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Determination of the Optimum Vapor Attack Angle on the Third Stage Blade of the Low Pressure Steam Turbine and Studying its Effect on the Output with Computer

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ABSTRACT*: the research includes studying the effect of vapor flow angle on the output of third stage blade of low pressure steam turbine / steam turbine in Jandar- Homs- Syria/, for analyzing and understanding the effect of this angle on isentropic output of third stage and determining the optimal angle using computationalFluid Dynamics (CFD) and the program of ANSYS Fluent.*
As a result of research, the optimal angle of vapor flow is determined at value (19°) as per the studied situation. This angle is advised to directing the fixed blade (Nozzle) in order to access favor into blade nearly tangentially.
KEY WORDS: *Optimal attack angle - steam turbine blade – low pressure stage.*

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I. INTRODUCTION

Low pressure turbine in Jandar station in Syria is considered an important portion 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. Notably, Jandar Station's archive and its diagrams have no design information concerning the angle of vapor flow into blade, therefore, it is necessary todetermine the field of studied attack angles and the value of optimal attack angle since it supports in identifying and determining one of the important Parameters effect the operation of station and the isentropic output of third stage.

II. IMPORTANCE OF RESEARCH AND ITS PURPOSES

The attack angle is considered one of the important Parameters that effect the isentropic output of third stage. The effect of attack angle is determined through occurring vapor flow tangentially in order to make use of utmost steam power and highest isentropic output of third stage.

Thus, the altering value range of optimum attack angle on third stage blade of low pressure turbine in Jandar Station has been studied using computerized programs such as (CAD) and computerized fluid science programs such as (CFD), for the reason that these tools are forceful and they help the researchers in analyzing and understanding problems appeared during exploitation during this stage and do a full description.

III. METHODS OF RESEARCH AND ITS MATERIALS

III. I: Actual blade simulation of moving turbine aided with reverse engineering

In this stage of research, it is counted on reverse engineering for building three-dimensional modeling computer of third stage blade of low pressure steam turbine at which it’s obtained a true actual model of third stage blade defined in Jandar station but it is of unknown specification. So, there is no choice in using reverse engineering to determine dimensions and specifications for computerized modeling blade as a first stage in research in order to start the test procedures.

Figure. 1. shows the actual blade and computerized modeling aided by Inventor, modeling illustrates all designed dimensions of blade [8] [2].

The table below illustrates the main dimensions of moving blade (fixed sector blade):

224.1 [mm]	Blade height
182 [mm]	Rotator part height
42.1 [mm]	Root height
34.3 [mm]	Root wide

III. II: Profile's classification for third stage blade of low pressure in Jandar Station

After defining the dimension of fixed and moving third stage blade which has been modeled using reverse engineering and Autodesk Inventor Professional program, Figure (2) and Figure (3), approaching dimensions of modelling blade with Atlas Russian blades to determining its sector [3], then arriving to compatible sector blade, which is sector No. C-9013II P, Figure (4). They are blades type of (Parsons); fixed blades, movable, identical, and they have input rectangular angles and output sharp angles [7].

Figure.3. displays profile of fixed bladeFigure.2.displays profile of movable blade

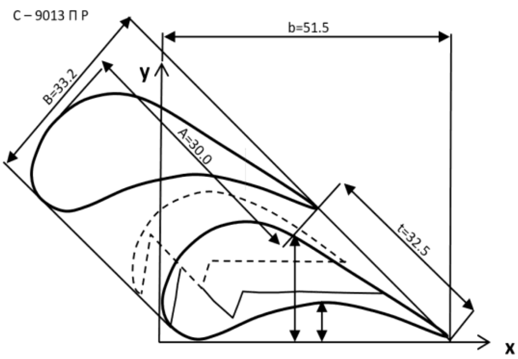

Figure. 4. displays profile of similar blade of fixed and movable of third stage due to Atlas Russian blades [3].

Parsons blades are reaction blades equal to 0.5, which are the most common reactive blades. the main feature of this type of turbines are on the contrarily of action turbines where the low pressure in each stage is lesser, the blades smaller, number of stages increase, on the other hand, reactive turbines are more efficiency [7].

