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FOREIGN AEROSPACE SCIENCE AND TECHNOLOGY CENTER



AVIATION PRODUCTION ENGINEERING
(Selected Articles)



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U. S. BOARD ON GEOGRAPHIC NAMES transliteration SYSTEM

Block	Italic	Transliteration .	Block	Italic	Transliteration
А а	<i>А а</i>	A, a	Р р	<i>Р р</i>	R, r
Б б	<i>Б б</i>	B, b	С с	<i>С с</i>	S, s
В в	<i>В в</i>	V, v	Т т	<i>Т т</i>	T, t
Г г	<i>Г г</i>	G, g	У у	<i>У у</i>	U, u
Д д	<i>Д д</i>	D, d	Ф ф	<i>Ф ф</i>	F, f
Е е	<i>Е е</i>	Ye, ye; E, e*	Х х	<i>Х х</i>	Kh, kh
Ж ж	<i>Ж ж</i>	Zh, zh	Ц ц	<i>Ц ц</i>	Ts, ts
З з	<i>З з</i>	Z, z	Ч ч	<i>Ч ч</i>	Ch, ch
И и	<i>И и</i>	I, i	Ш ш	<i>Ш ш</i>	Sh, sh
Й я	<i>Й я</i>	Y, y	Щ щ	<i>Щ щ</i>	Shch, shch
К к	<i>К к</i>	K, k	Ъ ъ	<i>Ъ ъ</i>	"
Л л	<i>Л л</i>	L, l	Ы ы	<i>Ы ы</i>	Y, y
М м	<i>М м</i>	M, m	Ь ь	<i>Ь ь</i>	'
Н н	<i>Н н</i>	N, n	Э э	<i>Э э</i>	E, e
О о	<i>О о</i>	O, o	Ю ю	<i>Ю ю</i>	Yu, yu
П п	<i>П п</i>	P, p	Я я	<i>Я я</i>	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ѐ in Russian, transliterate as yě or ě.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
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rot	curl
lg	log

GRAPHICS DISCLAIMER

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from the best quality copy available.

STRENGTHEN ENTERPRISE TECHNOLOGY RESEARCH
TO PROMOTE TECHNOLOGICAL ADVANCES

Yi Zhipin and Zhang Xuanxing
Xian Aircraft Company

This article describes the guiding principles management procedures and staffing of the Xian Aircraft Company Institute Of Manufacturing Technology Research. The major role it plays in converting scientific and technical research achievements into productive forces is also presented herein.

As reform has been developed in lower levels, one of the heated points of discussion has been how to accelerate company technological advances and improve company efficiency.

Some people have estimated that if passenger flow increases by eight percent annually, by the year 2000, the total world passenger flow will be twice what it is today, or two billion passengers per year. In order to meet the needs of the constantly increasing flow of passengers, it is estimated that it will take an additional 4,500 to 5,000 passenger jet aircraft. The changes in costs over the past ten years are that prior to the Gulf Crisis, the cost of fuel dropped from 42 percent of direct operating expenses to 18 percent and the cost of aircraft purchases rose from 28 percent to 42 percent. Therefore, aircraft companies in China and in Foreign countries paid a great deal of attention to new technologies. For example, Boeing and McDonnell Douglas both focussed technology operations on improving and modifying models and on production and manufacturing processes, stressing the economic benefits of new technology. This has dropped the cost of aircraft to an all time low. The various large aircraft companies and factories in China invest tens of millions of Yuan in technological reform every year to develop

production and manufacturing systems. We can see that technical research by companies is taken seriously by everyone.

The Nature, Role and Characteristics of Company Technical Research

It is stipulated in the Charter of The Xian Aircraft Company that the Technology Research Institute is service organ of the company responsible for applied experimental research for aircraft manufacturing technology (including new processes, new technology and new materials). It is also the unit responsible for management of technical system research under the direction of the chief engineer. Its primary missions are to be responsible for research and development of new aircraft, improving and modifying current models, subcontracting production and applied testing of new processes and new technology required for the development of civilian products. It is also responsible for promoting the applications of their successes.

The nature of company technology research institutes is research into the application of technology, and is not research into applied technology, nor is it basic scientific research. Therefore, the service guiding principle is research centered around company production in order to increase the efficiency of the company and to develop its operations. The success rate and application rate of the successes is the primary standards for the operations of these institutes. It should also base its operations on the actual situation in the company's production, combining long term and short range goals, focussing mainly on the short term goals where the successes should be applied.

