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Optimization of Service Operation for a Centrifugal Compressor for Gas Transport

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Abstract **- In this paper was presented the importance of using technology CAE (Computer Aided Engineering) in activity maintainer of a natural gas compression station. The aim of the project was to optimize the operation of a multistage centrifugal compressor, achieving both an improvement in reliability and reduce maintenance costs, using mechanical analysis and finite element investigation.**

Key-words : Optimize , Design , Investigation , FEM , Maintenance.

1. INTRODUCTION

This paper present a way of optimizing the operating mode for this type of equipment, but also a way to justify the importance of integrating technology in computer aided maintenance activities from our days. We decided to present the advantages of using computer-assisted technique for managing and optimizing maintenance activities using the software Microsoft Project to show the ease with which it can control a laborious database route to determinate an optimal way of interconnected activities, the rational management of human and material resources .So, investing in such software is a way to simplify and efficiently monitoring maintenance activities without requiring large physical infrastructure (laboratories, test stands, etc.) using only computer . Specifically, we studied the behavior of materials under different loads of manufacturing parts: stator, intermediate diaphragm and inner casing of the multistage centrifugal compressor.

2. CONTENT

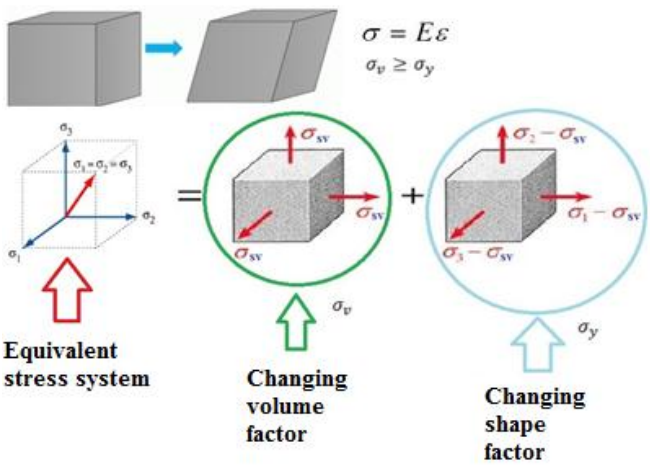
In the first part of the study were showen the notes and general maintenance activities on compression stations, which were stated purpose and technical objectives. Was continued with the presentation of maintenance stages program for compression station, the structure of activities, the components of compression group and monitoring of these activities.

In the second part was performed a simulation of a research project monitoring and maintenance of a natural gas compressor station, using computer-assisted technique in order to effectively manage the organization and maintenance activities, monitoring their activities and optimize the calculation procedure of critical path analysis.

In the third part has introduced the subject theme of research. Were presented ground and the importance of using CAE technology in optimizing the design and investigation, mechanical analysis using finite element for a multistage centrifugal compressor. Also, this chapter contains the results of research and personal contribution to the theme of the thesis.

3. INVESTIGATIVE HYPOTHESIS

Based on this theory of finite element analysis, was conducted the mechanical investigation to study the behavior of material in mechanical deformation phase. Function by this behavior, was realised the configuration of the architecture of compressor for new operating requirements.



$$u_d = \frac{1+\nu}{3E}\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right] \quad (1)$$

$$u_{d,sim} = \frac{1+\nu}{3E}\sigma_y^2 \quad (2)$$

$$\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2} \geq \sigma_y \quad (3)$$

$$\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2} = \sigma_v \quad (4)$$

$$\sigma_v \geq \sigma_y \quad (5)$$

$$u_d \geq u_{d,sim} \quad \text{Elastic deformation condition !!!} \quad (6)$$

[1][2]Fig.1. Maximum energy criterion change in shape(von Mises criterion)

It starts from hypothesis to configurate a multistage centrifugal compressor that was designed for a different mode of operation, and other parameters of the operator compression station. The new system requirements put as in a position to choose different ways to configure this compressor, within the limits of economic reasoning and logistics. Therefore, as proposed manufacturing materials logbook compressor does not met operating conditions, we decided to investigate, based on computer-assisted technique (FEM) another material namely ASTM F67 , a production of the titanium alloy. We decided to choose this excellent material in the behavior due to corrosion, low thermal conductivity and ductility of the material, so this material is a compromise between economic relatively low manufacturing technology and the high cost of buying titanium material. Whichever solution is chosen, the maintenance costs would be modified. So, we chose for retaining the compressor configuration at the expense of replacing stator elements and intermediate diaphragm alloy. The reason would be the high cost of adding another stage of compression within the compressor, which would have led to the adoption of new internal housing, a new shaft, adding another rotor, etc.

