

Numerical Study of Slip Factor in Centrifugal Pumps and Study Factors Affecting its Performance

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Abstract—Slip phenomenon is very important factor by it we can know the actual amount of energy transferred to fluid. In this study i test the different parameters which may affect on this phenomenon such as discharge, exit flow angle, number of blades, type of fluid. i found the old Busemann, Stodola, Stanitz, Wiesner, Eck and SRE is correct in some cases only because these relations don't study all factors affected on slip factor. Also the trend of the slip factor in new study such as in X. Qiu there are case which upward trend and others downward trend thus I focus on this phenomenon in this paper.

Keywords-component; Pumps; CFD; Impellers; fluid mechanics

I. INTRODUCTION

Slip phenomenon is very important phenomenon in radial impeller and not important in axial impeller because it's very small in axial machines. Thus we study it on the radial impeller . which is affected on the energy transfer between impeller and the fluid thus we should know this phenomenon at every point and study the factors effected on it I will study the important factor in this papersuchasdischarge ,exit blade angle (blade difference angle, number of blades).There are many models predict the slip factor in centrifugal pump such as X. Qiu [1], Wiesner [3]T. W. von Backström [3],stodla [7], , , M. Memardefzouli [4] , in the majority of this models study the effect of geometry of impeller only but in this study we notice the slip factor depend on geometry and flow characteristics but in the first I will show what is the slip phenomenon in some radial machines such as Pumps, Compressors, etc the actual amount of energy transfer to the fluid is less than the theoretical one .The blades do not guide the flow completely and fluid deviation occurs at exit of impeller and hence the liquid is discharged from the impeller at a mean relative angle β_2 less than the blade exit angle β_2' .Which results in less C_{u2} than the C_{u2}' as show in "FIG. 1" And hence affect the output head

$$H \text{ or } H_m = \eta_h \cdot \frac{C_{u2} U_2}{g} = \eta_h \cdot \sigma \cdot \frac{C_{u2}' U_2}{g}$$

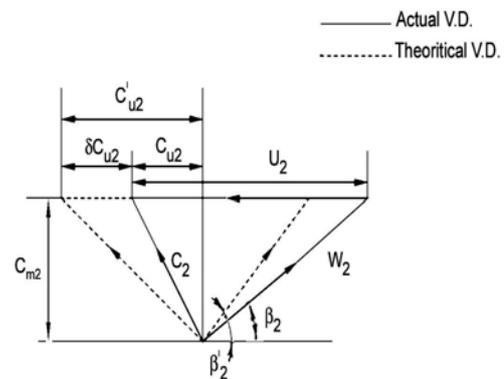


Figure 1 Actual and theoretical velocity triangles

In this study CFD package which is in the last years get high accurate results compared it to Experimental or analatical data thus we can depend on this tool to save more of time and money but take care in the boundary condition and turbulence model and mesh type and number maintaining the integrity of the Specifications

II. GEOMETRY & MESHEING OF THE CENTRIFUGAL PUMP

The considered centrifugal pump has five blades with relative inlet blade angle equal 33 degree and relative exit blade angle equal 30 and wrap angle equal 90 degree and mean inlet diameter equal 67.31 mm ,and exit impeller diameter and exit blade width equal 243.84 , 4.445 mm respectively in this model I change the number of blades to random values such as (6,7,10,12) and stop to the value which won't make blockage the flow and change the relative exit blade angle to 60 degree above the value 30 degree to change the value of the blade turning rate and the impeller rotate with speed 1400 rpm and pumping water in may model I used ANSYS -Turbogridto make mesh and I make structure mesh which have The geometry, leading to structured mesh with following advantages

- 1 Take lowest amount of memory for given mesh size.
- 2 Faster for solving the problems and more accurate
- 3 Post processing of the results much easier task because the logical grid planes.

Table 1 THE VALUES OF NODES AND ELEMENTS AT DIFFERENT NUMBER OF BLADES AND EXIT BLADE ANGLES EQUAL 60

Z	Number of Nodes	Elements	CPU time/point minute: second
5	21091	17088	5:24
6	21462	17424	5:41
7	22575	18360	5:34
10	18425	13980	5:10
12	19605	14920	3: 52

In Table 1 we show the number nodes and elements and CPU time the problem is to show the slip factor at different flow rates thus I solve the problem many times at different H&Q points for thus I calculate CPU time per point at processor core due T2350 @1.86 GHz

In “Fig. 2” we show the structured mesh in pump impellers and three cross section at LE, TE and around blade.

