# Investigate the Performance and Design Parameter for High Pressure Compressor Flow Track

**Mohsinali batti[1] Vimal Patel[2]**
[1] Research scholar [2] Assistant Professor
[1, 2] S. V. National institute of Technology, Surat, Gujarat, India

*Abstract*—This article deal with conceptual design the flow path and optimization the efficiency power and losses. In this paper concentrate on high pressure axial compressor and further discuss about the different type of flow path design and also investigate the effect on performance parameter and design parameters. Design parameters of gas turbine plant are used from available references. Investigation is done using Axstream software. The flow path design is most important for designer because some characteristic effect by flow path. This article carried out three type of flow path like that constant hub diameter, constant mean diameter and constant tip diameter further, investigate the different of performance parameter and design parameter of all the flow path.

## I. Introduction

For design new compressor lots of afford required lots of people and technology required for testing and analysis. Before the compressor go inside the engine lots of matching need then consider the compressor design reliable for the engine. Actual flow track annular area is computed from the mass flow and continuity apply to the local flow through the stage. In this paper discuss about preliminary flow path design and investigate the effect on efficiency, mass flow rate and power. Turbomachinery design and optimization suite gave the designer a possibility to use different tools to solve flow path design and analysis tasks. Optimization tasks formulations are very flexible. Software service functions provide convenient interface with data project, strong reliability and quick response during the design process.

## II. Nomenclature

- psi_= averaged work coefficient
- phi_= averaged flow coefficient
- eff_tt_= Total to total efficiency
- N = Power
- H = Heat loss
- Om=total pressure loss coefficient
- Deqx= equivalent diffusion factor
- R= degree of reaction
- AC = Axial compressor
- Gout = Outlet mass flow rate
- Ps = Static pressure
- Pt= total pressure
- eff_pt_ = Polytrophic efficiency
- c = Absolute velocity
- w= Relative velocity
- u= Blade velocity
- A=Flow angle
- B=Blade angle
- K1=blade inlet metal angle
- K2=blade outlet metal angle
- Rt – tip reaction
- Rh – hub reaction,
- MC1 – Nozzle outlet absolute velocity Mach number.
- R – Mean reaction
- MW2 –Blade outlet relative velocity Mach number

## III. Boundary Condition

Initially preliminary design specification and conceptual lay out used for Preliminary. Preliminary design specification includes, i. Inlet and outlet boundary conditions like inlet pressure, temperature, pressure ratio etc. ii. Conceptual design and sizing layout i.e. quantity of modules (group of stages) inside compressor, number of stages in each group, work coefficient For present analysis following boundary conditions are used, assuming working fluid as ideal gas.

Table. 1: Boundary condition

| Sr. No. | Input parameter | Value |
|---|---|---|
| 1 | Inlet total pressure | 101.3kPa |
| 2 | Inlet total temperature | 15 *C |
| 3 | Total Outlet pressure | 1500kPa |
| 4 | Mass flow rate | 20kg/s |
| 5 | IGV exit angle | 70deg |
| 6 | Rotational speed | 11833rpm |

Using above parameter, blade shapes are finalized; using that shape investigation is carried out to understand how the inter cooler related to performance of compressor.

| Sr. No. | Output parameters |
|---|---|
| 1 | Volume flow rate at outlet 2.7m^3/s |
| 2 | Specific flow rate 0.0033 |
| 3 | Average work coefficient 0.3153 |
| 4 | Average flow coefficient 0.5554 |
| 5 | Heat drop -391031J/kg |
| 6 | Total blade mass 4.2134kg |
| 7 | Specific speed 0.1474 |
| 8 | Flow change coefficient 0.9757 |
| 9 | Max rotor equivalent diffusion factor 1.6 |
| 10 | Max stator equivalent diffusion factor 1.73 |
| 11 | Number of stage 12 |
| 12 | Diffusion factor by de haller 0.7881 |
| 13 | Minimum reaction 0.6411 |
| 14 | Maximum reaction 0.6631 |

## IV. Design Procedure

First design the compressor flow track constant hub diameter and create the graph of design parameter like degree of reaction losses, flow coefficient, work coefficient and Mach number. In second stage create second design module which is constant mean diameter type compressor and also present all the graph and compare with previous design. The last portion design the final design which is constant tip diameter type compressor and also compare with both the design.

