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# Distortion Plate Design, Simulation Validation and Test Scheme for Stability Analysis on a Fan Component of an Aeroengine

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## Abstract

To process stability analysis on a fan component of an aeroengine, various level of comprehensive distortion indexes formed at inlet of the article are required. Aiming this target, in this article a series of distortion generators set with different blocking ratio of distortion plates are designed and validations of their design effectiveness by CFD method are applied right after that. Meanwhile, numerical relationship between distortion plate blocking ration and steady distortion index is sought after. Based on former test experience, steady distortion index is just equal to the value of the relevant dynamic distortion index. Since comprehensive distortion index is the summation of steady and dynamic distortion index, it is reasonable to simulate only steady distortion index enough to evaluate the level of comprehensive distortion index, and pick up comfortable blocking ratio for the later intake distortion test. Another task of this test is to obtain details of flow field at outlet of test article in a relatively short test period combined with high accuracy. To achieve this former test are considered particularly and a complete set of test and measurement scheme is built up and put in practice, detailed and reliable test data is obtained finally. In this article all of these efforts are described particularly, beneficial exploration on stability research test scheme is performed and much more abundant data obtained by this test can be supplied to support later high-pressure intake distortion test technology improvement.

**Keywords:** stability analysis, blocking ratio distortion index, simulation validation, test scheme

## 1. General Introduction

In a working process of an aeroengine, it is hard to avoid various kinds of distortion situations at inlet, and may severely influence the usable stability margin of the aeroengine. Familiar distortion situation at inlet includes intake total pressure distortion and total temptation distortion, etc. Among which, intake distortion is the widest and deepest research direction at today’s stage, and is an essential task in an engine design stage [1]. For this reason, all of the developed countries on aviation industry explore different technology system after costing a huge energy and effort. Of all countries, on the field of evaluating distortion level, namely intake distortion index, has extinctive characteristics in format explored by P&W, GE of USA, R&R of UK as well as Russia [2]. However, only Russia takes her stability assessment method as a standard of the country. China, on the other hand, follows Russia on this field, for test research specially, is plate-type total pressure distortion test method [3].

Plate-type total pressure distortion test method is to block part of intake at a place right in front of the inlet of the article in essential, introducing an uneven parameter distribution phenomenon at inlet of the article, namely distortion generation. The actual method is to set a lunette-shape plate at a certain location far away from the inlet of the test article. Forced by the plate, the intake air of the test article can only flow on the upside of the plate, and forms a low-pressure zone at downstream of the plate, by this way a distortion field is formed at inlet of the test article [4]. Obviously, the distortion level at inlet is decided by only two factors, one is the area ratio of the plate to the whole intake passage, namely the blocking ratio; the other one is the axial distance $L$ between the plate and the inlet. In China $L$ can follow the relevant standard, namely $L = 3D$, in which $D$ is the diameter of the inlet [5]. Generally speaking, this is followed by most total engine intake total-pressure distortion test, and an Aerodynamic Interface Plane (AIP) is assembled at a place between inlet and distortion plate, the distance $L_0$ between the AIP and the plate follows that: $L_0 = 2.5D \sim 3D$.

Although this standard is mainly for total engine test, it is also used to guide distortion plate assembled for fan and high-pressure component tests.

When the location of the inlet or AIP is fixed relative to that of the distortion plate, and total pressure measurement points disputing at AIP is of certain as well, the total pressure data at inlet is only relative to the blocking ratio of the distortion plate, which means that the comprehensive distortion index calculated by these data is relative to the blocking ratio only. In fact, in a practice, the distribution of measurement points at AIP is also recommended in relevant standard, a typical distribution of measurement points at AIP is indicated by Figure 1:

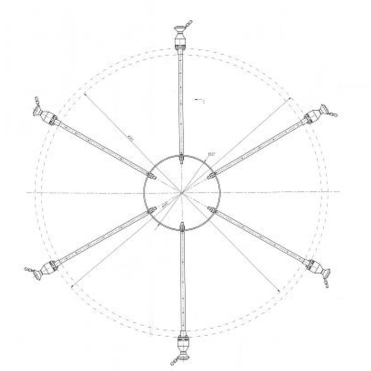


Figure 1 – typical distribution of measurement points at AIP.

According to relevant standard, comprehensive index $W$ is combined by steady distortion index $\Delta\sigma_0$ and dynamic distortion index $\varepsilon$, namely:

$$W = \Delta\sigma_0 + \varepsilon \tag{1}$$

In formula (1) the steady distortion index $\Delta\sigma_0$ is defined as:

$$\Delta\sigma_0 = (1 - \sigma_0 / \sigma_{cp}) \tag{2}$$

In which $\sigma_0$ is the average value obtained from integral of total pressure along radial and circumference on low-pressure of AIP, and $\sigma_{cp}$ is the average value of total pressure ones gained by all survey points on AIP.

