Theoretical Stress Analysis of Gas Turbine Blade Made From Different Alloys

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ABSTRACT

Blades may be considered to be the heart of turbine without blade there would be no power and the slightest fault in blade would mean a reduction in efficiency and costly repairs.
The centrifugal force is one of the problems faced by the designer of blades especially at the first stages. The designer aims at reducing the stresses with in the allowed limit.
The ANSYS 15 software was used as far as it is the most effective in analyzing the different numerous cases of stresses, the blades with limited root in all direction (X,Y,Z) were taken into consideration . The centrifugal forces were applied on the rotor blades at running speed of 6000 r.p.m., The finite element models of the blade were constructed using D3-10-noded Tetrahedron elements shape, SOLID 187, mesh of the entire blade 23406 Node,136575element. The average of normal stress, Von misses, Maximum principle stress, Minimum principle stress were calculated according to ANSYS 15 program, these stresses are as the result of the effect of centrifugal force for all planes along the blades and then values of stresses were compared to the curves for each alloy.The current research concluded that the Titanium alloy is the best alloy used in terms of reducing stresses due to centrifugal force, that is because density of Titanium alloy used is less than that of other used alloys, leading a reduction in centrifugal forcess that are directly proportional to mass.

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1. INTRODUCTION

Shattering of turbine blades are one of the most critical troubles in power generating industry. Rotor blades are the very generally used machine parts used in high-technics applications and in general are used as a lot of arrangement mechanical element. These blades are subjected to different loads like centrifugal loading. Centrifugal forces is the main component participate in to the stress produced in the blades [1].

Centrifugal loads are formed by high rotational speeds at (6000 r.p.m).The formed Centrifugal force depend upon the size of the rotor and the rotational speed of the rotor. As it is

well known, that the centrifugal force Fc can be defined as :

Fc = mrw², where, (m) is the mass (kg), (r) is the radius of rotation and w² is the angular speed. Gas turbine blades alloys are designed mainly to protect the structural material against loads, corrosion, oxidation, erosion and high temperature environments.

The main reason of shut down in turbo machine is the shatter of rotor blade. The failure of the rotor blade may guide to serious consequences both physically and economically. Hence, the suitable design of the turbo machine blade plays a necessary role in the suitable functioning of the turbo machine [5].

In the current study, the first stage rotor blade of a two-stage gas turbine has been analyzed for structural static using ANSYS 15.0Software which is powerful Finite Element Software. In the process of getting mechanical stresses in the rotor blade has been evaluated using four different alloys; namely: Inconel 718, Inconel 625, MarM200,

Titanium alloys .And the dimensions of the blade for the current study shown in Table.1.The blade was cut into twenty one sections along the length of the Airfoil with ANSYS software as shown in Fig.1The finite element models of the blade were constructed using D3-10-noded Tetrahedron elements shape, SOLID 187, mesh of the entire blade 23406 Node, 136575 element as shown in Fig. 2. And all results take from the option of the average of stresses in ANSYS software as shown in Fig.3.

Table 1: Dimensions of the blade

Total length of blade	Length of root	Length of Airfoil	Length of hollow
157mm	62mm	95mm	52.1mm
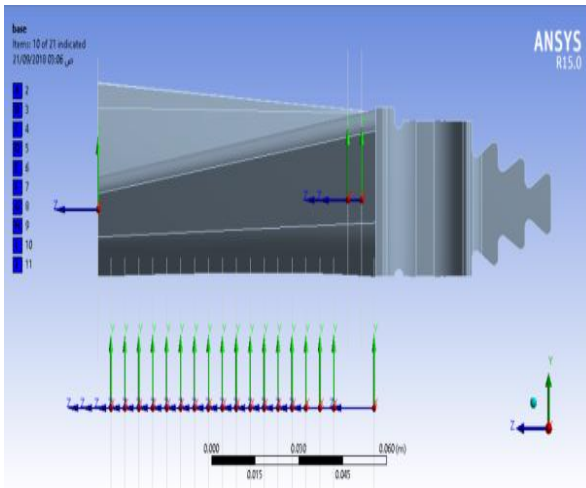
Fig. 1 Shown the sections along the length of blade used in the analysis
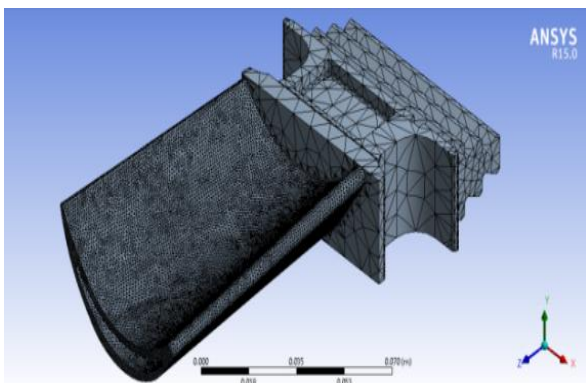
Fig. 2 Shows the generated finite element Mesh used in the current investigation
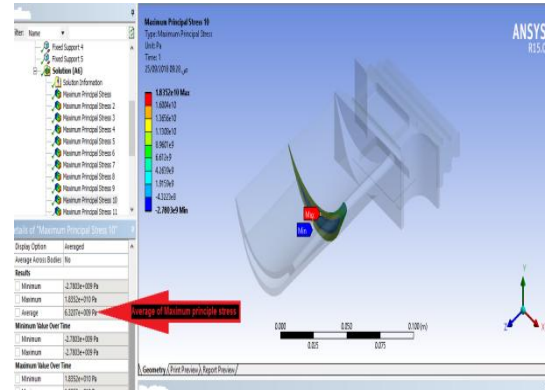
Fig. 3 Showsthe place of Max.principle stress in tenth section.

