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STUDYING THE EFFECT OF THE PROFILE CHANGE OF THIRD STAGE MOVABLE PITCH BLADE OF LOW PRESSURE STEAM TURBINE AND ITS EFFECT ON THE ISENTROPIC OUTPUT WITH PROGRAMS AIDED COMPUTER

Abstract: *This research contains a study involving the effect of pitch moving blade of third stage on the Isentropic Output of the third stage output of low pressure steam turbine / steam turbine in Jandar - Homs- Syria/, and identifying the optimum pitch of profile before modification and a profile after change via proceeding a numerical study of two dimensional of wet vapor inside closed wind tunnel using computational fluid Dynamics (CFD) for analyzing and understanding the effect of pitch of blade profile on isentropic output of third stage.*

In this study turbulence model of K-epsilon was applied using numerical analyzing program (Ansys Fluent), the research includes studying several values of pitch blade, and the effect of change of value of pitch of movable pitch blade on the isentropic output widely.

Getting the optimum pitch blade of profile before modification C-9013IIP is 27.5 mm, and the optimum pitch blade of profile after changing section C9015B is 25 mm that will gives the highest isentropic output of third stage.

Key words: *Blade of steam turbine - low pressure third stage – blade pitch- isentropic output - computational fluid Dynamics (CFD).*

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ИЗУЧЕНИЕ ВЛИЯНИЕ ИЗМЕНЕНИЯ ШАГА ПЕРЕДВИЖНОЙ ЛОПАТКИ ТРЕТЬЕЙ СТУПЕНИ ПАРОВОЙ ТУРБИНЫ НИЗКОГО ДАВЛЕНИЯ И ЕГО ВЛИЯНИЕ НА ИЗОНТРОПИЧЕСКИЙ КПД С ПОМОЩЬЮ ANSYS

Резюме: *В этом исследовании изучалось влияние изменения шага передвижной лопатки третьего стадия на изоэнтропический КПД третьей ступени турбины низкого давления на паровой Электростанции Jandar в Сирии. И определить оптимальный шаг для профиля лопатки до и после модификации, проведя численное исследование двумерного потока влажного водяного пара в закрытом воздушном туннеле с использованием CFD. Это делается для того, чтобы проанализировать и понять влияние изменения шага лопатки на изотропный КПД третьего этапа.*

Исследование проводилось с использованием турбулентный модели K-эпсилон с помощью программы численного анализа Fluent Ansys, которая включала изучение нескольких значений шага лопатки и влияния изменения значения шага на изотропный КПД третьей стадии.

Результаты расширили возможность использования двумерного численного решения для определения значения оптимального шага лопатки и определения значения изотропного КПД при каждом значении исследуемого шага лопатки.

Результаты показали значительный эффект изменения шага подвижной лопатки на изотропный КПД. Оптимальный шаг лопатки для профиля до регулировки С-9013ПР составлял 27,5 mm, а шаг для лопатки, оптимизированного для профиля после изменения сечения С-9015В, составлял 25 mm, что давало самый высокий КПД для третьей ступени.

Ключевые слова: *Лопатка паровой турбины, третья ступень низкого давления, шаг лопатки, изоэнтропический КПД, вычислительная динамика жидкости CFD.*

1. Introduction:

Low-pressure turbine in Jandar station in Syria is considered an important part for effectual and proper operation of steam turbine as a whole; since it is an essential part of the design and building up the station which is in operation since 1994. During exploitation, some problems (unknown reasons) appeared in the third low-pressure stage, and in 2010, the third stage is cancelled by cutting the blades, therefore the nominal capacity of station is minimized about 15%. [1]

We should understand all variables inclusive, when we start discussing a problem. Worth mentioning, Jandar Station's archive and its diagrams have not provide design information concerning the blade pitch required for effective operation for third stage, therefore, it is necessary to study the effect of blade pitch since it helps in identifying and determining the optimum blade pitch that affects the isentropic output of third stage. [1]