Dynamic distortion index $\varepsilon$ is defined as:

$$\varepsilon = \frac{\sum_{1}^{m} \frac{\sqrt{\frac{1}{t}\int_0^t \left[P_{cp}^* - P_i^*\right]^2 \cdot dt}}{P_{cp}^*}}{m} \tag{3}$$

Here $t$ is time interval, $m$ is the total number of time-variant instruments, $P_{cp}^*$ is average value of total pressure at a certain point during an interval time of $t$, $P_i^*$ is an instantaneous value of total pressure at a certain point during an interval time of $t$.

A huge amount of test data shows that $\varepsilon$ has a relationship with $\Delta\sigma_0$, although the relationship may not be a seriously positive linearity, it still can be simplified as an equal relationship in values between the two in engineering practice, especially for the test scheme design stage [6].

In the actual practice stage of a type of engine, the comprehensive distortion index formed at its inlet is discovered changing regularly, but can be classified as low, medium and high level. Limited by former technology level, evaluating an engine’s stability margin with different distortion strengths at inlet are often executed following “distortion sensitive coefficient invariable principle”, with this a usable stability margin under different situations can be evaluated. At that developing stage evaluating method does not require variety of distortion generators’ blocking ratios, in fact in an extremely long period only 3 kinds of blocking ratios of 15%, 20% and 25% were used in a fan component intake distortion test, among which only 15% blocking ratio (for large intake flow) and 25% blocking ratio( for medium and small intake flow) were regularly applied, and the data obtained by the former tests is not abundant to support a further discussion on “distortion sensitive coefficient invariable principle”. However, along with the development of engine application, as well as the advance of the test technology, it requires much more than before to have a further discuss and ameliorate former intake distortion test method in the design stage, leading to a strong demand on distortion generator re-design and blocking ratio variety.

In this article a series distortion generator with various blocking ratios is designed to form kinds of levels of comprehensive distortion indexes at inlet of some a type of an engine’s fan component to satisfy the requirement of the distortion test on distortion level. By CFD (Computational Fluid Dynamics) method, simulations on each distortion generator with different intake situations were processed to evaluate the steady distortion index values, and by the principle of that “steady index is nearly equal to the relative dynamic index in value”, evaluate the comprehensive index further. Since this investigate refers to a huge number of cases, to improve simulation efficiency, the work being processed above does not consider the influence of the pressure chamber and bell-mouth structure upstream of the distortion plate, and core-body of the test article downstream. The simplified models being simulated may not able to answer a question introduced by former test results, that the distortion index does not always has a positive linearity with intake flow, which is satisfy the academic anticipation. Checking the test data obtained to make sure the validity, and searching for the reason of the phenomenon, one proper matter may be that the AIP location selected is not perfectly well to obtain total pressure values to calculate distortion index and assess the distortion level. To make clear of it, flow details in generator are required. For this reason, in this article pressure-chamber, bell-mouth structure, distortion generator (with a plate of 15% blocking ratio and intake tube) as well as core-body of the test article are combined to be modeled and meshed to simulate the flow in practice, this is not for engineering application but for academic investigation only. By the simulation and with the analysis, the selection principle of AIP location has the possibility to be discussed further, and more determinant evidence can be provided for improving distortion test method.

## 2. Test Rig Introduction and Requirements for a Fan Component Intake Distortion Test

The test is going to be put into practice on a large-scale single- axis double-bypass compressor test rig. This is one of the largest same type of test rig in China, the structure of which (with distortion generator) is shown by Figure 2:

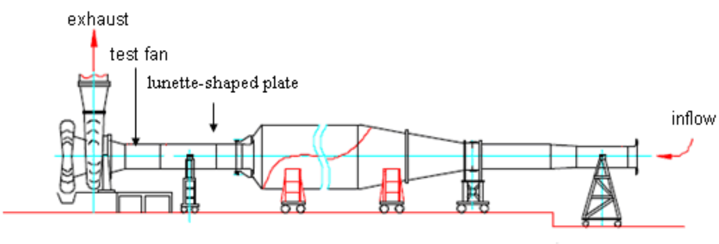



Figure 2 –the structure of the test rig with distortion generator.

After building up, various kinds of fan/compressor component performance tests have been carried out on the rig, contributes a lot for Chinese aeroengine industry. The plate-type intake distortion test is one of the earliest kinds of fan component test being processed on this rig, but not that abundant test data for supporting further investigation is obtained at that time because of its poor test ability and monitor method, and in a long period only 15% and 25% blocking ratios of plates were being in used according to Russian tradition.

However, in these years with a strong demand of high-performance engines, the test technology is required to be improved and ameliorated. To satisfy this new circumstance, scheme this test.

