Impact of Compressor Performance on the Flow Capacity of Gas Transmission Pipelines

- **Seyed Mohammad Fatemi[1], Morteza Esfandyari[2*], Mahdi Koolivand- Salooki[3]**

1. Petroleum Department, National Iranian South Oilfield company, Ahvaz, Iran
2. Department of Chemical Engineering, University of Bojnord, Bojnord, Iran
3. Gas Research Division, Research Institute of Petroleum Industry, Tehran, Iran

Corresponding author Email address: M.Esfandyari@ub.ac.ir

Received: Feb. 14, 2017 / Accepted: May. 01, 2017

Abstract

Flow capacity of a gas transmission pipeline is usually affected by different parameters. In this study several determining factor are selected for sensitivity analysis of flow capacity prediction in IGAT-IV. These parameters include; pipeline parameters, gas parameters, system parameters, heat transfer parameters, compression parameters and compressor fuel consumption parameters. Detail calculation has been performed by developing a computer program by Microsoft Visual Basic. Moreover, a computer program for generating the compressor performance curve has been written by MATLAB. This curve has been used to design and optimize the compressor stations. From the present investigation, it has concluded that AGA Fully Turbulent, Colebrook-White and Weymouth equations have the best prediction of flow rate in gas transmission pipelines. 87.85 % flow changes due to 1% isentropic exponent change, which has a very large effect on the flow capacity. 10% to 30% flow changes due to 1% suction compressibility factor and discharge compressibility factor change. They have large effect on the flow capacity. 1% to 10% flow changes due to 1% compressor horsepower, compressor suction and discharge temperature and adiabatic efficiency change. They have medium effect on the flow capacity. The other parameters have not significant effect on the flow capacity.

Keywords: Gas Transmission Pipeline, Flow Capacity, Compression parameters, Compressor Fuel Consumption Parameters.

1. Introduction

Oil and gas are the most important sources of energy in the world. They have prepared about 90% of total energy that is used in industries, homes etc. Modern people's lives are based on an environment in which energy plays a main role. Oil and gas are major participants in the study of energy, and pipelines are the primary means by which they are transport. These pipelines are mostly buried and operate without distributing normal pursuits. They carry large volume of natural gas, crude oil, and other products in continuous streams.

During the last 60 years, the transportation of natural gas from wells to city distribution systems has developed from a single low-pressure line 25 miles long, made of short lengths of 8-inch diameter wooden pipe, to one of the most important branches of the petroleum and natural gas industry. Thousands of miles of large diameter steel pipe are carrying natural gas between the sources of supply and points of consumption[1, 2]

Gas (or any Newtonian fluid) will flow through a pipe as long as there is a pressure differential between the inlet and outlet of the pipe. For natural gas pipeline systems, two main forces affect the movement of the gas from one point to another: frictional and gravitational forces. These frictional and gravitational forces reduce the pressure (or energy) of the gas as it moves down the pipe. In order to maintain flow in the pipe, there must be a counteracting force (or energy) to overcome these frictional and gravitational forces and still maintain a pressure differential between any point in the pipe and the terminal point and ultimately meet the delivery requirements of the downstream customer[1-4].

Demissie and Zhu [5] in 2015, conducted a literature survey of pipeline design and pipeline operations. Ríos-Mercado and Borraz-Sánchez [6] in 2015 conducted a literature survey on line-pack, pooling, and fuel cost minimization problems. Demissie el al.[7] In 2017 proposed models for gas pipeline operation, then they have optimized these models. These models are optimized for different structures of the gas pipeline network. Optimization of these models was done using NSGA-II algorithm. Chaczykowskia, and Zarodkiewicz [8] in 2017 Simulated the distribution of natural gas quality for pipeline systems. The results of this model show that gas quality has a significant impact on pipeline inventory and pipeline capacity of the pipeline system.

In the gas industry, the compressor frequently provides this counteracting force or pressure boost. Two types of compressors are used widely in the industry: reciprocating and centrifugal compressors. The reciprocating units boost (or increase) the gas pressure by a direct reduction of the gas volume through the displacement action of its pistons (Boyle's law). The centrifugal units, on the other hand, increase gas pressure by the dual process of radial acceleration of the gas by rotating impellers and velocity reduction by stationary diffusers (i.e., conversion of velocity to head or pressure).The horsepower and the changing compression ratio and the variation of adiabatic efficiency and the ambient temperature and the heat rate/constant and the isentropic exponent were the heat transfer parameters that were analyzed.