III. III: Thermodynamic Study for the third Stage of Low Pressure Turbine in Jandar Station

Low pressure turbine in Jandar station is a reactive turbine constituted of 12 stages distributed into two streams and each steam contains 6 stages [1].

Before starting to calculate Parameters of third stage, we define pressure value and temperature of inlet for third stage of low pressure turbine in Jandar station; namely:

T=109 °C,P= 1.4 bar [1]

The other inlet parameters values of stage from the thermodynamic tables, as follows: [6]

h= 2616.4 kJ/kg, s = 7.05 kJ/kg.k,ν = 1.21 m³/ kg

ρ= 0,826 kg/m³, x= 0.967.

X	ρ kg/m³	h kJ/kg	S kJ/kg.k	ν m³/ kg	*Symbol*
Dry vapor point	Vapor density	Vapor Intalbi	Vapor Introbi	Vapor specific volume	Name

It was obtained a movable blade of third stage – ongoing study – from Jandar station, and we did reverse Engineering [2], the length of movable blade is defined (182 mm), depending on that, vapor specific volume is defined at third stage outlet, as:

ν = 1.21 m³/ kg[4]

When obtaining the outlet vapor specific volume, we define the other parameters of third stage: [6]

h= 2660 kJ/kg , s= 7.05 kJ/kg.k, T= 90 °C

ρ= 0.423 kg/m³ , x= 0.935 , P = 0.7 bar

FORMING SPEED TRIANGLES

The peripheral speed is calculated at speed rotation turbine:

198 m/sec It is Value: n = 3000 r.p.m[1]

Table /2/ shows values of speed triangles of inlet & outlet: [4]

V_1 m/sec	V_2 m/sec	W_1 m/sec	W_2 m/sec	α_1	α_2	β_1	β_2
203.2	45.7	45.7	203.2	13°	90°	90°	13°

Figure. 5. illustrates Parsons Blade, in addition to speed triangles of inlet & outlet:

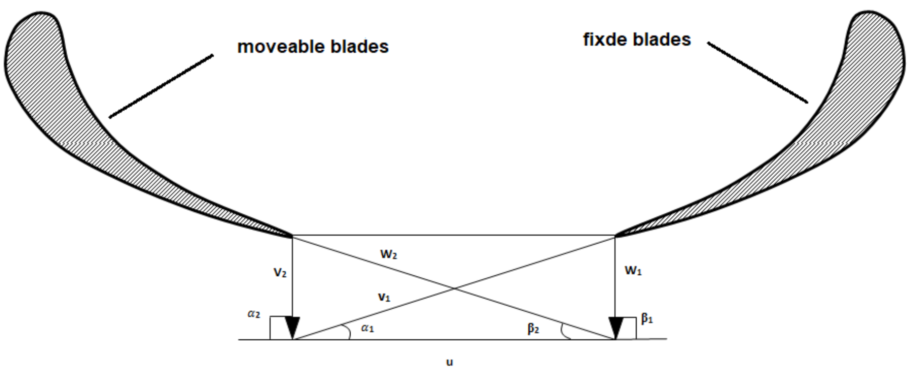

Figure. 5. Parsons Blade, illustrates speed triangles of inlet & outlet analogously [7].

At the end of Thermodynamic study, the required inlet and outletboundary conditions of third stage are determined for starting study and analysis using Ansys CFD program.

Values of inlet and outlet boundary conditions of third stage:

outlet Boundary conditions	inlet Boundary conditions
Pressure 7000 Pa	velocity 203.2 m/sec

Based on what mentioned above, it should study flow around blade profile, defining the turbulent areas, ANSYS analyzing, and determining the optimum attack angle of vapor entering blade tangentially. Previous information determines the Boundary Condition for inlet and outlet third stage, whereas the calculation method used later for CFD was k-epsilon standard.
However, all available calculation methods are chosen after test in ANSYS [5].