Rely on this, several fields are planned to be investigated:

Firstly, is to evaluate the validity of the basic principle on distortion test, namely “distortion sensitive coefficient invariable principle”. The principle can be simply described as: when encounter a distortion at inlet, the ratio of the lost stability margin of the test article (compare to the intake even condition) to comprehensive distortion index, namely distortion sensitive coefficient, is a fixed value, namely:

$$\alpha_W = \Delta SM / W = C \tag{4}$$

In formula (4) $\alpha_W$ is distortion sensitive coefficient, $\Delta SM$ is the lost stability margin of the test article, and $C$ is a fixed value.

Base on this principle, generally speaking by just one distortion test, after obtaining the distortion sensitive coefficient, at current speed the lost stability margins can be calculated with different comprehensive distortion indexes at inlet.

The relevant standard indicates that when the comprehensive distortion index not smaller than 3%, this principle is tenable, the “3%” is called “threshold value” [7]. However, with the test data accumulating, researchers find that the current “threshold value” may not accuracy, sometimes, although not always, the principle is not tenable even the comprehensive distortion value is larger than 3%. For this reason, new “threshold value” is required to be defined.

For this purpose, blocking ratio variety of distortion plates to form different distortion strengths at inlet is required to calculate each distortion sensitive coefficient and study the reliability and applicability of the principle.

Besides, when designing the plate blocking ratio, test safety and practicability are also required. Too big blocking ratio may lead a large loss of stability margin and make the test unsafe; too small one may not form sufficient distortion strength at inlet and fail the test. For this reason, before the test proper method is required to be introduced to evaluate the design effect of distortion generators and reduce the failure possibility or instability of test.

Secondly, theoretically, there is a numerical relationship between the distortion plate blocking ratio and comprehensive distortion index, primary guess is that the relationship is positive linearity, in this test this is required to be validated.

Thirdly, researchers guess that with the same blocking ratio, the intake flow has a positive linearity with comprehensive distortion index as well, this is also required to be validated in this test.

Fourthly, studying the flow field of outlet of the test article in a former test, only a few total pressure probes with denumerable measurement points can be used, the contour drawn by the points can only describe a simple total pressure distribution at outlet, important parameters such as Mach number and flow angle are unable to study. Since flow field of a fan’s outlet is the input of a high-pressure compressor, it is required to build up a new measurement scheme to obtain details of flow field of the outlet.

Upon the four important essentials, in this test plates with different blocking ratios are required to be designed out for 11 kinds of intake flow situations, every intake flow situation should be provided with at least 3 different plates to obtain 3 of low, medium and high level of comprehensive distortion indexes to obtain sufficient data to discuss the problems above.

## 3. Modeling of Flow in Distortion Generator and the Simulation

In this section selection of distortion plate blocking ratios is described in detail.

The section above has indicated the structure of a distortion generator, and pointed out that the blocking ratio is one of the most parameters in a distortion test, meanwhile the point required to be mainly studied in this article. The structure of a distortion generator is shown in Figure 3:

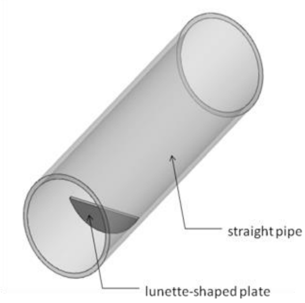



Figure 3 –the structure of a distortion generator.

Since the test requires the variety of blocking ratios, a number of blocking ratio plans are referred to, along with different intake flow situations, this demands a highly efficient design method to complete structure design for the plates in a short time. For this reason, structure characteristics of a lunette-shape plate are studied to obtain function relationship between the main structure parameters. The main view of the structure of the lunette-shaped plate in the tube is shown in Figure 4:

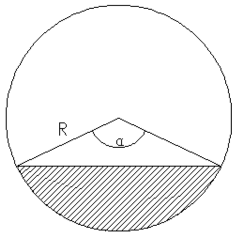



Figure 4 –the main view of the structure of the lunette-shaped plate in the tube.

In Figure 4, $R$ is the diameter of the tube, $\alpha$ is the center angle of the sector where the plate is set at, the unit is ° , and blocking ratio $K$ can be computed by formula (5):

$$K = \frac{\alpha}{360} - \frac{\sin\alpha}{2\pi} \tag{4}$$

When $K$ is fixed, formula (4) can be seen as an equation with one unknown quantity, it is extremely easy to write a program using software such as MATLAB to obtain the relative $\alpha$ , and then calculate other key structure parameters of the plate.