Low-pressure turbine third stage has been studied thermodynamically for determining the Bendery conditions which will be depended at input and output of wind tunnel. [6]

Pitch is considered the main engineering factors in orifice. By pitch change alters the velocity distribution at the blade surrounding, which involves forming the Bendery

conditions and occurrence friction losses, on the other side it affects at site of minimum pressure of blade back, which affects on losses of outlet sides [2]. The best ratio of pitch to chord is the designer selection to get the minimum level of losses. [3]

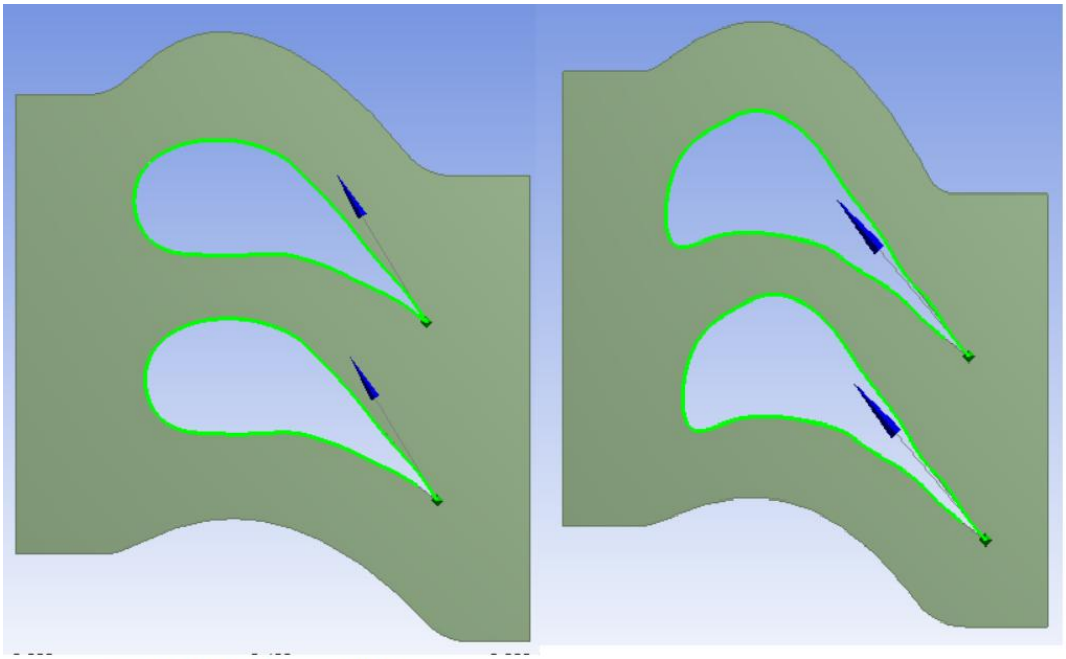
2. Research Importance and its Purposes:

The blade pitch is considered one of the important factors that affect on the isentropic output of third stage. The effect of blade pitch is determined through occurring vapor flow tangentially in order to make utilize of utmost steam power and highest isentropic output of third stage. The altering value range of blade pitch on third stage movable blade of low pressure turbine in Jandar Station has studied using computerized programs such as (CAD) and computational Fluid Dynamics science programs (CFD), that are forceful programs, and they help the researchers in analyzing and understanding problems appeared during exploitation during this stage and do fully description.

3. Methods of Research and its Materials:

Studying the Effect of Blade Pitch at Isentropic Output of the Third Stage, a two-dimensional study has been carried out for blade section C-9013IIP before modification and blade section C-9015B after alteration using ANSYS 18.1.