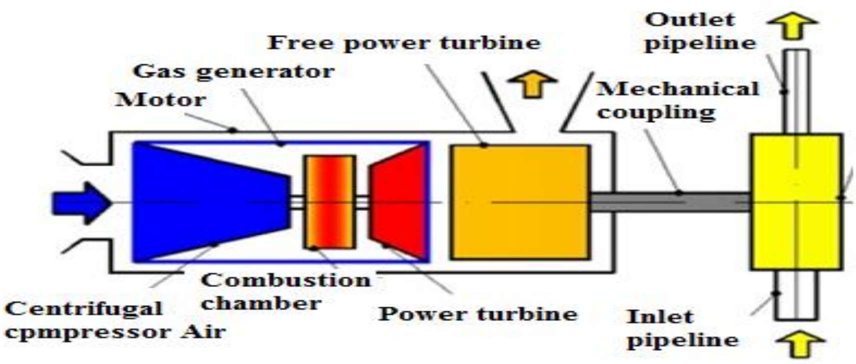
[3]Tab.1.Functional parameters for centrifugal compressor BCL506N

OPERATINGCONDITIONS	PARAMETERSwarranty
Gastransported	METHANE (80.51%) &ETHANE (14.69%)
Massflowkg/h	175300
INLET CONDITIONS	
Molecular weight	19.24
K=Cp/Cv	1.282
Compressibilityrate	0.922
PressureMPa	4.02
Temperature^{0}C	50
OUTLET CONDITIONS	
Pressure MPa	9
Temperature^{0}C	126
PowerKwtree	7750
Shaftspeed Rpm	6485

4.CALCULATION METHODOLOGY

[4]Tab.2.The main stagesandphases ofthe projectsubordinatedmaintenance

Task Name	Duration	Predecessors
MaintenanceGasCompressionStationProject	61 days	
1. Conceptprototype	32 days	
Documentationarea	3 days	
Studies, analyzes	7 days	3FS-1 day
Development ofmethods/new solutions	7 days	4FS-2 days
Developmentplans, sketches	8 days	5
CAEDesignof the experimental model	14 days	6FS-4 days
2.EquipmentMachineryand equipment	24 days	
Establishing the necessarymachineryandequipment	1 days	6
Determination oftechnical and qualityofmachinery and equipment	2 days	9
Establishconditions forthe technical bid	2 days	10
Drawingspecifications	4 days	10
Auctions	7 days	12
Acquisitionof machinery and equipment	10 days	13
3.Landscaping	11 days	
Workingarea boundary	6 days	13
Fittingconnecting pipesfor utilities	3 days	16
Access Roads	2 days	16
foundation	5 days	16
4. Assembly	15 days	
Transportequipment onlocation	3 days	16
Makingsubassemblies	7 days	21
Installationconnecting elements	3 days	22
Installationitself	2 days	24
5.Testsand trials	61 days	
The qualityof work	2 days	25
Preparing forcommissioning	2 days	27
Samples	7 days	28
Tests(simulation) FEAcomputer	4 days	28
6.Troubleshootingcorrections	7 days	
MechanicalTroubleshooting	4 days	30
Correctionsand Adjustments	3 days	32



[5]Fig.3.The maincomponents of agroup ofcompressiontypeturbocompressor

MECHANICAL PROPERTIES OF THE MATERIALS INVESTIGATED COMPONENTS

WHY WE ANALYZED THE STATOR AND THE INNER SHELL?

The stator is to convert the kinetic energy obtained from the discharge area of the rotor, in potential energy (static) from forced flow through the stator blades element.

Mechanical analysis was performed with finite element for each stator stage of centrifugal compressor since this element is to "influence" or generate about 50% of the gas compression ratio, as the rotor. The objective for this analysis was determining the maximum tensions existing in manufacturing material, operating under the new requirements.