2. LITERATURE RIVEW

Theju et.al[8]had mainly done the research work on jet engines turbine blade; the study was done on two different materials Inconel718 and Titanium T-6 alloy to discuss the effect of temperature and induced stresses on turbine blade. The study complemented that the Titanium T-6 would have minimum value of deformation and lesser strength.

Naga Bhushana Rao et.al[9] had done research on turbine blade used in marine applications. The blade was observed for structural analysis at elevated temperatures and under the action of large centrifugal force, the material used was nickel based super alloy, it was investigated that high stresses and strains were observed near to the root of the turbine blade and upper surface along the blade root, maximum temperature is observed at the blade tip and minimum at the root of the blade.

3. MATERIAL AND MATERIAL PROPERTIES

Four alloys have been used in the current study:

3-1- INCONEL 718&INCONEL 625 alloys

It is a high strength, heat resistant superalloy (HRSA) that is used extensively by the aerospace industry for the hot parts of gas turbine engines such as, turbine disks, blade .[2]

3-2-Mar M-200 alloy

The material of the blade is taken as MAR M-200 isconsider superNickel alloy. It is one of the proper material for blades of Gas turbineon account of its altitude yield strength,

endurance limit and its ability to stop therising of temperatures [1].

3-3-Titanium Alloy

Accelerates formation of chromia at metal/oxide interface; decrease thermal expansion coefficient in Ni base alloys. These titanium alloys are foundamentlly used for represent materials for hard tissues.[3].

Table2: Mechanical properties of Inconel 625, MarM-200 & Titanium alloy [6,4,1,3].

Property	Inconel625 alloy [6]	Inconel718 alloy[4]	MarM200 alloy[1]	Titanium alloy[3]
Density (kg / m³)	8400	8190	8526	4540
Poisson´s ratio	0.3	0.22	0.33	0.33
Modulus of Elasticity (Gpa)	145	200	220	206.84

