Integrating MSC Software and CADSA Program for the Aircraft Detail Stress Analysis

Ming Chiu†
Tian-Sheng Wu✶
Chun-Hui Lee
Nan-Horng Lee

Aerospace Industrial Development Corporation

Taichung, Taiwan, 40722 R.O.C.

email : tensionwu@ms.aidc.com.tw

ABSTRACT

AIDC has involved several international cooperation projects for commercial airplane for several years. From CAE viewpoint, Structural detail stress analysis and certification analysis reports (FAA/JAA Certification) are two major time and man-hour consumer. So, Standardization and automation can further improve analysis processes and shorten time schedules. Therefore, AIDC has developed a program, **C**omputer **A**ided **D**etail **S**tress **A**nalysis (**CADSA**), which cooperated with MSC/NASTRAN and MSC/PATRAN packages to manage the detail stress analysis. This program provided a fast and efficient method to help analyst to do the detail stress analysis and to output formal stress reports. This CADSA program has been actually applied to some international cooperation project, and it has been proven to be significant benefit on cost reduction and best quality.

† Manager of Structural Analysis Section
✶ Manager of PDM Program

Introduction

The main task of stress analysis on aircraft structure consists of three parts as shown in Fig. 1. They are Finite Element Modeling(MSC/PATRAN), Finite Element Analysis (MSC/ NASTRAN), and Computer Aided Detail Stress Analysis based on the Stress Analysis Manual. Although, commercialized Finite Element Analysis packages are available in the area of structure analysis, the usage of MSC/NASTRAN is the most popular one. Another CAE software MSC/PATRAN is also widely adopted by aerospace industries due to its perfect integrated interface with MSC/NASTRAN. Recently, MSC/SuperModel, a new module of MSC/PATRAN, has more considerate and powerful functions for the integration of finite element modules.