## V. DESIGN

First design the preliminary design after selecting best one solution which is best match with requirement. After the preliminary design start to post design also design flow path. The flow path important for compressor because some parameter change with all the stages like pressure, Mach number and losses. The flow path also important for analysis for pressure, Mach number, enthalpy, entropy, temperature etc.

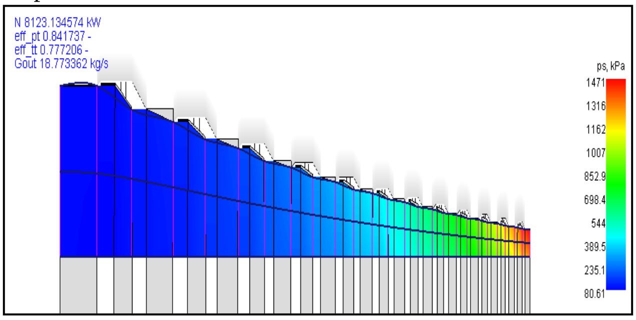


Fig. 1: flow path constant hub diameter

After the flow path design the other parameter also important for designer like that loss, degree of reaction and power use in each stage. In the first figure plot all type of losses for each stage. Show the figure in starting stage losses high due to fluctuation of inlet fluid and higher abstract ratio also degree of reaction higher and load also higher. The losses decrease second and third stage but after some stage losses increase because the temperature rise due to losses.

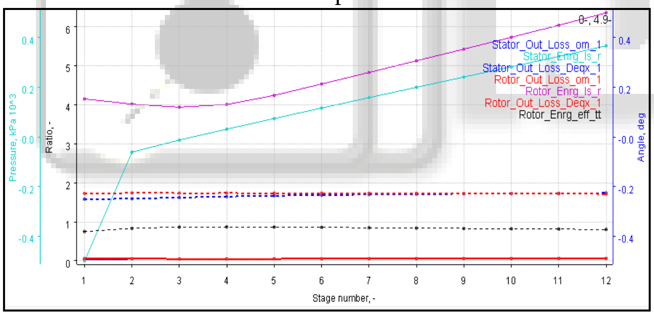


Fig. 2: Losses

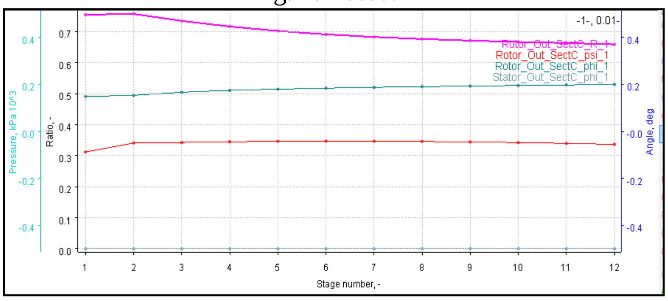


Fig. 3: Degree of reaction, flow and work coefficient

The degree of reaction in first stage is maximum after the first stage degree of reaction gradually decrease because in first stage load is higher compare to other stages. Also flow coefficient and work coefficient plot in diagram.

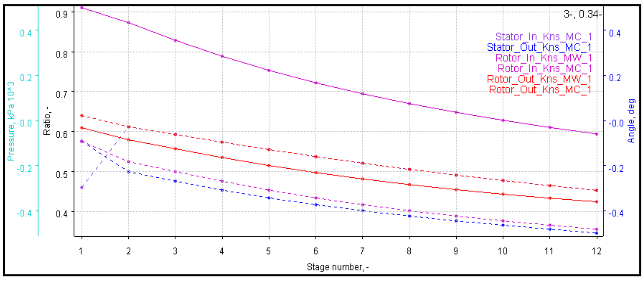


Fig. 4: Mach number

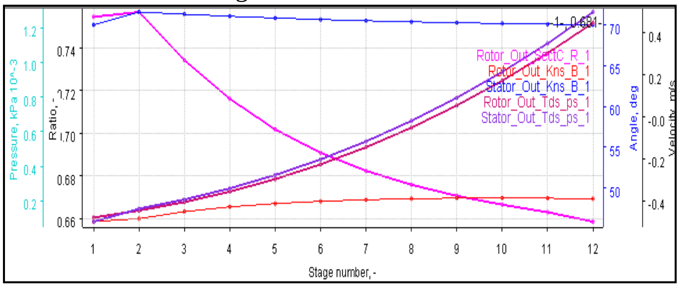


Fig. 5: entropy

Show the forth diagram the Mach number at inlet higher high value after the first stage Mach number value decrease. The first to last stage the Mach number value can't reached higher than one which is better for compressor design.