In the research and development of the Yun 7 aircraft in 1988, the carbo bay floor central rail forming became a key problem. This part is a channel shaped material 120 mm wide, 54 mm high, six meters long made of LD5. The Institute and production units focussed

their entire efforts on this, and in only four months they finished their mission using hot bending forming method, winning the praise of the production departments and the leaders. In 1990, during the test manufacturing of the Yun 200 aircraft, the key problems were the making of holes, dimpling and cutting of the wing tips of synthetic fiber composite material. In six months, the Institute had completed drill bit edge grinding, drill bit cutting edge, dimpling drilling improvement, cutting tool selection and parameter studies, as well as compiled a trial production booklet, resolving problems which had not yet been solved in China. The same year, in order to improve the level of conventional processes, it also undertook the task of developing a pneumatic polishing machine. In six months time it had completed design and prototype trial manufacturing, and had delivered this to production units for trial use. This equipment approximated imported products in weight, cost, revolution speed and torque. The achievements stacked up during the Sixth and Seventh Five-Year Plans illustrate that the application rate was increased from 87 to more than 95 percent.

How to transfer scientific and technological achievements to production is a key topic being explored by scientific and technical circles and industrial circles. For the enterprises, if they are to transfer scientific and technological achievements to production, they must have a corps of technicians to provide the matching software and hardware and to carry out the technical renovation of the production line. The Institute can play a positive role in these aspects.

Enterprise Institutes are bases for training technical personnel in understanding new techniques. From the early seventies to the mid eighties, as the application of such new technology as electrolysis processing, explosive forming, shot peening technology, numerical control technology, computer applications, composite materials and bonding technology, one batch after another of

technicians have continued to be transferred from the Institute to the production units, becoming technical backbone cadre on the production line. The changes in this corps have caused temporary problems for the Institute, but it was a good thing for the enterprises. Since the mid eighties, the Institute has made new advances in the areas of distributed numerical control systems and titanium alloy super plasticity forming/diffusion joint and hole strengthening interference techniques.

The enterprise technical research provides the matching software and hardware for new technology items appropriate for the production environment. The end result of applicability testing is production application. The primary standards for evaluating an item is an evaluation of the its application. At the same time, a review provides trial production applications and the corresponding software: technical materials such as production instructions, operating regulations and use instructions. In the past two years, the Xian Aircraft Company's Institute of Manufacturing Technology Research has compiled ten instruction booklets for new technology production. At the same time, during the trial application process, there must be corresponding hardware such as the installation of various types of equipment, instruments and gauges, the reliability and stability of which must be verified before this new technology can be placed into normal production channels.

Enterprise technological research is the basis for technical renovation of the enterprise. New process and technology items are constantly being perfected and familiarized through trial production testing. In order to meet new production needs, it is necessary to carry out technical renovation of the production line so that this technology can become part of the production line. It is only when this is done that it can be said that the entire process of transferring scientific and technological achievements to production is completed. According to partial statistics, time sequence for

various technical renovations and technical tests of the Xian Aircraft Company are listed in Table One:

表1 部分工艺研究项目与技术改造时序统计表

1 项目名称	2 筹建时间	3 开发应用时间	4 技术改造时间
5 爆炸成形	1963 年	1964 年	1973 年
7 电解加工	1962	1964	1969、1986
8 数控技术	1970	1975	1986
9 计算机	~1970	1971	1984
10 钛合金成形	~1972	1976	1985
11 复合材料	~1977	1984	1986
12 金属蜂窝	~1974	1981	1986
13 喷丸成形	~1966	1970	1986
14 胶接点焊	~1967	1970	1986
15 DNC	1985	1989	1986-1988

