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Design and Optimization of Inertial Particle Separator

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Abstract:
We have tried to design IPS system with different method. We are designing the vane type IPS system using multi-point element method. We have selected three airfoils by selecting camber and reflex airfoils. And create double glauret airfoil with inverse method using Xfoil, which is used to design airfoil. Here we are using design software tool called CAESES software which is design and optimization tool, which have some features like design, parameterization and optimization. And we are analyzing with tool called Ansys Fluent to study the flow pattern of mixture of dust, water droplets and air. Then we find the efficiency of the IPS system.
Keyword- IPS, Glauret, Xfoil, CAESES, Ansys Fluent.

I. INTRODUCTION

In march 1989, Headquarters, WESTCOM (Army headquarters in the Pacific Theatre) requested that a team consisting of the members of the CH-47 Project Manager Office (PMO), U.S Army Aviation Systems Command (AVSCOM) Directorate of Engineering, Textron Lycoming, Corpus Christi Army Depot (CCAD), Hamilton Standard and Howell Instruments be sent to Hawaii to investigate stating problems with four engines on two CHINOOK (CH-47) helicopters stationed in Hawaii. Test data from a Howell Instrument Portable Engine Analyser Test Set (PEATS) determined that compressor deterioration was causing the engine start difficulty. Similar results had occurred in 1981 in Egypt. Joint U.S-Egyptian manoeuvres were in progress. Helicopters from both countries filled the air. Performance fell far short of expectations. Sand and dust from the desert environment were eroding engine parts, causing abnormal wear. This was particularly prevalent on the U.S Army Cobra gunships.A medium-size helicopter operating from and to dusty bases can ingest up to 1 kg of particulate per minute.

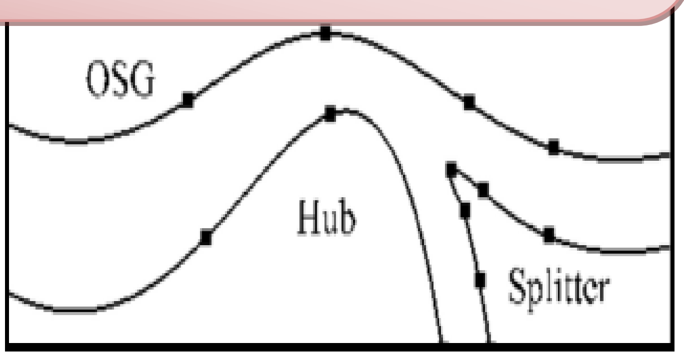

Fig.1 IPS section

II. PROBLEM STATEMENT

- Brownout’s is a very serious problem for helicopter pilots.
- The issue of particulate ingestion is synonymous with an operationalsituation known as “brownout”.
- The problem is not limited to airworthiness issues; blade erosion and wear on various mechanical parts, and a deterioration of engine performance due to ingestion of particulate are also caused by brownout clouds.
- The device performances containtwo key parameter which are separation efficiency and pressure drop.

III. OBJECTIVE

- To design a particle separator which removes sand, dust, and other particulate from jet engine airflow at a minimum power cost.
- Allowing more power at landings and increasing time between engine overhauls compared to similar systems.
- Optimizing the device to provide function without much loss in pressure and mass flow.

IV. METHODOLOGY

1.SELECTING THE PROFILE FOR IPS SYSTEM

In this step, we select the five airfoil profile which is suitable for inertial particle separation system where two of the airfoil is cambered and other two are symmetric to these airfoil. Other one is symmetric airfoil.

2.DESIGNING THE IPS SYSTEM

In this step, we design the inertial particle separation system considering some of the parameter constant like inlet or intake of the reference engine in CAESES software.

3.PARAMETERIZING OF THE PROFILE SELECTED

In this step, we parameterize some of parameter like scale, angle of attack, distance between any two airfoils and other some of parameters in CAESES software.

4.CFD ANALYSIS ON IPS SYSTEM

In this step, we importing parameterized design and then do CFD analysis in ANSYS Fluent. Then we find out some of the results like pressure distribution, velocity streamline and study of particle separation and soon.

5.OPTIMIZATION OF DESIGN OF IPS SYSTEM

In this step, we import results of CFD analysis from ANSYS Fluent to CAESES software to optimize the design based on some of the parameters like study of particle separation , pressure variation and soon.