4. RESULTS AND DISCUSSIONS

Following Fig.(4,to7) show the results of stress analysis in INCONEL625 alloy,we notice that the concentration of stresses rate is in the back of the base of the airfoil,which gradually decreases along the airfoil near the top of the blade, because the centirfugal force is higher at the base and lower at the top of the blade due to the decrease in the mass of blade whenever the direction from the base to the top of the blade and Table(3) show the average stresses on INCONEL625.
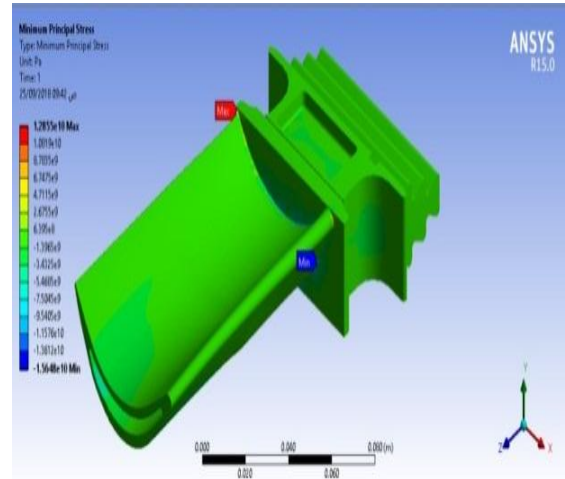
Fig. 5 Shows the minimum principle stress for the INCONEL625 alloy blade.
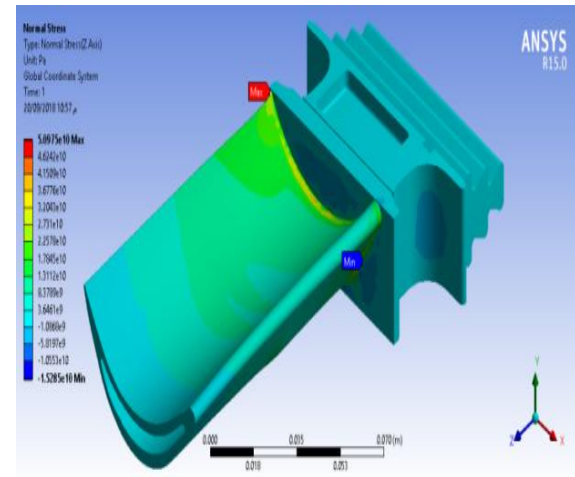
Fig. 6 Shows thenormal stress for the INCONEL625 alloy blade.
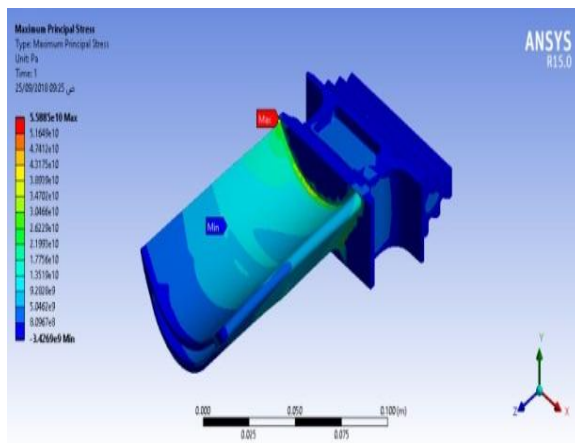
Fig. 4 Shows themaximum principle stress for INCONEL625 alloy.
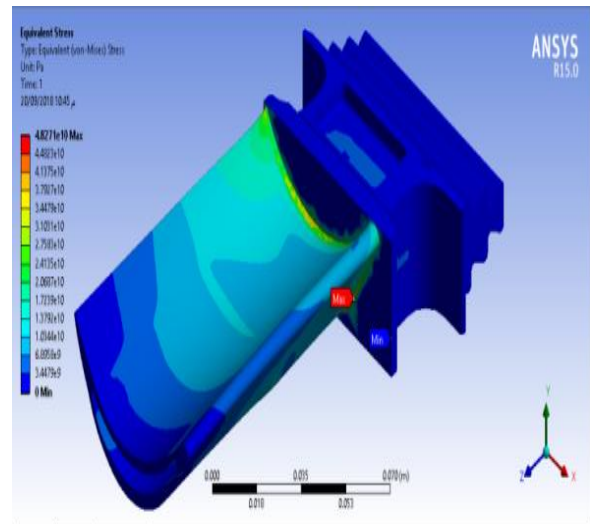
Fig. 7 Shows the Von misses stress for the INCONEL625 alloy blade.

Table 3: Results of averge stress analysis of blade of gas turbine made from INCONEL625 alloy by ANSYS program at all sections along the blade.

Sectio n No.	Normal stress (MPa)	Von misses (MPa)	Maximum principle stress (MPa)	Minimu m principle stress (MPa)
1	11942	10300	12510	2520
2	11700	10240	12030	1022
3	11034	10250	11110	239
4	10362	9950	10410	40
5	9662	9454	9714	12
6	8940	8865	9005	11
7	8197	8201	8276	-1
8	7428	7452	7521	-108
9	6666	6939	6853	-422
10	6198	8243	6321	-2367
11	9423	9399	9480	-124
12	8517	8592	8579	-148
13	7602	7727	7666	-121
14	6678	6831	6744	-296
15	5748	5917	5811	-349
16	4800	4997	4866	-395
17	3846	4079	3914	-439
18	3000	3174	2954	-488
19	1908	2305	1999	-541
20	1300	1539	1115	-600
21	0.5	1302	100	-788

The following Fig. (8 to 11) show the stress analysis for INCONEL718 alloy,the result obtaained can be discussed as an ANSYS program where the value of the largest stress at the base of the airfoil and the lowest at the top of the blade is explained by the fact the high centrifugal force at the base of the airfoil and less as we movement to the top of the blade, and Table(4) show the average stresses on INCONEL 718.
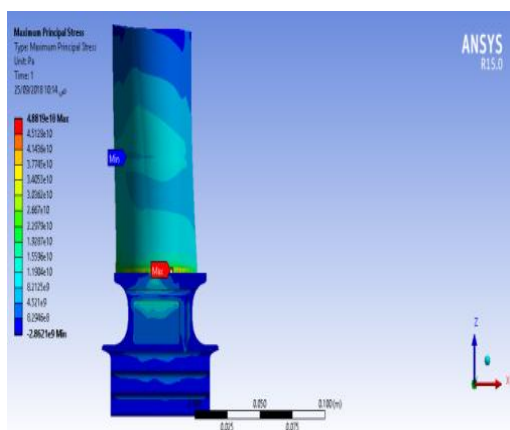