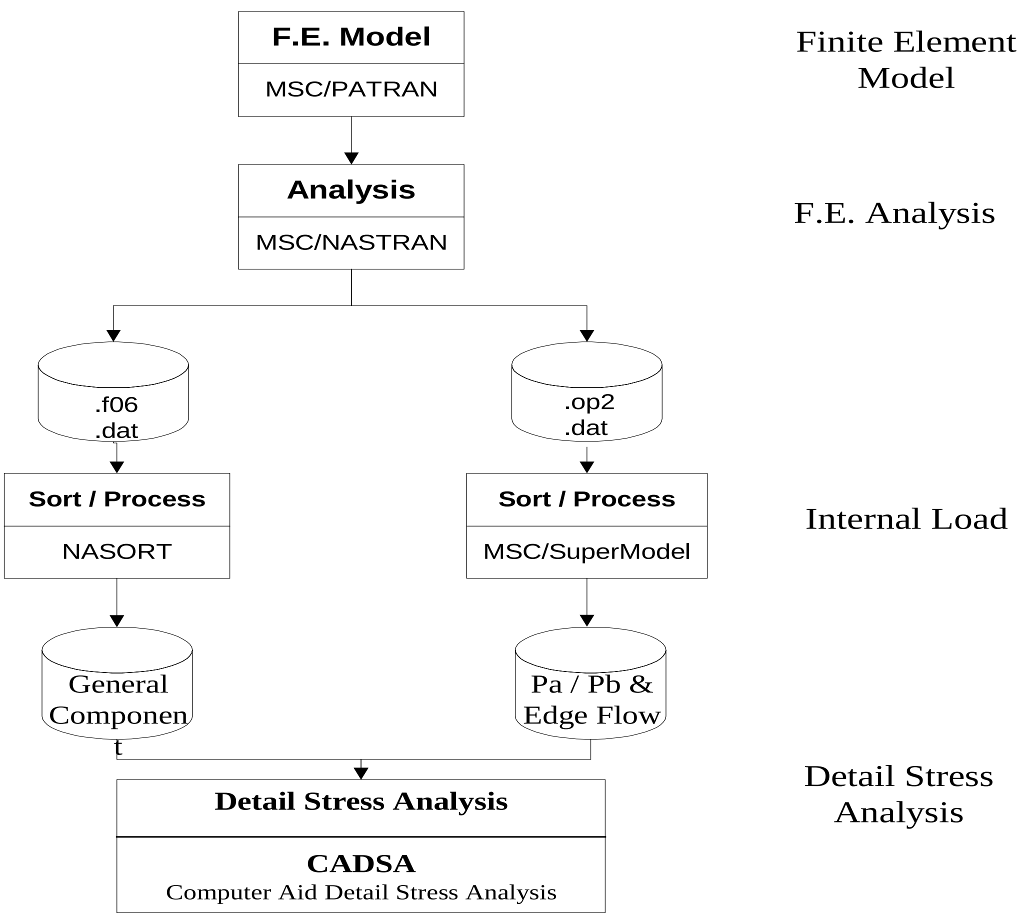

Fig. 1 Process for the aircraft structure detail stress analysis

Although using both of MSC/NASTRAN and MSC/PATRAN can elevate the efficiency of the Finite Element Analysis and the Pre- and Post-processing, yet some aspects exclude. For example, if an internal load plot is desired for the detail stress analysis in aerospace industry, MSC/PATRAN can provide interactive drawing dialogue in various formats. But, if you want to draw over hundreds of load plots in the same time, MSC/PATRAN seems lack of appropriate function and sophistical efficient; in addition, their non-adjustable output formats can not automatically print with the company special format and mark with the company logo for report standardization. In order to solve the situations, AIDC decided to develop the In-House program.

Stress analysis is a complicated and highly repeated routine work. Even an experienced engineer can not avoid taking much time in routine calculating. A computer program named CADSA (Computer Aided Detail Stress Analysis) is well developed to reduce the routine work of the stress analysis process. CADSA can accumulate the abundant stress analysis experience from the senior engineers, the analysis algorithms in the relevant references ([1], [2], [3]), and the specific methods by the cooperative company as well. As a consequence, CADSA not only combines the above action items but also links the database of material strength, analytical diagram, and element internal load. Furthermore, by the aid of high speed calculating capacity of computer, this program can calculate the Margin of Safety (M.S.) of all loading conditions, and sort out the lowest M.S. in the stress analysis report. The content of these reports will be also produced in Microsoft WORD format (related figures will be produced in the PostScript format and merge with the text automatically). As a result, it can generate hundred of pages of FAA/JAA certificate reports in single analysis processing. It will be very helpful to elevate the efficiency and quality of the stress analysis, such as elimination of human errors, standardization of report format, and approval of the aircraft certification eventually.

Integration of MSC/PATRAN & MSC/NASTRAN

The finite element analysis processed by MSC/NASTRAN will produce a large amount output (including displacement, internal load and stress), but in use of MSC/PATRAN can display and inspect the analysis result rapidly. The purpose of inspection is to evaluate the accuracy and reliability of the finite element model and the analysis result (qualitative analysis). But the general stress analysis is using element internal load accompanied with the Stress Analysis Manual to calculate the M.S. (quantitative analysis), such that the output data of MSC/NASTRAN must be processed to meet the requirement. Since CADSA has the fixed sorting format of internal load data, the present MSC/PATRAN can’t satisfy the requirements. Therefore, a program NASORT is developed to process the internal load data, to calculate the ending point axial force of BAR/ROD element, and to select the Max./Min. values of various conditions. Based on the different requirements, the hard copy can be printed by the choices of sorting in element ID, element type or load case ID.