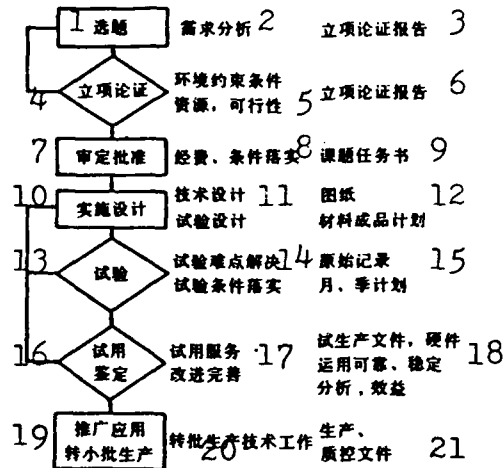
TABLE ONE: TIME CHART OF SOME RESEARCH ITEMS AND TECHNICAL REVISIONS

1. Item. 2. Date preparations begun. 3. Development and application date. 4. Technical revision date. 5. Explosive forming. 6. Year. 7. Electrolytic processing. 8. Numerical control technology. 9. Computers. 10. Titanium alloy forming. 11. Composite materials. 12. Metal honeycombing. 13. Pelletized spray forming. 13. Bonding spot welding. 14. DNC.

Management of Enterprise Technical Research

In order to ensure the success rates and application rates of enterprise projects for effectiveness, it is necessary to have a managerial program and a management system which conforms to the needs of that enterprise and which also takes into account the special characteristics of the experimental research. A flow chart of the project management at the Xian Aircraft Company Institute of Manufacturing Technology Research is shown in the illustration below. The illustration shows a simplified sequential diagram of the operations emphasized at each phase and the achievements of each phase. This allows each phase of the project to be investigated,

allows each phase to be operational in order to ensure the final success and application of the project.



FLOW CHART EMPHASIS ACHIEVEMENTS

CONTENTS OF TECHNICAL RESEARCH MANAGEMENT PROGRAM AND CONTROL

1. Selection. 2. Required analysis. 3. Establishment of project, demonstration and reporting. 4. Establishment of project and demonstration. 5. Environmental restrictions, resources, feasibility. 6. Establishment of project, demonstration and reporting. 7. Review and approval. 8. Financing and conditions. 9. Project tasking document. 10. Implementation design. 11. Technical design, experimental design. 12. Blueprint, material products plan. 13. Testing. 14. Resolving testing problems, achieving testing conditions. 15. Initial recording, monthly and quarterly plans. 16. evaluation of test use. 17. Test use service, improving and finalizing. 18. test production documents, hardware operational reliability, stability analysis, efficiency. 19. Promulgating application, transfer over to small batch production. 20. Transfer over to batch production technological operations. 21. Production, quality control documents.

Demonstration of project is the assurance that the project can achieve effective primary links. Requirements, environmental restrictions and future developmental connections and the degree of maturation of the technology, risk evaluation, benefit evaluation must all be clarified. Because the manpower and expenses for large projects are sizeable and the cycle is long, it is even more necessary to strictly review the feasibility report according to sequence. Enterprise Institute projects must also combine large, medium sized and small as well as long cycle and short cycle. The category of projects, their scopes and cycles are shown in Table Two.

TABLE TWO: PROJECT CATEGORIES

LARGE SCALE PROJECTS:

SCOPE: Directional tasks in the realm of manufacturing technology having a fairly large and long range impact on industrial development.

CYCLE: About five years.

NOTES: Large investment of manpower, material and finances, requiring cooperation inside and outside the enterprise.

MEDIUM SCALE PROJECTS:

SCOPE: Where there is fairly mature applicable technology, combining this with the short term plans for the factory, emphasizing providing practical research.

CYCLE: Two to three years.

NOTES: N/A.

SHORT TERM PROJECTS:

SCOPE: Major problems which exist in production, basic technological problems in conventional techniques.

CYCLE: About one year.

NOTES: Normally these can be solved within the enterprise.

The Xian Aircraft Company keeps the ratio of different categories of projects (large, medium and small scale) around 1:5:7 respectively. The chief engineer submits around ten items for

project completion to the institute every year. This is about three projects per technical researcher per year. The Institute conducts as many as 20 to 30 projects through the course of each year. Over the past three years, it has completed and made brake through in 30 projects. Of these, seven have passed evaluation at the ministry or provincial level.

