptance of the energy efficiency potential in industrial motor systems, is the lack of a transparent methodology for quantifying the magnitude and cost-effectiveness of these energy savings. This paper presents the results of ground breaking analyses conducted for five countries and one region to begin to address this barrier. Using a combination of expert opinion and available data from the United States, Canada, the European Union, Thailand, Vietnam, and Brazil, bottom-up energy efficiency supply curve models were constructed to estimate the cost-effective electricity efficiency potentials and CO_2 emission reduction for three types of motor systems (compressed air, pumping, and fan) in industry for the selected countries/ region. Based on these analyses, the share of cost-effective electricity saving potential of these systems as compared to the total motor system energy use in the base year varies between 27% and 49 % for pumping, 21% and 47% for compressed air, and 14% and 46% for fan systems. The total technical saving potential varies between 43% and 57% for pumping, 29% and 56% for compressed air, and 27% and 46% for fan systems.

Keywords: Industrial motor systems, Energy efficiency, Conservation supply curve

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