3.1 Geometry: the blade file of third stage is two-dimensional design using Autodesk Inventor Professional 2019[5], then sending this file to simulation program ANSYS, in order to study flow around the blade. At the beginning, wind tunnel is established to install blade inside and start simulation, the geometrical figure of wind tunnel was selected to look like the studied blade profile of third stage, and the same figure of back and belly of blade, upper and lower, the blade is declined 20^{o}.



profile C-9013IIP before modification

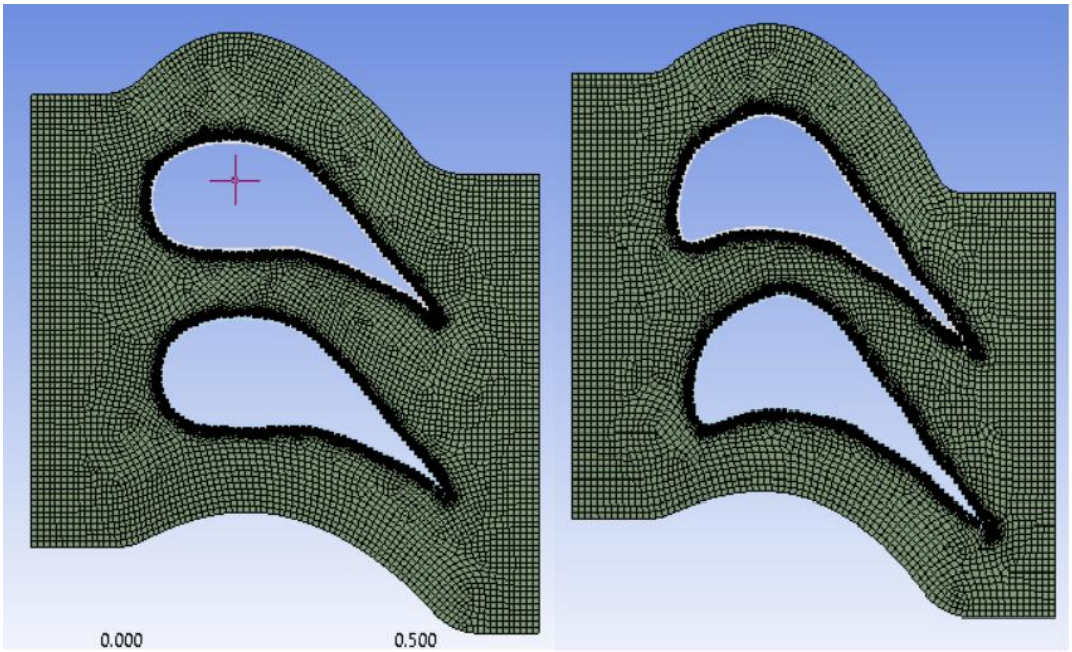
profile C-9015B after Changes

Figure /1/ shows the figure of wind tunnel and blade inside.

3.2 Meshing: this type (mesh) is selected to suit the two-dimensional study which are the types of (Triangles – Curvature & proximity). Mesh is selected accurately around the profile inside the whole tunnel because the step between blades is little. the biggest size of mish is $1*10^{-2}$ m and smallest size is $1.3625*10^{-4}$ m. The type (mesh) fulfilled good accuracy.

Table /1/ shows number of nodes and elements of profile before modification and other profile after alteration.

Studied blade profile section	**Number of elements**	**number of nodes**
profile before modification C-9013IIP	11663	12565
profile after alteration C-9015B	10759	11659



profile C-9013IIP before modification profile C-9015B after Changes

Figure /2/ shows the accuracy of mesh and layers refinement around the profile inside the wind tunnel.

3.3 Setups:

The type of simulation is selected "parallel", the choice of Solve:

Time: Transient, Type: Pressure-based.

Insert the gravity value: G= -9.81 m/sec at axis Y.

Turbulence model: K-epsilon [7] [8]

Studied environment: wet vapor

Bendery Condition of third stage blade: [6] [7]

Inlet conditions: V=203 m/sec.

Outlet conditions: P=7000 Pa .