This study is the product of questions raised from various groups and individuals within National Iranian Gas Company (and indeed in the rest of the industry) with respect to the significance of various parameters and criteria on the planning and design of pipeline facilities. An attempt is made here to quantify the impact of "reasonable" variations in each parameter or criteria separately. "Reasonable" variations imply possible variations in the design parameters criteria that are likely to affect the physical state, performance and cost or service of the pipeline system during its projected service life. Such variations may occur due to seasonal changes (e.g. ambient temperature, thermal conductivity), age and service (e.g. roughness, compressor, and pipe deration), changes in the physical state and conditions of the pipeline system (e.g. new pipe/ compression facilities, gas composition, terrain, etc.), or perhaps changes in business and regulatory environment (e.g. rate of return, interest rates, etc.)

2. Gas transmission methods

Gas is difficult to store because of its physical nature and needs high pressures and/or low temperatures to increase the bulk density. It needs to be transported immediately to its destination after production from a reservoir. There are a number of methods of exporting gas energy from an isolated field for use elsewhere. The methods include: Pipelined Natural Gas(PNG), Liquefied Natural Gas (LNG), Gas to Liquids (GTL), Gas to Commodity (GTC), Gas to Wire (GTW), Compressed Natural Gas (CNG), Gas to Solids (GTS)[9, 10].

3. Gas physical properties prediction

The physical properties of a natural gas may be obtained directly either by laboratory measurements or by prediction from the known chemical composition of the gas. In the latter case, the calculations are based on the physical properties of individual components of the gas and upon physical laws, often referred to as mixing rules, relating the properties of the components to those of the gas mixture. For gas compressibility, factor calculation used Standing-Katz chart that curve-fitted by Gopal. For calculation of pseudo critical pressure and temperature and apparent molecular weight and heat capacity of gas mixtures used kay's rules. For calculation of gas thermodynamic properties and density of gas mixtures used real gas laws. For calculation of gas viscosity used Lee-Gonzales-Eakin method [11-15].

4.Flow equations and correlations for gas compressors

4.1.Adiabatic work gas compression

The pressure-volume relationship in an adiabatic process is defined as $P.V^k = cte$, to calculate the work required to compress a gas adiabatically we have this relation[14]:

$$-W = \int_1^2 V.dP \tag{1}$$

Substituting for V

$$-W = \int_1^2 cte^{1/k}.P^{1/k}.dP$$

Moreover, after integration and further simplification in Imperial Units:

$$-W = \frac{53.28}{G}.T_1.\frac{k}{k-1}.\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] \tag{2}$$

Where $-W$ is a Work (head) to be done on the compressor to adiabatically compress gas from P_1 to P_1 $(ft.lb_f\ /\ lb_m)$, G is a gas gravity, dimensionless, T_1 is a suction temperature,(°R) , k is an adiabatic gas exponent, dimensionless, P_1 is a suction pressure, psia, P_2 is a discharge pressure, psia and P_2/P_1 is a compression ratio (CR), dimensionless.

4.2.Temperature change in adiabatic gas compression

In adiabatic gas compression, gas temperature increases according to the equations described below[15].

$$\frac{Z_2.T_2}{Z_1.T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \tag{3}$$

4.3.Compressor head and horsepowern

Head is the amount of work or energy injected into the gas to raise its pressure from P_1 to P_2 . It has the units of kJ/kg in SI or $ft.lb_f\ /\ lb_m$ in imperial units. On the other hand, horsepower (HP) is defined as[15]:

$$HP = \frac{MassFlow\ .\ Head}{Thermal\ Efficiency\ of\ Compression} \tag{4}$$

With some assumption and simplification [1], we have:

$$HP = 0.0857.\frac{k}{k-1}.T_1.\frac{Z_1+Z_2}{2}.\frac{1}{\eta_a}.\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] \tag{5}$$

Where HP is an adiabatic power requirement, (HP/l MMSCFD), T_1 is a suction temperature, (°R) , P_1 is an adiabatic gas exponent, dimensionless, is a suction pressure, psia, P_2 is a discharge pressure, psia and P_2/P_1 is a compression ratio (CR), dimensionless and η_a is an adiabatic (isentropic) efficiency, which is typically in the range of 0.75 to 0.79.

4.4.Adiabatic (isentropic) efficiency

Adiabatic (isentropic) efficiency η_a is defined as the ratio between adiabatic (isentropic) head and the actual head as follows[14]:

$$\eta_a = \frac{(Head)_{adiabatic}}{(Head)_{actual}} \tag{6}$$

Adiabatic (isentropic) efficiency of a gas compressor could also be represented by the following equation[15]:

$$\eta_a = \frac{T_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]}{T_2 - T_1} \tag{7}$$

k is normally determined at the average of suction and discharge temperatures.