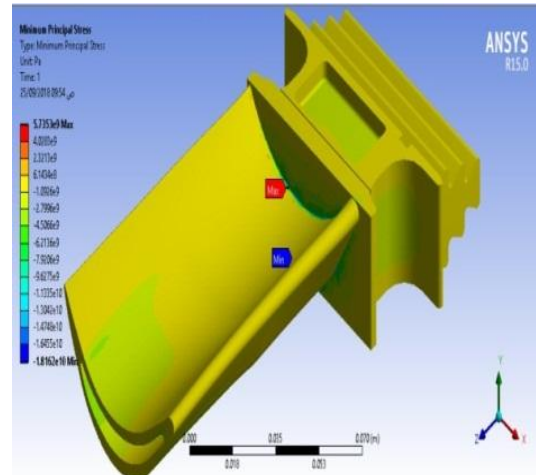Fig. 8 Shows the maximum principle stress for the INCONEL718 alloy.

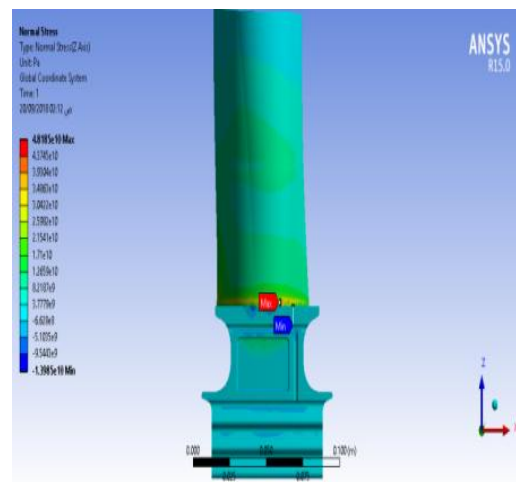Fig. 9 Shows theminimum principle stress for INCONEL718 alloy.

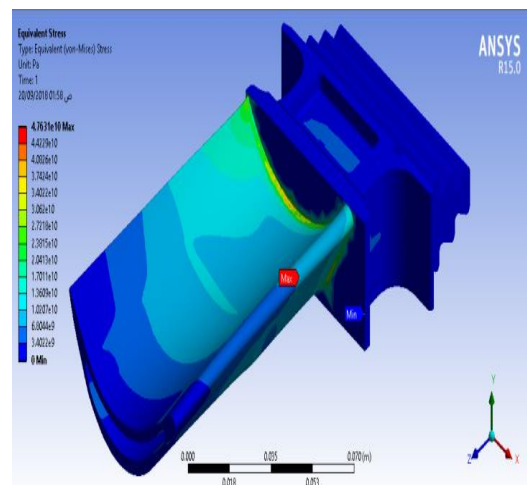Fig. 10 Shows thenormal stress for INCONEL718 alloy.

Fig. 11 Shows the Von misses stress for the INCONEL718 alloy.

Table 4: Result of average stress analysis on blade of gas turbine made from INCONEL718 alloy by ANSYS programat all sections along the blade.

Section No.	Normal stress (MPa)	Von misses (MPa)	Maximum principle stress (MPa)	Minimum principle stress (MPa)
1	12263	10278	11700	1664
2	11423	10247	11680	896
3	10750	10125	10820	234
4	10103	9763	10150	38
5	9421	9240	9474	7
6	8716	8640	8782	5
7	7993	7983	8071	4
8	7241	7245	7335	-70
9	6498	6716	6680	-331
10	6060	8007	6192	-2263
11	9187	9238	7245	-190
12	8304	8400	4557	-168
13	7412	7535	4525	-215
14	6511	6655	4515	-280
15	5600	5765	3684	-330
16	4681	4868	2773	-373
17	3709	3970	1865	-440
18	2811	2799	1127	-460
19	1860	2237	1121	-511
20	899	1488	1090	-572
21	0.7	1234	559	-748

The following Fig. (12- to 15) show the resultof MarM-200 alloy blade,the highest value of the stresses is at the base of the airfoil,the reason is that the centrifugal force are high at the base of airfoil and decrease as we move up at the top of the blade this is due to the gradual reduction of the blade mass along the airfoil, and Table(5) show the average stresses on MarM-200.
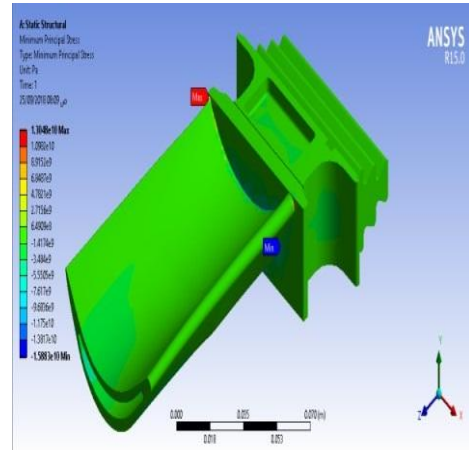

