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Design of Steam Turbine Blade Under Centrifugal Force Effect with Mutation of Rotational Speed and Blade Tongue Length

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ABSTRACT

Steam turbine converts the heat energy of steam into useful work. The steady deals with the structure of turbine type (HP) and the effect of centrifugal force during rotation which is directed outwards, away from center of curvature of the path within range of rotation speed (1800, 2500, 3600rpm). The increasing of rotation speed will cause progressive values of stresses and strains. The paper deals with increase of blade tongue length due to increasing of stresses and strains values especially in the root of blade tongue, also the excessive increase in rotation speed and blade tongue length posing led to increase of stresses and strains to an accepted value.
Keywords: Steam turbine, Blade steam turbine, Design of blade steam turbine, Stresses and strains in steam turbine blade.

1. INTRODUCTION

The steam turbine is a main rotor that diverts kinetic **energy** in steam into rotational mec**hanical** energy thru the impact or reaction of the steam against the blades. The study deals with steam turbine design for small scale steam power plant with aim of outputting electricity. The palm kernel shells are used as renewable energy source to drive turbine by heat energy because it is low cost. The study was focused on elements turbine design and its chumming used computer packages. The micro turbine design was bounded to design, modeling, simulation and analysis of the rotor, blades and nozzle under palm kernel shell fuel for the micro power plant [1, 2, 3].

The wide application of steam turbine is the advance of design technology, this is become lades important research field. The design of turbine blade is important factor to evaluate efficiency of steam turbine. The originality of research deals with structure of steam turbine blade, analysis factor is effect on blade operation, design principle, comparing traditional design of root tooth of steam turbine blade with optimization design after improved of parameters. Finally, was proposed feature design of steam turbine blade [4, 5, 6].

The turbine blade is important part in thermal power generation plants. These blades are exposed to high temperature and pressure in thermal power cycle. The design of blade and its root is important element. The failure always is occurred in root section. The distribution of stress is very important in blade design. The analysis of stress is along of blade turbine in present research. The distribution and analysis of stresses can be done in different rotational velocity (rpm), while the natural velocity for operation is (6728rpm). In research, the velocity is increased 30% for one material, hence, the failure is occurred at 15% increasing of velocity. The other material at 25% increasing of velocity [7, 8, 9,10].

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2. METHODOLOGY:

2.1 1-STEAM TURBINE BLADE STRESSES:

The effective stresses on s**team** turbine blade are static and dynamic stresses. The turbine blade length is considered effective variable on stress value, where the turbine blade in nuclear power plant is longer. The stresses are same on any blade. The machine that the turbine blades are fitted on it, these machines was in tow groups, one from 1500 – 1800 rpm and the second from 3000 – 3600 rpm, these speeds rotation are produce high centrifugal force and led to high centrifugal stress. In present paper takes three speed rotation (1800, 2500 and 3600 rpm) experimental and theoretical.

1-2 The centrifugal force:

The direction of centrifugal force out of blade, mean away anent of path center of curve for blade moving. The general rule of centrifugal force [10,11].

$F \quad = m.r.w^2 \ldots\ldots\ldots\ldots\ldots\ldots (1)$

The small part of mass (δm), in width (δr) and in distance (r) from center, therefore the centrifugal force (δF) on small part of blade mass [12, 13].

$$\delta F = \delta m \,.\, r \,.\, w^2 \ldots\ldots\ldots\ldots (2)$$

$$\delta m = \rho \,.\, A \,.\, \delta r \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$dF = (\rho . A) r . w^2 dr \ldots\ldots\ldots\ldots\ldots (4)$$

$$F = \rho . A . \; w^2 \int_{r1}^{r2} r dr \ldots\ldots\ldots\ldots\ldots (5)$$

$$F = \rho . A . \; w^2 \left(\frac{r2^2 - r1^2}{2} \right) \ldots\ldots\ldots\ldots\ldots (6)$$

$$w = \frac{2\pi N}{60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

From above equations can be find relationship between centrifugal force and rotational speed, experimental available information from steam turbine in Al-Nasiriya electric generation plant in Iraq (A=175mm, ρ=7850 Kg/mm^2, r_1=225mm, r_2=270mm) was draw the relationship between them in figure 1 , and simulate centrifugal forces which is calculated in Auto desk inventor program to determine stresses produced by these forces in figures 2, 3, 4.