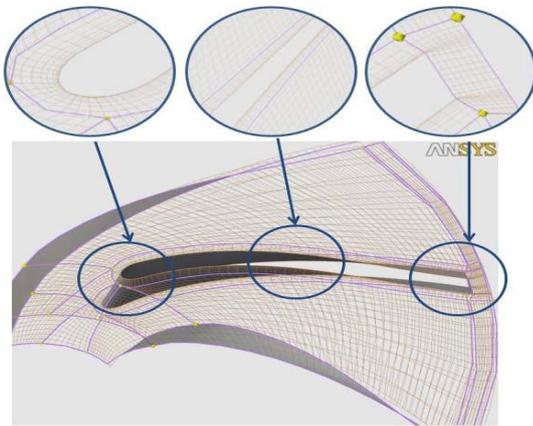


Figure 2 General view of mesh in centrifugal pump impeller used for flow analysis

III. TURBULENCE MODEL:

I take in solving this problem in the ANSYS(CFX) and use turbulence model Shear Stress Transport (SST)[6] which is proper for flow separation under adverse pressure gradients by the inclusion of transport effects into the formulation of the eddy-viscosity. This results in a major improvement in terms of flow separation predictions These features make this model more accurate and reliable for a wider class of flows (e.g. adverse pressure gradient flow, airfoils, transonic shockwaves).and solving with error smaller than (1*e-5 seconds).

IV. RESULTS

A. Effect of number of blades:

There is a problem in the most slip factors equation which depend on the geometry only and get slip factor at best efficiency point thus I will compare my CFD slip model with this models and with various flow rates. slip model is equal to is the ratio between actual and theoretical tangential velocities at outlet from impeller . we can calculate the theoretical tangential velocity

$$C_{u2}' = U2 - \frac{Q}{\Pi * D2 * b2 * \tan \beta 2} \quad \text{And} \quad \sigma = \frac{Cu}{C_{u2}'},$$

we show in this “Fig. 1” with increasing number of blades the slip factor increase (i.e. increase the energy transfer to the fluid)but there are many problems with increasing the number of blades blockage area increase with decrease the capacity of the impeller .we show in “Fig. 2”scatter points at BEP at different number of blades and interpolate between points and may be like linear equation between of the number of blades and the slip factor thus we can expect roughly the slip factor for the certain number of blades.

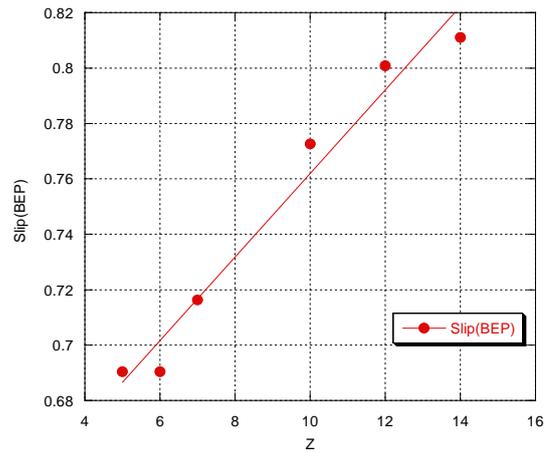


Figure 3Slip factor at different number of blades at design exit angle

But there is a big mistake in “Fig.3”because most of the pumps not work only on its best efficiency point but also work on different H&Q Points thus we must show the effect of different discharge the effect of this in “Fig.4” at the design exit blade angle. Which show different methods of calculation slip factor [3],[3],[7] .In this study I used CFD to calculate slip factor at different flow rates and make curve fit between them to show the general trend and compare this trend with the other relations trends.

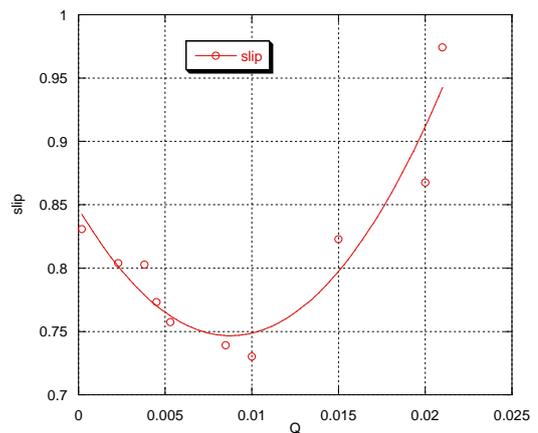


Figure 4Effect of flow rate on the slip factor

B. Effect of exit flow angle:

I take into consideration the effect of exit and inlet angle thus I take value above and below the inlet angle 30 and 60 respectively in “Fig.5” in this figure I change the number of blades and flow rate and exit flow angle and look at the effect on the slip factor but the number of blades of impeller is limited (in order not to block the flow), the blades do not guide the flow completely the scatter points geted from CFD and curve fit between points and noticed Upward trends of slip factor with increase of flow rate and no model predict this trend the only one who showed Qiu , jaspikse[1] also confirmed this trend in one of there models . but this occurs when($d\beta < 0$) .but at “Fig. 6” where ($d\beta > 0$) when the exit blade angle equal 60 degree the slip factor decrease with increase the flow rate . The second conclusion of two figures in the “Fig. 5” The upward change of slip factor approach to polynomial and “Fig.6” the downward of the slip factor is approach to linear equation.

There are many reasons which cause this phenomenon in “Fig. 7”and “Fig. 8”Which represent the flow between two parallel plates in case of BEP. We see that by increasing the number of blades the separation increase in the passage between the two blades.