The new module of MSC/SuperModel, which is constructed under the MSC/PATRAN, can provide the ending point axial force of BAR/ROD and the shear flow of QUAD4, this result can be extended to the stress analysis of attachment. Although MSC/SuperModel can convert the calculating values into a text format and record to an indicated file, yet there are some functions need to be reinforced; for example, if you want to save the data of the end point axial force, there are no identified codes to differentiate the varieties of load data and the user would be confused easily. Besides, MSC/Super Model can only deal with one load case at a time, it will be quite inconvenient to the user to deal with the load data. A solution of this problem is by coding the aided program to generate the session files of MSC/PATRAN, then proceed the "play session" to calculate the axial force of the end point for all load cases. Finally, remark the identified code and save the data to the indicated files.

Detail Stress Analysis of Aircraft Structure

The detail stress analysis of aircraft structure is to set up the finite element model first, then refer to the stress analysis manual which is defined by the individual manufacture to calculate the allowable strength of each failure mode and the appropriate dimensions(Fig. 2).

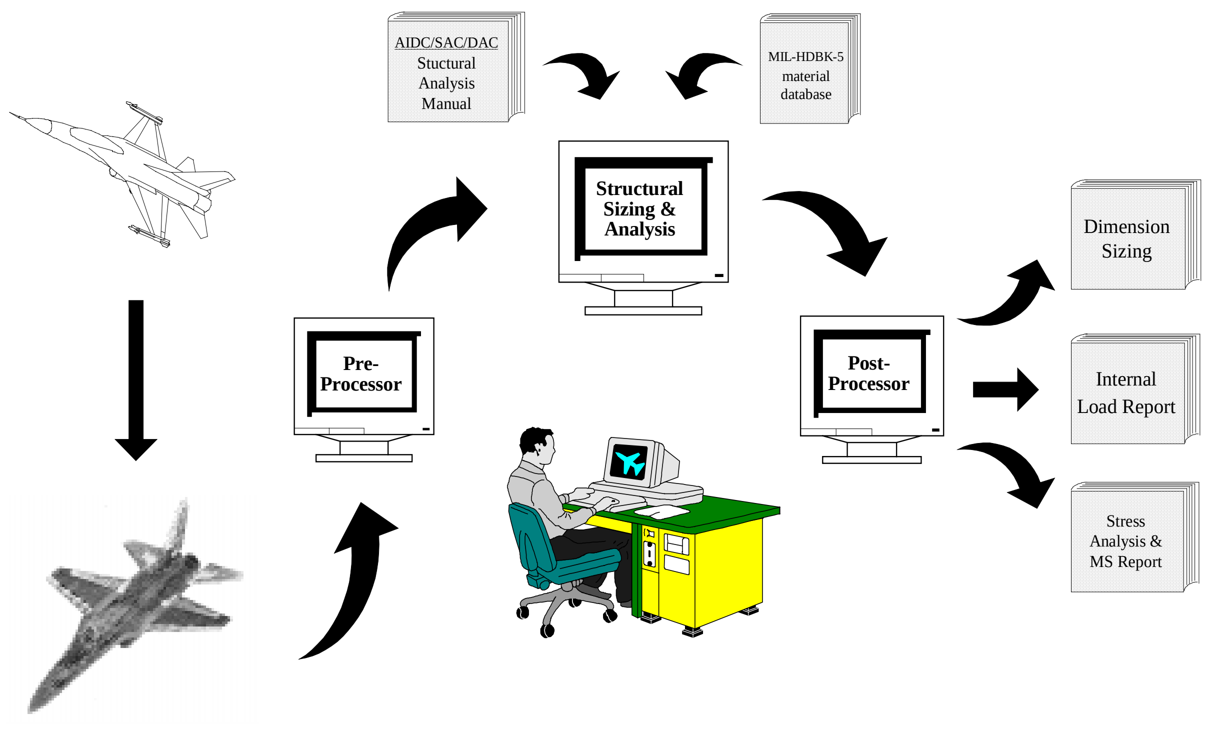

Fig. 2 Computer Aided Structure Stress Analysis

The tasks such as finding the internal load, calculating the allowable strength, determining the structure dimension and preparing the certification report always require more manpower and time to achieve (some of the aircraft companies hired a lot of experience job-shoppers or contract engineers to solve the problem). Due to the processes of redesign and update the loads frequently, it will take at least one year to complete the all and the cost would be increased tremendously. In order to reduce the manpower and cost, AIDC has successfully developing the all-in-one software of Computer Aided Detail Stress Analysis (CADSA, Fig. 3), which will integrate the Finite Element Model, structure internal load, stress analysis manual, database of material/joint strength, and report format.

