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Modelling of the non-reactive deposits impact on centrifugal compressor aerothermo dynamic performance

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ABSTRACT

The centrifugal compressor blockage is considered an important issue in compressor operation and one of the main causes of machine failure. This is normally initiated by the presence of deposits with the process gas yielding to reduce the effective flow area, increase the frictional losses and distort the pressure distribution profile. The influences of flow blockage cover the thermodynamic, aerodynamic and rotordynamic performance parameters of centrifugal compressor as will be investigated further in this study. Accordingly, this paper introduces a novel approach to model the impact of non-reactive deposits flow on the centrifugal compressor aerothermodynamics performance. The developed set of empirical equations in this study provides a new way to derive the equivalent compressor performance map at various degrees of fouling with a consideration of gas properties and stage efficiency variation and without a prior knowledge of the detailed geometrical features. In order to emphasize the validity of the new method, it has been tested with two operating cases and the obtained results were compared with the internal inspection findings from the stage overhauling process. Besides, this approach has been proven to be valid for the modelling of flow blockage effect at the suction side, compressor internals and downstream equipment. Furthermore, a new methodology has been established to assess the possibility of deposits accumulation in the gas path of the compression system based on the operational data of the discharge parameters.

1. Introduction

The centrifugal compressor is used in a wide range of applications and it is considered as one of the key components in oil and gas industry. The high availability and efficiency of the operated machine are essential to maintain the gas productivity and to reduce the downtime and life cycle costs. One of the main causes of instable and inefficient operation of centrifugal compressors is the fouling which occurs as a result of deposits and contaminations build-up in the flow channels of the compression system. This leads to narrow the flow passages and to increase the surface roughness which in turn yields to higher pressure drop along the gas path.

There are two main categories of contaminations that deteriorate the compressor performance. The first group is the non-reactive contaminations which flow with the process gas through the compression system without experiencing any change in their physical state including: dust, scale and catalyst fines. This kind of contaminations is expected to settle down in quiet flow regions inside the compressor such as: the erode labyrinth and the leading edge of the first impeller blade. The adverse effect of this sort of deposits can vary greatly depending on the rate and composition of the deposits [1]. The slow buildup on the stage

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Nomenclature

Mu	Tip Speed Mach Number
D_2	Impeller Exit Diameter
MW	Molecular Weight
$\varnothing$	Flow Coefficient
s	Work Coefficient
Re	Reynolds Number
CMF	Cubic Metre per Feet
MSCMD	Metric Standard Cubic Metre per Day
$\dot{m}$	Mass Flow Rate
h_p	Polytropic Head
R	Gas Constant
HFT	Hydrate Formation Temperature
GVF	Gas Volume Fraction
k_s	Correlation Coefficient
d	Design Point
$\dot{V}$	Inlet Volume Flow
Q	Flow capacity
BP	Blockage Percentage
Z	Compressibility Factor
k	Specific Heat Ratio
n_v	Volume Polytropic Exponent
X,Y	Compressibility Functions
v	Absolute Flow Velocity
u	Tip Blade Speed
W	Relative Flow Velocity
n_T	Temperature Polytropic Exponent
BHP	Brake Horsepower
$IGVs$	Inlet Guide Vanes
N	Rotational Speed
C_s	Slip Velocity

List of Subscripts

r	Rated Point
i	Different Rotational Speed
c	Choke Point
b	Basic
Ref	Reference Conditions
act	Actual
std	Standard
rel	Relative
s	Compressor Suction
p	Polytropic

internals alters the state of balance leading to a high vibration level and deterioration in the compressor performance. However, the fast buildup can cause immediate shutdown due to the high induced vibration and possibly internal components damage.

Unlike the non-reactive deposits where appropriate filtration system is enough to reduce the risk of accumulation, the other type is relatively more difficult to deal with due to the change in the physical state of these contaminations as they pass through the compression circuit. So, they enter the suction line of the compressor as gas or liquid but they become as adhesive or abrasive polymers while flowing through the compression stage and discharge system depending on the working conditions and hydrocarbons compositions of the process gas. This polymer material can agglomerate in the labyrinth, drain lines and intercoolers creating more severe pressure drop [2]. Besides, the chemical reaction between the reactive contaminations and the flow bath surface has an adverse effect on the internal components life. Hence, it is important to consider the overall compression system component and to understand the chemistry of the generated fouling material. In general, the physical and chemical reactions of these contaminations are highly influenced by the surface finish, deposit material, gas composition as well as the gas temperature and pressure.