MODERNIZATION OF DYNAMIC EQUIPMENT FOR AMMONIA PRODUCTION INCREASE IN THE CIS COUNTRIES

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In the paper concrete example of modernizations centrifugal compressors and turbines at ammonia large-capacity production companies in Russia and the CIS is given. Increasing productivity to 1700 - 2000 t/days, reducing prime cost and operational specific energy consumption is considered. The modernizations of the 101J and 103J compressor for production of 1700 t/day and the application of this experience in project “Ammonia 2000” is shown.

INTRODUCTION

The ammonia large-capacity production companies in Russia and the CIS constructed in the 70s of the last century were equipped with the turbocompressor units designed for a capacity of 1360 tons of ammonia per day.

In 1970s most of the ammonia production processes were launched based on the TEC, Japan technology. Turbocompressors of such reputable companies as Mitsubishi Heavy Industries, Dresser-Rand, Hitachi, Fuji and Nuovo Pignone were used in the ammonia production facilities.

Meanwhile, own technical solutions based on GIAP’s process technology (State Institute of Nitrogen Industry) and domestic turbocompressors of Nevskiy and Kazanskiy plants were created.

Recently, the output of the ammonia production in the amount of 1360 t/day is not enough, so the modernization process of production lines and dynamic equipment (turbines and compressors) was initiated to provide better performance.

In the last decade, in Russia and the CIS-countries almost all enterprises of the nitric industry are increasing productivity to 1700 - 2000 t/days, and also reducing prime cost and operational specific energy...
consumption. The defining role has the centrifugal compressor of technological air, synthesis-gas, natural gas and ammonia.

The mismatch of centrifugal compressor sections characteristics at technological parameters change leads either to impossibility to provide these parameters, or to essential decrease in productivity of compression process, decrease in efficiency and reliability because of growth of aerodynamic forces. Drive turbines do not meet modern level, they do not correspond to technical requirements on power and steam consumption that lead to large energy losses.

**CENTRIFUGAL COMPRESSOR MODERNIZATION**

In 2011, the Russian company Entechmach and the Polish ALSTOM Power together with the Ukrainian TRIZ started a joint project on development of the offer on modernization of turbines and compressors, meeting the requirements of the Producers – the “Ammonia 2000” project.

Such huge production of ammonia demands careful study of changes which should be made both in the production techniques and in the turbine units.

The main tasks of modernization of compressors and turbines were determined by the design organizations, for example Ammonia Casale which analyzed the whole technological process entirely with the Producer of ammonia.

The role of the Producer consists in use of long-term operating experience of processing equipment for definition of separate tasks of modernization, the changes made to the equipment and basic data with new working conditions.

On the basis of the process analysis and the experience of ammonia producers, the need for modernization of compressors and turbines in the 103J/JT synthesis gas line was defined, as well as in the 101J/JT technological air line for obtaining capacity 2000 tons of ammonia per day.

Entechmach RPC has already previously done modernizations of the 101J and 103J compressor for production of 1700 t/day and has used the experience gained in this project “Ammonia 2000”. In figure 1 the external view of the technological air turbocompressor unit 101J/JT is shown.

![Fig.1 technological air turbocompressor unit 101J/JT](image)

The Ammonia 2000 project is based on several main requirements for the dynamic equipment, namely:

- achievement of the required capacity and parameters of synthesis gas and air compressors;
- Provision of the corresponding power and speed of the turbine drives of compressors with minimum steam consumption;
- ensuring uninterrupted and smooth operation in continuous mode, the corresponding reserves in the parameters provided by the API 612 and API 617 standards;
On-site Refurbishment of badly corroded Urea Reactors

- increase of equipment efficiency (compressors and turbines) for the reduction of the specific energy consumption in the ammonia production.

Entechmach RPC provides complex solution of a compressors modernization problem to raise capacity, polytropic efficiency of sections and also to improve the characteristics of the intermediate gas coolers for increase in production of ammonia up to 45% of initial design value. High-efficient centrifugal stages with "compressor" type impellers with exit angles $\beta_2 = 48^\circ$ and $32^\circ$ and bladed diffusers are used in flow parts of the revamped 101J and 103J compressors.