IV. RESULTS & DISCUSSION

IV. I:Determination the field of studied attack angle:
At the beginning, a simple step performed starting a test of small attack angles, and then gradually increased till we get the highest value of outcome. When the value of outcome decreased, then the turning point is defined at the diagram at the highest outcome value and optimum angle. In this study, the field of attack angles is [0-40].
IV.II: Steps of Flow Simulation Process in program ANSYS 18.1:
Two-dimensional study is carried out for a blade sector using ANSYS 18.1.
All steps of simulation procedures fixed**,** besides altering the value of attack angle only within Boundary Condition for each studied angle.

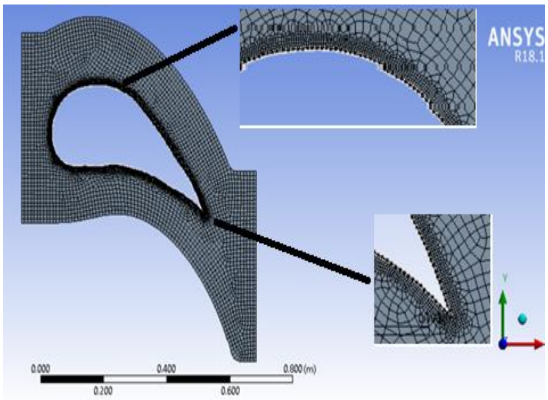

Figure. 6. shows blade in the supposed air tunnel.

The steps of simulation are as the following:
IV. II. I: Geometry: The blade file of third stage is two-dimensional design using Autodesk Inventor Professional 2019, then sending this file to simulation program ANSYS, in order to study flow around the blade.

IV. II. II: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 mesh is $1*10^{-2}$ m and smallest size is $1.6533*10^{-4}$ m.

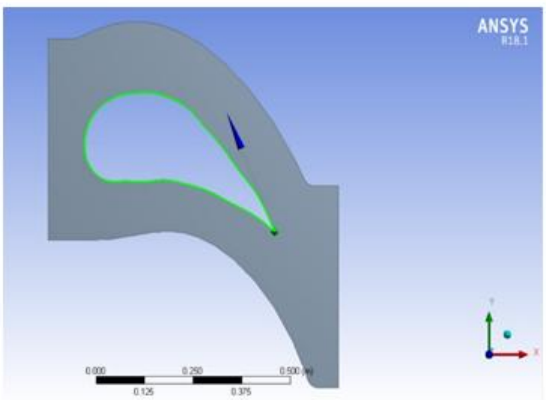

Figure. 7. shows the accuracy of mesh.

The Mesh achieved a good accuracy with fair number of nodes 6691 and elements 6052.

IV. II. III: Setups:
Insert the Boundary Condition
Inlet conditions: velocity at tunnel inlet V=203 m/sec.
Outlet conditions: pressure at tunnel outlet P=7000Pa.

IV. II. IV: Results:
The theoretical Isentropic outcome value of third stage: [4]

During the result analyzing, it is concentrated on dropping pressure and velocity for each value of attack angle.

Table /3/ shows values of pressure and velocity for each angle of attack angles.

Values of attack angles	Inlet pressure Pa(1)	Outlet pressure Pa(2)	Dropping pressure Pa	Inlet velocity m/sec(1)	Outlet velocity m/sec(2)	Dropping velocity m/sec
0°	55630.8	19682.9	35947.9	38.226	10.718	27.508
5°	58135.2	20307.1	37828.1	29.779	10.972	18.807
10°	59772.1	20643.4	39128.7	21.731	11.471	10.26
13°	60399.5	20773.1	39626.4	18.000	11.212	6.788
15°	60642.3	20810.7	39831.6	16.073	11.236	4.837
18°	60756.1	20797.4	39958.7	14.073	11.247	2.826
19°	60761.8	20773.1	40024.2	13. 858	11.244	2.614
20°	60653.4	20737.6	39915.8	13.812	11.236	2.576
25°	59777.5	20441	39336.5	16.396	11.144	5.252
27°	59196.4	20261.6	38934.8	18.209	11.084	7.125
30°	58120.2	19945.5	38174.7	21.532	10.969	10.563
33°	56666.8	19531.4	37135.4	26.209	10.813	15.396
35°	55779.1	19285	36494.1	28.779	10.716	18.063
37°	54345.1	18888.7	35456.4	32.372	10.559	21.813
40°	52386.5	18358.9	34027.6	37.057	10.337	26.72