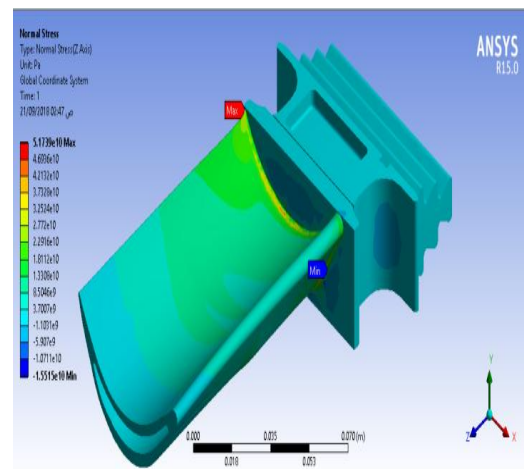Fig. 12 Shows themaximum principle stress for Mar-M200 alloy.

Fig. 13 Shows the minimum principle stress Mar M-200 alloy.
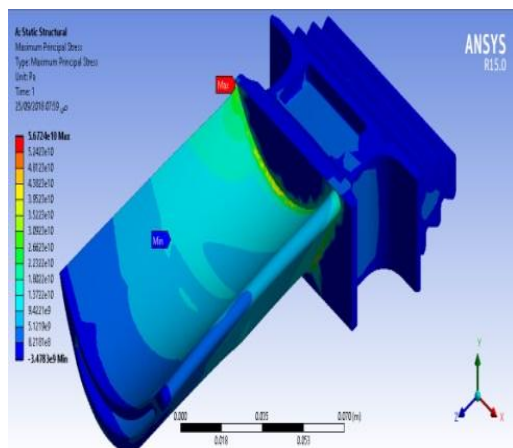
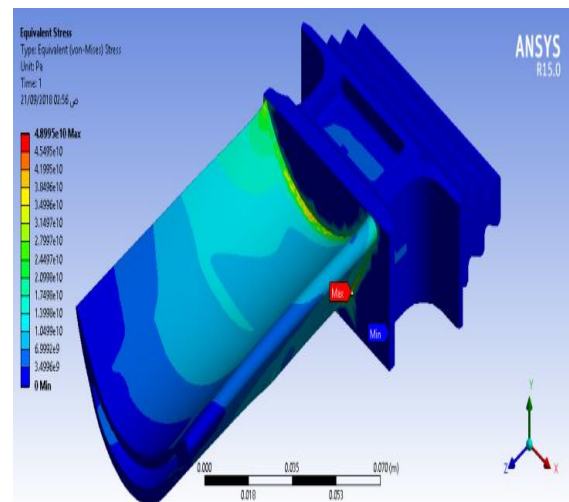

Fig. 14 Show the normal stress for Mar M-200 alloy.

Fig. 15 Show theVon misses stress for Mar M-200.

Table 5: Result of average stress analysis on blade of gas turbine made from Mar M-200 alloy by ANSYS programat all sections along the blade.

Section No.	Normal stress (MPa)	Von misses (MPa)	Maximum principle stress (MPa)	Minimum principle stress (MPa)
1	12100	10400	12690	2558
2	11880	10390	12200	1037
3	11199	10412	11280	243
4	10518	10101	10560	41
5	9808	9596	9859	12
6	9074	8996	9140	11
7	8320	8324	8400	-2
8	7539	7564	7633	-109
9	6766	7043	6956	-428
10	6291	8367	6415	-2402
11	9564	9540	9622	-126
12	8644	8722	8707	-150
13	7716	7843	7780	-224
14	6778	6933	6845	-300
15	5831	6006	5898	-354
16	4873	5073	4939	-401
17	3905	4141	3970	-446
18	2926	3222	2998	-495
19	1937	2340	2029	-549
20	935	1562	1132	-609
21	0.8	1322	606	-800

The following Fig.(16-to19) result of TITANUM alloy blade,it was observed that the highest value of the stresses at the base of the airfoil and gradually decrease as the hight reaches the top of the blade to reach the least value of the stresses where the stresses are located at the back of the base of the airfoil, and Table(6) show the average stresses on TITANUM alloy.