The shifting out of feasible technology from practical technical research, the development of technology application testing and finally bringing it down to the enterprise production line, which is the bringing of scientific research achievements down to the construction level, is the major difference between industrial Institutes and research institutes and scholastic institution research operations. For the enterprise, the specific contents of this process includes providing the complete set of production technology documentation required to conform to the enterprise production; providing the industrial equipment and special use equipment through industrial technology document control channels of testing, revision and finalization and fixed model technology application departments. Through test use and assessment, modification and finalization, provide this to departments responsible for performing the work, and entering thee into normal management channels. Projects requiring technical revisions are provided by the institute with basic technical data including plant layout and necessary facilities. This process also requires that the customer work hand in hand, especially in comprehensive large scale new technology projects. Foreign countries also have "turnkey" type methods where the objectives of the customer are served, stressing the role of the customer.

These contents are stipulated very clearly in the specific responsibilities and duties of the Xian Aircraft Company Institute of Manufacturing Technology Research. It is just because it has had a firm grasp of bringing this down to the engineering level that the

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application rate and application results have been markedly increased over the past few years.

SETTING UP ENTERPRISE TECHNOLOGY RESEARCH ORGANS

Setting up enterprise technology research organs and manning them are a way of insuring that tasks are completed. Based on the characteristics of the operations of our institute, the Xian Aircraft Company management has made breakthroughs in dynamic management and open management. In the project application stage, there have been a number of technical backbone cadre who have been transferred to the production departments, and during the initial stages of the projects, there have been a number of technical backbone cadre transferred to the institute. For example, there is a researcher grade engineer who on his first trip to the institute completed research on the application of CAD/CAM technology to low resistance wing tips, playing an active role in the initial stages of that technology. On his second trip to the institute, he completed development of the aircraft structural component numerical control system NC-87, playing a major role in the programming of numerical control components. It is also worth mentioning that, depending on the requirements of the tasks, technical personnel from the institute are sent work in production workshops. For example, in the DNC project there were about five comrades who worked for a long time in the numerical control workshop in order to solve problems with DNC applications. This type of open management enhances the active roles and the sense of responsibility of the technical personnel, ensuring the project is applied in production.

The arrangement of organs within the institute should also be altered at appropriate times according to the projects. The Xian Aircraft Company currently is organized in a manner similar to the manufacturing developmental research departments of the Boeing Aircraft Corporation civil aviation department in the mid eighties.

At that time, the Boeing Corporation manufacturing developmental research departments in addition to assistance units, also set up automation, assembly, systems and manufacturing technology units. The emphasis was on research and development of automation and composite material technology.

Because of the rapid development of technology, projects change rapidly. Some testing equipment and computers become outdated in a short time. Therefore, the technical testing base construction emphasizes universality and flexibility. There is a clear difference here from the situation in the production units. Current projects cannot be used as the basis for testing base construction. The arrangement must be changed for projects with room for maneuverability. Equipment required for testing should be equipment the company already possesses when possible. However, common base instruments and machine tools should also be set up. Adaptability of the testing base should be improved to meet the needs of enterprise technology development.

Constant coordination and perfecting the relationship between the institute and other management departments within the company is also an important aspect of structural construction. The Xian Aircraft Company scientific and technical management departments, the technical technology management departments, the material supply management departments and the technical renovation and equipment management departments all place great importance on and support enterprise technical experimental operations. This is also one of the major reasons that the Xian Aircraft Corporation technical experimental research operations has met with such good success.

The monumental tasks facing China's aircraft enterprises in the nineties has made the raising of the level of manufacturing technology and the improvement of enterprise technical research work one of the key points of the operations of the enterprise. Recently,

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the National Defense Science Commission and the Ministry of Aerospace have both published instructions that they want to place importance on manufacturing technology. They have also called for those concerned to take this seriously. Under these conditions, the aircraft industry's technical research operations must reach a new level.

DESIGN MANUFACTURE AND CERTIFICATION OF THE
TOTALLY COMPOSITE MATERIAL BEECH "STARSHIP"

TRANSLATED BY: Jiang Shuguang

The "STARSHIP" is an eight to eleven passenger business aircraft developed by Beech Aircraft of the United States. It's 85 percent test aircraft was first test flown in August of 1983. Its first full size prototype production model was first test flown in February of 1986. Because this aircraft structure is "totally of composite materials", its development not only required special design considerations, but also required diligent and careful planning and cooperation to meet air worthiness certification requirements by the FAA. This article specifically introduces several considerations of the FAA for civilian aircraft composite material certification and how some designs have been certified.