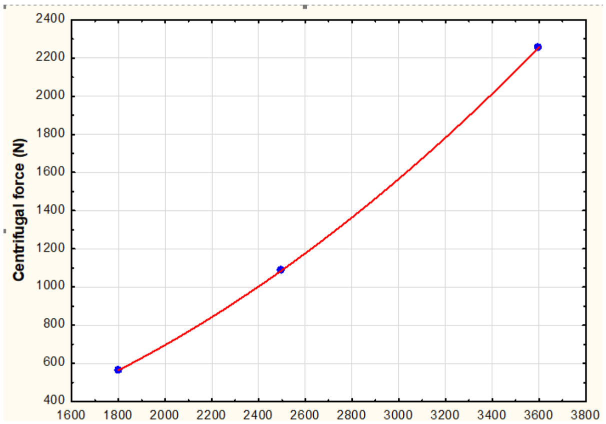


Fig. 1, The relationship between centrifugal force and rotational speed for steam turbine blade.

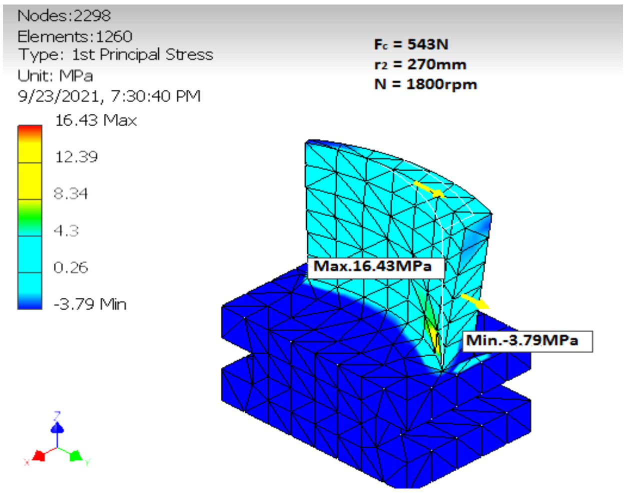


Fig. 2, The centrifugal stress on steam turbine blade with centrifugal force (564N)

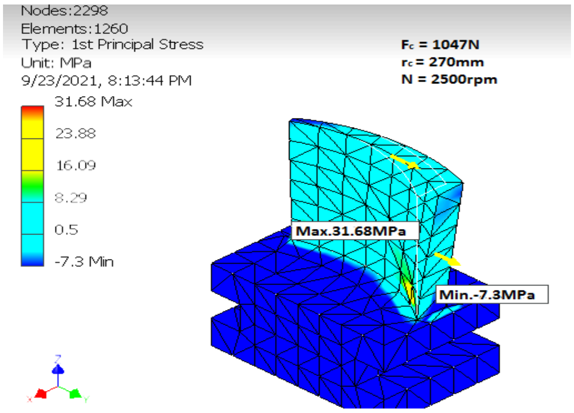


Fig. 3, The centrifugal stress on steam turbine blade with centrifugal force (1088N)

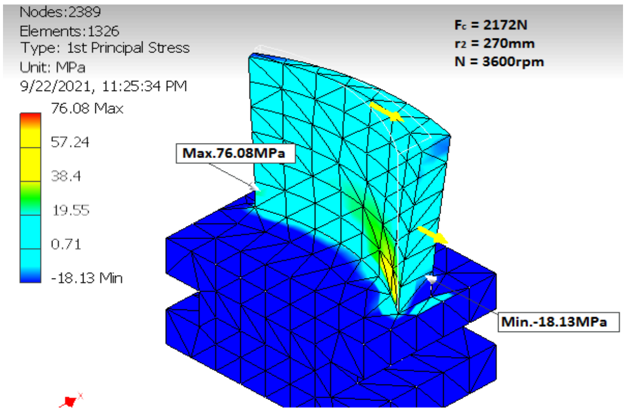


Fig. 4, The centrifugal stress on steam turbine blade with centrifugal force (2257N)

2.2 EXPERIMENTAL WORK

(2-1) TURBINE BLADE LENGTH EFFECT ON CENTRIFUGAL FORCE, STRESS AND STRAIN:

The increasing of steam turbine blade tongue led to change centrifugal forces and stresses which produce from it. The steam turbine in Al-Nasiriya power plant which have different tongues length of turbine blades. The different measures of tongues from root to tip are (45, 60, 75mm). The strain gage technique is used with dispatcher and receptor for variable resistance strain and translate the readings from un-log to digital dynamic strain, then save the readings of different (r2) with constant rpm. The ratio of dynamic strain to static strain is regarded the same ratio of dynamic stress to static stress, then can be get dynamic stress for turbine blade, the relationship between blade tongue length, strain ratio and dynamic stress is draw in figure 8. The figures 5, 6, 7 are represented practical dynamic strain of blade [10,11,12, 13].

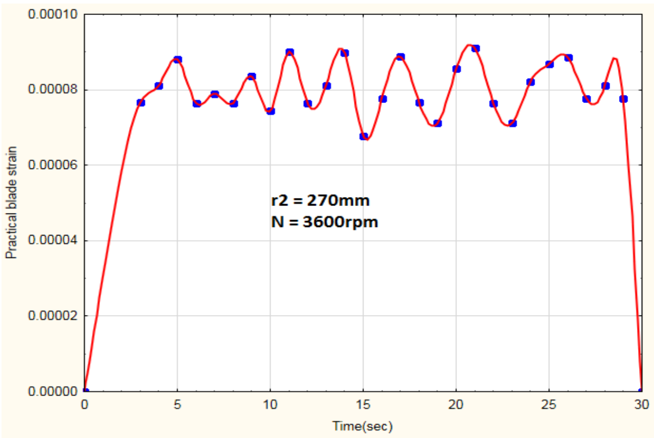


Fig. 5, The practical readings of blade strain with tongue length 45mm.

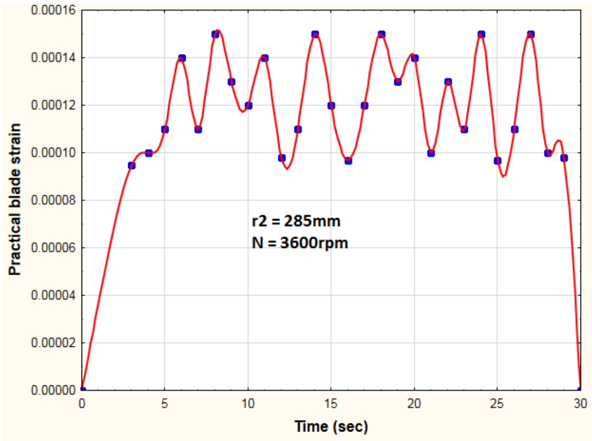


Fig. 6, The practical readings of blade strain with tongue length 60mm.

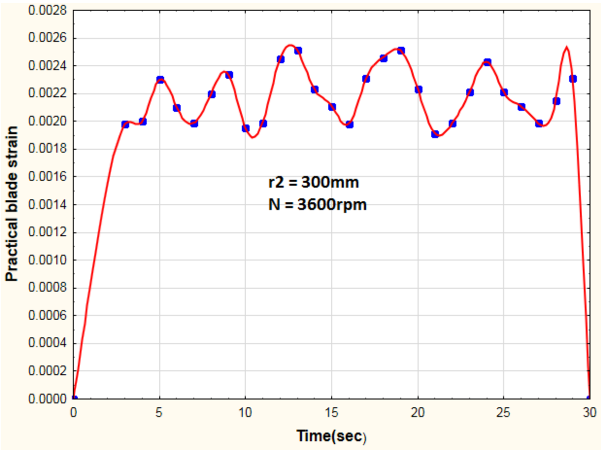


Fig. 7, The practical readings of blade strain with tongue length 75mm.