In order to improve the efficiency and capacity of structure analysis, and to ensure the quality of the results, we can easily fulfill with the powerful software of CADSA to all kinds of international cooperative projects and obtain the approvals of the FAA/JAA certification.

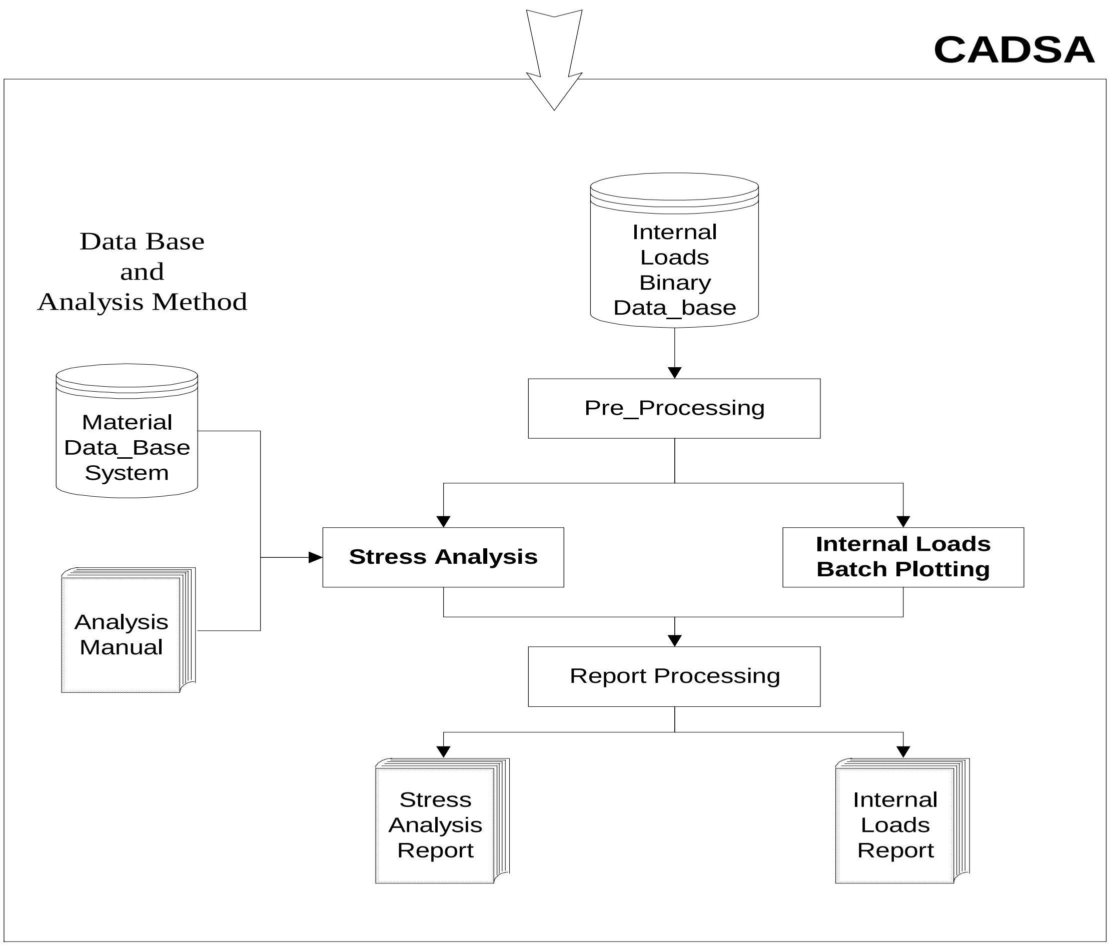

Fig. 3 The Main Function of CADSA

The Main Function of CADSA

Pre-processing of CADSA

For simplify the input data, CADSA would calculate the dimension of length, width, curvature and area according to the coordinate data and element connection automatically. Moreover, it provides a number of reference data to increase the flexibility in all kinds of situation, such as unit transposition. For extending the flexibility of CADSA, it is allowed that the analysis engineers can key in the dimension data from the drawings directly.

Finite Element Model and Internal Load Analysis

Although MSC/PATRAN can provide the plots of the FEM model and the results, it can only print out the content on the screen page by page. However, it would be very inconvenient if you must complete numerous internal load reports. Also, it would be very costly if the report must be printed on the sheet with company's logo. CADSA provides the alternative of interactive way and the type of batch job. Meanwhile, it can produce the plots and merge into the required report format. Fig. 4 shows that a partial internal load and the finite element model are presented in the required format with company's logo(AIDC or others).

Internal Load of the Analysis Object

Usually, the engineers need to process the structure internal load in the numerous finite element results. It would be very difficult if you want to point out the critical condition from 10 ~ 100 load cases. Furthermore, it would be a catastrophe, if the difference of shear flow were required. According to the element ID, CADSA can sort out the internal load. In the same time, it would calculate the average and maximum internal load of the structure part according to the element connection of the finite element model. The advantage of this function is that engineers only have to set up the connection of structural object and element IDs (the connection is quite stable in general), without worrying about the increasing or decreasing of the load**.** In the process of calculating, CADSA would go through every load to pick up the lowest Margin of Safety. Consequently, it would avoid man-made missing and save man-hours.

