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COMPARATIVE STUDY BETWEEN AXIAL FLOW COMPRESSOR AND RADIAL FLOW COMPRESSOR

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Abstract: In this paper, we have made a comparison study between the Radial Flow Compressor (also called as Centrifugal Compressor) and the Axial Flow Compressor. We have made our analysis based on various research articles obtained from various journals uploaded by various authors of this field. We have provided brief description of Radial as well as Axial flow compressor in this paper, followed by a thorough comparison table of both the compressors. We have summarized various articles by authors in a precise manner for better and easy understanding of this topic in detail. A proper Future scope of this study is provided in a brief manner followed by an appropriate conclusion of this topic. This article is intended to provide a clear knowledge of both the types of compressors to the reader in a very precise manner.

Keywords: Radial compressor, Centrifugal Compressor, Axial Flow Compressor, Aviation, Drones.

INTRODUCTION

Ever since turbo charging became part of the mechanical and Aerospatiale engineering, there has been changes through each phase of Turbo charging, depending on the specific requirements for compressors and turbine engines from time to time in the field of turbo machinery. The first invention in the turbo machinery industry was that of radial flow single or two-stage compressors, incorporating backswept vaned shrouded impellers which is below shown as Fig.1. As a result of technological advancement during World War II, the first axial flow compressor, for experimental reasons, a few turbochargers were created employing multi-stage axial flow compressors, as shown in Fig 2. Because it was highly useful during World War II, I've included it below.

Over a decade ago, due to technological development in the field of internal combustion engines which are highly super charged such as Diesel engines, diesel gas and the gas turbine, there was a need to test the high aerodynamic efficiency thereby manufacturing “turbo compressors”.

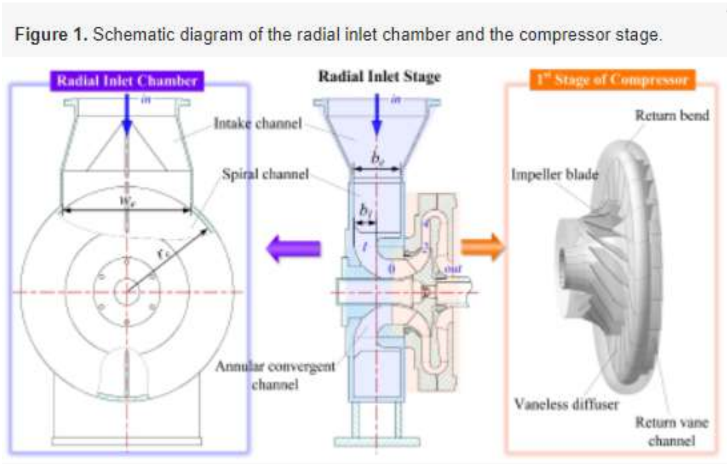
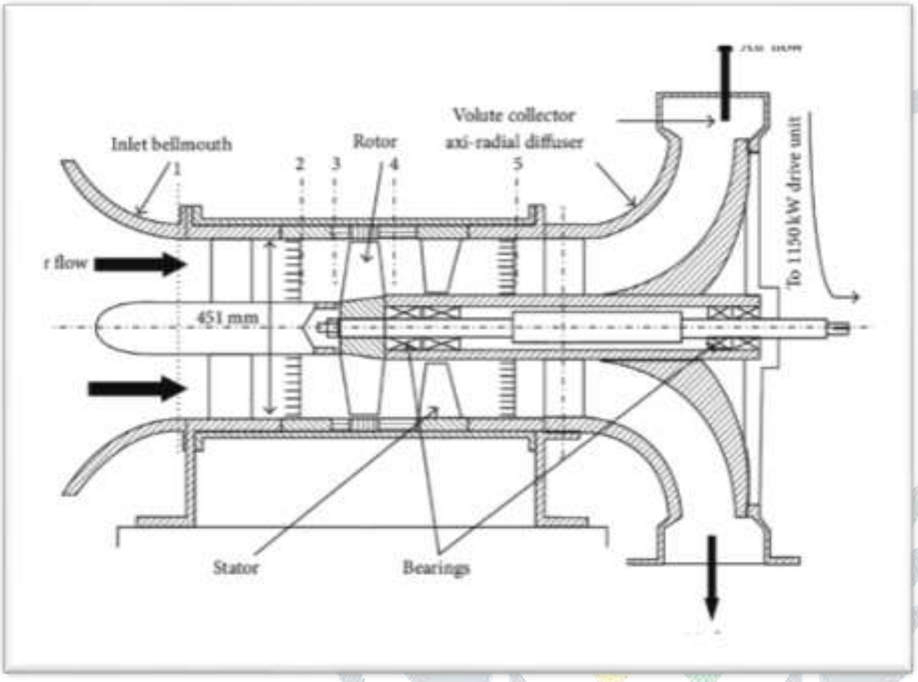


Figure 1: Schematics of Radial flow compressors



The features of compressors depend essentially on the method through which they are being operated.