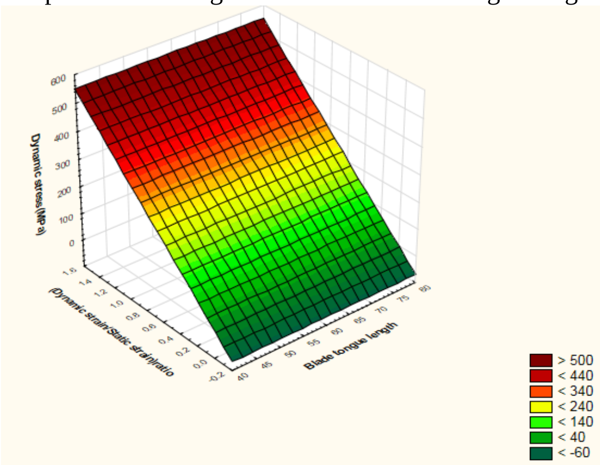


Fig.8, the relationship between blade tongue length, strain ratio and dynamic stress.

3- SIMLUTION OF CENTRIFUGAL FORCES EFFECT ON BLADE TONGUE:

For comparison of the practical results theoretical results, the auto desk inventor program is used. The same values of centrifugal forces which are calculated by equation 6 and with different tongues length of steam turbine blade (45, 60, 75mm), as illustrated in figures (9, 10, 11).

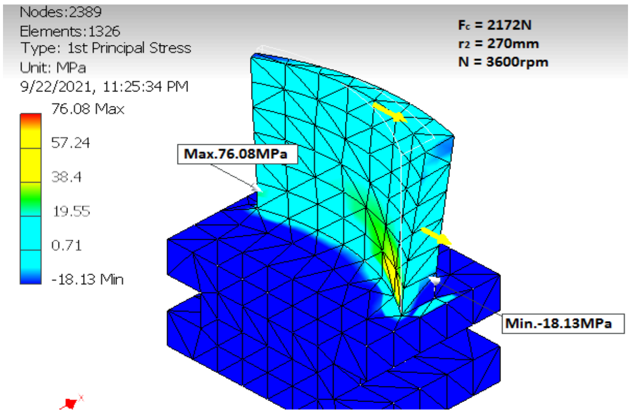


Fig.9, Stress simulation of blade tongue with (564N) centrifugal force and (r2=270mm).

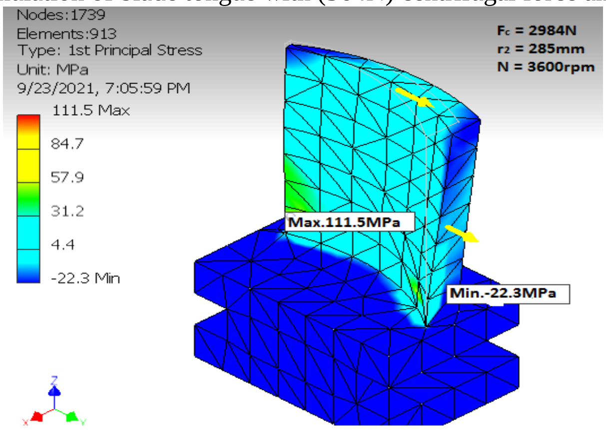


Fig.10, Stress simulation of blade tongue with (2984N) centrifugal force and (r2=285mm).

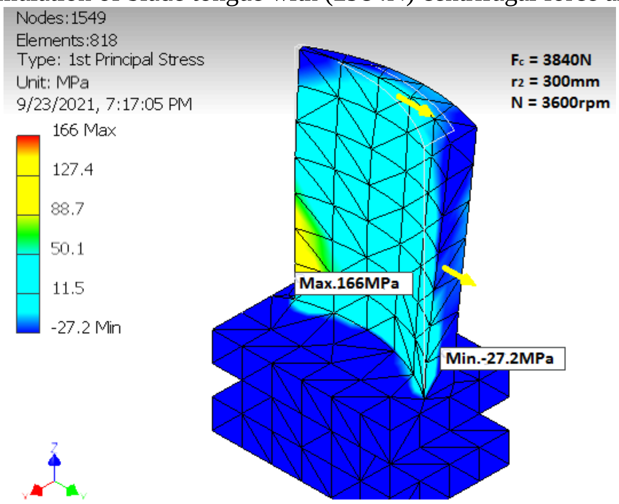


Fig.11, Stress simulation of blade tongue with (2984N) centrifugal force and (r2=285mm).

