*International Journal of Research in Engineering and Science (IJRES)*
*ISSN (Online): 2320-9364, ISSN (Print): 2320-9356*
*www.ijres.org Volume 4 Issue 10 ǁ October. 2016 ǁ PP. 01-07*

# A Research on Turbochanrging Blades

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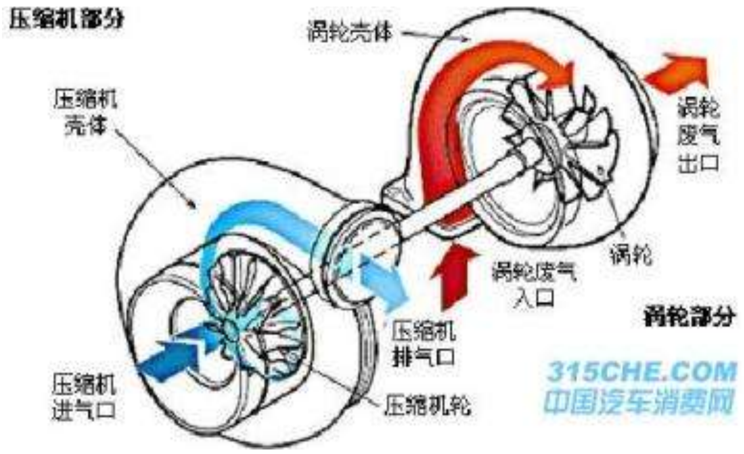
*（Shanghai University of Engineering Science, Shanghai 201620）*

**Abstract**: Turbocharger had become the centre of technology recently，not only for its convience for the aircraft ，but also for its significant influence in electric power generators，diesel engines and gasoline engines.）Hence，the researchers had become more and more interested in developing newly efficient and high profits engines.Turbochargers can improve the efficiency of the engine.The revolving turbocharing blades are constanly under the forces of the high temperature air when working，what's more，the centrifugal force of its own can not be neglected.We can see that the turbine blade can be hard to analysis when it is working.However the design of a turbocharger blade can decide the turbine's final efficiency and life-time.So，the design part can be an important work before we produce the turbocharing blades.
This ariticle is based on the analysis of the turbocharging blades，We will use the Ansys software to study the characteristic of the turbocharging blades，and to support the engineering work.
**Keyword:** turbocharger blade stress deformation

## I. INTRODUCTION

Turbines are not strange to us in the modern world,it was widely used in aircrafts airplanes and engines.Although it is the part of engine which gives out the power,it can be make a significant difference to the engines.It can improve the engine's efficency and reduce the pollutions,what's more it can also cut down the noise of the engines.[1]But what the basic principles it was based on to reach such a beneficial effects?The picture can tells.




We can tell from the picture,that the red flow is the turbine engine flow.It was the air comes from the exhuated gas,and it will flow into the turbine ,and during this progress,it will turn the turbine blades to revolve.From the view of energy,the thermal engery of the air was transformed into the dynamic power of the revolving turbine engines.We can also tell from the picture that the compressor and the turbine are connected through a aix,and hench the revolving turbine would make the compressor to rotate with it.And,when the dynamic power of turbine would be transferd to the compressor.The air would be lead to the compressor ,and in it ,the air would be compressed to high pressure.And the higher the pressure of the air,the larger working area of the engines.[2]
And that is the what makes the turbocharger necessary for a engine .

Recently,all kinds of study of the turbochargers had been made by the researchers .We had found that it can be used to achieve one of the most encouraging combustion progess,HCCI.And the pollutes would be cut down by using a suitable turbine[3].

But,we can not neglect the turbine.As I had said before, it was under the influence of the high temperature exhausted gas constantly,and that means it could be broke like every other machine.It has a life time and it has its own limits.So,the study of it can be important.And in this article we are going to do a research of the charecteristics of the turbocharging blades.

## II. THEORY

The basic theory of the research is mechanics of material and finite element analysis.

Firstly,we will discuss the mechanics of materials.The force per unit area,or intensity of the forces distributed over a given section ,is called the stress on that section and is denoted by the Greek letter σ.

$\sigma=\frac{P}{A}$.

And we use V to denote the force tangential to the section,and A means the area of the section.Then we get $\tau=\frac{V}{A}$.

And in the three dimension aixs.We had equations.