4.5. Horsepower and gas flow

From section 4.3 we have following relation:

$$HP = 0.0857.\frac{k}{k-1}.T_1.\frac{Z_1+Z_2}{2}.\frac{1}{\eta_a}.\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] \tag{8}$$

Where HP = adiabatic power requirement, (HP/l MMSCFD). So we can rewrite the relation in the following form:

$$\frac{HP}{Q} = 0.0857.\frac{k}{k-1}.T_1.\frac{Z_1+Z_2}{2}.\frac{1}{\eta_a}.\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] \tag{9}$$

$$Q = \frac{HP}{0.0857.\frac{k}{k-1}.T_1.\frac{Z_1+Z_2}{2}.\frac{1}{\eta_a}.\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]} \tag{10}$$

4.6.Compressor available power

The compressor power, available at pressure and temperature of site condition is calculated as follows:

$$HP_{site} = HP_{ISO}.F_p.F_t \tag{11}$$

Where HP_{site} is a site available power (HP), HP_{ISO} is a sea level (ISO) power (HP), F_p is a site elevation adjustment factor and F_t is an ambient temperature adjustment factor.

4.7.Compressor fuel consumption

The fuel consumption of compressors is calculated by flowing methods:

1. Use heat rate curve of compressor and following formula:

$$fuel = Heat\ Rate, HP \tag{12}$$

Where $fuel$ is a fuel consumption (kJ/h), $Heat\ Rate$ is a heat rate (kJ/kWh) and HP is compressor power (kW). For the relationship between fuel and power, generally we have a curve or correlation, which shows the heat rate as a function of temperature and speed. With the known speed and power, the heat rate will be defined. Generally the standard curves have been generated at 15 $^{\circ}C$. In order to convert to another temperature the following correction factor will be used.

$$Correction\ Factor = \sqrt{\frac{273.15 + T_{amb}}{288.15}.(0.9895 + 0.0007\ T_{amb}} \tag{13}$$

Where T_{amb} is ambient temperature $^{\circ}C$.

2. Use the following formula:

$$fuel = A_f + B_f.HP \tag{14}$$

Where is $fuel$ consumption (kJ/h), A_f is a fuel gas constant (ft^3/day) and B_f is fuel gas rate constant ($ft^3/day.HP$)

The fuel coefficients are related to the compressor heat rate coefficient as follows:

$$A_f = 24\frac{A_H}{LHV} \tag{15}$$

$$B_f = 24\frac{B_H}{LHV} \quad (16)$$

Where A_H is heat constant (BTU/hr) , B_H is a heat rate constant (BTU/hr.HP) and LHV is lower heating value.

Therefore, the fuel gas flow is calculated as follows:

$$Fuel\ Gas\ Flow = \frac{fuel}{24 \times LHV \times \eta_T} \quad (17)$$

Where η_T is turbine efficiency.

5.Impact of different parameters on the hydraulic and flow capacity of gas transmission pipelines

The parameters that affect flow capacity of gas transmission pipelines are:

1.Compressor parameters

The compressor parameters are essentially those parameters, which affect the fuel consumption and therefore flow behavior of the gas during transmission. The compressor parameters are shown in Table. 1.

Table. 1: Compression parameters

Items	Parameter
1	Suction pressure
2	Discharge pressure
3	Compression ratio
4	Suction temperature
5	Discharge temperature
6	Suction compressibility factor
7	Discharge compressibility factor
8	Adiabatic efficiency
9	Isentropic exponent
10	Horse power

2.Compressor fuel consumption parameters

The compressor fuel consumption parameters are essentially those parameters, which affect the compressor fuel consumption. These parameters are shown in Table. 2.

Table. 2: Compressor fuel consumption parameters

1	Ambient temperature adjustment factor
2	Site elevation adjustment factor
3	Gas lower heating value.
4	Heat rate curve
5	RPM of compressor
6	Turbine efficiency
7	Compressor performance curve(wheel map)

6.Case Study

For the sensivity analysis, we choose the special part of IGAT-IV pipeline that has maximum change in parameters. Therefore, we choose the following part of IGAT-IV for sensivity analysis with properties that shown in Table.3 and Table.4

Table. 3: Compression parameter for compressor#6 of IGAT IV pipeline

Compression Parameters	Value
Suction pressure(psia)	947.52
Discharge pressure(psia)	1319.7
Compression patio(Pout/Pin)	1.39
Suction temperature(R)	549.66
Discharge temperature(R)	605.62
Suction compressibility factor	0.87
Discharge compressibility factor	0.89
Adiabatic efficiency	0.75
Isentropic exponent(Kin+Kout)/2	1.51
Horse power(hp)	73727.11

Table. 4: Gas composition of refinery outlet

Gas Composition	Mole Percent	Gas Composition	Mole Percent
Methane	0.9	n-Hexane	2.00E-04
Ethane	5.00E-02	n-Heptanes	2.00E-04
Propane	6.00E-03	Nitrogen	3.20E-02
n-Butane	1.00E-03	CO_2	1.00E-02
n-Pentane	6.00E-04	-	-

7.Sensitivity Results

The data from IGATIV pipeline were introduced to the written program by Microsoft visual basic. At first the physical properties of gas calculated. Then sensitivity analysis for each parameter. The sensitivity results from generated program are shown in the following figures.