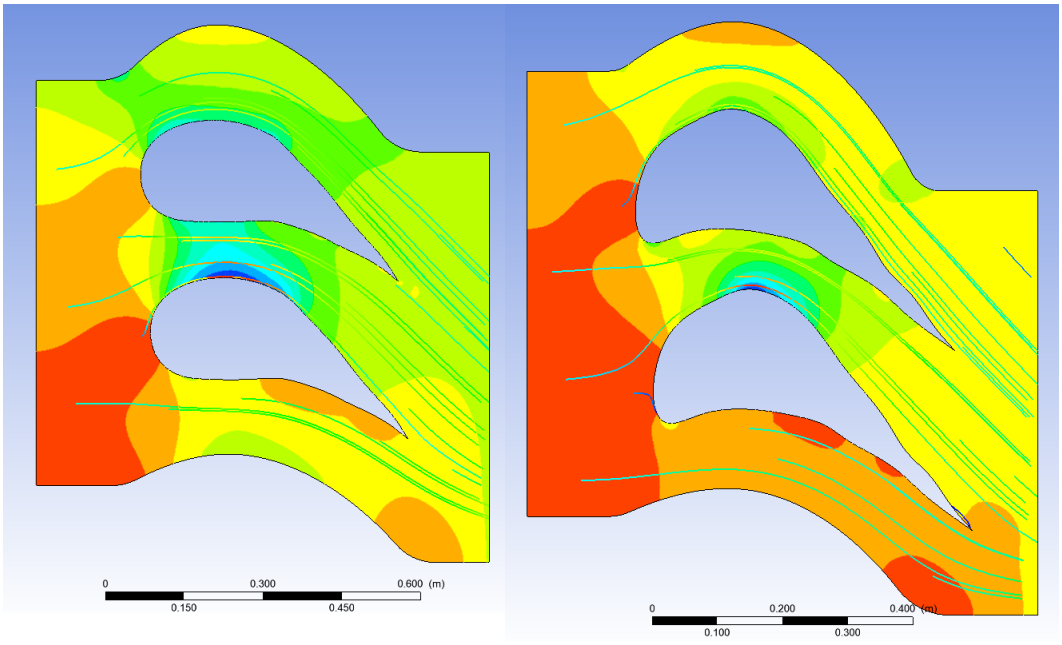
Initialization method: standard Initialization

3.4 Results:

The results analysis is concentrated on the values of pressure, these values are defined as per the following charts:

Table /2/ shows values of pressure and velocity at middle-front blade and at outlet blade:

Value	Pressure before profile modification (Pa)	Velocity before profile modification (m/sec)	Pressure after profile alteration (Pa)	Velocity after profile alteration (m/sec)
At middle-front blade	37491.15	6.892	51113.5	75.93
At outlet blade	12368.84	77.41	16923.15	111.59



profile C-9013IIP before modification

profile C-9015B after Changes

Figure /3/ shows the distribution of values of pressures around profile of moving blade third stage.