7 blocking ratios are selected primarily in this article, as is shown in Table 1:

Table 1 –blocking ratios to the relative $\alpha$ .

| $K$ | 12.5% | 15% | 20% | 25% | 30% | 40% | 45% |
|---|---|---|---|---|---|---|---|
| $\alpha$ (°) | 101.2 | 108.37 | 121.07 | 132.35 | 142.71 | 161.85 | 170.68 |

According to former test data, each blocking ratio for the 11 intake flow situations (marked as M1 to M11) is indicated in Table 2:

Table 2 –scheme for blocking ratio selection with different intake flow.

| Intake flow | Blocking ratio | | | | | | |
|---|---|---|---|---|---|---|---|
| | 12.5% | 15% | 20% | 25% | 30% | 40% | 45% |
| M1 | | | | | √ | √ | √ |
| M2 | | | | | √ | √ | √ |
| M3 | | | | | √ | √ | √ |
| M4 | | | | | √ | √ | √ |
| M5 | | | √ | √ | √ | | |
| M6 | | | √ | √ | √ | | |
| M7 | | | √ | √ | √ | | |
| M8 | √ | √ | √ | | | | |
| M9 | √ | √ | √ | | | | |
| M10 | √ | √ | √ | | | | |
| M11 | √ | √ | √ | | | | |

There are totally 33 cases list in Table 2, of which 7 cases has been used in former test, as is shown in Table 3:

Table 3 –cases in used in former test.

| Blocking ratio | Intake flow | | | | | | |
|---|---|---|---|---|---|---|---|
| | M5 | M6 | M7 | M8 | M9 | M10 | M11 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15% | | | | √ | √ | √ | √ |
| 25% | √ | √ | √ | | | | |

Traditional wind tunnel tests will of course cost a huge time and research bankroll, which is unable to burden. However, by CFD, with only a proper meshing scheme and a high-performance computer several cases can be simulated all together, this is especially comfortable for engineering application. Take a distortion generator of 25% blocking ratio as an example, the meshing scheme is shown in Figure 5:

a) meshing scheme (all) b) meshing scheme (near the plate)

Figure 5 –meshing scheme of the distortion generator (of 25% blocking ratio).

The mesh number is about 730,000. The mesh quality is perfectly well.

The boundary conditions set in this article are shown in Figure 6 and Table 4:

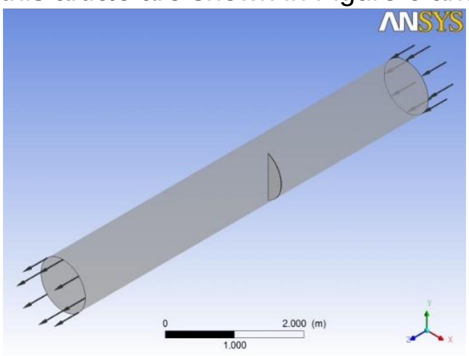



Figure 6 –boundary conditions set for the model.

Table 4 –details of boundary conditions.

| Name of the boundary | Boundary type and parameters |
|---|---|
| inlet | Inlet, total pressure |
| outlet (namely AIP) | Outlet, intake flow |
| others | No slip wall, smooth wall |

After obtain a simulation result, the total pressure values of measurement points in practice are probed and used to calculate steady distortion index in a special Russian program, which is just the same as what is done in a test data processing. The cases in Table 3 are first simulated to be compared with the test results, as is shown in Table 5:

Table 5 –comparison between test data and simulation one.

| Blocking ratio | Intake flow | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | M5 | M6 | M7 | M8 | M9 | M10 | M11 |
| 15% | Test data | | | | 4.01% | 5.53% | 6.31% | 6.59% |
| | Simulation data | | | | 4.32% | 5.5% | 6.07% | 5.99% |
| 25% | Test data | 3.34% | 4.88% | 7.18% | | | | |
| | Simulation data | 3.5% | 4.56% | 5.99% | | | | |

According to Table 5, for most cases, the simulation data satisfies test data well, the simulation scheme using in this article is reliable.

All of the 33 cases simulated has been done, the results have been listed in Table 6:

Table 6 –simulation results summarized for all of the 33 cases.

| Intake flow | Blocking ratio | | | | | | |
|---|---|---|---|---|---|---|---|
| | 12.5% | 15% | 20% | 25% | 30% | 40% | 45% |
| M1 | | | | | 0.69 | 1.1 | 1.8 |
| M2 | | | | | 1.1 | 1.87 | 2.99 |
| M3 | | | | | 1.9 | 3.2 | 5.23 |
| M4 | | | | | 2.82 | 4.84 | 8.02 |
| M5 | | | 2.51 | 3.5 | 4.48 | | |
| M6 | | | 3.27 | 4.56 | 5.97 | | |
| M7 | | | 4.22 | 5.99 | 7.13 | | |
| M8 | 4.06 | 4.32 | 5.46 | | | | |
| M9 | 4.88 | 5.5 | 6.41 | | | | |
| M10 | 5.43 | 6.07 | 7.26 | | | | |
| M11 | 5.67 | 5.99 | 7.46 | | | | |

According to Table 6, the relationship curves of steady distortion indexes $\Delta\sigma_0$ to intake flow can be seen in Figure 7, and the relationship curves of steady distortion indexes $\Delta\sigma_0$ to blocking ratios can be seen in Figure 8:

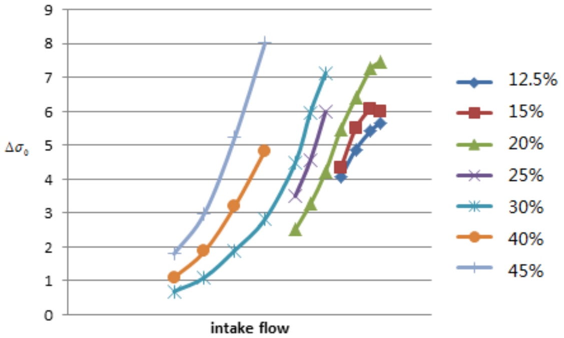



Figure 7 –the relationship curves of steady distortion indexes $\Delta\sigma_0$ to intake flow

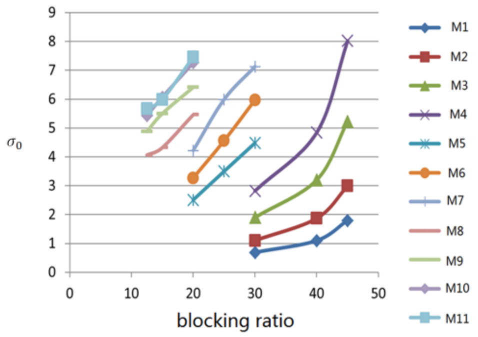



Figure 8 –the relationship curves of steady distortion indexes $\Delta\sigma_0$ to blocking ratios

According to Table 6, Figure 7 and Figure 8, when one of the two parameters, intake flow and blocking ratio, is fixed, the steady distortion index has a nearly positive linearity relationship with the other one, which requires to be validated further according to the test data.

As what has been pointed out, the simplified models with no pressure chamber, bell-mouth structure and core-body of the test article are only used for engineering application, but to obtain details of the flow in a distortion generator, all of the components up and down stream of the generator are required to be modeled together, as is shown in Figure 9:

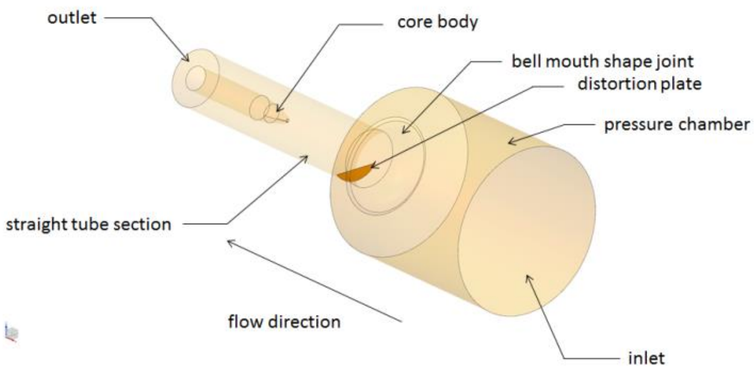



Figure 9 –distortion generator modeling combined with other components

Aiming to offer detail flow conditions for improve the distortion test method, checking for the influence factors to the distortion strength formed at inlet of the article (namely the outlet of the model in Figure 9), the combined model is mesh respectively with and without a distortion plate. The model without distortion plate is called “quasi-uniform” case, while the one with distortion plate is called “distortion” case. Only the blocking ratio of 15% case is done for the investigation. The meshing scheme of the “quasi-uniform” case is shown in Figure 10:

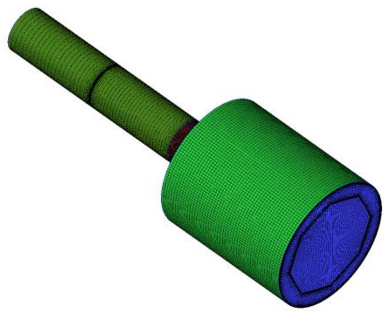


Figure 10 –meshing scheme for “quasi-uniform” case

The mesh type is hexahedral mesh, the thickness of the first layer near all of the walls is 10-3mm, and the quality of the mesh is well. The number of the mesh is about 2,800,000, nearly 4 times of the simplified model ones. The “distortion” one is similar, with the number 3,100,000.

Simulations for “quasi-uniform” and “distortion” cases focus on two points:

Firstly, the axis distance between the outlet of the bell-mouth structure and distortion plate is actually very short, since that it must be considered that the flow field parameters at the distortion plate location may not distribute that even, aiming to this a simulation for no plate assembled (namely quasi-steady test in an intake distortion test process, which is called “quasi-steady case” next in short, and case with a distortion plate is called “distortion case”) in front of the inlet is taken into practice, the evenness of the flow field at that location can support this study;

Secondly, when processing a distortion test, the distance between distortion plate and AIP is fixed, although the distance satisfies the relevant standard, but former investigations show that there is a vortex behind the plate, the scale of the vortex has a relationship with the dimension of the plate as well as the intake flow. If the AIP is right locating at the place near the center of the vortex, the total pressure probed at AIP may be influenced, leading to a distortion in calculating distortion index, for that reason the scale of the vortex behind the plate should be considered.