Structure Plot of the Object

A proper drawing of the specific component is always needed. The drawing job inevitably became a burden of engineers. CADSA would use the related geometry data and the Finite Element Model to draw the picture of a structure part. Meanwhile, it will output the file in PostScript language for the use of quotation in the report.

Cross Section Properties

When engineers are calculating the allowable strength and the internal stress of cross section, they must base on the data of cross section properties and coordinate. Consequently, calculating and the cross section properties and measuring the coordinate would be a great burden. If the cross section dimension changed, the whole cross section properties and coordinate might be calculated and measured again. No doubt, any changing of the cross section dimension would increase the burden of engineers. In order to solve the above problems, first, CADSA would break all kinds of cross section into many small blocks. Then, it would use the length, thickness, initial position with polar coordinate system to simplify the input. After that, based on the Boolean operation to obtain the close-curve of the cross section, then to calculate the properties of the cross section and the geometries. Finally, CADSA would calculate cross section properties and coordinates. For the regular cross section, such as **L**-type**, T**-type**, Z-**type**, C**-type**, I**-type**,** it only have to key in the length and thickness. By doing so, it would be easier for engineers to key in the data of cross section properties and coordinates and to deal with any changing of cross section dimension

Material and Joint Strength Database

Calculating the allowable strength of failure modes, engineers needed to know the material/joint strength. CADSA can establish the strength and material properties database of MIL-HDBK-5X, and the searching tools, then merged into the applying software of CADSA to calculate the allowance strength. Through this tool, it would be not necessary for engineers to check the related strength and property, in stead; they only have to know the name of material/joint. This tool would be helpful to lessen the burden of engineers.