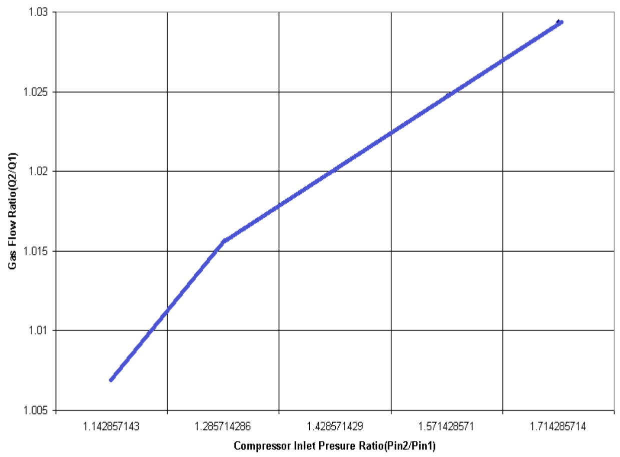

Figure 1. The impact of compressor suction pressure ratio on gas flow ratio

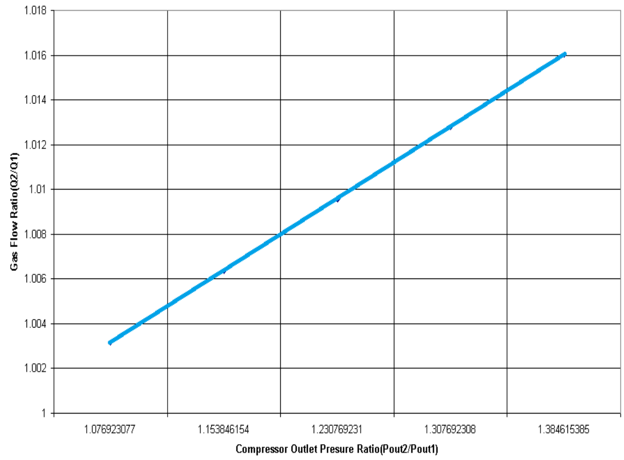

Figure 2. The impact of compressor discharge pressure ratio on gas flow ratio

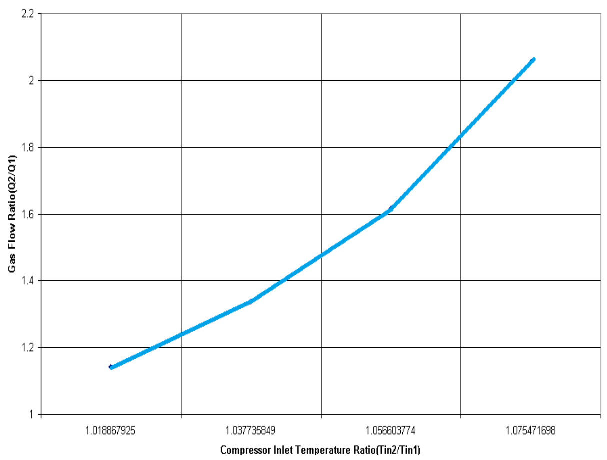

Figure 3. The impact of compressor suction temperature ratio change on gas flow ratio

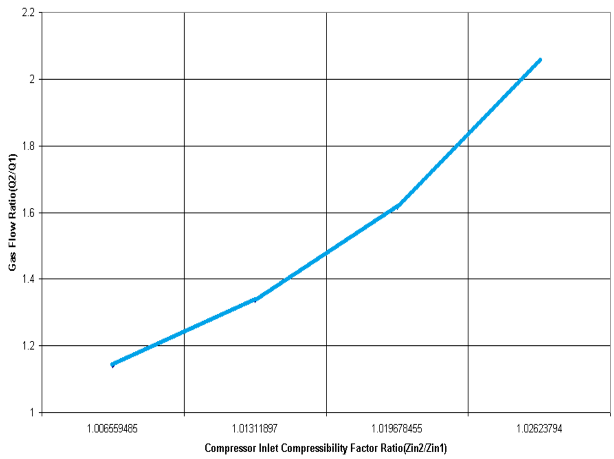

Figure 4. The impact of gas suction compressibility factor ratio change on gas flow ratio