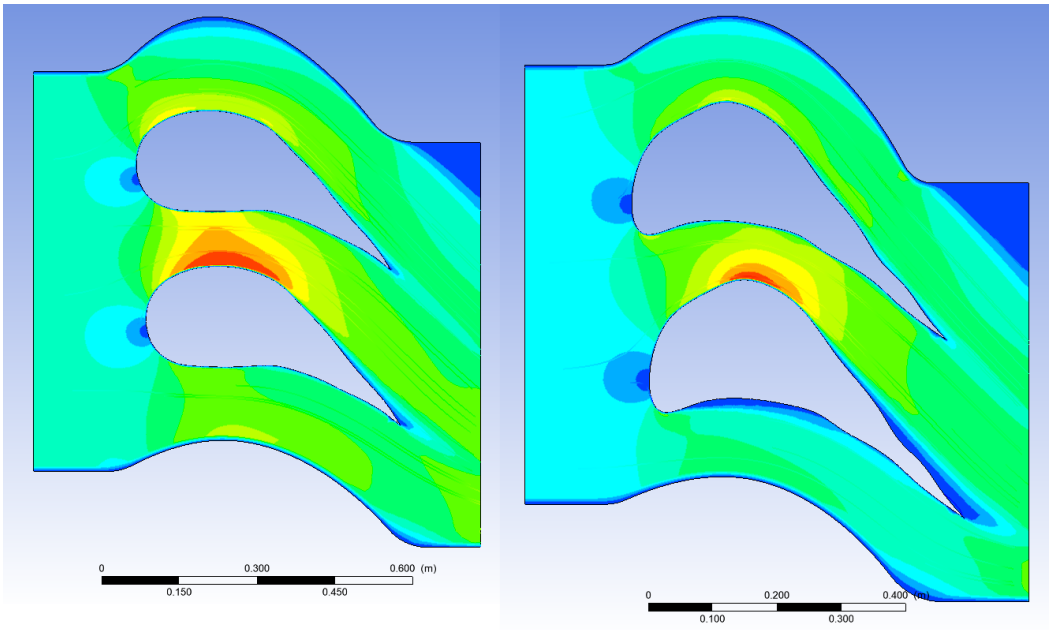


Figure /4/ shows the distribution of values of velocity around profile of moving blade third stage.

4- Results & Discussion:

Throughout studying, fixing the axel chord at actual length (54 mm) for profile before modification and after alteration. And the values of studied pitch range between (25 – 35 mm), because the applied value of blade pitch of third stage at Jandar station is 32.5 mm.

The ratio of pitch to chord at current operation of third stage: 32.5/54 = 0.601

4.1 : Studying the effect of blade pitch profile before modification C-9013IIP at the Isentropic output of Third Stage:

After completing the stimulation of two-dimensional study using Ansys Fluent for studying the effect of blade pitch profile before modification C-9013IIP at the isentropic output of third stage. Whereat the values of studied pitch range between (25 – 35 mm), selecting high and law values of blade pitch of the value (32.5 mm) which is depended at the third stage [4]. The results are shown in table /3/ as follows:

Value of blade pitch profile before modification C-9013IIP (mm)	Isentropic output of third stage
25	54.58 %
27.5	55.09 %
30	49.11 %
32.5	48.09 %
35	46.57 %

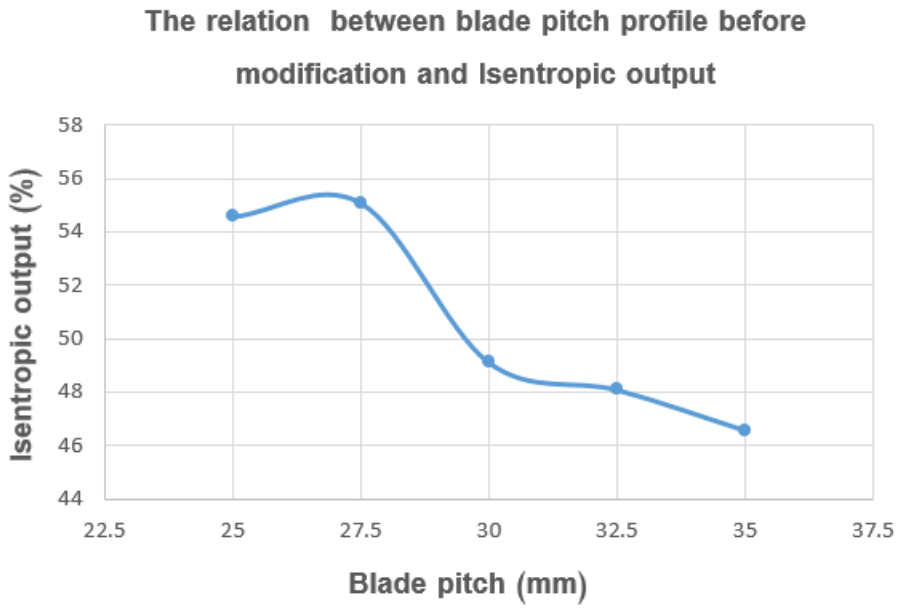


Figure /5/ shows the relation between blade pitch profile before modification and Isentropic output.