6.COMPARISION OF NEWLEY DESIGNS

In this section, we compare the newly designed IPS system and the design from the thesis by varying some of the flow properties like changing flow angle of air, changing flow velocity and soon. From this, we can get to know how effective the new design comparative to the thesis design.

V. PRELIMINARY DESIGN

The preliminary design is based on the calculation for the first iteration to get the gross idea of the flow pattern. The design of first model taking the central body which is the prime splitter as the resemblance of spherical ball which deviate the flow accordingly.

A. XFOIL

Xfoilis an interactive program for the design and analysis of subsonic isolated airfoils. Given the coordinates specifying the shape of a 2D airfoil, Reynolds and Mach numbers, XFOIL can calculate the pressure distribution on the airfoil and hence lift and drag characteristics. The program also allows inverse design – it will vary an airfoil shape to achieve the desired parameters. It is released under the GNU GPL.

The procedure followed is:

- Step1 : To download the source file and also the xfoil.
- Step2 : To load the coordinate of the airfoil, the difficult part is to load the airfoil to Xfoil. The loading need proper format to read and display the airfoil.
- Step3: After loading airfoil, display the foil to check.
- Step 4: To perform the operation, i.e to provide the inlet parameter such as mach number, Reynolds number.
- Step 5 : To specify the number of the iteration.
- Step 6 : Hit enter to perform the analysis.

B. CAESES

CAESES stands for "CAE System Empowering Simulation" and its ultimate goal is to design optimal flow-exposed products. It focuses heavily on simulation engineers that need automation,in particular in the context of geometry generation.

Advantages of CAESES:

- Automation Ready
- Efficient Geometry
- Find Optimal Designs

Application:

CAESES is used in various industries. Typical areas of interest include shiphulls, turbomachines, ducts and manifolds, engine components, aerodynamic bodies such asaircraft and race car components, mixers, propellers, etc. CAESES® is suited for both internaland external flow applications.

C. DESIGN

For designing the Inertial Particle Separating system (IPS) we are using software called CAESES, which is the designing and optimization software.

For designing 2D IPS system, we are divided the design into 3 different phases, namely

- Designing the upper or lower airfoil (cambered airfoil) and it's placing.
- Designing intermediate airfoil (reflex airfoil) and its placing.
- Designing Centre airfoil and its placing.

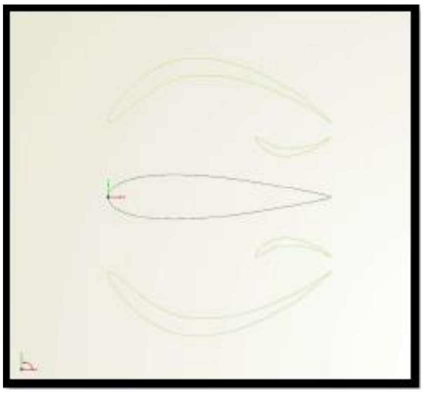

Fig.2 Preliminary Design

Designing of reflex airfoil

This is similar to the designing of cambered airfoil. But the changes have to made in the transformation chain of image curve is take offset as -1 in y direction for mirroring. Fewcondition for designing reflex airfoil the chord length should be less than chord length of cambered airfoil, trailing edges of all the airfoils should be in one single line along y axes. And the final condition is the length between the centre line and trailing edge of airfoil should be equal to the radius of reference inlet.

Designing of symmetric airfoil

In this phase design, the symmetric airfoil used is Double Glauertairfoil. As per ourresearch, so we have to design it. As mentioned above it can be done by the method of inverse airfoil design which is also known as profoil coding. This is one of the challenging task in the process. Because it need knowledge of all the parameter of flow for the inlet of the engine.This completes the overall 2-D design. The method provide the preliminary design only. The accuracy is obtained further by the adaptation of many parameter and also analyzing the flow.Hence the 2-D profile is designed.