Table /4/ shows the relation between values of attack angles and isentropic actual outcome for third stage.

values of attack angles	Actual pressure dropping (pa)	Theoretical pressure dropping	isentropic actual outcome
0°	35947.9	Theoretical total Antelopicdropping pressure of third stage, equal: $45.6*10^3$ kJ/Kg[4] $\Delta h = \Delta(u + p.v)$ Altering internal energy is fixed, vapor flow is fixed, so the Antelopic dropping is equal to pressure dropping.	78.8 %
5°	37828.1		82.9 %
10°	39128.7		85.8 %
13°	39626.4		86.9 %
15°	39831.6		87.35 %
18°	39958.7		87.62 %
19°	40024.2		87.77 %
20°	39915.8		87.53 %
25°	39336.5		86.26 %
27°	38934.8		85.3 %
30°	38174.7		83.7 %
33°	37135.4		81.4 %
35°	36494.1		80 %
37°	35456.4		77.7 %
40°	34027.6		74.6 %

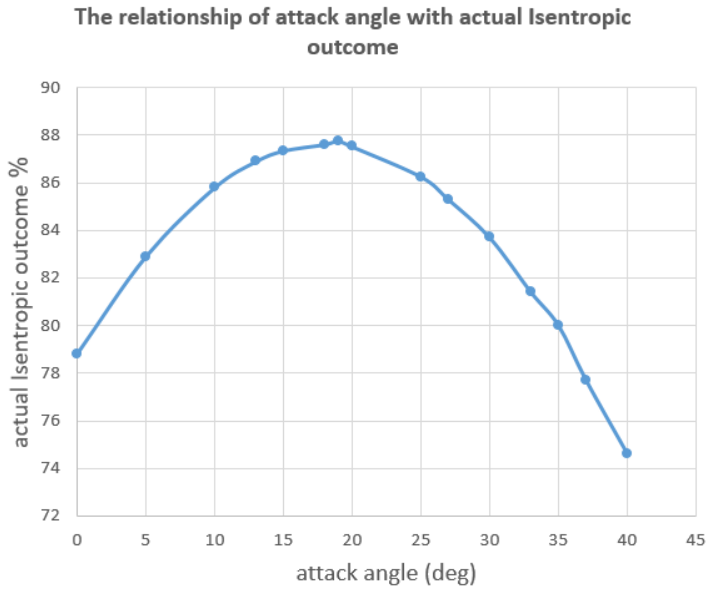

Figure. 8. shows the relationship of attack angle with actual Isentropic outcome.

Figure. 8. shows the relation between isentropic actual outcome and taking into consideration that the highest isentropic actual outcome for third stage that obtained at attack angle 19° is 87.77%, then isentropic outcome started dropping.