Now modified the design with change of flow path geometry with taken constant mean diameter for all the stages in compressor. The blade hub and tip side diameter change equally. The tip side and hub side almost mirror to each other but in modern engineering that is not mirror design the hub side curvature slightly less than tip side in mean position because of smooth flow.

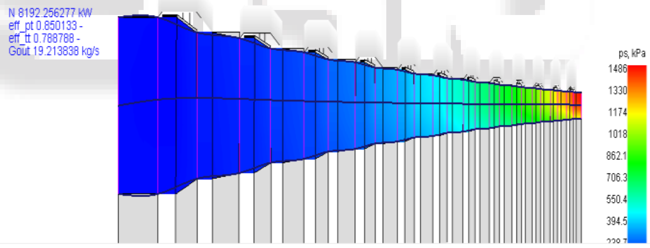


Fig. 7: Flow path constant mean diameter

Now discuss about varies parameter which are effected by modified design. Some important parameter like losses, degree of reaction, Mach number and flow coefficient. Show the losses graph in first stage losses low compare to previous design and in this design losses gradually increase. Compare to previous the degree of reaction at starting stage lower and ending stage are higher that mean the load in last stage higher compare to previous design.

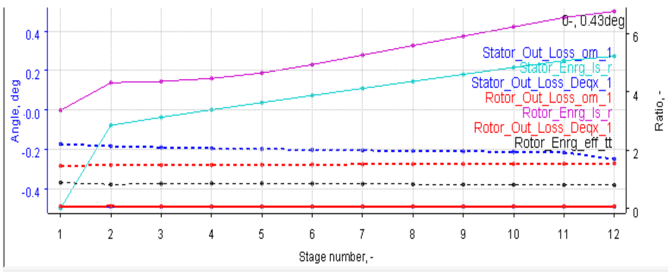


Fig. 8: Losses

 

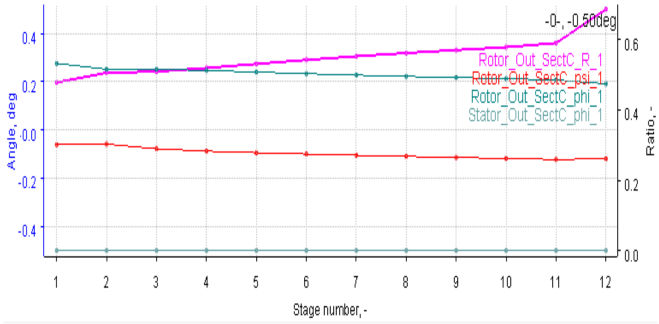


Fig. 9: Degree of reaction and flow coefficient

Compare to previous the degree of reaction at starting stage lower and ending stage are higher that mean the load in last stage higher compare to previous design. The Mach number and enthalpy-entropy influence in both the stage all most same but value different in different stage.