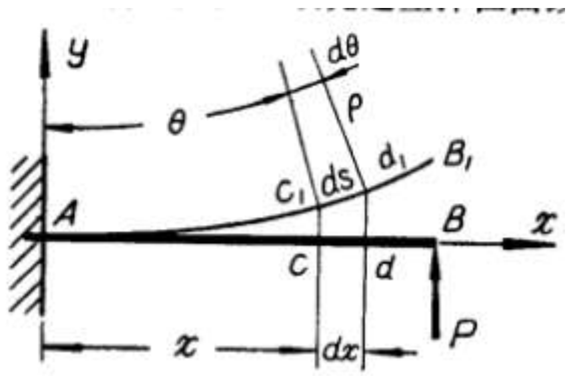
$$\frac{\partial(\sigma_x)}{\partial t}+\frac{\partial(\tau_{yx})}{\partial y}+\frac{\partial(\tau_{zx})}{\partial z}+f_x=\rho\frac{\partial^2 u}{\partial t^2}$$

$$\frac{\partial(\tau_{xy})}{\partial x}+\frac{\partial(\sigma_y)}{\partial t}+\frac{\partial(\tau_{zy})}{\partial z}+f_y=\rho\frac{\partial^2 v}{\partial t^2}$$

$$\frac{\partial(\tau_{xz})}{\partial x}+\frac{\partial(\tau_{yz})}{\partial t}+\frac{\partial(\sigma_z)}{\partial z}+f_z=\rho\frac{\partial^2 w}{\partial t^2}$$

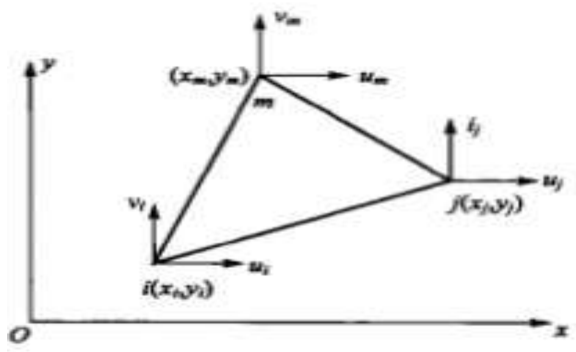
we use $f_x$, $f_y$, $f_z$ to represent the force of the particle beared in x,y,z.And we use u,v,w to represent the three dimensional displacements of the pariticle.[4]

With the equations above ,we can calculate the stress the blade once we were given the right conditions of the mechnicals.And when it comes to the deformations ,we need new equations.We will start with a grider,




We had the equations $\frac{d^2y}{dx^2}=\frac{M_w}{EJ}$.And once we were given enough conditions ,we can solve this equation to get the y,which means deformation.[5]

But engineering is a complex situation.And in recent years,the engineers had came up with a new method to solve the real problems with the development of the computers,finite element analysis.




We will use the picture to demonstrate the basic principles of the finite element analysis.We had points i,j,m separately in the pictures,and they all had their positions in the pictures.We use $(x_i,y_i)$, $(x_j,y_j)$, $(x_m,y_m)$to represent those three points.We also had $u_i,v_i,u_j,v_j,u_m,v_m$ for the displacements for the three points.We also get the displacement matrix $\delta$ the load matrix F,and $\delta=[u_i\ u_j\ v_i\ v_j\ u_m\ v_m]^T$ $F=[F_{xi}\ F_{yi}\ F_{xj}\ F_{yj}\ F_{xm}\ F_{ym}]^T$.We also give three displacement functions of the three points.

$u=a_1+a_2x+a_3y$ $v=b_1+b_2x+b_3y$

with these equtions we can get

$u=\frac{1}{2A}\left[(a_i+b_ix+c_iy)u_i+(a_j+b_jx+c_jy)u_j+(a_m+b_mx+c_my)u_m\right]$ $v=\frac{1}{2A}\left[(a_i+b_ix+c_iy)v_i+\right.$ aj+bjx+cjyvj+am+bmx+cmyvm

$a_i=x_iy_m-x_my_i, b_i=y_j-y_m, c_i=-x_j+x_m$.

And those two equations can be written in the forms of the matrix,and we will not show it here.And we can also get the deformation matrix and stress matrix.And with those matrix and the help of the computer,we can finally get the deformations and stress of the complex machanicals,and it is for sure we can use the method to calculate the deformaions and stress of the turbocharging blades[6].