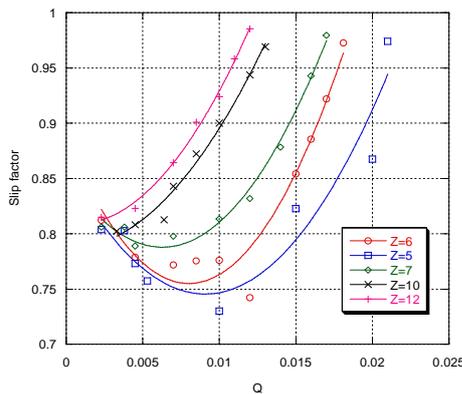


Figure 5 Effect of exit blade angle on slip factor

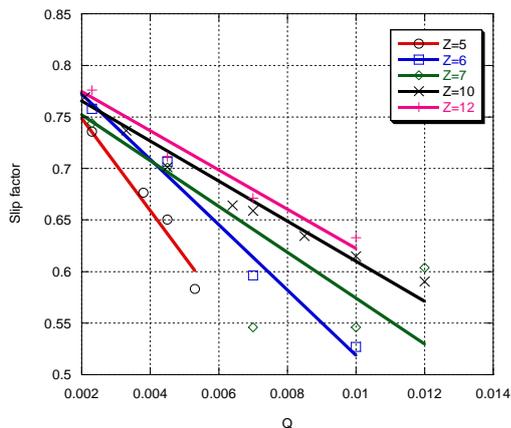


Figure 6 Effect of exit blade angle on slip fact

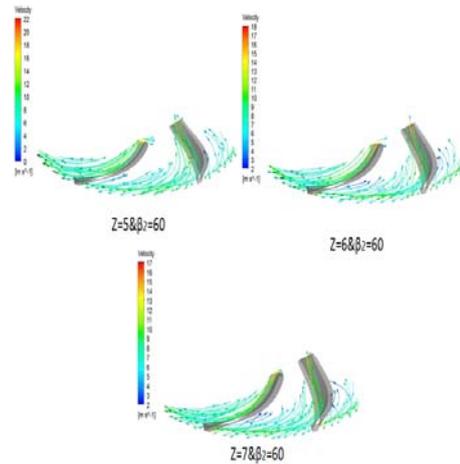


Figure 7 The separation in the different number of blades at exit blade angle 60 degree

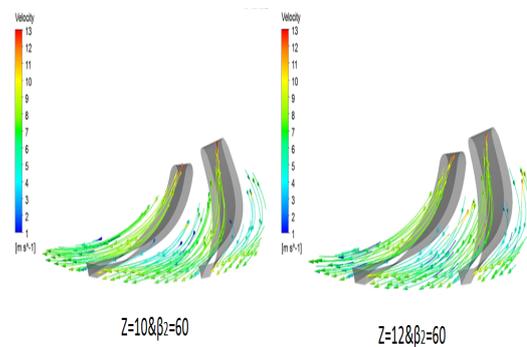


Figure 8 The separation in the different number of blades at exit blade angle 60 degree

And also we notice that the seperation increase in case of the 60 degree than in the 30 degree.

V. VALIDATION AND SUMMERY

In this study I use ANSYS-CFX 12 and compare my results to the analytical models [3],[3],[7] and get the results with the same trend at BEP in “Fig. 9”

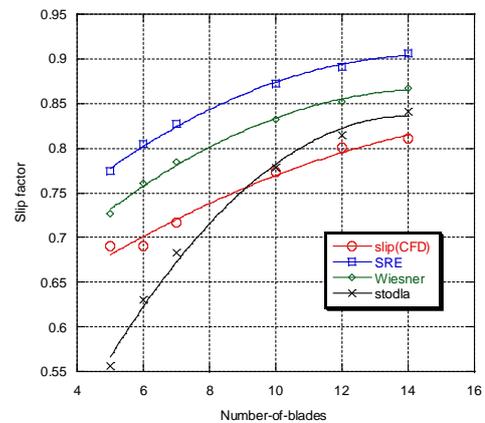


Figure 9 validation of CFD slip & Different model at BEP

VI. CONCLUSION

There are many factors that affect the value of slip factor but the most important are exit blade angle ($d\beta$) which effect on the trend i.e(upward or downward) of the slip factor and the condition of operation of the impeller. i also recommended the new graph should be added to define the impeller behavior like H-Q Curve and efficiency-Q curve is slip factor– Q curve which shows the effect of operation on the energy transfer to the fluid.

Nomenclature

σ Slip factor coefficient

C_u Actual tangential absolute velocity ,m/s

C_u' Theoretical tangential absolute velocity, m/s

U Impeller peripheral speed, m/s

D Diameter of the impeller, m

z Number of blades

b Impeller blade width, m

t Blade Thickness of the impeller , m

BEP Best efficiency point for centrifugal pump

η_h Hydraulic efficiency of the pump

LE Leading edge of the blade

TE Trailing edge of the blade

GREEKS

β Relative blade angel, degree

β_2' Relative flow angel, degree

Θ_w wrap angle of the impeller, degree

SUBSCRIPTS

1 At the impeller inlet

2 At the impeller exit

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