THE BASIC SITUATION

The most obvious objective in composite material aircraft structure is a reduction in weight, and not every aircraft can achieve economic effectiveness from a reduction in weight. For example, the Boeing 767 costs about 600 U.S. Dollars fore every kilograms of structural weight. This level of efficiency cannot justify the expanded use of composite materials (except for auxiliary structure). However, more specialized aircraft such as military aircraft, helicopters and high level business aircraft cost 1,400 to 3,300 U.S. Dollars or more for every kilogram of structural weight. Therefore, it is easier to achieve efficiency through the use of composite materials. Other advantages of totally composite material structure include ease in manufacture of complex form structural elements, corrosion resistance and relative non sensitivity to fatigue.

全复合材料“星舟”机的设计制造和取证



The "STARSHIP" business aircraft takes advantage of just these advantages of composite materials. This aircraft cruises at an altitude of 12,500 meters, has a cruise range (with maximum fuel capacity and at long range cruise power) of 4,860 kilometers. Its maximum take off weight is 6,580 kilograms. Its empty weight is 4,500 kilograms. Of this, structural weight is about 1,800 kilograms. Composite materials make up over 1,200 kilograms of the structural weight. Metal parts are only used in high loading positions or such areas as the leading edges and landing gear.

Engineers have chosen the materials for the STARSHIP based on the inherent characteristics of composite materials. These characteristics include stress at fiber destruction (destruction tolerance), resin solidification temperature (economy of process and toughness) and the resin vitrification conversion temperature (environmental adaptation capabilities). For composite materials, purity and strength are equally important. Precision wire drawing is one method of obtaining purity. Adding resin to fibers to make

layered boards, and after they have been made to meet stability and fatigue life requirements, under extreme loading maximum design stress can reach 410 MPa. By comparison, aircraft aluminum alloy has a maximum strength of 580 MPa. However, there are fatigue life restrictions, an under extreme loading, the design stress can only reach 310 MPa.

FAA CERTIFICATION OF CIVIL AIRCRAFT COMPOSITE MATERIALS

In order to handle use problems of structural composite materials, the FAA has already established wide ranging regulations. Currently, the regulations which target composite materials certification are FAR 23, 25, 27 and 29. In addition to basic air worthiness regulations, informational reports concerning composite material design are also basic documents for certification. Recently the FAA has produced an advisory draft concerning quality management of composite materials. This draft is an additional requirement in the certification process.

The definitive document for composite material certification in FAR regulations is AC20-107A. This document can be used as a guideline for certifications requirements and for preventive measures. For raw materials and manufacture, FAA participated in and presided over MIL-HDBK-17, which is the guiding document for setting testing and design tolerances. The definitive document for certain special national certification requirements is the AC21-2

Structural certification is divided into three major areas: Statics, fatigue\destruction tolerances and vibration. This can be accomplished through analysis or testing. If the structure is basically determined through analysis, the effects of multiple loading should be studied, because it can lead to a reduction in

capabilities. For this portion of the process, an operational flow chart should be established, beginning with samples and parts, through component testing to full scale testing.

The fatigue\destruction tolerance analysis can be done through damage safety analysis or safe life analysis. For all structural parts, testing must be carried out all the way to maximum loading. Part tested should intentionally have defects which cannot be detected by visual observation or by non-destructive testing.

Analysis of composite materials has been conducted for a number of years. The use of computers has greatly reduced the amount of work in this analysis and has allowed for a suitable simplification of the analysis. Large model design details can be analyzed using large model limited element programs. This sort of program has special programs or subprograms to process different materials.

The key conversion in composite material analysis is the use of strain (and not stress) as the criterion for maximum design tolerances. This is because in the composite material layered plate, the strain of each layer is the same, but because of changes in the modules of the materials, the stress of each layer is not the same. This makes stress analysis very difficult. Therefore, strain limit criterion is used.

Structural design certification requires three levels of testing which are material properties, material interference and component/full scale testing. Normally, these are also called single layer plate, multiple layer plate and structural testing. Table one lists the conventional tests for these three levels of testing.

Controlling the number of holes is the crux of design value determination. This value is closely related to the holes and faults which exist in the samples. Normally, a number of samples with different numbers of holes and different processes and uses with different defects are tested in order to determine the effect of these factors on design tolerances.