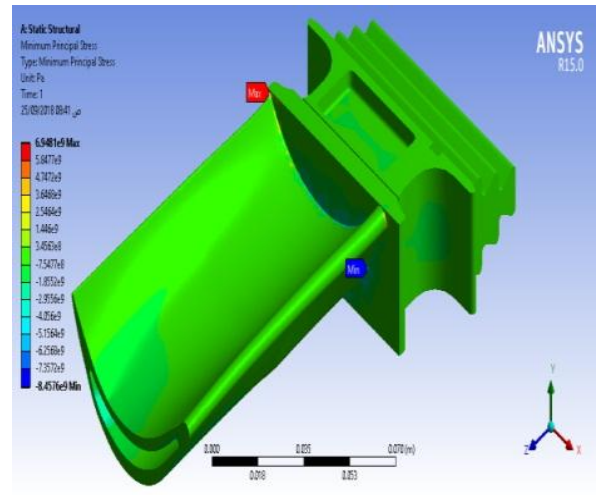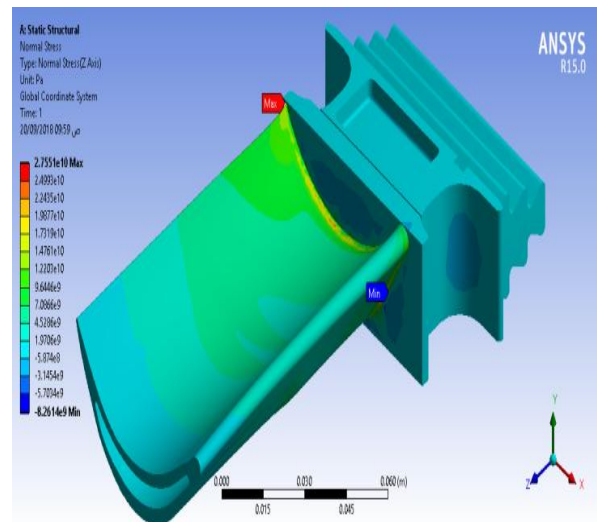Fig. 16 Shows themaximum principle stress for TITANUM alloy blade.

Fig. 17 Shows theminimum principle stress for TITANUM alloy blade.

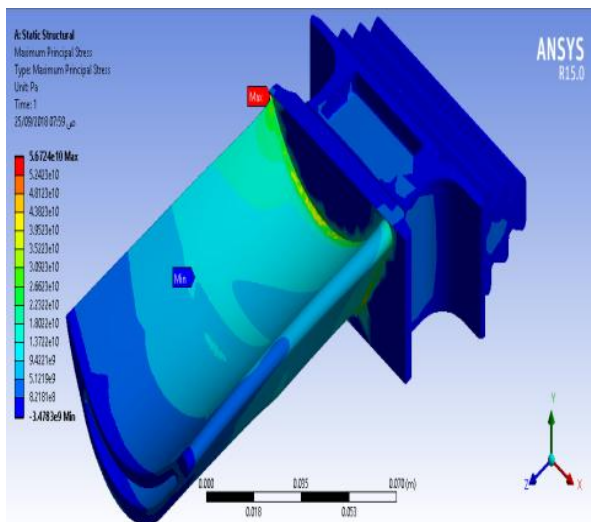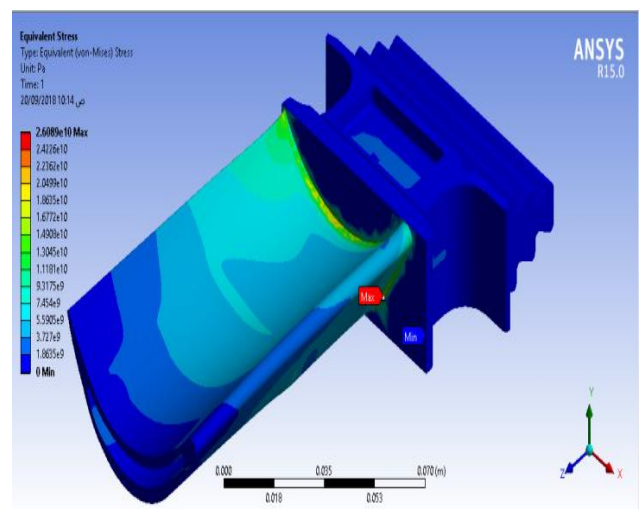Fig. 18 Shows thenormal stress for TITANUM alloy blade.

Fig. 19 Shows the Von misses stress for TITANIUM alloy blade.

Table 6: Result of average stress analysis on blade of gas turbine made of TITANIUM alloy by ANSYS program in all sections along the blade.