Polytropic efficiency of 101J compressor sections are specified in table 1.

<table>
<thead>
<tr>
<th>Section №</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
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<tbody>
<tr>
<td>Compressed gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polytropic efficiency</td>
<td>0,83</td>
<td>0,81</td>
<td>0,83</td>
<td>0,80</td>
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</table>

As a result of modernization the compressor with improved technical and economic characteristics is created, with the maximum use of regular components of the unit: power cases, piping gas lines, valves, lubrication system, etc. During the reconstruction, in fact, all internal parts of the compressor are renewed. Their efficiency is not less than that of the flow parts of machinery designed in brand-new cases. Such compressor can be in operation for several decades.

In figure 2 the sketch of a cross-section of low pressure case (LPC) of the 101J modernized compressor (1700 t/day) is shown, the cross-section of LPC 101J (2000 t/day) is similar, in figures 3 and 4 – cross-sections of high pressure cases (HPC) designed for receiving 1700 and 2000 tons of ammonia per day respectively.

![Cross-section of low pressure case (LPC) of the modernized 101J compressor 101J (1700 t/day)](image-url)
Fig. 3 Cross-section of high pressure case (HPC) of the modernized 101J compressor (1700 t/day)

Fig. 4 Cross-section of high pressure case (HPC) of the modernized 101J compressor 101J (2000 t/day)

In figures 5 and 6 rotors of LPC and HPC of the modernized compressor 101J (1700 of t/day) are showed.

Fig. 5 LPC rotor of the modernized 101J compressor (1700 of t/day).
Power consumption of the modernized compressor on comparable modes is significantly lower than that of the one being operated now.

**TURBINE MODERNIZATION**

Especially considerable effect is gained at the complex modernization of turbocompressor units which includes both the compressor, and the ALSTOM Power turbine.

ALSTOM Power in Elblag possesses a vast experience of production and modernization of high-speed turbines, with use of different technologies (active and reactive). The company has also adopted the production technologies of high-speed turbines developed in the center in La Courneuve/France (all design base of turbines of this type is adopted also).

The 101JT turbine being the compressor drive is a high-speed machine designed to operate in condensing mode. The turbine is an axial one-case reactive machine.

Reconstruction consists in replacement of the existing reactive blading part with a new modern blading possessing highest efficiency such as 8000 or 9000 (3D stages), as shown in Figure 7. The regulating stage is removed.
The turbine reaches the following capacities and speed specified in table 2. The turbine is characterized by the high extent of detuning from a blading resonance on working speed ranges.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Unit</th>
<th>Normal parameters</th>
<th>Max power</th>
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<tr>
<td>Turbine speed</td>
<td>n</td>
<td>rpm</td>
<td>5200</td>
<td>5500</td>
</tr>
<tr>
<td>Shaft power</td>
<td>N</td>
<td>MW</td>
<td>13.63</td>
<td>15.8</td>
</tr>
</tbody>
</table>

Entehmash and ALSTOM Power with Triz also have joint modernization projects of synthesis-gas with recirculation stage, ammonia and natural gas units.

References

Евдокимов В.Е., Репринцев А.И. Эффективный способ совершенствования ступени ЦКМ, 9, Энергомашиностроение (1986) [Evdokimov V.E., Reprincev A.I. Jeffektivnyj sposob sovershenstvovaniya stupeni CKM, 9, Jenergomashinostroenie (1986)]


Любимов А.Н., Евдокимов В.Е. О расчете газодинамических характеристик ступени центробежного компрессора, Компрессорная техника и пневматика. 2012. №7., 28-33 [Lubimov A.N., Evdokimov V.E. O raschete gazodinamicheskikh harakteristik stupeni centrobezhnogo kompressora, Kompressornaja tehnika i pnevmatika. 2012. №7., 28-33]


Евдокимов В.Е. Банк экспериментальных данных по модельным ступеням и их элементам для проектирования ЦКМ. Турбины и компрессоры. [Evdokimov V.E. Bank eksperimental'nых dannых po model'nym stupenjam i ih elementam dla proektirovaniya CKM. Turbiny i kompressory.]

Cumpsty N. Compressor aerodynamics (2000)