Stress Analysis

Every aircraft company has its own stress analysis manual, which contains the detailed procedures and methods of stress analysis. Most of the manual contains large a part of formulas and diagrams to calculate the allowance strength of all kinds of failure modes. Since the calculating procedure is rather complicate and enormous, it takes a long time to do it by hand. CADSA integrated the analysis methods, diagram database, formula, material/joint database, and internal load calculating and searching, and crossing section calculating into a whole object. For example, if an engineer wants to analyze the object of intermediate diagonal tension, which is composed of strength analysis, attachment analysis, buckling analysis, and crippling analysis (the tension or compression analysis which depends on the internal load), he doesn't need to pay much attention on the stress analysis. In stead, he just needs to know the basic dimension and nomenclature of material on the drawing, then decides which analysis method is most suitable for the target structure part. After that, he can rely on CADSA to calculate how the Margin of Safety and Critical Load distributed in the structure. The final report could be both the analysis report and the base of weight reduction.

Post-Processing of CADSA

During the design stage of an airplane without CADSA, the load data is provided phase by phase. It's a definitely nightmare for the analysis engineers to comprehend the influence of the structural part by comparison. After that, engineers still need to complete the stress analysis for the first and the final set of load at least. This solution can't reduce burden of engineers effectively. CADSA can reuse input data to calculate repeatedly. Whenever the load change, it can find out the critical load and the Margin of Safety. Thus, CADSA provides a better solution for engineers to compare the load in different phase.

Concurrent Engineering of Analysis and Certification Reports

The safety of commercial airplane could secure the passengers' life and the airliner's profit. That's why all the design and analysis of a new airplane must be certified by FAA/JAA strictly, and the structural analysis report plays an important role to the certification. This report must clearly explain and indicate the adopted internal load, the reference data, the finite element model concept, internal load plot, structure configuration, and analysis method and process. The whole certification analysis report should be simple, clear and easy to understand. Almost every aircraft company uses their in-house software to proceed the analysis, however, the final report still made by manual. In order to reduce the cost and the manpower. CADSA can integrate the functions which described in "The Main Function of CADSA" to produce the certification report in required.

Fig. 5 and Fig. 6 were present the certification analysis report of international cooperation project (such Sikorsky, Alenia, …etc). The upper part of the report sheet is the required logo and report number in the contract, and the lower part is the signature space, date and page number. The final report contains the structural configuration, internal load to be adopted, and the analysis result. Finally, the analysis engineers only need to add the structural description and additional instruction. It could save much time to produce the report.

CADSA could solve the calculating and reports making problems for analysis engineers. In the same time, engineers could have more time concentrating on deciding the most suitable analysis method and judging the analysis result. CADSA not only can provide a rapid detail stress analysis method but also can produce the final report automatically. The integration of CADSA can effectively raise the productivity of engineers and improved the quality of detail stress analysis. The most important is it would be helpful to be certified by FAA/JAA.

Expansion in the Future

Since the integration of CADSA has well established the automatic analysis model and the standardized operation flowchart, AIDC has actually utilized the package to two of the international cooperative projects; additionally, it can be tailoring and customizing based on the special request in project. While facing the pressure and the challenge from the global competitors, the only solution shall be focused on quality improvement, budget control, and program management. In order to involve more international ODM cases, the following categories should be emphasized:

- CADSA will be tailored and customized in the new cases according to the request of the contract the analysis methodology of the original company. Also we will apply the experience of the two cases on the new cases.
- Since advanced composite material has been widely used on the aircraft structure, and the fatigue problem is also crucial, CADSA will support both functions of advanced composite material and fatigue in the future.