RADIAL COMPRESSORS

This are the most known compressors, also known AS Centrifugal compressor, with its operating mechanism of compressing either liquids or gases purely dynamically without the use of displacement bodies or pistons of any sort.

The centrifugal machine was first implemented and used in construction and later pump industry before it was finally applied in the compressor systems in engines.

The flow of liquids or gases through this compressor tends to exit in a direction perpendicular to the shaft's axis.

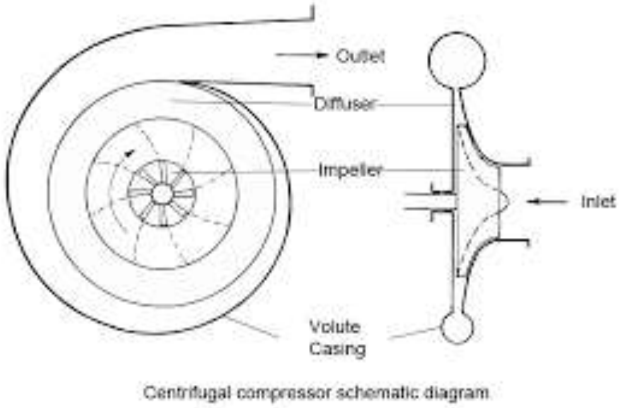


Figure 2: Diagram illustration of Radial compressor

AXIAL COMPRESSORS

Axial compressors are a subset of axonal compressors. The flow enters from the axial side and exits from the radial side of the compressor. The gas turbine is also rotated in an axial direction, parallel to the shaft's axis. Axial flow compresses its fluids by speeding the fluids and so spreading the compressed liquid to increase pressure. Its main application is vivid on the operation of Airfoils since airfoil's mechanism is based on the acceleration and diffusion of air in a compressor, The majority of axial flow compressors are based on research and experiments conducted on isolated airfoils.

The compressor blades are also identical to that of the wings of an aircraft hence more relatable and applicable in the Aerospatiale industry.

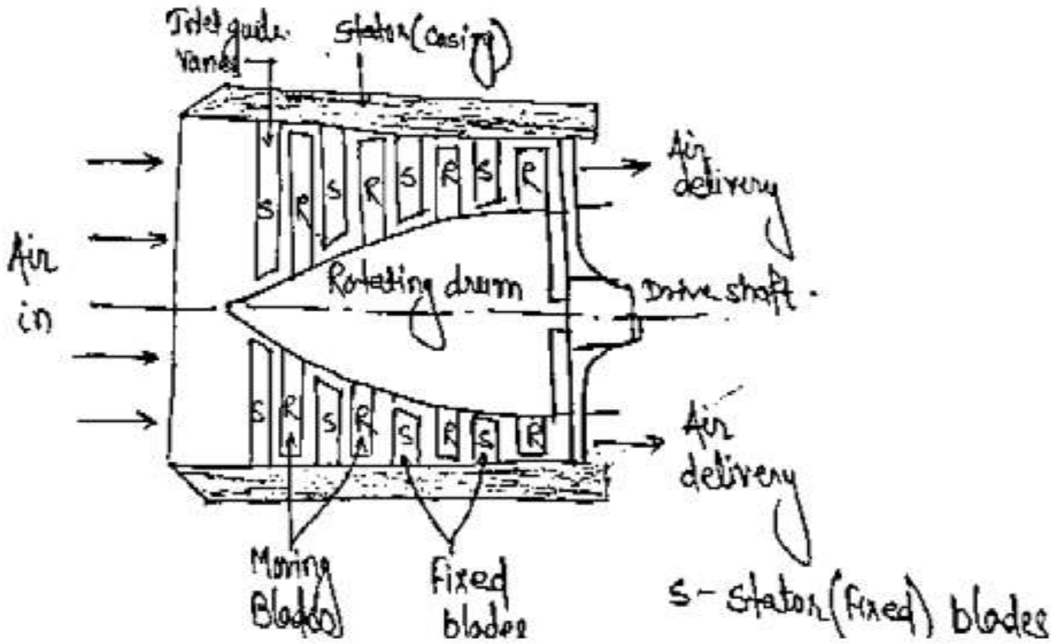


Figure 3: Schematics of Axial Flow Compressor

For easier and clearer comparisons between Radial and Axial flow compressors, the below table was made to pinpoint the recognizable differences between both compressors and their uses.