## III. MATERIAL AND METHOD

The material of the turbocharig blade is High nickel heat resistant steel,and the main characteristics of the material[7] are listed in the chart.

| | | | |
|---|---|---|---|
| density（kg m^-3） | 8000 | Melting point（℃） | 1295-1395 |
| Young's modulus（Gpa） | 144-211 | Coefficient of thermal conductivity（W/(m℃) | 10.15 |
| coefficient of thermal expansion | 20-100℃ | Poisson radio | 0.31 |

We use the ansys workbench to do the research.

(1)Open the "steady structural".

(2)Import the geometry model into the program.

(3)Generate the mesh of the geometry.

(4)Find the face of the turbine and insert a "remote displacement." set the "rotation x"free,and make others parameter zero.

(5)insert rotational veolocity,and put "x component" 40000rpm.

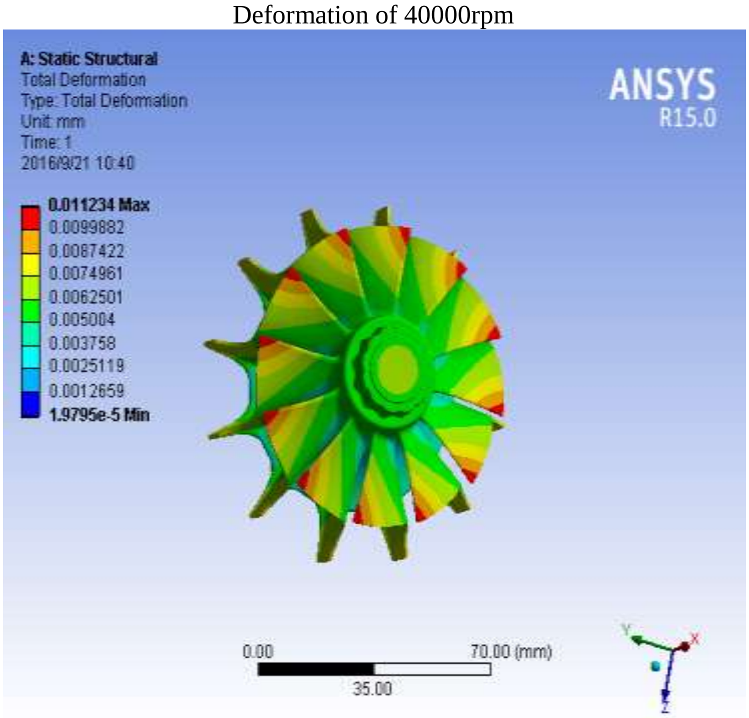
(6)insert the deformation and stress.

(7)solve it.and repeat the steps from 1 to 6,while put the rotational velocity to 50000rpm,60000rpm and 66500rpm .

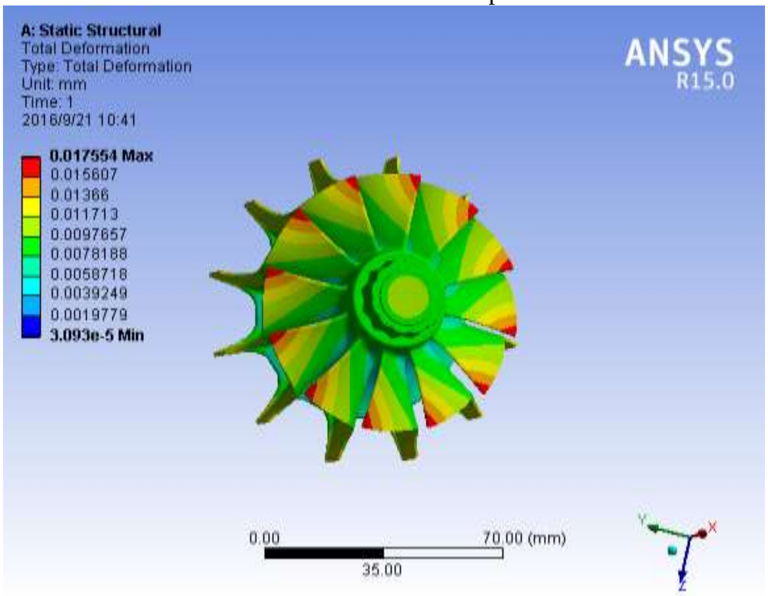
## IV. ANALYSIS

(1) Deformation analysis.