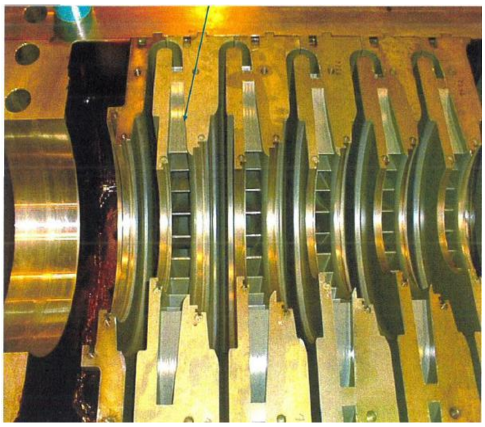
The stator element is most commonly subject to change by designers from economic reasoning (manufacturing technology and constructive form).

In short, it was examined whether the current ASTM A302 material Gr.B. can ensure safety in operation for all the five stages of compression.

[6]Tab.3.Determination of parameters estimated compression stages

Stage	I	II	III	IV	V	VI
P_{asp} MPa	4	5	6	7	8	9
T_{asp} ^{0}C	50	65.2	80.5	95.6	111	126

In the first stage of the case study, we analyzed the state of stress and strain specific internal housing and the stator of the first stage compressor operated at the required temperature and pressure at the suction and materials for manufacturing.



[7]Fig.4.The casingbottom section.

The analysis was made in view of the properties of materials mentioned in Tab.4and Tab.5.

[8]Tab.4.Mechanical properties material for stator

Mechanical properties					
Material	Yield stress, s_c MPa	Tensile Strength,s_R MPa	Specificelongation A%	Coefficient Poisson , µ	Modulus of elasticityE MPa
ASTM A302 Gr. B	550	690	15	0.27	190000
ASTM F67	270-450	345	20	0.37	105000
blue	Material proposed by the operator				
red	Material proposed for research				

