BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXII No. 3B/2010	135 - 142	Seria Tehnică

Considerations on the Design and Implementation Screw Compression Equipment Driven by Heat Engines that Use Natural Gas as Fuel

Liviu Adam*, Pavel Masiliev*, Mariana Ştefănescu*, Alina Rusu**

* National Research and Development Institute for gas Turbines COMOTI Bucharest, Bd. Iuliu Maniu, nr. 220D, Bucureşti
e-mail: liviu.adam@comoti.ro

** E.ON Gaz România, Justiţiei, nr. 12, Târgu Mureş
e-mail: alina.rusu@eon-romania.ro

Abstract

This paper presents the design and the development of compression equipment with screw compressor driven by a piston engine gas injection and electronic control, the installation has been designed and built as a result of research carried out by a complex team of engineers

Key words: *efficiency, screw compressor, heat engine*

Introduction

The current requirements on environmental protection and sustainable development, lead to modernization and efficiency of the gas compression stations, whether they are in the property of Petrom-OMV or ROMGAZ, upgrading the equipment of these stations is achieved by the installation of gas compression screw compressors. They are located in the collection parks of crude oil where is made the separation of crude oil, gas and water, near the gas extraction wells located in various locations: plains, hills, mountains. The training of such equipment is usual with explosion proof motors.

The equipment with screw compressors began to be increasingly widely used, especially in the petrochemical industry due to their comparative advantages to other types of compressors.

Although they are modern installations with many use advantages, these equipments continue supports modernizing and technological adaptations.

The paper proposes to amend the installation of compression by replacing the electric motor driving the worm screw type compressors with a piston engine adapted for this purpose, electronically controlled, and using natural gas as fuel even in the network compressor. The efficiency of the heat engine using instead of the electric motor also results from the following reasoning: when using electricity must be transported to a combustible gas power plants, converted into electricity to be transported to the location again consuming compression station. All these imply that efficiency gains multiplied lead to substantially decrease the overall efficiency of use of primary energy source, so therefore a higher consumption of fuel gas, almost double, in the power plant. Another advantage is that there is not necessary an electrical power grid in remote areas often inaccessible.

The change of the compression equipment primarily involves the processing of the piston engines operate on spark ignition gasoline into engines operating with natural gas. Also coaching problem to be resolved by the compressor motor connected to the mains gas compression equipment and operation at the variable parameters of the gas networks. The functioning of the entire ensemble is managed by modern plant automation.

Description of equipment

In a scaffold extraction, the technological facilities are designed to ensure the deployment of the technological process of operating the wells in terms of rational use of energy and economic efficiency of deposit in terms of oil extraction and transport and recovery, transport and gas distribution.

Because the gas prices are increasing, on the one hand and on the other hand free or purged gas fired power pollute the environment is necessary to develop a technology for gas recovery from extraction wells to be compressed and routed the pipeline bus.

The complexity of the equipment is based on several factors, forced by the solution to separate natural gas from oil in oil tankers. Recovered gas pressure is low and therefore the compression unit should have a high volume compared to the pipe carrying compressed gas.

Essentially the equipment (Fig. 1) consists of a frame on which are placed two screw compressor driven by a coupling system 4 by a piston engine ignition and electronically controlled gas injection 1 a gas-oil separator vessel 3, a installation of oil for lubrication and cooling the compressed natural gas compressor, an engine radiator 15, an oil-air heat exchanger 16 located in front of the radiator, an air supply gas engine and command and control units for compressor and engine. The cooling is achieved by air flow driven by the fan of the engine. It eliminates the motofan with variable speed electrical power via a frequency converter - an expensive installation, expensive and energy consuming.