Acknowledgement

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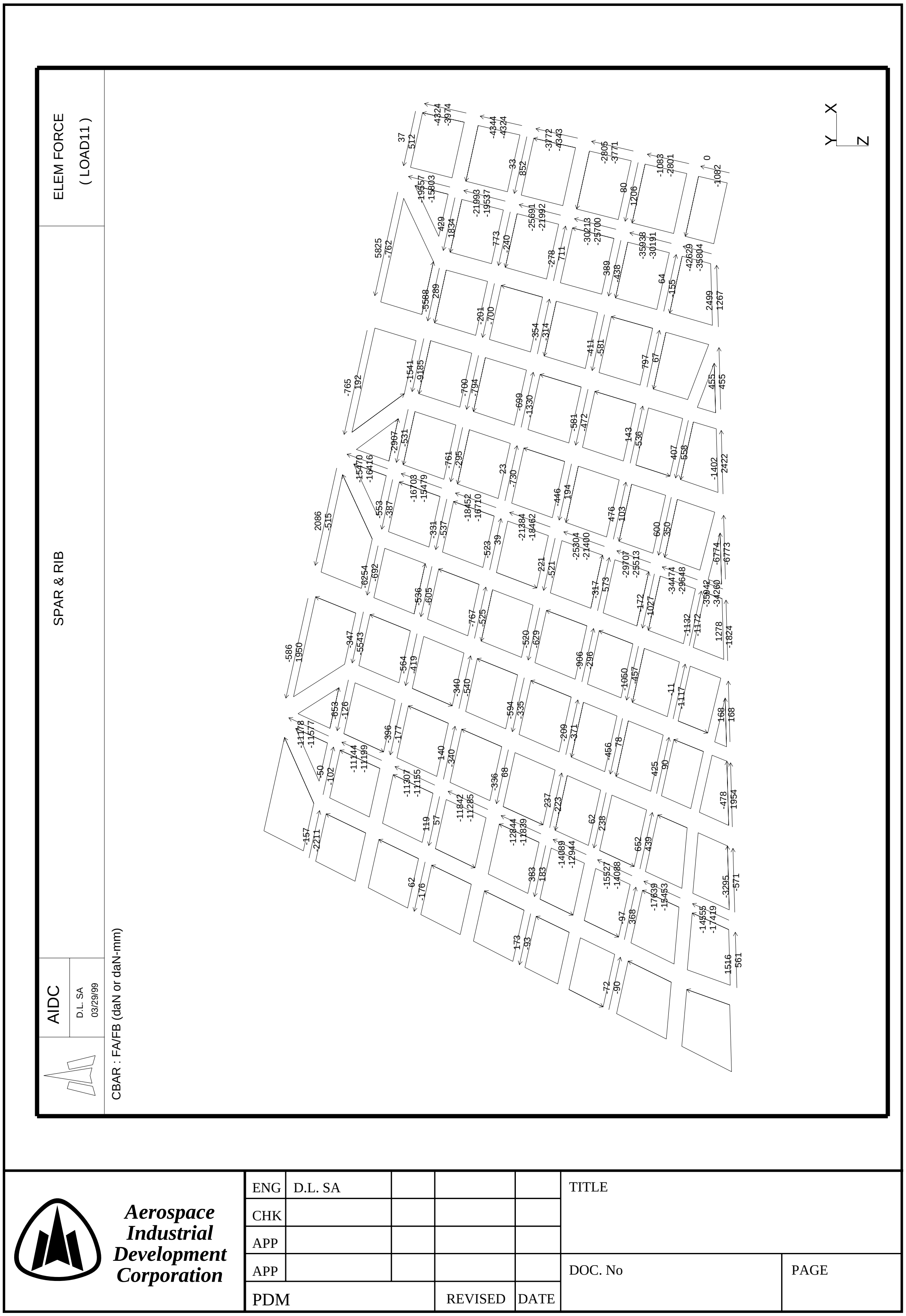

Fig. 4 Internal load analysis report

Computer Aided Stress Analysis

1.1 ANALYSIS(Cont'd) :

Drawing No : 92203-01201-101

Configuration of Shear Panel (FEM)

Configuration of Shear Panel with Cutout

Fig. 5 Configuration of analysis object

Computer Aided Stress Analysis

1.1 ANALYSIS(Cont'd) :

Internal Load for Shear Panel

Side 1 : q^1_{SU} = 326.99 (lb/in) q^1_{SC} = 326.99 (lb/in) Δq^1_S = 270.28 (lb/in)