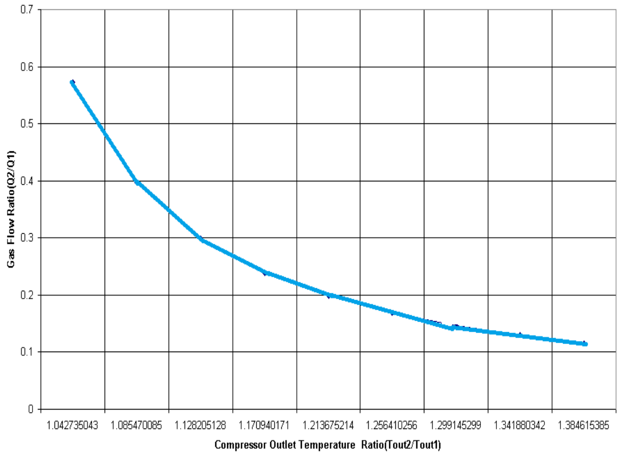

Figure 5. The impact of compressor gas discharge temperature ratio change on gas flow ratio

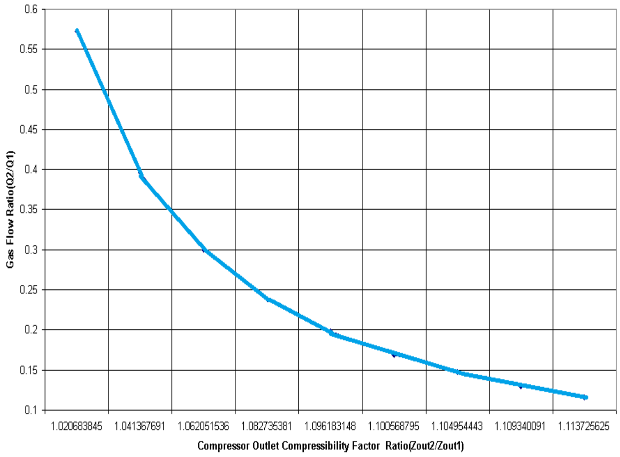

Figure 6. The impact of compressor discharge compressibility factor ratio change on gas flow ratio

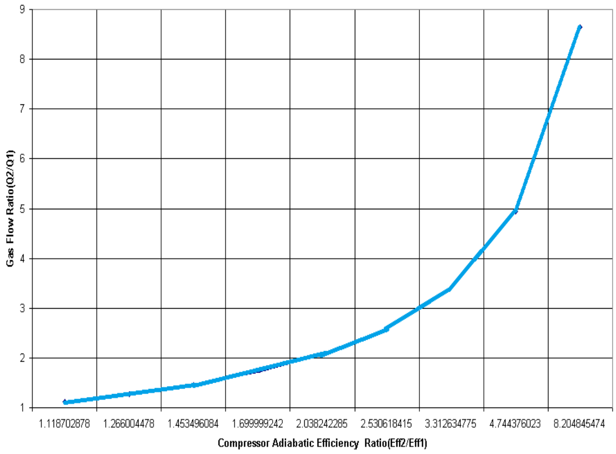

Figure 7. The impact of compressor adiabatic efficiency ratio change on gas flow ratio

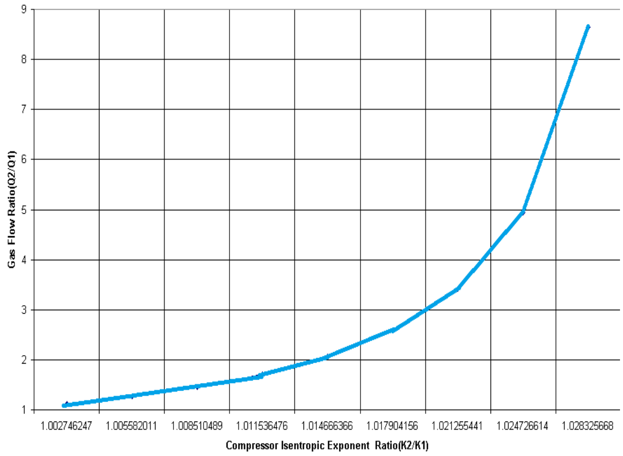

Figure 8. The impact of compressor isentropic exponent ratio change on gas flow ratio

8.Results

The main objective of this work was to investigate the impact of different parameters on the hydraulic and flow capacity of a gas transmission pipelines. To achieve these objectives, the impact of gas compression parameters and compressor fuel consumption parameters on the physical properties of gases was firstly studied. The result of this study were introduced into general flow equation of gas transmission pipelines and compression equations, for estimating the effect of these changes on the hydraulic and flow capacity of pipelines. From the present investigation, the following results are concluded:

- All of commercial software's get the flow as an input data, therefore they cannot easily used for sensitivity analysis on flow.
- The fuels of compressor stations are taken from the transmission pipelines. Therefore, it is too important to optimize the compressor performance. For this reason, we should use compressor performance curve.
- If horse power, suction pressure, discharge pressure, compression ratio, suction temperature, suction compressibility factor, adiabatic efficiency, isentropic exponent, turbine efficiency, gas lower heating value increases the flow capacity increases.
- If discharge temperature, discharge compressibility factor, ambient temperature adjustment factor, site elevation adjustment factor, heat rate curve increases the flow capacity decreases.
- 87.8578% flow changes due to 1% isentropic exponent change. It has a very large effect

on the flow capacity.

- 10% to 30% flow changes due to 1% suction compressibility factor, discharge compressibility factor change. They have large effect on the flow capacity.
- 1% to 10% flow changes due to 1% compressor horse power, compressor suction and discharge temperature and adiabatic efficiency change. They have medium effect on the flow capacity.
- 0% to 0.1% flow changes due to 1% compressor suction and discharge pressure, compressor compression ratio change. They have very small effect on the flow capacity.
- If ambient temperature increases (decreases), the air mass flow rate decreases (or increases) and the power output of the compressor decreases (or increases) .Therefore fuel consumption of compressor increases and then fuel gas flow increases. Increase in fuel gas flow means decrease in gas flow of pipeline.
- If site elevation increases (or decreases), the air mass flow rate decreases (or increases) and the power output of the compressor decreases (or increases). Therefore fuel consumption of compressor increases and then fuel gas flow increases. Increase in fuel gas flow means decrease in gas flow of pipeline.
- If turbine efficiency increases the fuel, gas flow decreases. Decrease in fuel gas flow means increase in gas flow of pipeline.
- If gas lower heat capacity increases, the fuel gas flow decreases. Decrease in fuel gas flow means increase in gas flow of pipeline.
- If heat rate increases the fuel of the compressor increases. Therefore, fuel gas flow increases. Increase in fuel gas flow means decrease in gas flow of pipeline.
- The heat rate curve is usually plot for different RPM of compressor with experimental data. Therefore, the effect of RPM is dependent on heat rate curve.
- Results that are more detailed are shown in below tables.

Table. 5: Summary of Results, Design Criteria and Parameters Impact Study

Compression Parameters	Variation in Parameter	Change in Flow (MMSCFD)	Remarks
Horse power	-------------- increase	-------------- increase	$Q = Gas\ Compressor\ Parameters \times HP_t$ $GCP = \dfrac{1}{0.0857.\dfrac{k}{k-1}.T_s.\dfrac{Z_s+Z_d}{2}.\dfrac{1}{\eta_a}.\left[\left(\dfrac{P_d}{P_s}\right)^{\frac{k-1}{k}}-1\right]}$
	1% flow change for 1% parameter chang		
Suction Pressure	700 psia<Ps<1200 psia Stepsize=100 psia Change=14.28% increase	3788.967<Q<3900.19 Average change per stepsize=0.587% increase	Suction compressibility factor, Adiabatic efficiency, Compression ratio are change due to change of Suction Pressure
	0.04110% flow change for 1% parameter change		
Discharge Pressure	1300 psia<Pd<1800 psia Stepsize=100 psia Change=7.6923% increase	3853.769<Q<3915.498 Average change per stepsize=0.3173% increase	Suction compressibility factor, Adiabatic efficiency, Compression ratio are change due to change of Suction Pressure
	0.04112% flow change for 1% parameter change		
Compression ratio	1.372<CR<1.899 Change=7.6922% increase	3853.769<Q<3915.498 Average change per stepsize=0.3173% increase	CR change due to change of Suction and Discharge pressure of compressor
	0.0412% flow change for 1% parameter change		
Suction Temperature	530 R<Ts<570 R Stepsize=10 R Change=1.8867% increase	2899.797<Q<5959.408 Average change per stepsize=16.8781% increase	Suction compressibility factor, Isentropic exponent, Adiabatic efficiency are change due to change of Suction Temperature
	8.9454 flow change for 1% parameter change		