Section No.	Normal stress (MPa)	Von misss stress (MPa)	Maximum principle stress (MPa)	Minimum principle stress (MPa)
1	6637	5540	6760	1362
2	6031	5535	6504	552
3	5963	5530	6004	130
4	5601	5379	5625	22
5	5223	5110	5250	7
6	4832	4791	4867	6
7	4430	4433	4473	0
8	4014	4027	4064	-58
9	3603	3750	3704	-228
10	3350	4455	3416	-1279
11	5097	5080	5123	-67
12	4603	4644	4636	-79
13	4109	4176	4140	-119
14	3609	3691	3644	-160
15	3105	3198	3140	-186
16	2595	2701	2630	-214
17	2079	2205	2115	-238
18	1559	1715	1597	-264
19	1031	1245	1080	-292
20	498	831	602	-324
21	0.4	704	322	-426

The following Fig.(21,22,23,24) comparison for all alloys used in current research.The concentration of the stresses is at the base of the airfoil for all the alloys used in this study.and the resulting stresses, such as normal stress,maximum&minimum principle stress and von misses stresswhich were analyzed by the ANSYS software are lower in Titanium alloy than other alloys because the density of Titannium is less than the density of other alloys.

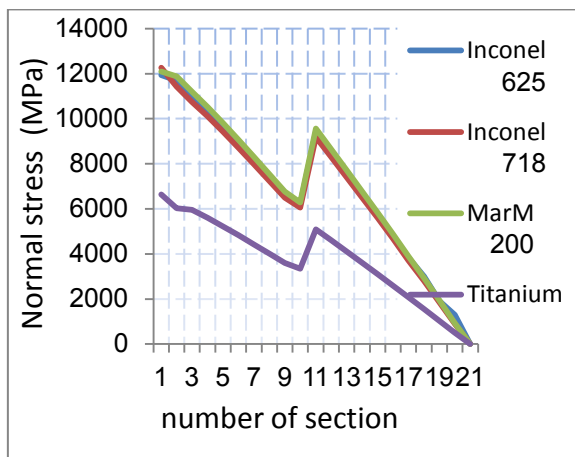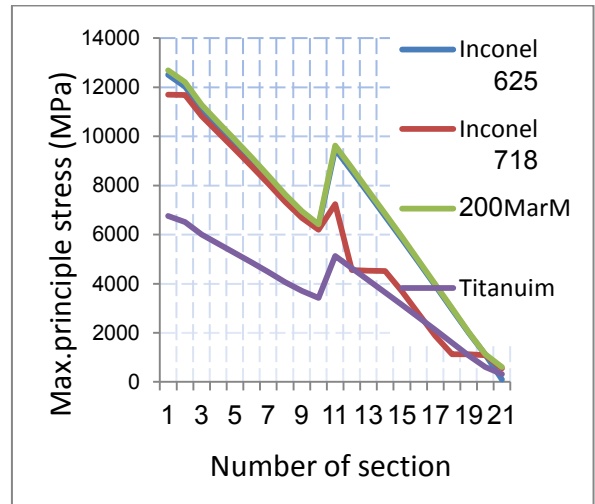Fig. 21 Shows thecomparison of normal stresses for four different alloys used in this study.

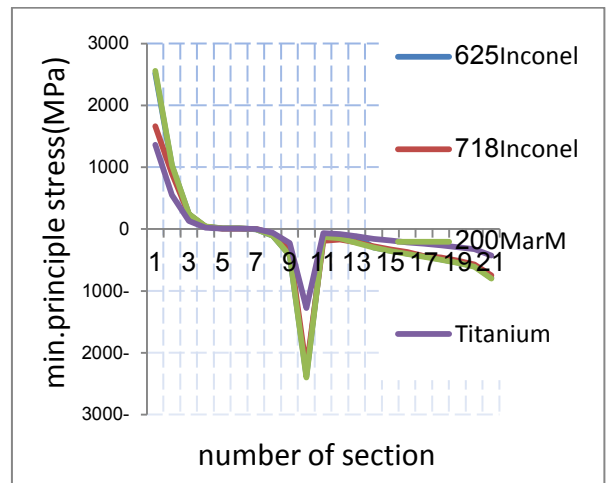Fig. 22 Shows comparisonof Maximum principle stresses for four different alloys used in this study.

Fig. 23 Shows comparison of Minimum principle stresses for four different alloys used in this study.
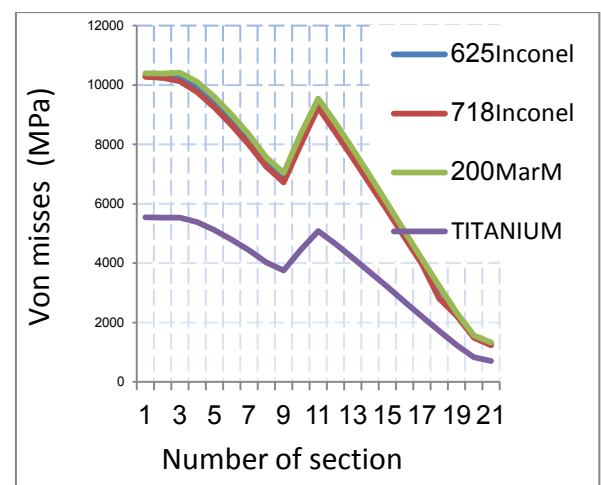

Fig. 24 Showscomparison of Von misses stresses for four different alloys used in this study.