Throughout the past diagram, it is observed that the highest Isentropic output is at pitch (27.5 mm), then Isentropic output dropped which means that the optimum pitch profile before modification C-9013IIP.

The ratio of the optimum pitch to chord of profile before modification (0.509), and the Isentropic output of third stage at the maximum value which is stated 55.09 %.

4.2: Studying the effect of blade pitch profile after alteration C-9015B at the Isentropic output of Third Stage:

After completing the stimulation of two-dimensional study using Ansys Fluent for studying the effect of blade pitch profile before modification C-9015B at the isentropic output of third stage. Whereat the values of studied pitch range between (25

– 35 mm), selecting high and law values of blade pitch of the value (32.5 mm) which is depended at the third stage [4]. The results are shown in table /4/ as follows:

Value of blade pitch profile after alteration C-9015B (mm)	Isentropic output of third stage
25	74.97 %
27.5	74.29 %
30	69.37 %
32.5	66.09 %
35	55.12 %

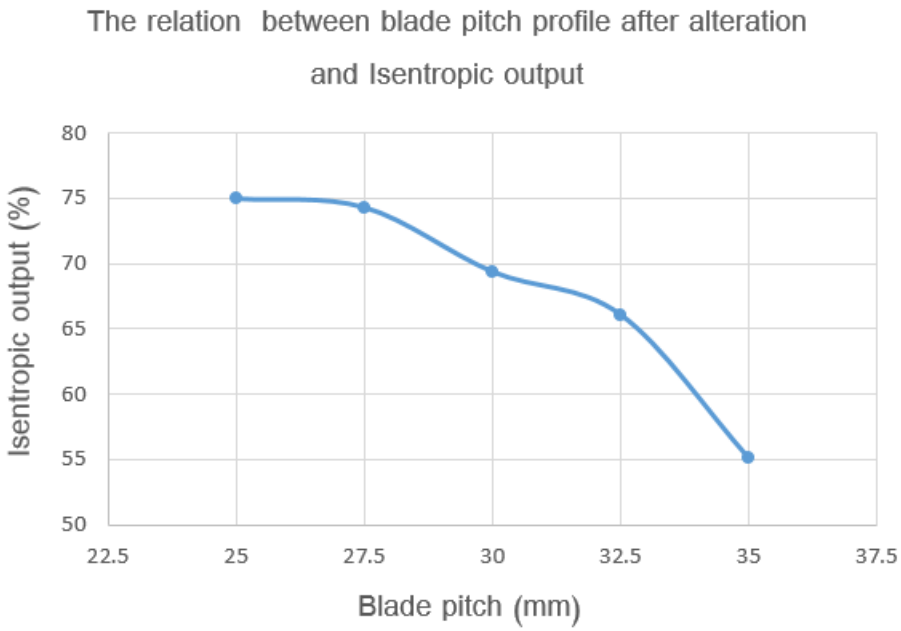


Figure /6/ shows the relation between blade pitch profile after alteration and Isentropic output.

Throughout the past diagram, it is observed that the highest Isentropic output is at pitch (25 mm), then Isentropic output dropped which means that the optimum pitch profile after alteration C-9015B.

The ratio of the optimum pitch to chord of profile after alteration (0.462), and the Isentropic output of third stage at the maximum value which is stated 74.97 %.