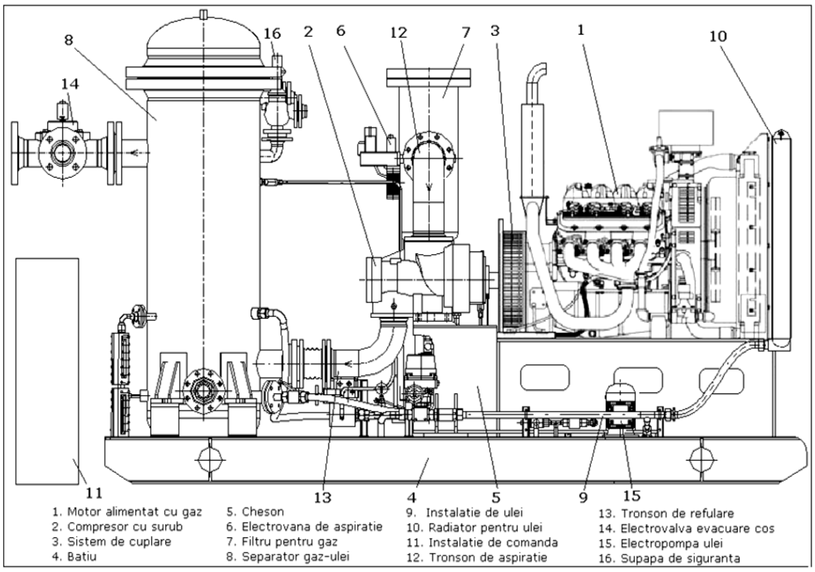

Fig. 1. Equipment for heat engine and compressor compression screw

Compressors

Making a technical-economic study for the introduction of recovery equipment and gas compression accompanying oil wells to extract with high-performance, emerged that one of the solutions offer many advantages is the introduction of compression devices equipped with screw compressors (screw).

The technical arguments were supplemented by the performances that refer to the maintenance costs of these machines but also that such machines massive entered the market as air compression equipment and other fluids as well as natural gas.

Screw compressors are compressors, "rotary piston" with two trees. Because they have rotating mass them together in many advantages, namely speed operating turbomachines higher and the absence of inertial forces as the piston compressor. Their ability to maintain a high efficiency over a wide range of operating pressures and flow rates, high life that they cause is a substantial percentage of all compressors now sold and which are currently in operation.

Importance and growing manufacturing screw compressors are objective facts that these machines bring advantages over conventional compressors. Among these advantages are worth mentioning: - the low weight and small size combined with high efficiency, where the rotating machinery operating at high speed regimes. These features are specific screw compressor components make these machines ideal for advanced fixed and mobile devices - high efficiency derives from the principle of volumetric compression. Moreover, high efficiency does not diminish service life parameters for that zone does not contain any body susceptible to wear by friction - simplicity of design in terms of the mechanical and high reliability in operation. To remember for instance a screw compressor works against a piston compressor, without valves. Failure frequency curves highlighted by statistical projections showed that the frequency of reported faults are 1:4 piston compressor - automatic operation, adapting to complex processes, with reduced operating staff.

Volumetric screw compressors are machines, therefore for adjusting the parameters can occur in compression ratio and gas flow machine allowed. In terms of functional parameters adjustment screw compressors but especially those with oil injection are multiple possibilities that allow operation with low energy consumption.

Inlet flow adjustment can be done by three methods:

- Changes in engine speed drive compressor. If the engine is internal combustion drive, this is done via an automated loop that reduces engine power that its speed depending on parameters such as: discharge pressure, flow, temperature or other parameters established by the scheme of operation of the facility; If the drive motor is electric, speed variation is carried out either by changing the supply voltage or supply current frequency. Reduce suction using speed change drive is the most efficient method in terms of energy.
- Clogged suction section is usually fitted with butterfly valves suction section. Tabs of fillings can also be included in an automated loop to maintain constant parameters.
- A variation to reduce the power consumed is the regulation of gas flow using a butterfly valve in combination with adjusting the engine speed drive compressor.

From analysis undertaken by specialized companies most recommended method if the compressor is built with compression ratio is constantly adjusting drive motor speed.

Engine

Reciprocating internal combustion engine is a heat engine in which combustion products enter the engine fluid composition and its evolution is performed through a piston, whose reciprocating inside a cylinder is transformed into rotational motion by crank rod mechanism.

Today, after nearly a century of developing the internal combustion engine there is a wide variety of engines, which require grading. Most important criterion for classification is the process of fuel ignition, because the difference between internal combustion engines, large differences in grades behave in terms of functionality (a mixture formation and combustion of its process so regulating pregnancy.), in terms of design (dimensions, weights, shapes, constructive solutions) in terms of operation (ease of use, quiet, quiet operation, durability, etc.) in terms of technical and economic performance (efficiency, power liters reported mass etc.).. After the process of ignition, heat engines are divided in spark ignition engines, called MAS and shortened compression ignition engines, called abbreviated MAC.

Criterion for assessing the economic efficiency of the engine is the cycle thermal efficiency is the ratio of ηt which indicated the work Li and heat released from burning fuel in the cylinder, the cycle Q [kJ / cl kcal / cl]

$$\eta_t=L_i/Q \text{ (a)};\ \eta_t=AL_i/Q \text{ (b)} \quad (1)$$

In (1), are expressed in kgfm Q in kcal and calorie equivalent of mechanical work, A = 1 / 427 kcal / kgfm.