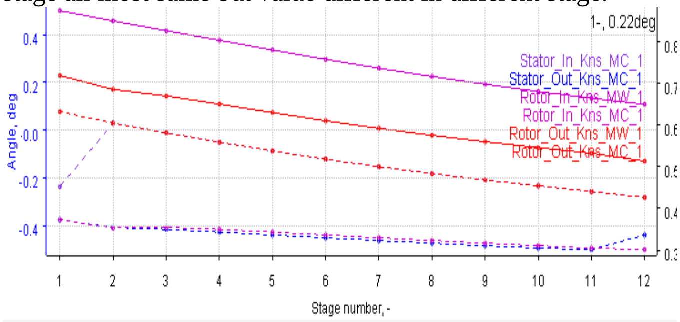


Fig. 10: Mach number

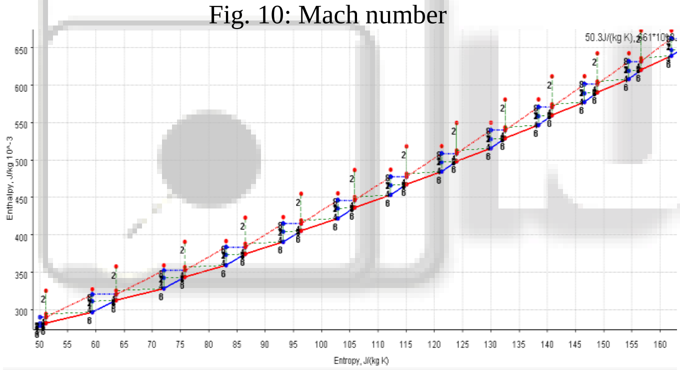


Fig. 11: entropy-enthalpy diagram

Now discuss about the last design module this module design based on tip diameter constant. In that type of compressor module efficiency low compare to hub diameter constant because in end stage blade become very small so some energy loss due to aerodynamic losses.

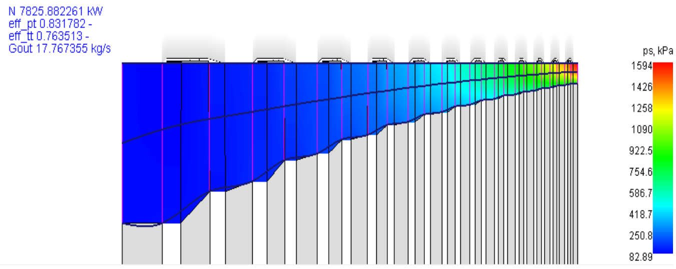


Fig. 12: Flow path constant tip diameter

The degree of reaction much difficult to design that type of compressor. show the diagram in second stage degree of reaction is law compare to first stage after the second stage degree of reaction gradually increase up to eleventh stage. The last stage degree of reaction much higher compare to other stage.

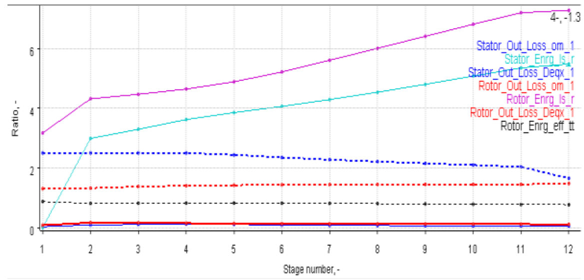


Fig. 13: Losses

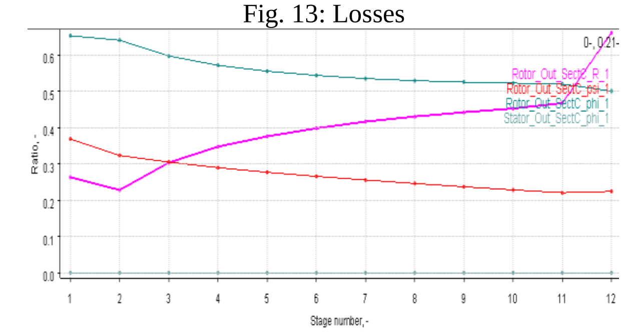


Fig. 14: Degree of reaction, flow coefficient and work coefficient

Now discuss about the Mach number. In starting stage Mach number value higher compare to last stage after the first stage value decrease but some variation create due to phenum. Small amount of Mach number value increase but that value acceptable for compressor no higher losses occur due to that much Mach number.