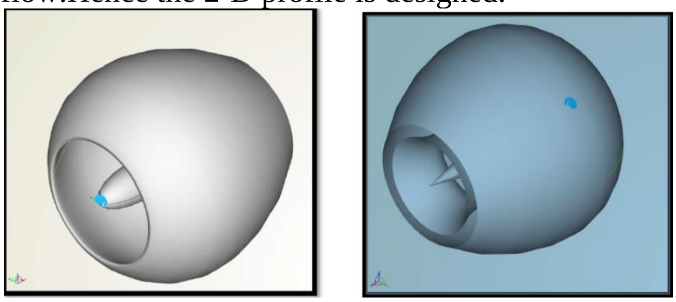

Fig.3 3-D Design of the IPS

Designing real profile(3-D)

The completion of the 2-D profile as the procedure mentioned above. Our next step is to form the real time model. The model mimics the real time design. This is design is later analyzed after defining the parameter of the flow and also listing out the various method to analyze it. The best,accurate, feasible and easy method is chosen by examining and analysis is done.

D. MESHING

The first form design is done from the formation of central body design. The proper central body design is done from the initiation of the MATLAB code. The profile thus created is been design in CAD and profile is created. To ensure the design we need to analyze our design, the main and most important step is to mesh the model. The analysis result completely depends on the types and nature of mesh. So validation of the mesh from the important in analysis. This form of study to know the accuracy of the mesh in fetching result is known as grid independent study. The study will give the nature of mesh which will give the accurate result even any changes in design.

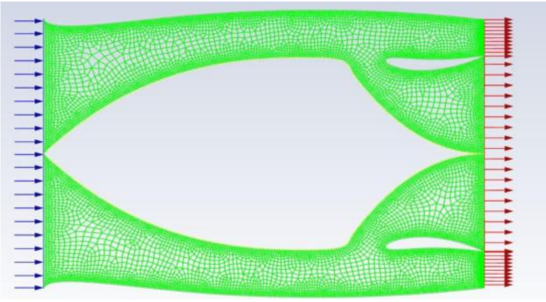

Fig.4 Meshing

VI. RESULT AND DISCUSSION

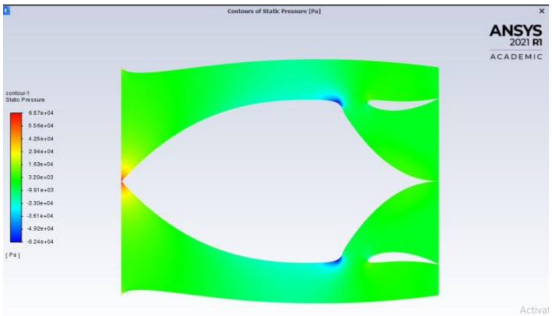

Fig.5 Pressure Contour

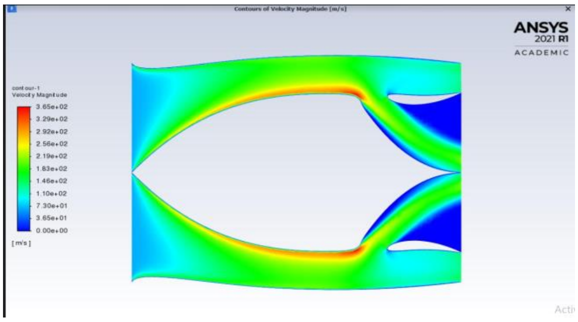

Fig.6 Velocity Contour

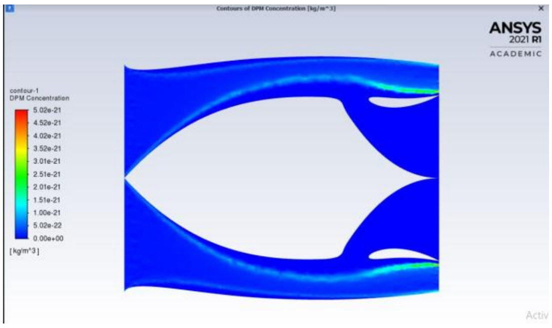

Fig.7 Particle Tracking

VII. CONCLUSIONS

The complete building block of analytical code has been developed and integrated to the IPS system as the central body of it. The code was made in the MATLAB and the coordinate of the code was extracted. The design of central body took many iterations to form a convenient design. The design iteration was carried by CAESES software. The software provided enormous amount of UI to modify the design as per required. Finally, the smooth profile with no congestion of flow is successfully created and shown. The fluid simulation through ANSYS with necessary setup provided clear understanding of the flow inside the design. The design is able extract about 85% of the dust particle which will provide more power to the engine during landing by eliminating the problem of brown out.

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