Thermal efficiency is determined as the practical difficulty due to incomplete combustion; heat released by combustion is that size does not stand out simply and directly. It is therefore preferred to refer to the heat available Li Qdis cylinder and not the heat released by combustion. A size that specifies the heat available from complete combustion of fuel and is determined easily and securely is lower calorific power of fuel Qi. Let [kg], [kp] fuel cycle, for a cylinder, called single dose of fuel and Qi [kJ / kg or kcal / kgf] lower calorific power of fuel. It is obtained:

$$Q_{dis} = Q_i\overline{m_c} \quad (2)$$

where Qdis is the heat available from complete combustion. The degree of incomplete combustion is defined by the following report:

$$\eta_{in}=Q/Q_{dis} \quad (3)$$

where ηin is called incomplete combustion efficiency. It eliminates ηin at the appreciation of the economic efficiency assessment cycle if they relate Li directly to Qdis. This report is called indicated yield and is denoted ηi:

$$\eta_{in}=L_i/Q_{dis} \quad ; \quad \eta_{in}=AL_i/Q_{dis} \quad (4)$$

Note that the conventional yield ηin is reported by Li at the same level of reference for all engines, that the heat available from complete combustion of a kg of fuel. It is a perfect index of the cycle, easily determined in standard conditions (It is measured Li and Qi is known on the basis of laboratory). If you multiply and divide relation (2) to Q it is obtained:

$$\eta_i = \frac{L_i}{Q_{dis}}\frac{Q}{Q} = \frac{L_i}{Q}\frac{Q}{Q_{dis}} = \eta_t\eta_{in} \quad (5)$$

ηi hence appears as an overall efficiency as a more complex size that satisfies the condition ηi = ηt only when ηin = 1 which, for the current combustion processes applied to internal combustion engines, it never happens. Thermal calculations are carried out usually for relief, assuming that the engine cylinder cycle to burn 1 kg (1kgf) fuel. In this case

$\overline{m_c}$=1 kg, $Q_{dis}=Q_i$ and η_i becomes:

$$\eta_i=L_i/Q_i \text{ or } \eta_i=AL_i/Q_i \quad (6)$$

where Li is the work on burning a kg (kp) of fuel in kJ / kg or kgfm / kp.

Based on relationship (5) it is determined the actual yield ηe engine, replacing the Li in one of previous relationships, for example, (6) to give ηi = Le / ηm Qi, hence:

$$\eta_e = L_e/Q_i = \eta_i\ \eta_m;\ \eta_e = AL_e/Q_i = \eta_i\ \eta_m, \qquad (7)$$

i.e. effective yield is the ratio of mechanical work effectively (or caloric equivalent of mechanical work actually) and heat available from complete combustion of fuel. The definition shows that ηe is a conventional yield, which arises from the fact that is the product of ηi (conventional yield) and η_m

The efficiency of use the heat engine that operates with natural gas in place of electric motor

The energy efficiency in case of using a heat engine to drive the screw compressor compared to an electric motor can be highlighted by studying the total returns of the two technical solutions as follows:

Efficiency heat engine piston

$$\eta_{mt} = 0{,}35$$

Efficiency of gas transport

$$\eta_{tg} = 0{,}75$$

Thermal power plant efficiency

$$\eta_{ct} = 0{,}35$$

Efficiency of electricity transmission

$$\eta_{tee} = 0{,}8$$

Electric motor efficiency

$$\eta_{me} = 0{,}8$$

The total efficiency when using electricity

$$\eta_{total} = \eta_{tg} \text{ x } \eta_{ct} \text{ x } \eta_{tee} \text{ x } \eta_{me} \text{ x } \eta_{tg} = 0{,}75 \text{ x } 0{,}35 \text{ x } 0{,}8 \text{ x } 0{,}8 = 0{,}168$$

It results that the yield heat engine fueled by gas, of **0.35** *is approximately double compared to the total energy yield of 0.168 in case of using the electric motor that uses energy provided by a boiler running the same fuel.*

The economic efficiency is much higher and the energy costs resulting from the comparison of two different solutions:

The electricity consumption in a time of electric motor driving the compressor

$$Q_{me} = \frac{P_{me}}{\eta_{me}} t = \frac{64 \text{ kw}}{0{,}8} * 1\text{h} = 80 \text{ kw}$$