Table. 6: Summary of Results, Design Criteria and Parameters Impact Study

Compression Parameters	Variation in Parameter	Change in Flow (MMSCFD)	Remarks
Suction Compressibility Factor	0.8681<Zs<0.8908 Change=0.6559% increase	2899.797<Q<5959.408 Average change per stepsize=16.8781% increase	Suction compressibility factor change due to change of Suction temperature
	25.7323% flow change for 1% parameter change		
Discharge Temperature	585 R<Td<810 R Stepsize=25 R Change=4.2735% increase	6221.131>Q>720.1678 Average change per stepsize=30.2032% decrease	discharge compressibility factor, Isentropic exponent, Adiabatic efficiency are change due to change of Discharge Temperature
	0.04110% flow change for 1% parameter change		
Discharge Compressibility Factor	0.8754<Zd<0.9750 Change=2.0683% increase	6221.131>Q>720.1678 Average change per stepsize=30.2032% decrease	discharge compressibility factor change due to change of Discharge Temperature
	14.6028% flow change for 1% parameter change		
Adiabatic Efficiency	1.19<η_a<0.14 Change=23.3303% increase	6221.131>Q>720.1678 Average change per stepsize=30.2032% increase	Adiabatic efficiency is change due to change of Suction and Discharge Temperature, Isentropic Exponent and Suction and Discharge Pressure
	1.2945% flow change for 1% parameter change		
Isentropic Exponent	1.286<K<1.251 Change=0.3437% increase	6221.131>Q>720.1678 Average change per stepsize=30.2032% increase	Isentropic exponent change due to change of Discharge Temperature
	87.8578% flow change for 1% parameter change		

Table. 7: Summary of Results, Design Criteria and Parameters Impact Study

Compressor Fuel Consumption Parameters	Variation in Parameter	Change in Flow	Remarks
Ambient temperature adjustment factor	increase	decrease	$HP_{site} = HP_{ISO}.F_p.F_t$
Site elevation adjustment factor	increase	decrease	$HP_{site} = HP_{ISO}.F_p.F_t$
Heat Rate Curve	increase	decrease	$fuel = HeatRate.Hp$ $Q_{out} = Q_{in} - fuel$ $Q = Gas\ Compressor\ Parameters \times HP_t$
RPM of compressor	------------	------------	Depend on Heat Rate curve
Turbine Efficiency	increase	increase	$FuelGasFlow = \frac{fuel}{24 \times LHV \times \eta_T}$
Gas Lower Heating Value	increase	increase	

9.Conclusions

Main flow capacity parameters are selected in this study and their impact is investigated on one of the Iranian gas trunk line. These parameters includes pipeline variables, gas properties, system limitations, heat transfer factors, compressor variables and parameters. The results of sensitivity analysis are utilized by compression equations, for prognosticating of the selected factor effeteness on the gas pipelines flow capacity. In this study for making the calculation re a computer program is developed VB. Input data of developed program were selected from IGAT-IV pipeline data has been used as an inlet data for our developed program. This research highlighted that Fully Turbulent AGA, Colebrook-White and Weymouth equations predicts the flow rate of the gas transmission pipelines by a good accuracy.

Acknowledgment:

Author would like to appreciate national Iranian oil company (NIOC) and national Iranian south oil company (NISOC) for financial support of this study.

Nomenclature Symbol

P	Pressure (pisa)
P_1	suction pressure (psia)
P_2	discharge pressure (psia)
T	Temperature (°R)
T_1	suction temperature (°R)
T_2	discharge pressure (°R)
T_{amb}	ambient temperature (°C)
W	Work (($ft.lb_f / lb_m$))
G	gas gravity (-)
k	adiabatic gas exponent (-)
HP	compressor power (HP/l MMSCFD)
HP_{site}	site available power (HP)
HP_{ISO}	sea level (ISO) power (HP)
η_a	adiabatic (isentropic) efficiency (-)
Z	compressibility factor (-)
F_p	site elevation adjustment factor (-)
F_t	ambient temperature adjustment factor (-)
A_f	fuel gas constant (ft³/day)
B_f	fuel gas rate constant(ft³/day.HP)
A_H	heat constant (BTU/hr)
B_H	heat rate constant (BTU/hr.HP)
η_T	Turbine efficiency (-)

Abbreviation

PNG	Pipelined Natural Gas(-)
LNG	Liquefied Natural Gas (-)
GTL	Gas to Liquids (-)
GTC	Gas to Commodity (-)
GTW	Gas to Wire (-)
GTS	Gas to Solids (-)
HP	Horsepower (kW)
CR	compression ratio (-)
LHV	lower heating value(-)
VB	Visual Basic (-)

References

1. Mohitpour, M., H. Golshan, and A. Murray, Transient Flow in Liquid and Gas Pipelines. 2007: ASME press.
2. Tabkhi, F., et al., Improving the performance of natural gas pipeline networks fuel consumption minimization problems. AIChE journal, 2010. 56(4): p. 946-964.
3. Wong, P. and R. Larson, Optimization of natural-gas pipeline systems via dynamic

programming. IEEE Transactions on Automatic Control, 1968. 13(5): p. 475-481.