The boundary conditions set for this simulation is just as what has been list in Table 4 with the data obtained in practice, the simulation result of the quasi-steady case is first given out, note that the parameters have been normalized before giving out. Firstly, take the longitudinal section of the combined model as a research object, consider the total pressure and Mach Number distribution in front of the inlet, as are shown in Figure 11 and Figure 12:

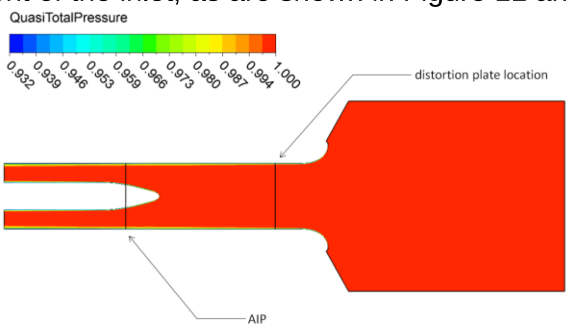



Figure 11 –total pressure distribution in front of the inlet

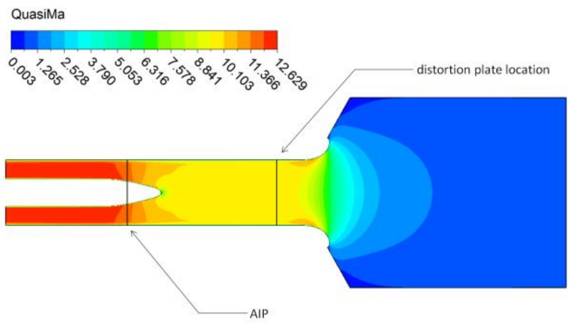



Figure 12 –Mach number distribution in front of the inlet

According to Figure 11, in front of the test article’s inlet (namely the outlet of the model), total pressure distributes equably at the longitudinal section of the combined model, while Mach number changes along with the axis direction, but when arriving the location of the distortion plate, Mach number comes to stability. However, after passing the core-body, the Mach number changes again.

To review the uniformity of the total pressure and Mach number distribution at the location of distortion plate and AIP, Figure 13 to Figure 16 are given out:

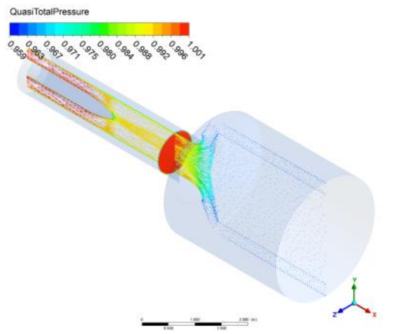



Figure 13 –total pressure distribution at the section of distortion plate (quasi-steady case)

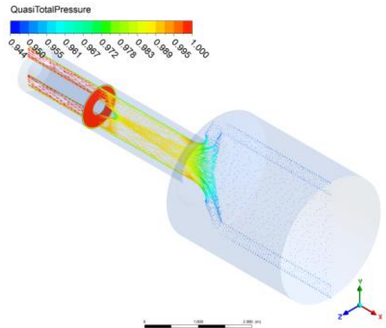



Figure 14 –total pressure distribution at AIP (quasi-steady case)

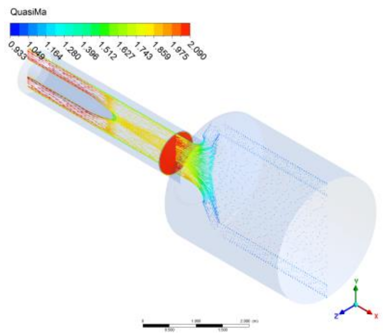



Figure 15 –Mach number distribution at the section of distortion plate (quasi-steady case)

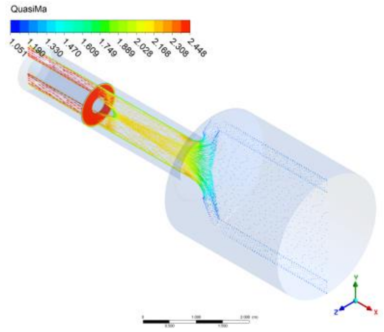



Figure 16 –Mach number distribution at AIP (quasi-steady case)

From Figure 13 and Figure 14 it can be seen that for quasi-steady intake condition, total pressure distributions at the section of distortion plate and AIP are actually even; from Figure 15 and 16 it can be seen that the Mach number distributions at the sections above are similar to the ones of total pressure, but by the influence of the core-body of the test article, there are differences in value. By post-solve module, the average Mach number at the section of distortion plate, AIP and outlet of the model are 2.06, 2.37 and 2.51 respectively (the values above are after normalization, the flow in front of the inlet is subsonic, the actual Mach number is no more than 0.5).