4- EXCESSIVE SPEED ROTATION AND BLADE TONGUE:

The final state of steam turbine blade (tongue length=75mm, i.e. r_2=300mm) is used to increase speed rotation of machine that blade fixed on it at (500 rpm) and analysis of stresses and strains which are subjected on blade as shown in figure 11, then the value of speed rotation is constant at 3600 rpm while the blade tongue is increased to (125mm, i.e. r_2=350mm) and analysis stresses and strains in figure 12.

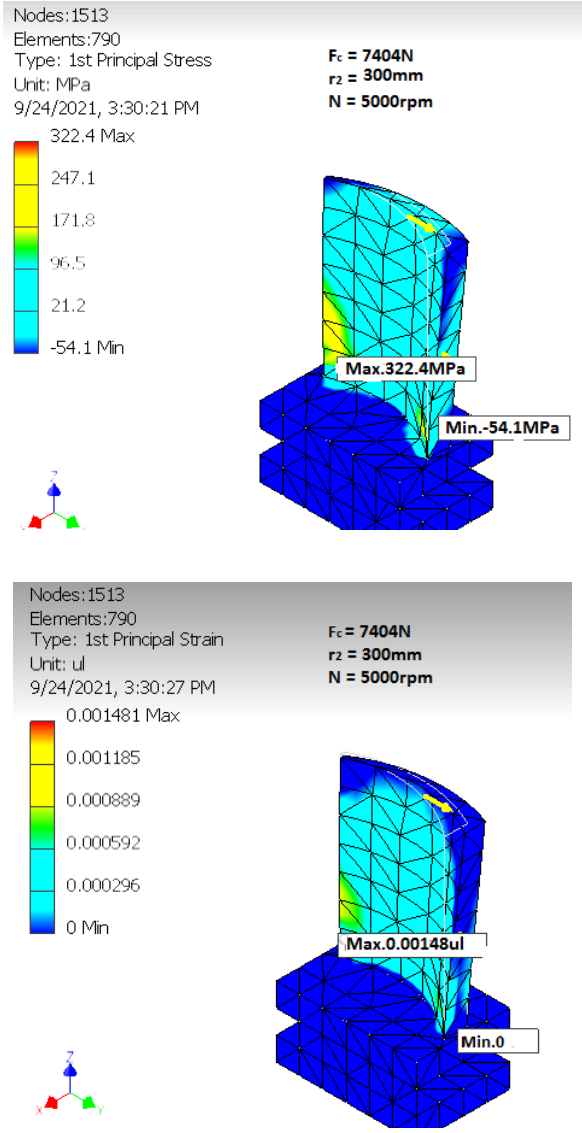
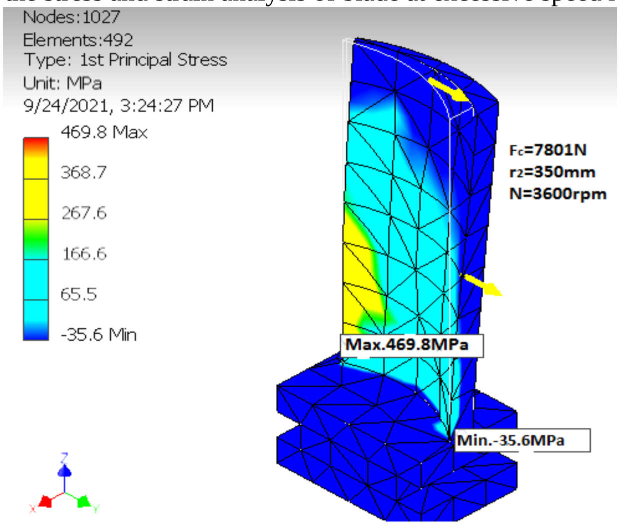


Fig.12, the stress and strain analysis of blade at excessive speed rotation.