NO	AXIAL FLOW COMPRESSOR	CENTRIFUGAL FLOW COMPRESSOR
1.	The flow direction in an axial flow compressor is parallel to the shaft axis.	The entrance flow direction of a centrifugal compressor is parallel to the shaft, whereas the flow direction of the output is perpendicular to the shaft.
2.	Large engines use an axial flow compressor.	Small engines employ radial flow compressors.

3.	The mass flow rate of this compressor is around 100 kg/s.	This compressor's mass flow rate is quite modest, at roughly 15kg/s.
4.	Its thermal efficiency is about 94 %.	The thermal efficiency of a radial compressor is around 85%.
5.	Axial flow compressors require a lot of beginning torque.	Low starting torque is required for centrifugal compressors
6.	At high altitudes, this compressor is quite sensitive.	The radial compressor has low sensitiveness at high altitudes.
7.	Axial compressor stages have a low-pressure ratio.	Radial compressor stages have a high-pressure ratio.
8.	This compressor is much more costly than a centrifugal compressor.	Axial compressors are more costly than radial compressors.
9.	More suited to jet engines	Jet propulsion (flight) technologies are a better fit.
10.	This compressor has a lower frontal area for about the same mass flow rate.	Has a larger frontal area for the same kind of mass flow rate.
11.	An axial compressor has a low-pressure loss.	A centrifugal compressor has a significant pressure loss.
12.	This compressor includes a lot of stages, thus it's great for multistage applications.	It has fewer phases and is therefore unsuitable for multi-stage projects.

LITERATURE REVIEW

A. WENNERSTORM (1)

Mr. Wennerstorm made a presentation giving information on design and experimental results on transonic axial compressor, having a stage passing 195 kg/ s-m2 at a pressure ratio of 1.95 and a tip speed of 457 m/s.

The design was undoubled able to attain the highest isentropic efficiency of about 88% at it's design speed. The rotor tip strength was roughly 1.5, and this was selected as a preliminary design for the fixed number of rotor blades at 20.

The solidity resulted at an approximation of 3 in solidity, with a variation that was almost linear. The Rotor isentropic at the stage was 83% while its efficiency was 85.9%.

B. BRYCE, CHHERRETT, LYES [2]

The crew tested a transonic fan at its single stage at DRA Pye stock, with a particularly high amount of aerodynamic stress at the center (hub). The goal of this test was to make extensive observations on the flow field, with a focus on assessing the three-dimensional viscous component of the flow. The complex unsteadies 3-D which is viscous flows in blade end wall region which can cause eroding of fans and compressors that are heavily pressured at high speeds. More experiments and well comprehensive investigations are required before numerical models of this design is manufactured.

In reality, the problem is minor in the heavily loaded military type transonic fans, However, it has implications for about the first stator hub area, which has a significant deflection, resulting in a situation known as Hub Stalling. As a result, at the corner area, the flow divides. C148 rented the first stages of a pre-existing multiphase Rolls Royce transonic fan. The stage contained 25 rotors and 52 stator blades, with tip hub ratios of 0.39 and 0.62 at the inlet and exit, a rotor tip speed of 442m/s, and a staging pressure ratio of 1.807.

C. MAGDY S. ATTAIA [3]

To ensure that the design, which includes both axial and radial compressors, is sound, the observations were not only accurate at the flow and efficient but also dependable and reliable conclusions for both compressor's distribution was of vital importance, so as to be able to verify the design with all clarity and find solutions for unforeseen circumstances and problems .

Also an accurate compressor system will of course minimize any doubt that could lead to further tests on the system, and this will also avoid unforeseen expensesS1S2 type systems are fast, but they are uncommon and restricted in transonic and subsonic systems; also, the systems typically break at the end walls, making them unreliable. Computational Fluid dynamics though also of much importance also has some errors in meshing, turbulence designs and mixing formulations of planes. Due to this a setup of multistage compressor makes Computational fluid dynamics less efficient and there is the necessity of expert users for its functionality This work presents a simple, Using a mix of single row CFD and streamline curvature codes, a theoretically sound, more efficient, and reliable technique for axial compressor performance has been developed. This approach has been presented and utilized in companies with multistage compressors of various sizes and loadings, and the forecast and results were correct for each observation.