According to the results above, under quasi-steady intake condition, the selection of AIP does not influence the measurement of total pressure, but in fact the Mach number values at different sections have been changed by the bell-mouth structure and core-body of the test article along the axis direction. This will not influence the calculation of distortion index, but the essential of an intake distortion test is a Mach number distortion at inlet, whether Mach number of different level influences the distortion strength still require for a further study.

What need to be pointed out is that since the Mach number distribution at the section where distortion plate locates at is properly even, namely in this test the influence to the Mach number of the bell-mouth structure does not spread to the location of the distortion plate, it can be said that the distance between the plate and the outlet of the bell-mouth structure is appropriate, there is no additional influence to the flow in front of the inlet of the article.

Although in this simulation it is proved that the distance between the plate and the bell-mouth structure outlet is appropriate, the study does not possess engineering significance. Actually speaking, if the Mach number distribution at the section of distortion plate is not even, after assembling the plate, the scale of the vortex behind the plate will be influenced, which may affect the rationality of the AIP selected. Former investigation indicates that the Mach number distribution evenness at each section downstream of the bell-mouth structure is related with the bell-mouth itself and the intake flow, further study will also be carried out for this subject.

The simulation result of distortion case is given out below. The flow condition in front of the inlet of the test article is considered firstly, as what is shown in Figure 17:

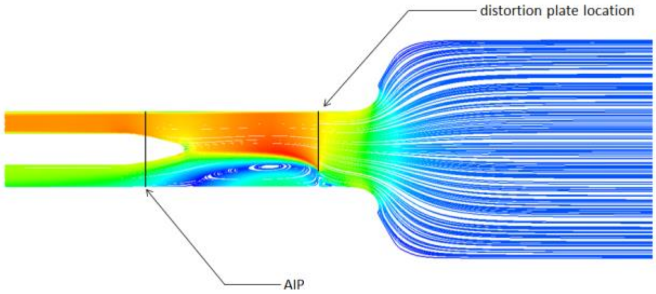



Figure 17 –plan flow at longitudinal section of the combined model (distortion case)

Figure 17 indicates that behind the distortion plate there is a large-scale vortex, the end of which has nearly arrived at AIP. To consider the total pressure distribution in a further view, total pressure contour at longitudinal section of the combined model is shown in Figure 18:

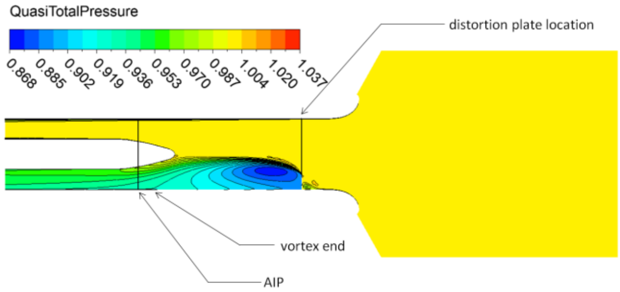
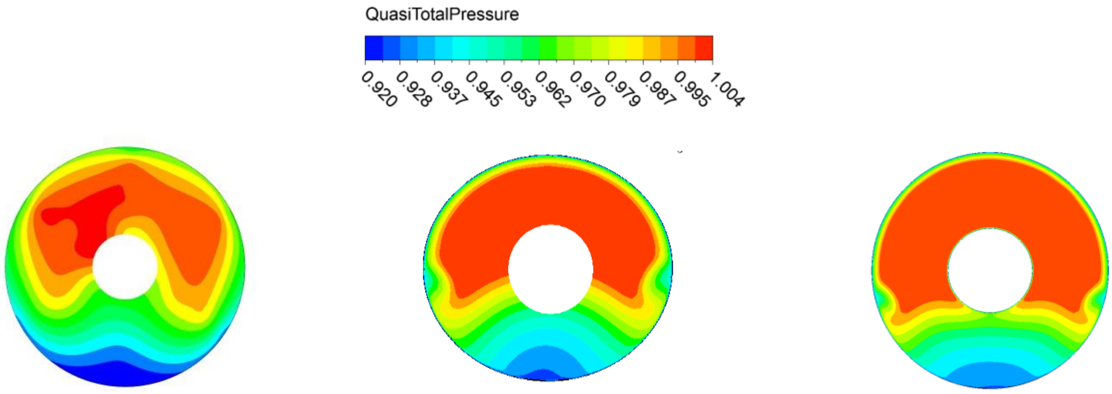



Figure 18 –total pressure contour at longitudinal section of the combined model (distortion case)

From Figure 18 it can be seen that at AIP of the vortex downstream, the total pressure has become nearly stable along intake flow direction, there is no distinct difference between distortion index at AIP which moves a small distance along with or opposite to the flow direction. However, if the vortex scale is large enough and the AIP is right fall at a place near the center of the vortex, the distortion index may be contorted, this will of course mislead the evaluation of distortion strength at the inlet of the test article. For this reason, in the next similar test, especially for big blocking ratio and intake flow cases, the evaluation on the rationality of the AIP selected should be carried on all the same.