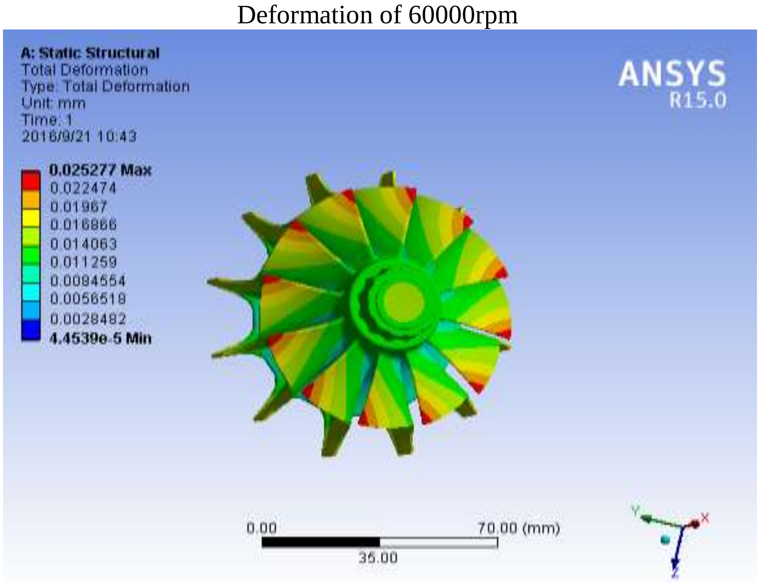
Deformation of 40000rpm



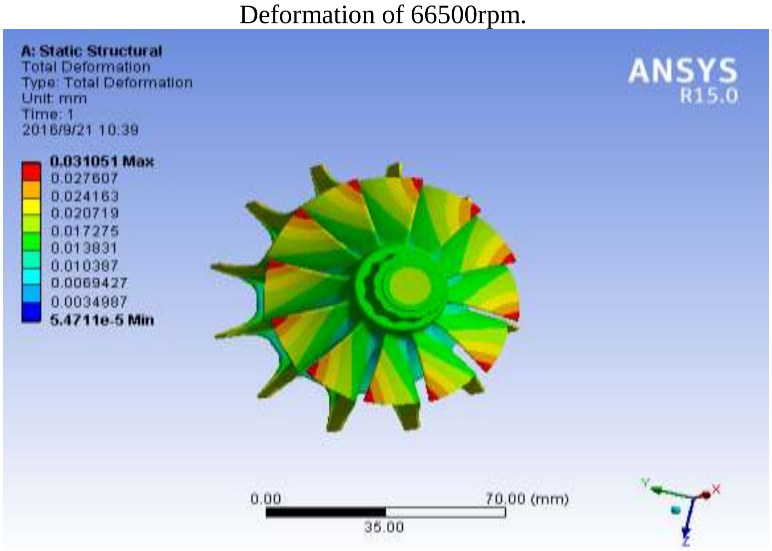
Deformation of 50000rpm




Deformation of 60000rpm




Deformation of 66500rpm.

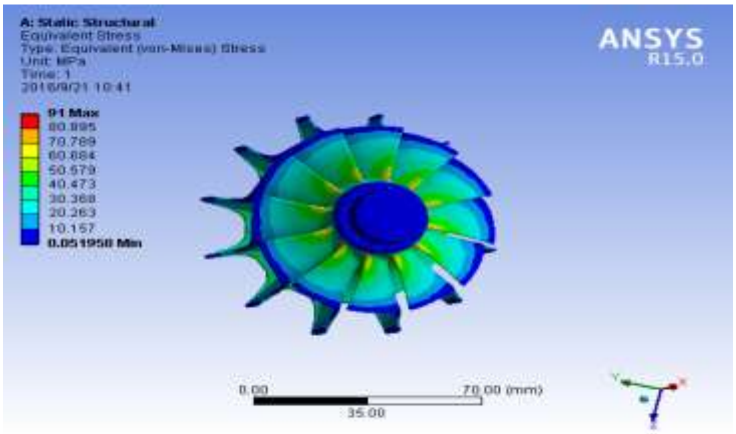


From the pictures above ,we can give the chart of the maximum deformaiotn of  different rotational speed.