4. Yaqub, M. and S.M. Zubair, Performance evaluation of hot-gas by-pass capacity control schemes for refrigeration and air-conditioning systems. Energy, 2000. 25(6): p. 543-561.

5. Demissie, A. and W. Zhu. A Survey on Gas Pipelines Operation and Design Optimization. in IIE Annual Conference. Proceedings. 2015. Institute of Industrial and Systems Engineers (IISE).

6. Ríos-Mercado, R.Z. and C. Borraz-Sánchez, Optimization problems in natural gas transportation systems: A state-of-the-art review. Applied Energy, 2015. 147(Supplement C): p. 536-555.

7. Demissie, A., W. Zhu, and C.T. Belachew, A multi-objective optimization model for gas pipeline operations. Computers & Chemical Engineering, 2017. 100: p. 94-103.

8. Chaczykowski, M. and P. Zarodkiewicz, Simulation of natural gas quality distribution for pipeline systems. Energy, 2017.

9. Kumar, S., Gas production engineering. Vol. 4. 1987: Gulf Professional Publishing.

10. 10. Petroleum, I.o., Modern petroleum technology. 2000: Wiley.

11. McCain Jr, W., The properties of petroleum fluids: Penn Well Publ., 1984, Co.

12. Abbott, M.M., J.M. Smith, and H.C. Van Ness, Introduction to chemical engineering thermodynamics. McGraw-Hill, Boston, 2001: p. 619-626.

13. Association, G.P.S., Engineering data book. 1994: Gas Processor Supplier Association.

14. Danesh, A., PVT and phase behaviour of petroleum reservoir fluids. Vol. 47. 1998: Elsevier.

15. Mohitpour, M., H. Golshan, and A. Murray, Pipeline design and construction: A practical approach The American Society of Mechanical Engineers. Three Park Ave., New York, NY, 2007. 10016.

تاثیر عملکرد کمپرسور بر ظرفیت جریان خطوط انتقال گاز

• سید محمد فاطمی[۱]، مرتضی اسفندیاری[۲*]، مهدی کولیوند سالوکی[۳]

۱. ستاد مهندسی نفت، شرکت ملی نفتخیز جنوب ، اهواز، ایران

۲. گروه مهندسی شیمی، دانشگاه بجنورد، بجنورد، ایران

۳. پژوهشکده گاز، پژوهشگاه صنعت نفت، تهران ، ایران

(ایمیل نویسنده مسئول: M.Esfandyari@ub.ac.ir)

چکیـــــده

ظرفیت جریان گاز خط انتقال گاز معمولا تحت تأثیر پارامترهای مختلف قرار می گیرد. در این مطالعه چند عامل تعیین کننده برای تحلیل حساسیت پیش بینی ظرفیت جریان در IGAT-IV انتخاب شده اند. این پارامترها شامل پارامترهای خط لوله، پارامترهای گاز، پارامترهای سیستم، پارامترهای انتقال حرارت، پارامترهای متراکم پذیری و پارامترهای مصرف سوخت کمپرسور می باشند. محاسبات مورد نیاز با توسعه برنامه نویسی توسط Microsoft Visual Basic به صورت دقیق انجام شده است. علاوه بر این، یک برنامه کامپیوتری توسط MATLAB برای بدست آوردن منحنی های عملکرد کمپرسور نوشته شده است. این منحنی برای طراحی و بهینه سازی ایستگاه های کمپرسور مورد استفاده قرار گرفته است. از تحقیقات حاضر، معادله های کاملاً آشفته AGA ، Colebrook-White و Weymouth جریان خطوط انتقال را به خوبی پیش بینی می نماید.۸۷/۷۵ درصد تغییرات جریان به دلیل ۱ درصد تغییرات ایزونتروپیک است که تاثیر بسیار زیادی بر ظرفیت جریان دارد و همچنین ۱۰ تا ۳۰ درصد تغییرات جریان ناشی از ۱ درصد ضریب تراکم پذیری مکش و تخلیه می باشد. در نهایت ۱ تا ۱۰ درصد تغییرات جریان به دلیل ۱ درصد تغییرات اسب بخار کمپرسور، دمای مکش و تخلیه کمپرسور و تغییرات بازده آدیاباتیک می باشد که آنها تاثیر متوسط بر ظرفیت جریان دارند. و پارامترهای دیگر تاثیر قابل توجهی بر ظرفیت جریان ندارند.

واژگان کلیدی: خطوط لوله انتقال گاز، ظرفیت جریان، پارامترهای تراکم پذیری، پارامترهای مصرف سوخت کمپرسور.