EID	LOAD ID	q_{SU} (lb/in)	LOAD ID	q_{SC} (lb/in)	L (in)
613219	359	326.99 (1-2)	359	326.99 (1-2)	6.00
LOAD ID	EID (I)	q^a_{SU} (lb/in)	EID (O)	q^b_{SU} (lb/in)	Δq_S (lb/in)
367	613219	293.03 (1-2)	613217	22.75 (3-4)	270.28

Side 2 : q^2_{SU} = 327.01 (lb/in) q^2_{SC} = 327.01 (lb/in)

EID	LOAD ID	q_{SU} (lb/in)	LOAD ID	q_{SC} (lb/in)	L (in)
613219	359	326.99 (2-3)	359	326.99 (2-3)	6.30
613220	359	327.03 (2-3)	359	327.03 (2-3)	7.00

Side 3 : q^3_{SU} = 327.03 (lb/in) q^3_{SC} = 327.03 (lb/in) Δq^3_S = 327.03 (lb/in)

…

Note:1.$q^i_{SU/L}=\Sigma(-1)^{m+n1+n2}q_{SU}L_k)/\Sigma L_k$ $\Delta q^1_S=(\Sigma| q_S| L_k)/\Sigma L_k$

2.Side 1:EID=613219,613217 :$\Delta q_S=(-1)^{m+n1+n2}q^a_{SU}+(-1)^{m+n1+n2}q^b_{SU}$

…

3.L_k : Length of element k. n1,n2 = Number of side for panel, element.

m = 0/1,for panel and element proceed in the same/opposite direction.

Computer Aided Stress Analysis

1.1 ANALYSIS(Cont'd) :

Shear Panel Analysis (Slot Hole):
Drawing No : 92203-01201-101
Material : 7075-T62(QQ-A-250/12)
Strength : F_{CU} = 78000/80000 psi (A/B Basis) , F_{SU} = 47000/48000 psi (A/B Basis)
Element ID : 613219,613220

SIDE 1 & 3 CUT : L_2=13.300in , W_1=2.500in , R_h=1.25in , t_W=0.040in
L_4=13.300in , $E_W=10.3\times10^6$psi , t_d=0.060in , $E_d=10.3\times10^6$psi

SIDE 1 LIGAMENT: h_{W10}=3.780in , h_{W1}=4.308in , h_{d10}=0.480in , h_{d1}=1.008in
h_{C1}=1.300in , t_{C1}=0.050in , $E_{C1}=10.3\times10^6$psi
$A_1=0.298in^2$, C_1=2.147in , $I_1=0.593in^4$, k_1=45.5%

CASE ID	$q^{2,4}_{SU/C}$(lbs/in,UL)	M_U(in-lb)	f_{CU}(psi)	(psi)	MS
359	327.01(side 2)	2474	8965	6646(f_{SU})	4.49(S)
359	327.01(side 2)	2474	8965	15059(F_{CC})	0.68(C)

SIDE 2 & 4 CUT : L_1=6.000in , W_2=10.840in , R_h=1.25in , t_W=0.040in

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JOINT: (ref. SER920031,CHAP. 2)

Side 1:Load ID = 367, Δq_s = 270.28 lbs/in. (U.L.), L_1 = 6.00 in

Fas.□: Type = HL20-6, n = 2, d = 0.189 in, F_s = 2690 lbs $F_b=F_{bru}\cdot d\cdot t$= 156000·0.189·0.040 =1181 (lbs)

Fas.□: Type = NAS1097AD6, n = 2, d = 0.187 in, Fs = 862 lbs Fb=Fbru·d·t= 156000·0.187·0.040=1167 (lbs)

$F_{A1}=\Sigma n\cdot\min(F_s,F_b)=2\cdot1181+2\cdot862=4086$ (lbs,bearing)

JOINT **MS** =min[$F_{Ai}/(\Delta q_s^i Li)$-1]=min[4086/(270.28·6.00)-1, 5538/(327.03·6.00)-1,7872/(327.01·13.30)-1] =**0.81**

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Fig. 6 Detail stress analysis report