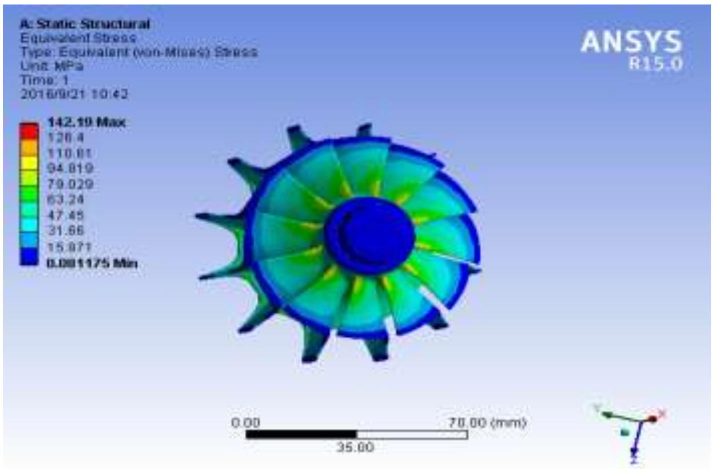
| 40000rpm（mm） | 50000rpm（mm） | 60000rpm（mm） | 66500rpm（mm） |
|---|---|---|---|
| 0.0112 | 0.0175 | 0.0253 | 0.0311 |

And, from the chart ,we can see that the maximum deformations are increasing when the rotational speed of the turbine is increasing.And the maximum deformation appears to be at the edge of the turbine blades,and that is because the turbochargine blades are under centrifugal force,and the edge's centrifugal force are bigger than the other parts of the turbine,and hence the moment of the force is bigger.