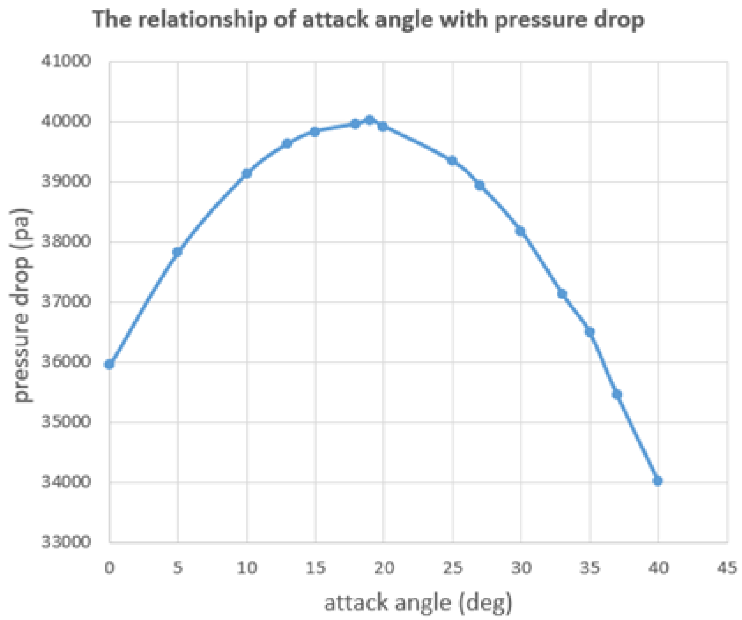

Figure. 9. shows the relation between attack angle with pressure drop.

It is noticed that the highest value of pressure is at center of front blade as a result of vapor collision directly at front blade. Also, the lowest value of velocity at center of front blade, besides to observe gradation of velocity values at interior and back of blade.

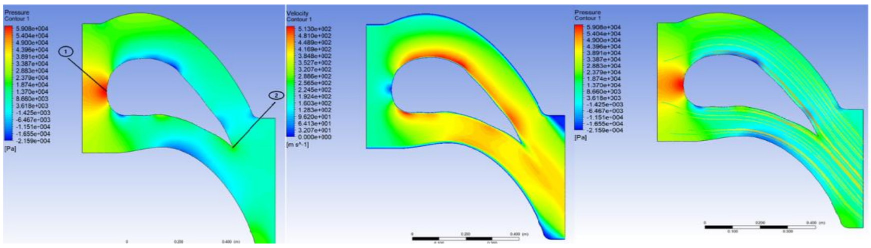

Figure. 10. shows the distribution of pressure and velocity around the blade of third stage at attack angle 19°.

V. CONCLUSIONS & RECOMMENDATIONS

V. I:Conclusions:

The result of study displayed that the Optimum Attack Angle is 19°then the value of velocity dropping is the minimum, whereas the value of pressure dropping is the maximal. Therefore, isentropic outcome of third stage will be maximal, the value is: 87.77 %.

At the end of research, it is recommended to change the attack angle to correspond the Optimum Attack Angle, equal to19°.In addition to fixing the blade figure illustrated in design.

V. II: Recommendations:

Starting to change the blade profile to obtain optimum profile, (the aim of changing profile is elongation of tangency flow, and to make flow disturbed before the end of blade profile). Whereat, the optimum profile has landscape sector and gives the highest isentropic outcome of third stage.

Study the blade three-dimensionally, studying the blade twist, and decrement the landscape sector between basis and top.

REFERENCES

[1]. ABDULDAEIM. A, 2009 – Estimation and improving performance of combined cycle (STAG) in Jandarpower plant. Syria, 141.
[2]. KAFA. S, BAKIR. M, MANDOW. A, Reverse Engineering Of A Jandar Steam Turbine Rotor Blade By Computer, 2018, Vol. 40.
[3]. MILEWSKI. J, Blade profiles. Russia, 1989.
[4]. KAFA. S, BAKIR. M, MANDOW. A, Determination of the actual tromodynamic Parameters effecting the third stage of the low-pressure turbine at the Jandar station in Homs city,2019 Vol. 41.
[5]. KAFA. S, BAKIR. M, MANDOW. A, Aerodynamic analysis of the third stage blade for low-pressure turbine at the Jandar station with the help of ANSYS Fluent and selection of the optimal calculation method. 2019 Vol. 41
[6]. BAKER. M, 1999 – Thermodynamic Engineering. Directorate of books and university publication. Syria, 482.
[7]. YAKHOUR. Y, BATAL. M, 2014 - Steam turbine. Syria, 710.
[8]. Turner, M. G., Bruna, D., and Merchant, A., 2007. “Applications of a turbomachinery design tool for compressors and turbines”. AIAA Paper Number 2007-5152.

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Akl Jihad Mandow. "Determination of the Optimum Vapor Attack Angle on the Third Stage Blade of the Low Pressure Steam Turbine and Studying its Effect on the Output with Computer."*American Journal of Engineering Research (AJER)*, vol. 9(05), 2020, pp. 10-17.