TABLE ONE: TESTING PROGRAM REQUIREMENTS

**SINGLE LAYER
(MIL-HDBK-17)**

0 Degree	Tension	ASTM D3039
90 Degree	Tension	ASTM D3039
0 Degree	Compression	ASTM D 3410
90 Degree	Compression	*
45 Degree	Surface Internal shear	*

**LAYERED PLATE
(MIL-HDBK-17)**

Open hole tension	NASA 1092
Open hole compression	NASA 1092
Post stamping compression	NASA 1092

STRUCTURAL ELEMENTS AND PARTS

Directional strength	MIL-HDBK-17
Layered plate	MIL-HDBK-23, MIL-2-25463
Geometric effect	Set up special testing plan
Channel, I bar	
Full scale testing	Set up special testing plan

Note: * Testing methods currently being reviewed for MIL-HDBK-17.

Under normal conditions, before determining the materials certification program, it is necessary to reduce the number of candidate samples to a reasonable number. See MIL-HDBK-17 for screening tests for composite materials. For many requests, after the screening tests are completed, special tests related to design criterion are carried out in order to determine the best one or two

candidate materials.

Single layer plate tests are to determine the basic properties of the materials one is prepared to use. They provide basic tendencies of the materials to change under a series of temperature and humidity conditions.

The layered plate properties tests are to provide the interaction between the plates of the composite materials and properties when typical defects are included. Even though computer programs can be used to determine the ability to withstand stress with different orientation of the supplementary layers, simulation of other properties is very difficult.

Open holes and defects influence greatly the structural safety design of composite materials. It is necessary to conduct tests in order to determine the hole effect, the strength after punching and the directional strength. Under most conditions, the directional testing must be carried out in accordance with MIL-HDBK-17 requirements. Structural tests are used to handle interference between geometric forms, components and complex parts which are difficult to precisely simulate. This is the final step in structural design verification. Single element testing is done first, requiring that standard geometric forms are individually tested in order to determine if their properties meet estimated requirements. Then the structural component and the full scale tests are done (including the boundary conditions effect) in order to determine the overall reaction capabilities of the components. This test must take into consideration the primary modules which can cause destruction in order to determine if the designed structure is suitable for the stipulated uses.

Just like the physical tests of the major components, the accuracy of the test values are affected by several variables. The causes of the errors are primarily testing methods (variables in the methods, failed tests and imprecise testing requirements), testing conditions (environmental conditions, calibration and instrument wear), samples (processes, mechanical processes and defects) and data reduction (statistical analysis and sampling methods).

There is not total agreement concerning current composite materials testing. For example, the use of single directional samples to determine single direction strip directional characteristics. Careful investigation has led to the belief that this is too conservative because this type of sample boundary effect does not include the effect of intersecting the supplementary layers. This problem is considered in MIL-HDBK-17.

Another testing procedure which has evolved is the determination of the shear strength and shear modulus. Currently most use either the shear test within a ± 45 degree surface or a longitudinal shear test. The American Society of Testing of Materials (ASTM) has proposed a dual cut shear testing method called IOSIPESCU which may be more precise than current methods.

In order to verify the supplementary layer azimuth angles of single direction samples, it is possible to test layered plates along a zero degree angle break. The break can disclose the inside for testing. By inspecting the rough tear, it is possible to determine imprecise supplementary layers.

Inappropriate reduction of the amount of data can also lead to

overall ineffectiveness of the testing. Before obtaining data, it is necessary to evaluate the data reduction plan based on the testing procedure and other material sources.

When approving producers of new prefabricated materials, to conduct complete verification testing and evaluation of these producer's composite materials, it would take a great deal of work and expense. In order to solve this problem, the FAA and the JAA have begun to determine a set of programs which can reduce testing items in the determination of secondary materials.

The first step in the recommended program is to determine the size of the range of variations in the material and the production batch numbers. This can greatly reduce the amount of testing for materials with only minute variations. Furthermore, overall design tolerance testing is only required when both the resin and fibers have been changed. The amount of testing required for the next testing level is primarily determined by the relationship between the design use and the properties of the material.

The data obtained from single layer board and multiple layer board must be put through statistical analysis in order to determine the properties of the material in order to ensure there is sufficient margin of safety. The MIL-HDBK-17 contains a complete set of statistical analysis tools for processing composite materials. The statistical process flow chart used for composite materials is shown in Illustration One.