[9]Tab.5.Mechanical propertiesfor rolling diaphragm inner shelland the lastterm

Proprietăți mecanice					
Material	Yield stress,s_c MPa	Tensile Strength, s_R MPa	Specificelongation A%	Coefficient Poissonµ	Modulus of elasticityE MPa
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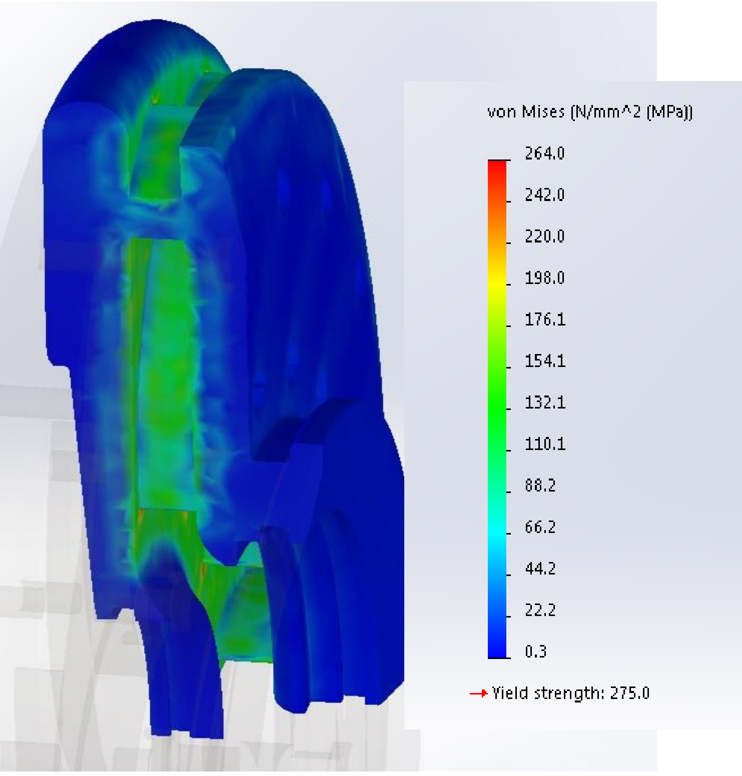
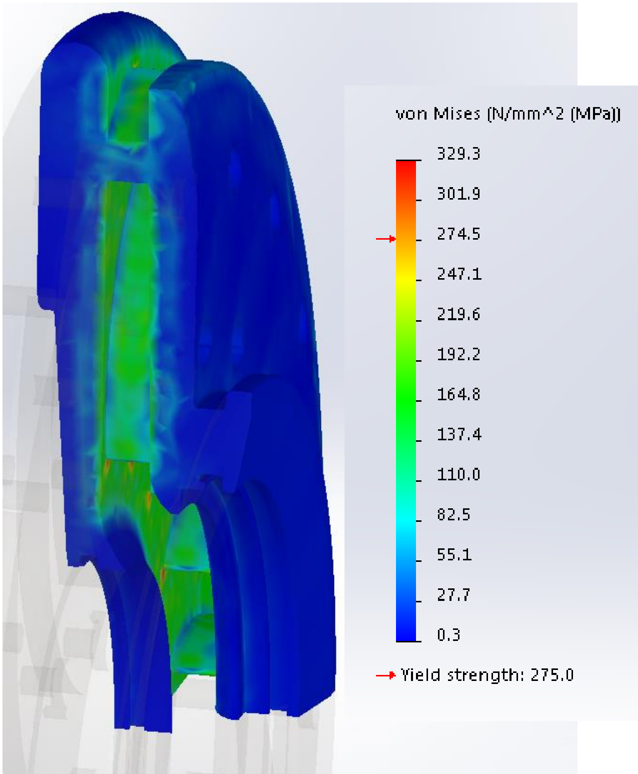
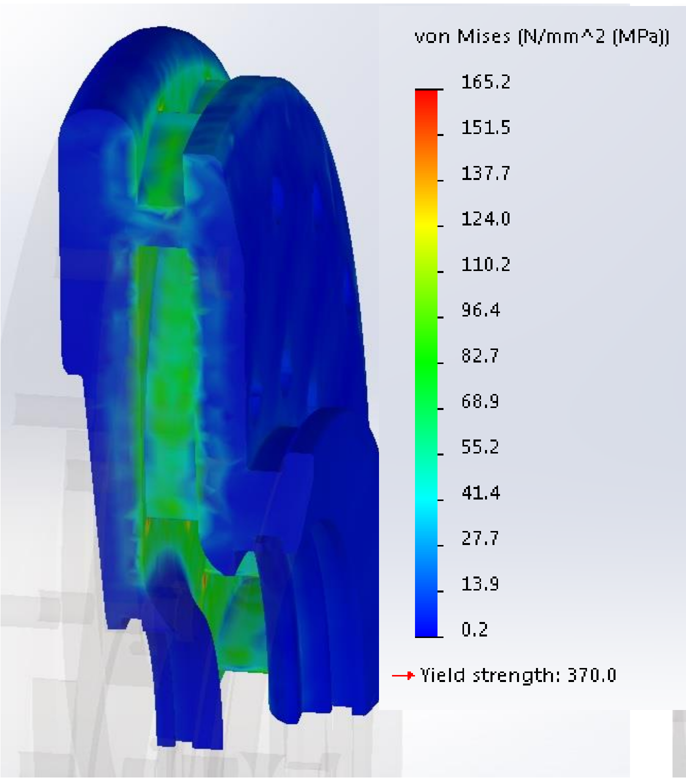




[10]Fig.5.Stator , stage3 , material ASTM A302 [11]Fig.6.Stator , stage4 , material ASTM A302[12]