As a result, he determined that the approach for analyzing and predicting compressor performance at design or off-design operating circumstances was correct, was presented and proven accurate after so many tests were done to proof its reliability. It was based mostly on sound physics and proved to be repeated upon several tests. Simple computational fluid dynamics, together with single size mesh, was then used for all airfoils studied which gave an easily automated process, Even after further testing for measurements in two distinct circumstances, the predictions were quite trustworthy in each case.

D. LEONID MOROZ, YURI GOVORUSHCHENKO, PETR PAGUR [4]

This group of three found a solution for the problem of conceptual level of axial turbines and compressors using a uniform approach. This approach was used at the expansion of turbo machines, flow path integrated CAD systems. The importance of the approach was mostly in an organized manner at which data was presented and stored also on optimization analysis. But most importantly, their success was in the development of algorithms, aerodynamic analysis and geometric similarities. All of this was done by taking reference from turbomachine samples. For the users, the approach makes it easier for any user to be able to have access to software’s advanced features. Developers, on the other hand, can continue to extend the software's primary features.

M. JOSEPH, P. VERES [5]

The goal of this research was to look at the aerodynamic characteristics of single and multiphase axial and radial compressors. During the conceptual design process, the compressor code COMDES allows compressors to be single-sized and multi-staged. When the system is functioning, the code may estimate exit blade and rotor inlet angles using Euler's equation and compressible fluid flow equations. This diagram displays the rotor effectiveness and stator losses that are utilised as code inputs. This may be used to build performance maps based on basic concepts for rotor incidences and intake guiding when utilizing the off-design analysis method. Losses in vane reset angle. The code aids in the comprehension of basic aerodynamic factors such as the fusion factor, loading levels, and incidents. When evaluating multiphase compressor blade rows in terms of starting torque during the design stage. The relative velocity ratio and rotor loading levels are linked to the start of compressor surge. NASA stage 37 axial compressor test data and three NASA 74-A stages were analyzed and compared. Since then, the approach has been used to create a performance map versus geometry for NASA's three-staged axial compressor, the NASA 76-B. At design speeds, the compressor phases were aerodynamically balanced by altering intake guiding veins and stator rates geometry angles to be able to check the incidents angles and rotor diffusion factor.

E. J. ERNESTO BENINI [6]

This research was applied on NASA rotor 37 in which a multi objective transonic compressor was developed. The test was designed to determine the viscous flow structures in three-dimensional transonic blades. By limiting the mass flow rate, the purpose was to improve the pressure ratio and isentropic efficiency of the rotor. Aerodynamic study of the blade designs was performed using the Navier-Stokes algorithm. The usefulness of the code was made valid by comparing experimental results to the computed results which were found in the open literature and through probe travels downstream of the rotor. For the handling of optimization problem, a multi objective algorithm was used which is governed by Pareto optimality concepts and allows diversified evaluations for each assignment. Optimal rotor configurations having maximum pressure and ratio efficiency were compared to the original design after they were obtained.

The outcome was that a three-dimensional multi-objective optimum solution of transonic rotor blades was designed and tested using the Naiver-Stoke algorithm. This approach was utilized to optimize NASA rotor 37 in order to achieve optimum efficiency and pressure ratio while limiting mass flow rate. The rotor blades were generated by specifying three profiles with parametric curves throughout the span. The differences in the three curves' mutual tangential coordinates demonstrated the impact of the blades' lean. At one operational point, this increase was visible in the blade's overall efficiency. It also demonstrated that if efficiency is reduced by -0.8%, the pressure ratio may be raised by 5.5 percent. Bend the blade in the motion and enhance the profile curving towards the back to facilitate subsonic diffusion. Although at a lesser proportion of capacity, shock waves were seen. Both the shock and the boundary level at the rear of the surface have contact. This aided in determining the decrease while using a range of compressors.