Quality management for composite materials is more complicated than that for other structural materials. Because it is formed and manufactured into parts at the same time, it is not only necessary for assembly plants to inspect individual parts, but they must also

ensure that the raw materials used can be made into quality products.

Because composite material raw materials are of indeterminate form, it can also be a problem selecting samples. The standard sampling plan commonly used can miss several basic quality problems in composite materials prefabrication materials. Therefore, it is necessary to carefully review all testing technology used. The key is how to make sure that enough raw materials are sampled in the tests to ensure uniformity in the quality between rolls of raw materials and within the same roll of raw material.

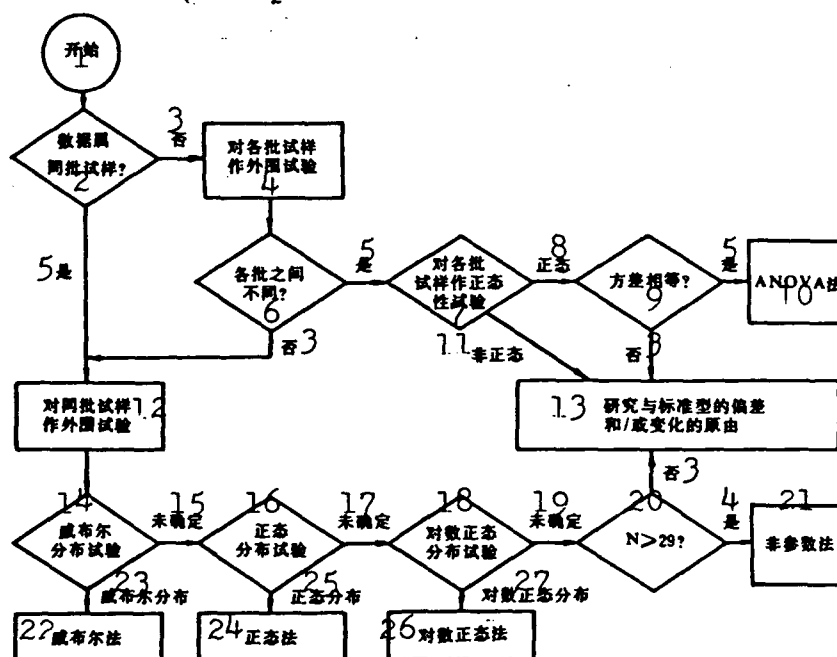


ILLUSTRATION ONE: MIL-HDBK-17 STATISTICAL PROGRAM FLOW CHART

1. Begin. 2. Data for same batch of samples? 3. No. 4. Perform periphery tests for each batch of samples. 5. Yes. 6. Differences between batches? 7. Perform normality tests for each batch of samples. 8. Normal. 9. Variance similar? 10. ANOVA Method. 11. Not normal. 12. Perform periphery tests for each batch of samples. 13. Reason for deviation and/or variance of studied and standard.

14. Weber distribution test. 15. Not stable. 16. Normal distribution test. 17. Not stable. 18. Log normality distribution test. 20. $N \geq 29$? 21. Non parameter method. 22. Weber method. 23. Weber Distribution. 24. Normal method. 25. Normal distribution. 26. Log normality method. 27. Log normality distribution.

In the production process, the testing of production operations for composite materials is also very crucial. It is also usually a major requirement for certification of composite material manufacturing processes. The properties of advanced composite materials easily lead to production errors while they are being made and defects appearing during installation. The use of manufacturing process testing can prevent this type of problem occurring during part production. The specific testing is the responsibility of the installation personnel. The quality management personnel are responsible for supervising and sample checks.

In order for all of the parts of the composite material certification program to proceed smoothly, a certain amount of additional work must be added to the design and analysis stages. This additional work (estimated at about 50 percent), when selecting samples for comparison, should be considered in the analysis.

STRUCTURAL DESIGN AND MANUFACTURE OF THE "STARSHIP"

In the composite material structure of the STARSHIP, layered plates are largely used on modules with a small number of parts, using co-curing hardening. Metal connectors are only used in areas of high loading, making wide use of gluing, simplifying the assembly of the aircraft. The shell of the pressurized cockpit is a module with a small number of component parts. This removable

cockpit shell is made up of two parts. The two parts are glued and rivetted together along a line in the center of the top and bottom. It does not have an internal frame or purlins. It only adds the necessary reinforcement material into the surface layer of the layered plate with one time curing.