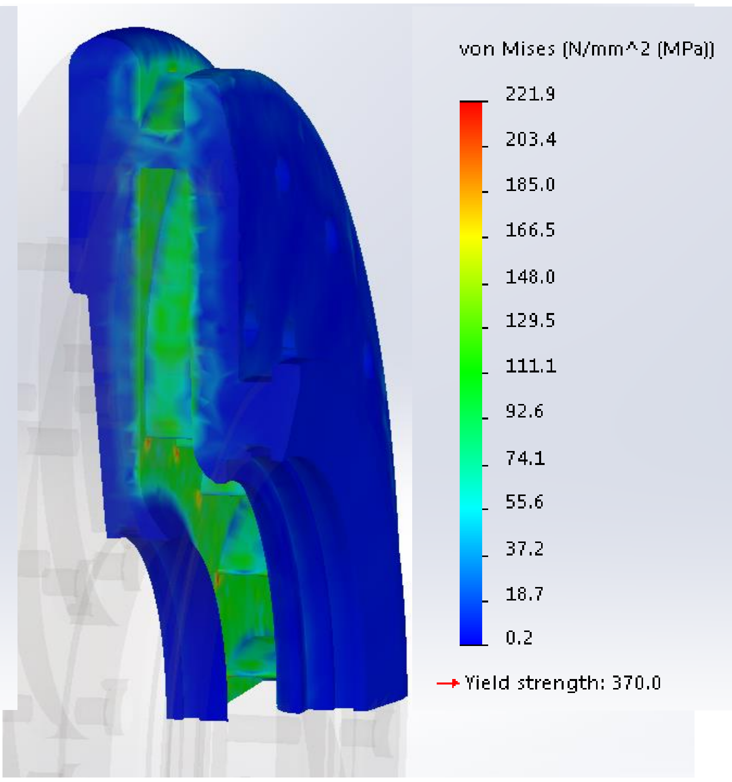
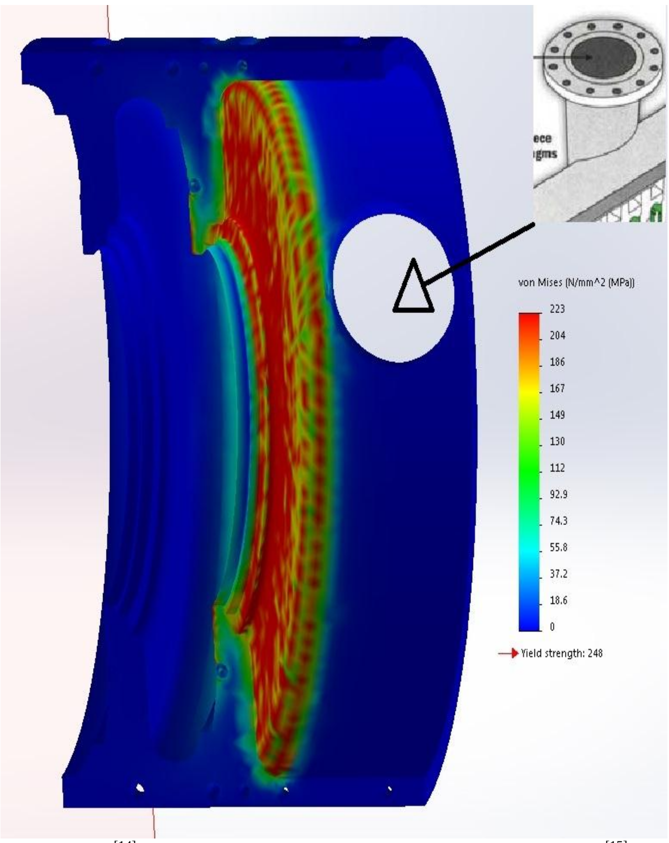


Fig.7.Stator , stage 4 , material ASTM F67[13]

Fig.8.Stator , stage 5 , material ASTM F67



[14]Fig.9.Diaphragm material ASTM A302 Gr.B ,stage5-6[15]