FUTURE SCOPE

Axial Flow Compressors and Radial Flow Compressors (also known as Centrifugal Compressors) are the two most common types of compressors. has almost similar application but vary in design and performance up to a certain extent. Some of the applications of these compressors depends upon the technical characteristics as well. Such as in aviation sector there is a requirement for high air flow to generate appropriate thrust, hence only axial flow compressors can be employed. Radial flow compressors have low air flow rate as compared to axial flow compressors, hence can be used in Industrial purposes such as electricity generation, pumps, Mechanical systems, Aircraft systems, etc. Multiple stage compression is utilized by axial flow compressors to produce a high compression ratio. Various Research is still going on at various Institutes across the globe in this field with minor design modifications to obtain sophisticated design and maximum efficiency out of these compressors.

If we see economically, we can say that centrifugal compressors are comparatively cheaper as compared to the axial flow compressors due to their manufacturing and design parameters. Axial flow compressors require more accurate and sophisticated manufacturing facility to be produced as compared to the Radial Flow Compressors. For Axial flow compressors, the major end user industries are Propulsion in Aviation and defense, Oil & Gas, Chemical, Steel, etc. Whereas, for Radial Flow compressor, the major end user Industries are Power Sector, Petrochemical Industries, Aviation (small drones, other systems on aircraft except Propulsion), Oil & Gas, Mechanical systems, etc. The expected growth rate of usage of Compressors is estimated to be around 5-10% in the upcoming 10-15 years. Some of the countries with this growth rate lies in the Asia-Pacific region such as- India, China, Pakistan, Iran, Australia, Taiwan, Japan, Indonesia, Myanmar, Singapore, South Korea, Bangladesh, Vietnam, Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, and other countries are projected to witness significant growth in this area. The scope for Compressors is huge in this region in the upcoming future.

Figure 4: Axial Flow Compressor market growth by region.[8]

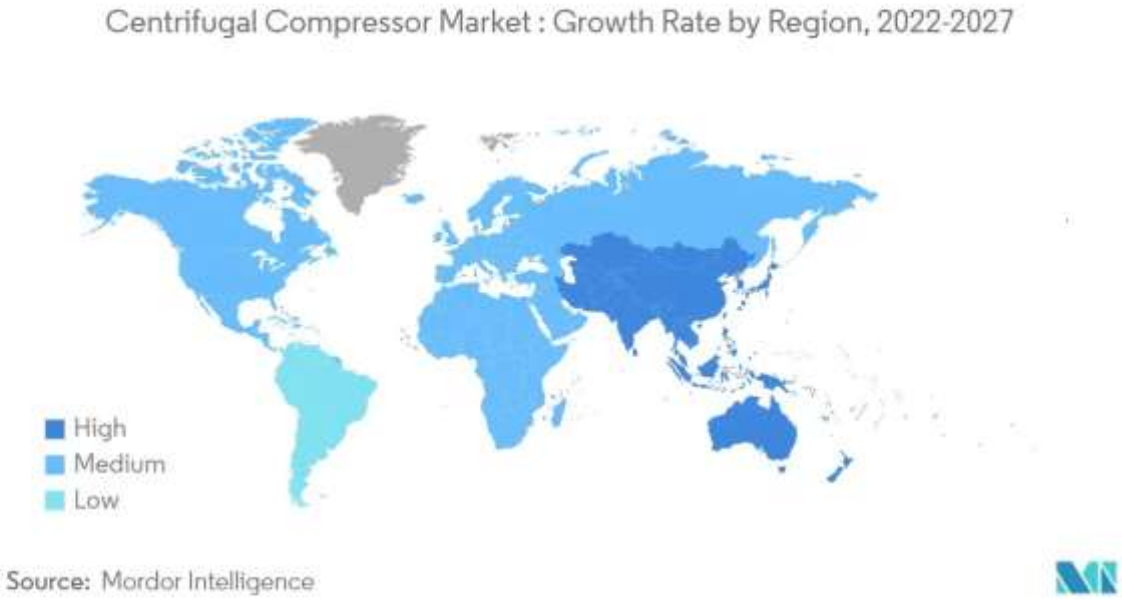


Figure 5: Radial flow compressor market growth by region.[7]

CONCLUSION

Over time, there have been changes in new technology. These changes enable designers to implement new designs as required. The main parameters, however, which are a particular flow, mean phase loading, and axial matching, are established in turn using one- or multiple approaches. In addition, CFD is useful for design analysis. But, we must nonetheless recognize that there are still some unresolved limitations which designers must be conscious of To summaries, computational fluid dynamic approaches for the prediction and analysis of compressors in design and off-design operating circumstances have been explored and presented.

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