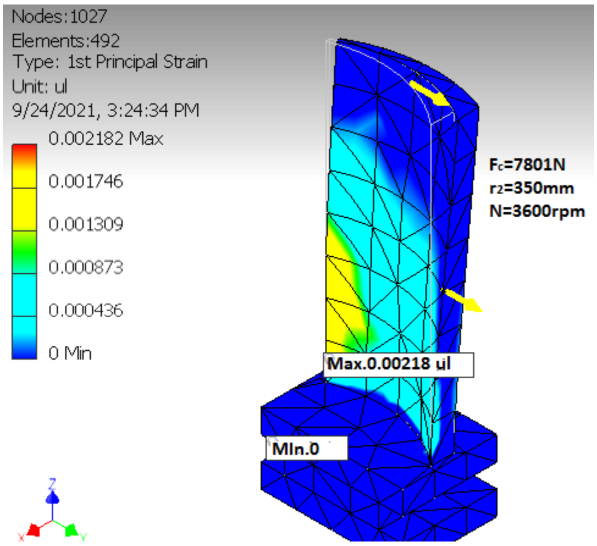


Fig. 13, the stress and strain analysis of blade with excessive in tongue length.

RESULTS DISCUSSION

The centrifugal force which is affected on steam turbine blade is regarded small when the size of blade is small also speed rotation must be limited value in design. The centrifugal force has away direction of path curvature center of rotating machine. As well as the centrifugal force, there is bending force and steam pressure. They are regarded effecting parameters on steam turbine blade. In this paper deals with the effect of centrifugal force in state of increasing when increasing of speed rotation and increasing of steam turbine blade tongue, also deals with excessive of increasing for tow state are mentioned previously.

From equation 6 is showed that the variable rotation speed of machine which is represented in angular speed square. The top curvature radius (r_2) when is change effected on blade tongue area which is subjected of loads and pressure. The rotation speed range in design is (1800, 2500, 3600 rpm), they are applied in equation to calculate centrifugal force for every speed. The incremented relationship between them is represented in figure 1.

By auto desk inventor program is simulated centrifugal force that calculated in figure 1 of turbine blade type (HP) made of steel (σ_{ul} = 345MPa, σ_y = 207MPa) as shown in figures 2, 3, 4 to calculate stress value by using 1st principle stress theory in method of (finite element analysis). The relationship is incremental between speed rotation (1800, 2500, 3600rpm) and stresses (16.43, 31.68, 76.08MPa).

The figures 5,6, 7 are represented practical dynamic strains readings for steam turbine blade in Al-Nasiriya power steam plant in Iraq and with different blades tongue (45, 60, 75mm) and same theoretical state and by using strain gage technique with transmitter and receptor. The readings of dynamic strains are un log and translated to digital, then then dividing them on static strains to determine strain ratio and stress ratio, all these parameters are drawn in figure 8.

The figure 8 is showed the incremental relationship between blade tongue length because of increasing r_2, strain ratio and dynamic stress (is regard practical dynamic stress because of produce from practical strain) and knowing of static stress for steam turbine blade metal with constant speed rotation.

In figures 9, 10, 11, the auto desk inventor program is used to simulate dynamic stress which produce due to increase of steam turbine blade tongue (45, 60, 75mm). In figures 10,11 can be showed value of deformation is represented turbine blade inclined to back because of centrifugal force effect that is increased (2172, 2984, 3840N), therefore the stress is increased also (76.08, 111.5, 166MPa) respectively.

In figure 12 can be showed excessive in increasing of speed rotation of turbine machine (5000rpm). The producing stress due to centrifugal force (7404N) will increase to (322MPa) also the strain (0.00148) and tongue deformation to back in (8^{o}) angle from basic position, and these values may be led to fail of turbine blade tongue especially at root area as shown in figure.

The figure 13 is showed excessive of turbine blade tongue increase to (125mm) with same previous rotation speed (3600rpm). The centrifugal force is increased to (7801N) with stress and strain (460.8MPa, 0.00218) respectively. Also, can be shown blade tongue deformation to back in (12^{o}) angle while fail area is in blade tongue root.

Conclusions:

1-This paper introduce the structure of steam turbine blade and a**nalyzes** the research status of blade parametric design at laboratory and abroad.

2-The study is giving clear picture about important of centrifugal force calculation which is caused stresses and strains in steam turbine blade tongue and when there increased led to failure.

3-The tow parameters in study are rotation speed of turbine machine and blade tongue length of turbine. The study is proved the interesting of limiting their values in design according to turbine size and power generation.

4-The excessive increase in rotation speed of turbine is not good, whereby led to increase of centrifugal force then blade tongue deformation from basic position. Also, the excessive increase in turbine blade tongue length is led to increase of centrifugal force and increase of turbine blade tongue deformation.

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