The electricity consumption in an hour time of the electric motor driving the fan

$$Q_{mv} = \frac{P_{mv}}{\eta_{mv}} t = \frac{3 \text{ kw}}{0{,}8} * 1\text{h} = 3{,}75 \text{ kw}$$

Total consumption of electricity in an hour

$$Q_{tee} = Q_{me} + Q_{mv} = 80 + 3{,}75 = 83{,}75 \text{ kwh}$$

The cost of electricity consumed in an hour

$$C_{tee} = Q_{tee} * 0{,}4\frac{\text{lei}}{\text{kw}} = 83{,}75\ \text{kwh} * 0{,}4\frac{\text{lei}}{\text{kwh}} = 33{,}5\ \frac{\text{lei}}{\text{h}}$$

The consumption of the natural gas for heat engine for the same power is

$$Q_{mt} = 24{,}7\ \text{mc/h}$$

The cost of the natural gas consumed in an hour of heat engine

$$C_{mt} = Q_{mt} * 0{,}07\frac{\text{lei}}{\text{mc}} = 24{,}7\ \text{mc/h} * 0{,}07\frac{\text{lei}}{\text{mc}} = 1{,}73\ \frac{\text{lei}}{\text{h}}$$

Resulting energy cost $\frac{C_{tee}}{C_{mt}} = \frac{33{,}5}{1{,}73} \cong$ 20 times lower.

The hourly economy is 33,50-1,73= 31,77 lei

The economy accomplished in one month

30x24x31,77= 22.874,4 lei

Considering the group cost 500,000 lei compression damping its only result in energy savings of 500,000: 22874.4 = 22 months.

Performance

Table 1.

Name		Unit	Value
Gas flow naturally aspirated		Nm^3/day	15.000
Molar mass		Kg/kmol	18,66
Terms of inlet gas	Suction pressure	bara	0,6÷1
	Temperature	ºC	0 –20
	Solid impurities (maximum allowed)	mm	0,1
	Moisture (maximum allowed)	%	0,01
Gas discharge conditions (after the separator)	Nominal pressure (continuous maximum)	bara	7
	Minimum discharge pressure	bara	4,5
	Maximum temperature	ºC	75 – 80
Heat engine	Nominal	kW	75
	Speed	rot/min	1600
Type of oil for lubricating and injection		-	Glygoyle 22
Coolant oil		-	Air
Noise		dBA	80
Rating		kW	4
Of transfer pump motor drive		ASA 80a – 4 0,55 kW/380V/1400 rpm	
Protection		Normal Climate	

Fig. 2. Compression equipment

Conclusions

The novelty of this work is to bring purpose, namely on one hand, to reduce energy costs to users of such equipment and energy efficiency, and on the other hand to achieve a more flexible functioning of the variable parameters natural gas networks, through easy and cost variation of the heat engine speed.

Also, motor driven compression equipment may be used heat and energy recovery centers of biodegradable waste as biogas. In order to introduce biogas as fuel gas distribution network of settlements, compression equipment can be easily adapted to operation on this fuel.

References

1. Stosic, N. Smith, I. Kovacevic, A. - *Screw Compressors Mathematical Modelling and Performance Calculation*, Springer-Verlag Berlin Heilderberg 2005
2. Cox, G.B. DelVecchio, K.A. Hays, W.J. Hiltner, J.D. Nagaraj, R. - *Development of a Direct-Injected Natural Gas Engine System for Heavy-Duty Vehicles*
3. Arbon, I. M. - *The Design and Application of Rotary Twin-shaft Compressors in the Oil and Gas Process Industry*, MEP London, 1994
4. Negrescu, M., s.a. - *Motoare cu ardere interna – procese*, vol. I, Editura Matrixrom, Bucuresti, 1995
5. Negrea, V.D. - *Procese în motoarele cu ardere interna*, *Economicitate. Combaterea poluarii*, vol.I, Ed.Politehnica, Timisoara, 2001
6. Negrea, V.D. - *Procese in motoarele cu ardere interna*, *Economicitate. Combaterea poluarii*, vol.II, Ed.Politehnica, Timisoara, 2003

Consideraţii privind proiectarea şi realizarea echipamentelor de comprimare cu şurub antrenate cu motoare termice ce utilizează gaze naturale drept combustibil

Rezumat

Lucrarea prezintă concepţia şi realizarea unui echipament de comprimare cu compresor elicoidal antrenat de un motor cu piston cu injecţie de gaz natural şi comandă electronică, instalaţie ce a fost proiectată şi construită ca rezultat al cercetărilor efectuate de către o echipă complexă de ingineri.