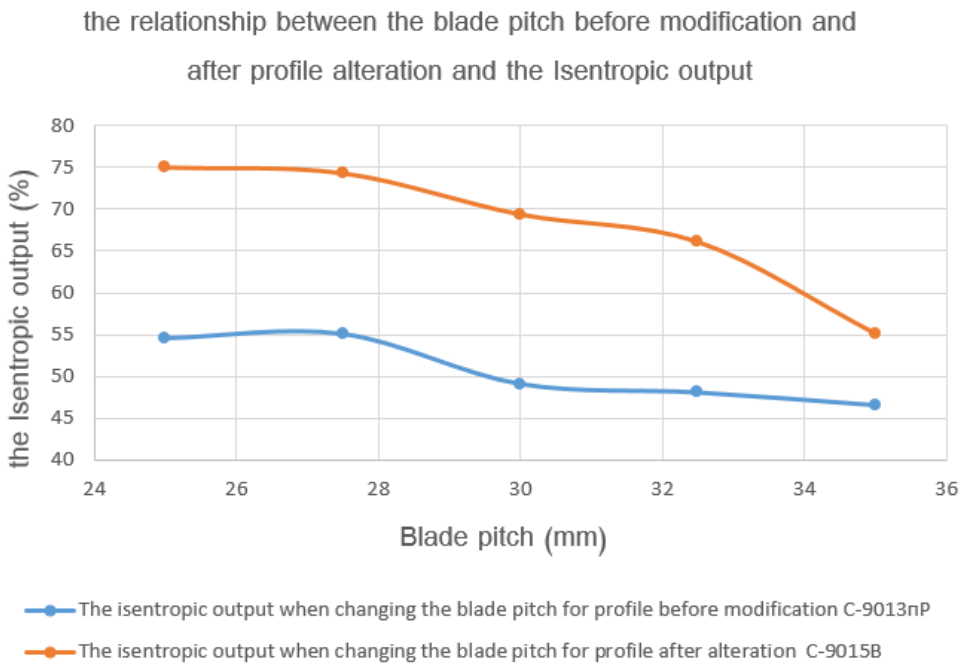


Figure /7/ shows the relationship between the blade pitch before modification and after profile alteration and the Isentropic output.

With fixing the axial chord of blade profile third stage at (54 mm), as a result of changing pitch ratio to chord of profile before modification (pitch value 32.5 mm), and profile after alteration (pitch value 25 mm), the Isentropic output of third stage is increased about 35.85 %.

In order to present a practical solution suitable for current situation of stage, keep up the value of blade pitch of movable third stage (32.5 mm) at axial chord (54 mm) of blade. The value of Isentropic output of third stage pointed out in table /5/ as follows:

Comparative	**The value of Isentropic output of third stage at operation conditions (pitch value 32.5 mm)**
Profile section before modification C-9013IIP	48.09 %
Profile section after alteration C-9015B	66.09 %

Preserving the operation conditions of third stage (pitch value 32.5 mm), we obtained increasing of Isentropic output of third stage about 27.23 % at alteration blade profile section C-9013IIP to blade profile section C-9015B.

5. Conclusions & Recommendations:

5.1 Conclusions:

1. the value of optimum blade pitch profile before modification C-9013IIP is determined (27.5 mm), and this pitch gives the highest Isentropic output of third stage value 55.09 %.
2. the value of optimum blade pitch profile after alteration C-9015B is determined (25 mm), and this pitch gives the highest Isentropic output of third stage value 74.97 %.
3. Preserving the operation conditions of third stage (pitch value 32.5 mm), we obtained increasing of Isentropic output of third stage about 27.23 % at alteration blade profile section C-9013IIP to blade profile section C-9015B.
4. With fixing the axial chord of blade profile third stage at (54 mm), as a result of changing pitch ratio to chord of profile before modification (pitch value 32.5 mm), and profile after alteration (pitch value 25 mm), the Isentropic output of third stage is increased about 35.85 %.

5.2 Recommendations:

1. Study the blade three-dimensionally analyzing the flow behavior, studying the blade twist, and decrement the landscape sector between root and top.

2. Structural study of blade for the sake of defining the points where fatigue is concentrated

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