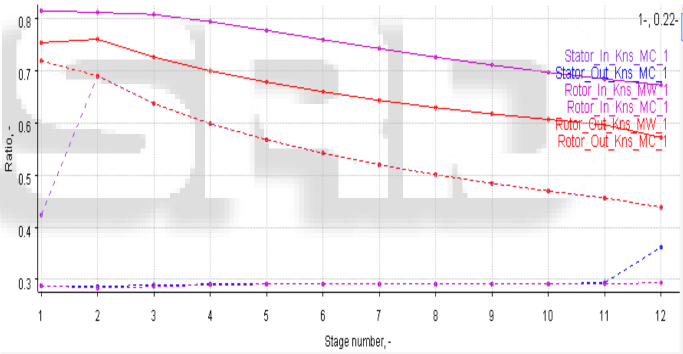


Fig. 15: Mach number

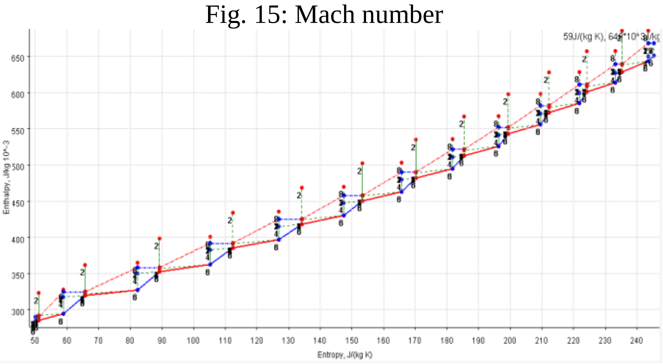


Fig. 16: Entropy-enthalpy diagram

For Mach number decrement is less compare to other design and show the h-s diagram the value of each stage are different compare to other stage

In all the design use same boundary condition and now discuss about the different of the all the compressor parameters. The power, outlet pressure and efficiency most important parameters so focus on this two parameters. Each design has their oven specification so all the important parameter put in single table for better comparison.

Table. 2: Comparison between performances of both the compressors.

| Parameter | Hub diameter constant flow path | Mean diameter constant flow path | Tip diameter constant flow path |
|---|---|---|---|
| **Power [kW]** | 8123.13 | 8192.25 | 7825.88 |
| **Total to total Efficiency [%]** | 84.17 | 85.01 | 83.17 |
| **Pleotropic efficiency [%]** | 77.72 | 78.87 | 76.35 |
| **Pressure outlet [KPa]** | 1471 | 1486 | 1594 |

## VI. Conclusion

Present investigation indicates the effect the flow path on power requirement, efficiency and heat loss of compressor also investigate effect on design parameter for same boundary condition. Following conclusions can be derived after analysis in Axstream software. Each design have their specification so based on over requirement select the best flow path. Also with help of this paper understand the compressor design parameter.

## Reference

[1] A.V. Boiko, Yu.N.Govorushchenko, S.V. Yershov, A.V. Rusanov and S.D. Severin. "Aerodynamic Computation and Optimal Projection of Turbomachine Flow Paths." - Kharkov, NTU "KhPI" 2002. - 356 pp. (in Russian)

[2] Miller, M. J., Durschmidt, D. F., Medlock, A. and Sandel, W. A. "An Integrated Design System for Fans, Compressors, and Turbines: Part I: Overview", Proceedings of Turbo Expo 2004. June 14-17, Vienna, Austria.

[3] Moroz L., Govorushchenko Y., Pagur P., 2006, A Uniform Approach to Conceptual Design of Axial Turbine/Compressor Flow Path, Future of Gas Turbine Technology, 3rd International Conference, Brussels, Belgium

[4] Zienkiewicz O.C, and Taylor R.L. "The Finite Element Method". 4-th ed., McGraw-Hill, London, UK, 1991.

[5] H. S. WANG, J. J. ZHONG and Z. Q. Wang, "Numerical Investigation of Secondary Flows in a Compressor Cascade with positively leaned Blades," Journal of Engineering for Thermal Energy & Power, Vol. 17,No.4, pp. 375-378, 2002

[6] Gutzwiller, D.P., M. Turner, M. Downing. 2009. "Educational Software for Blade and Disk Design". Proc. of GT2009, ASME Turbo Expo 2009, Orlando, Florida.

[7] Marineau, E., M. Reggio. 2007. "A Matlab Toolbox for the Intuitive Knowledge of Turbomachinery". Proc. of GT2007, ASME Turbo Expo 2007, Montreal, Canada.

[8] Mund, F., A. Kalfas, R. Abhari. 2002. "Integration of Software into a Multi-disciplinary Undergraduate Student Design Project". Proc. of 2002 American Soc. for Engineering Education Annual Conf., ASEE, Montreal, Quebec.

[9] Turner, M., A. Merchant , D. Bruna. 2006. "A Turbomachinery Design Tool for Teaching Design Concepts for Axial Flow Fans, Compressors, and Turbines". Proc. of GT2006, ASME Turbo Expo 2006, Barcelona, Spain.

[10] Wiggins, E., 2008. "Teaching COGAS Design with Mathcad". Proc. of 2008 American Soc. for Engineering Education Annual Conf., ASEE, June 22-25, 2008. Pittsburgh, Pennsylvania.