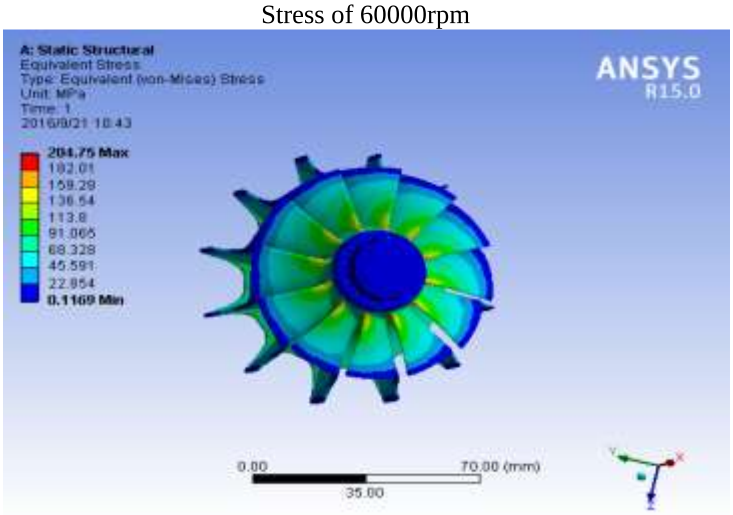
(2) Stress analysis stress of 40000rpm



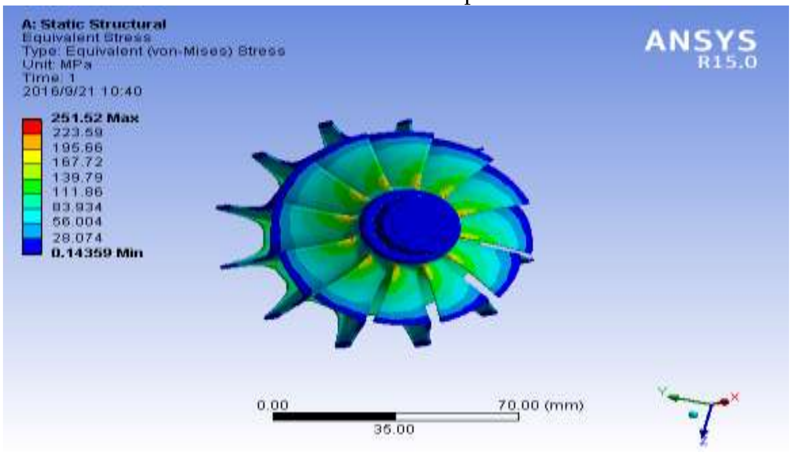

Stress of  50000rpm




Stress of 60000rpm



Stress of 66500rpm



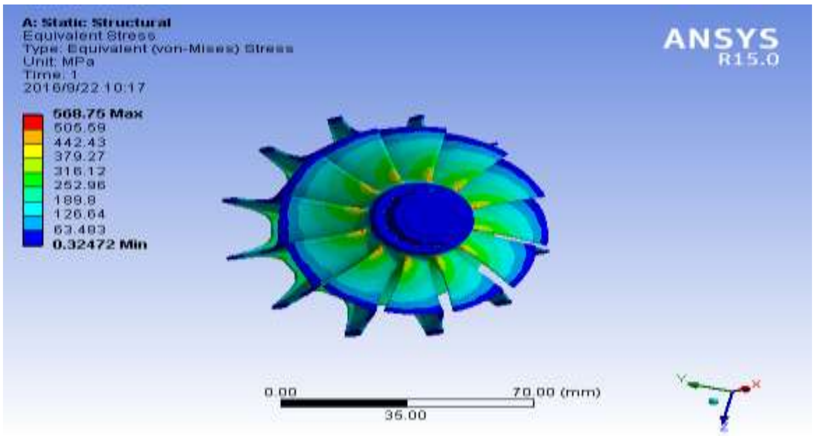

We can put the data of the maximum stress of different rotational velocity into the charts.

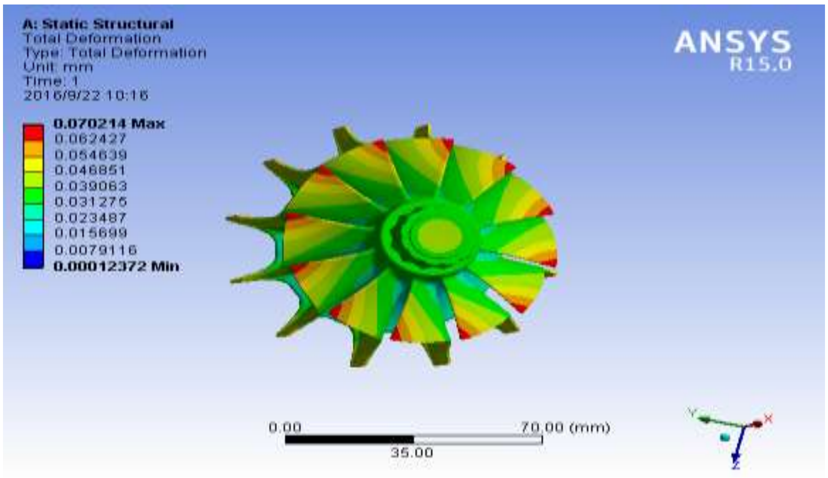
| 40000rpm（Mpa） | 50000rpm（Mpa） | 60000rpm（Mpa） | 66500rpm（Mpa） |
|---|---|---|---|
| 91．00 | 142.19 | 204.75 | 251.52 |

We can tell that from the chart that the maximum stress increases when the rotional velocity increases.And it reaches 251.52Mpa when the rotational velocity is 66500rpm.And the maximum stress of the material is 252Mpa,so we can not increase the rotational velocity anymore.If we add the velocity,it is probable that the turbocharging blades are going to broke.And ,we can also see that the maximum stress was at the bottom of the blades,and this is different from the deformations.

(3) the deformation and stress in super rotational velocity.

Set the rotational velocity to be 100000rpm,and see the results.



We can tell from the picture that maximum stress is 568.75Mpa,and it is bigger than the permitted stress 252Mpa,so this could cause the damage to the turbocharging blades.What's more the deformation reaches 0.07mm,and this can not be neglected.So,we can see that 100000rpm would not be permitted when we are using the turbine.

## V. CONCLUSION

Turbocharging blades are very important to modern vehicles,and the design of the turbochargin blades are also important.When we try to desgin the turbocharing baldes,the finite element analyis can be a effective way to design the baldes.The turbocharing blades had to bear the air force and the centrifugal force when it is working,and it has deformation and stress when it is working.And when the rotational velocity increases,the deformation and the stess also increases.And there is a up limit of the rotational velocity.The biggest deformation area of the turbocharging blades is the at the edge of the blades,and the biggest stress is at the bottom of the turbocharging blades.When the turbine rotational velocity is bigger than the permitted rotational velocity,it cause damage to the turbine.

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