5. CONCLUSION

The results achieveddue to the centrifugal forces on the blade is debated below.

1-It was conclusion that the stresses produced by the centrifugal forces (normal stress, maximum and minimum principle stress, von misses stress) were concentrated at the base airfoil from the back.

2-It was observed that stresses along the blade be higher value when back to the root and less at the top of the blade as shown in Fig.(21,22,23,24).

3-The centrifugal force depends on the mass where all less than the mass of the blade less centrifugal force and thus reduce the stresses resulting from this force , which was observed in the Titanium alloy of less density compared with the other alloys .

4-The tensile strength(normal stress) of the centrifugal force on the blade made of the Titanium alloy density is less than the tensile stress caused by the other alloys because the Titanium alloy density is lower than that of the other alloys thiscauses to reduce centrifugal force then causes to reduce stresses as shown in Fig.(21).

5-Maximum principle stress of the blade made of Titanium alloy has less than the maximum principle stress of the blade made of alloy s Inconel625,Inconel718,MarM-200) because the Titanium alloy density is lower than that of the other alloys so causes to reduce centrifugal force then causes to reduce stresses as shown in Fig.(22) & Fig.(4,8,12,16).

6-That the negative value of the minimum principle stress of all alloys used indicate that the blade is subjected to compression stress in some blade parts of all alloys used as shown in Fig.(23) .

7-It was noted that the highest stress equivalent to the blade made of Titanium alloy is 26089Mpa, and the equivalent stress of the blade made of Inconel625 is 48271Mpa, and the highest equivalent stress of blade made of Inconel718 is 47631Mpa, and the equivalent stress on the blade made of Mar M200 is 48995MPa this shows that the best on the safe matter of the high stresses is the titanium alloy this is due to the fact that Titanuim alloy density is less than the density of the alloys used as shown in Fig.(6,11,15,20) .

8-It is conculosion thatthe Titanium alloy is the best alloy used in terms leading to reduce stresses due to centrifugal force, because density of Titanium alloy used is less than of other used alloys,so,leading a reduction in centrifugal forcess which are directly propotional to mass,there by reducing the stresses of these forces to the Titanium alloy that is density less than of the alloys used in this study.

9-It was noted that the results of stresses for the INCONEL718,INCONEL625 and MarM-200 alloys are closer, they are nicle base alloys and they have the nearestdensity

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التحليل النظري لاجهاد اتريش التوربين الغازي المصنوع من سبائك مختلفة

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الخلاصة:

تعتبر الريش قلب التوربين وبدون الريش لا توجد طاقة وإن اي خلل فيها يؤدي الى انخفاض الكفاءة وبتصليحات مكلفة, استخدمت العناصر المحددة ببرنامج (ANSYS15) للحصول على حلول تقريبية لمجموعة واسعة من المشاكل الهندسية, يتم تحليل الإجهادات الميكانيكية باستخدام العناصر المحددة للأغراض العامة بوصفه أداة فعالة في تحليل الإجهادات المختلفة, إذ تم اعتبار الريشة مقيدة الجذر في جميع الإتجاهات (X,Y,Z) واضافة جميع الخواص الميكانيكية للريش وباستخدام برنامج (ANSYS15) تم تقطيع الريشة الى ارتفاعات متساوية على طول الريشة, قوى الطرد المركزي مسلطة على الريش ناتجة من دوران الدوار بسرعة (6000 دورة / دقيقة), تم بناء نماذج العناصر المحددة باستخدام D3-10 عقدة من نوع رباعي السطوح, صفيحة 187, ونسجة العناصر المحددة لكامل الريشة المكون من 23406 شريحة, 136575 عقدة, تم استخراج معدل الإجهاد العمودي , الإجهاد المكافيء , الإجهاد الرئيسي الأعلى والإجهاد الرئيسي الأدنى ببرنامج (ANSYS15), وهذه الإجهادات ناتجة من تأثير قوى الطرد المركزي وهذه القيم قورنت بمنحنيات لكل سبيكة, تستنتج الدراسة الحالية الى إن سبيكة التيتانيوم هي افضل سبيكة من حيث تقليل الإجهادات الناتجة عن قوى الطرد المركزي مقارنة بالسبائك الأخرى المستخدمة وذلك لأن كثافة سبيكة التيتانيوم اقل من كثافة السبائك الاخرى المستخدمة حيث إن قوة الطرد المركزي تتناسب طرديا مع الكتلة مما يؤدي الى تقليل الإجهادات الناتجة عن هذه القوى لسبيكة التيتانيوم الأقل كثافة من بين السبائك المستخدمة في هذه الدراسة .

الكلمات الدالة. ريش التوربين الغازي,سبائك مختلفة ,تحليل الإجهادات