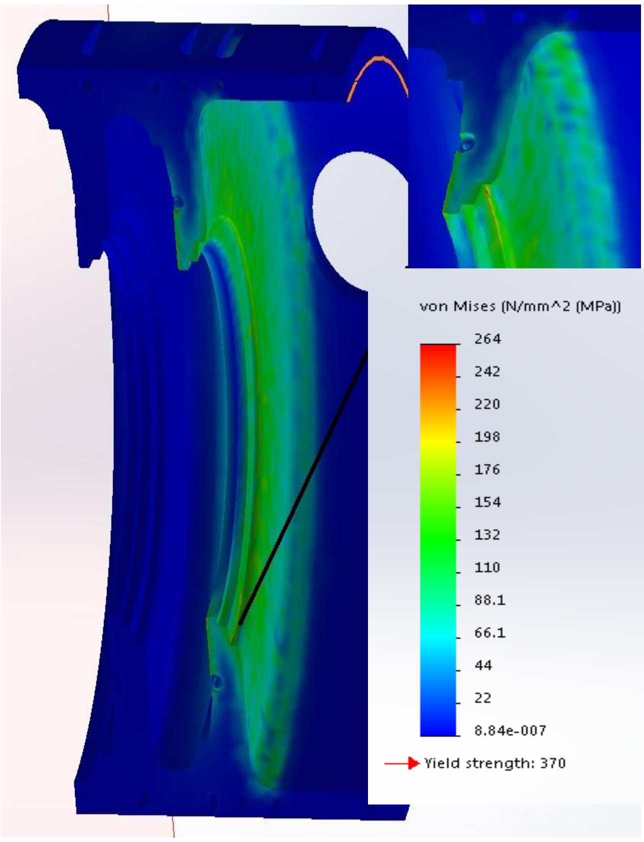
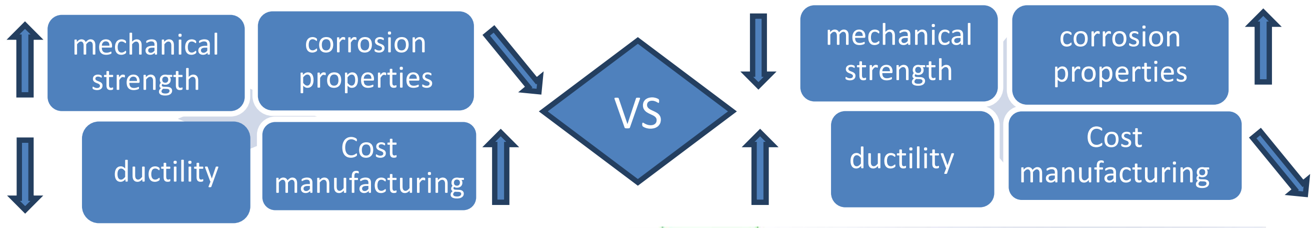
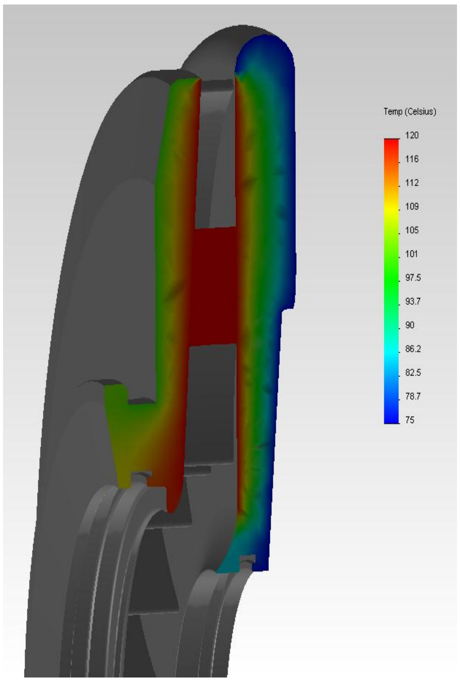


Fig.10.Diaphragm material ASTM F67 ,stage 5





[16]Fig.11.Stator , stage 5, thermal analysis[17]