At the end of the section, total pressure contour at AIP from test, simplified model simulation and combined model simulation are given below respectively, as are shown in Figure 19:




a) Test data

b) Simplified model simulation

c) Combined model simulation

Figure 19 –total pressure contour at AIP from different methods

From Figure 19 it can be seen that the 3 total pressure contours are actually the same, the contour from test data can show more details on the influence from the rotor downstream of AIP, the contour performs not strictly symmetrically, the deflexion angle of the axis are same to the rotation direction of the rotor.

The steady distortion index calculated from combined model simulation is more close to the one from test data than that from simplified model, but not distinctly, proving that the simplified model simulation still has a high feasibility and accuracy in engineering application.

## 4. Measurement Scheme for Flow Field at Outlet

In current stage most high-pressure compressor intake distortion test also apply plate-type distortion test method, and follow total engine evaluation method to evaluate high-pressure compressors' anti-distortion ability [8]. However the fan component distortion test results show that after a strong mixing, the distortion strength at the inlet of a high-pressure compressor decreases heavily, and the flow field at inlet of the high-pressure compressor shows distinct characteristics to that of a fan component outlet. Researchers wish to obtain detail flow field of a fan component outlet to design a proper distortion generator for a high-pressure compressor. The common method for a detail flow field is scanning the field by a five-point probe, driven by a motion mechanism, however this is only applied for the condition that the intake flow is even, since the flow field at the outlet is periodically changed around the circle, which means only one passage of the outlet is needed to be scanned. However, when encounter a distortion at inlet, the outlet flow field is not periodically changed around the circle, to obtain a detail flow field the whole outlet is required to be scanned, which will cost a huge amount of time and not be burden. To solve this problem former test result is carefully studied to pick up suitable passages to scan, the detail scheme of the test cannot be made public, only a passage scanned in the test is shown in Figure 20:

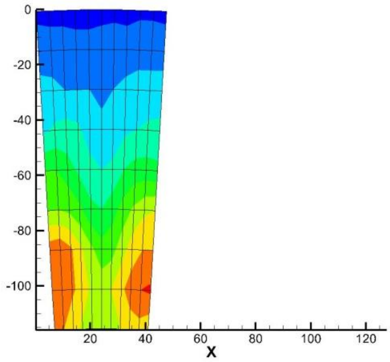



Figure 20 –scanning result of a passage at outlet

A scanning scheme with more scanning points is also carried out in the test, in this article the result is not mentioned anymore.

## 5. Conclusions

In this article, upon the intake distortion test of an aeroengine's fan component, aiming to design a series of generators, numbers of simulations are carried out to predict steady distortion indexes under conditions of various blocking ratios with every intake flow condition, meanwhile pressure chamber, bell-mouth structure, distortion generator as well as core-body of the test article are combined modeling and simulated to consider the detail flow in front of the inlet, every factor which may influence the measurement of distortion strength is list and deeply analyzed, and an efficient measurement scheme for obtaining a detail flow field at outlet of the test article is built up and processed, the conclusions are below:

1. according to the comparison between test data and simulation results for all the cases which has been carried out in former test, it is improved that the simulation results are well coupled with test data, indicates that the simulation scheme applied in this article is reliable;
2. of all the 33 cases of simplified models, the simulation results indicate that when one of the two parameters, intake flow and blocking ratio, is fixed, the steady distortion index has a nearly positive linearity relationship with the other one, which requires to be validated further according to the test data;
3. simulation results of the combined model( pressure chamber, bell-mouth structure, distortion generator and core-body of the test article) shows that when without a distortion plate, total pressure distribution at longitudinal section of the combined model is nearly even, while bell-mouth structure and core body may influence the Mach number distribution, distance between distortion plate and bell-mouth structure as well as location of AIP still require evaluation;
4. there is a large scale vortex behind the distortion plate, in this test the vortex cannot influence the distortion index calculation, however the influence of the vortex should be evaluated to

validate the location of AIP, especially for a large scale of blocking ratio and intake flow conditions;

5. a new scanning scheme has been built up to obtain details of the flow field at outlet of the test article, and successfully applied to get abundant data for high-pressure compressor distortion generator design.

Combined with former test data, in this article the simulation scheme is provide to be highly reliable, and CFD method has been applied for evaluating the design effect of 7 types of distortion generators with different blocking ratios with various kinds of intake flow conditions, the scheme offers an efficient method for evaluating the distortion indexes of different cases, satisfies the need of an engineering application, and provide criterion for blocking ratio selections. Besides, based on a carefully review of the former test data a new test scheme for obtaining detail outlet flow field is built up and processed successfully, which contributes a huge of time saved. The way of test scheme design in this article provide a successful experience of similar projects, and carried out a successful taste on distortion test technology development.

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## 7. Copyright Statement

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