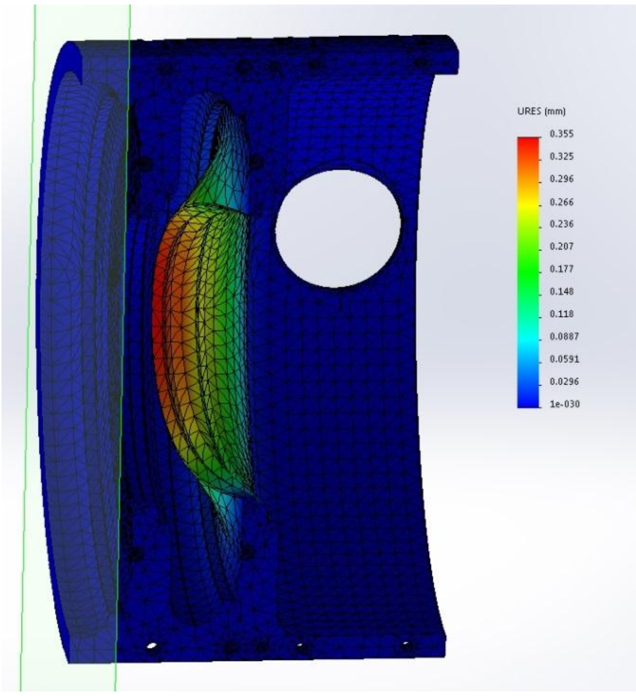


Fig.12. Diaphragm , stage 1 and 5 , elastic deformation analysis

5. CONCLUSIONS

1. For efficiency of compressor configuration to another operating mode, you have to consider the potential changes in size and construction of internal components such as the number of rotors, stators, intermediate diaphragms, seals, shaft and inner casing.
2. Optimization of the main working parameters of BCL 506 compressor replacement depended on manufacturing material for static elements such as stator (stage 3,4,5) and intermediate diaphragm (stage 5-6).
3. If our study proposed replacing the expense manufacturing using other auxiliary systems gave rise to the same parameters of the operators, such as the use of cooling systems and forced drying gas to reduce temperature and pressure for new operating conditions. These would be complicated the architecture of natural gas compression station.
4. An alternative to replacing manufacturing material was changing the mounting of the stator, which would be a disadvantage for personnel responsible for maintenance of all, because this change requires a full investigation of the compressor, which would have extended the period of investigation and also costs of this intervention.
5. The compression in stage 3, the proposed material in technical documents of the compressor (see Figure 5), withstand the stresses below the yield strength but for economic reasoning, we decided to replace it for safety operational reasons. The new material (see Figure 6) behave the same requests than expected, which is a plus for reliability.
6. As an alternative design to ensure that the required parameters of the controller is to change the internal architecture by the addition of a stage, which would result in reduced mechanical stress and the components of the last stage. So, a part of the mechanical stress present in the last stage would be moved backward. This solution was not profitable as standpoint economic, requiring many changes.
7. Using mechanical analysis software based on finite element (CAE) for these activities significantly reduce maintenance time work, research and database management, and waiting times of the following activities which are directly dependent on this phase (see Table 4). For example: In phase 5 "Tests and trials", subtask. The quality of work and preparation for commissioning depend directly following research using CAE technology.

Duration Phase 6 "Troubleshooting corrections" depends on the time required using CAE analysis. Therefore, management of maintenance activities can be significantly optimized by CAE technique.

8. Regardless of the chosen solution, maintenance costs would be modified. We opted for keeping the current configuration / architecture compressor at the expense of replacing stator elements and intermediate diaphragm alloy. The reason would be the high cost of adding a another stage of compression within the compressor, which would have led to the adoption of new internal housing, a new shaft, adding another rotor, etc.

In conclusion, we chose reduce acquisition costs, manufacturing, increased reliability, storage configuration dimensional compression station at the expense of a costly material.

6. PERSONNEL CONTRIBUTION TO RESEARCH

1. The new material used ASTM F67, proposed personnel with previous used in the aircraft industry because it has a yield strength between 275-450 MPa, which can exceed the breaking strength (about 345MPa), which gives the manufacturer the advantage of advantageous fabrication conceptually economic, and high corrosion resistance and low thermal conductivity.
2. ASTM F67 material has a superiority in operation since tensile strength is lower (about 345 MPa) than the material ASTM A302 gr.2 (about 850 MPa) is titanium base alloy with excellent corrosion properties, density material more small (advantage in operation, low moment of inertia, low vibration). Also creep behavior of titanium material is more stable (linear) than the stainless material.
3. ASTM F67 material due to higher yield strength, will yield only fatigue (which through periodic maintenance interventions will not be achieved even if exploited) without producing plastic deformations, while stainless steel ASTM A302 gr.2 exploited over critical parameters, it will suffer plastic deformation, and therefore the disposal of the compressor element.

REFERENTS:

[1] https://www.youtube.com/watch?v=Smj_F7MN3S4 (accesat 05.03.2015)[1]

[2] http://www.docstoc.com/docs/83009322/The-Distortion-Energy-Theory(accesat 05.03.2015)[2]

[3] http://www.networkintl.com/contents%2Fauction%2FQFPIRA00KREB%2FQFPIRA00OBOW%2F!QFPIRA00OCEK1101756%20Vol%201.pdf (accesat 05.03.2015)[3][6]

[4] Nae I., Managementul proiectelor – tehnici de planificare şi de control, Editura Universităţii Petrol-Gaze din Ploieşti, Ploieşti, 2009[4]

[5] http://www.transgaz.ro/sites/default/files/uploads/users/admin/ntm_scg.pdf(accesat 05.03.2015)[5]

[6] http://turbine3.blogspot.ro/2009/09/aerodynamic-performance-of-centrifugal_24.html(accesat 05.03.2015)[7]

[7] http://www.efunda.com/Materials/alloys/alloy_steels/show_alloy.cfm?ID=ASTM_A302_GradeB&show_prop=all&Page_Title=ASTM%20A302%20Grade%20B(accesat 05.03.2015)[8]

[8] http://wenku.baidu.com/view/2ab38b8bd0d233d4b14e692f.html (accesat 05.03.2015)[9]

[9] Cosmos Express***[10]...[17]