The main wings are also modules of very few components stuck together. The wing skin is a self stabilizing honey comb structure. There are no spanning trusses and relatively few struts. The wing skin is one complete piece which is cured at one time. During wing assembly, the ribs are first inserted into the lower wing skin. After they are glued together and covered with hemp cloth strips, the top wing skin is put into place. The top and bottom wing alignment is controlled by positioning blocks. Then it is sent into the kiln with the wing module where it is sealed and cured at 120 degrees Celsius. The crucial part of this assembly technology is the patented woven fiber connection method. This allows a sliding shear connection without any complicated equipment in the wing mold.

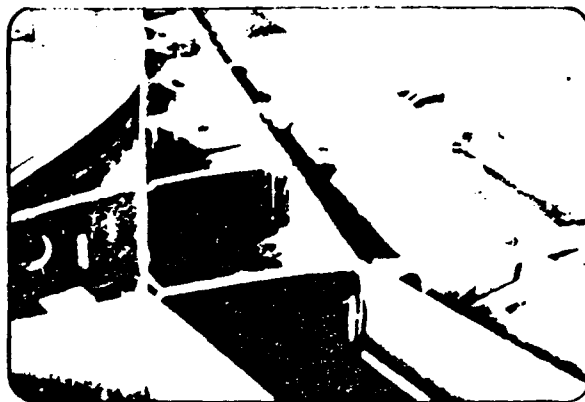


ILLUSTRATION TWO: WING MODULE

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The forward wings are variable backswept angle. These are used to make up for the pitch force generated when the flaps of the main wings are opened. The wing spar edge strips with overall connectors are used to withstand the loading transmitted from the forward wing to the forward fuselage and also allow for altering the backswept angle. The wing spars are manufactured using racetrack winding with carbon fibers and fluid epoxy resin. Then the wing spar edge strips are cured and preassembled as the a part of the wing skin module. After the forward wings are built they are fairly simple. Since there are no stringers or chord supports except for one support each at the wing base and the wing tip, all gluing is accomplished in one curing.

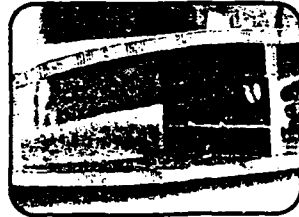


ILLUSTRATION THREE: WING CROSS SECTION

The main fuel tank is not a honey comb structure. This fuel tank design can resist internal pressure and uses separated membrane method to transmit the force to the shell surface. In order to reduce the weight and the cost, it uses internal plates and bulkheads to support the structural form of the thin outside walls. In addition to considering the structural loading, it is also necessary to check the fuel tank's resistance to lightning and its sealing properties. When an aircraft is struck by lightning, it is possible that the rivets in the walls can carry sparks into the fuel tank. However, a cementing agent has been added to



ILLUSTRATION SIX: FUEL TANK MODULE

prevent this from happening. The shell is glued together using Keflar "Pi" connectors and internal support plates. The seal of the fuel tank is thereby enhanced. A flow rectifier seal is used at the gas tank connection to prevent internal corrosion and to act as an anti-sway seal.

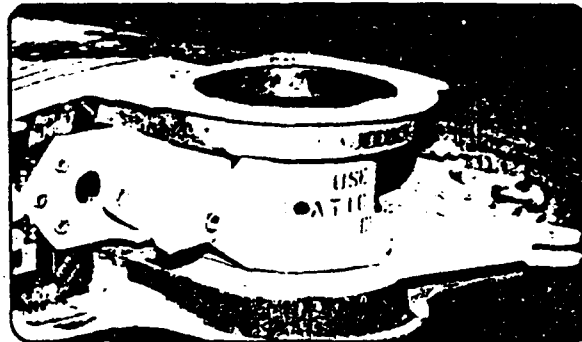


ILLUSTRATION FOUR: FORWARD WING CONNECTION

The control surfaces are made by gluing skin to the supports and spars. In order to avoid problems with the trailing edges, the skin is cured in one piece in a positive mold. The wing supports

are cut from flat plate and honey comb plate of different thicknesses and their edges are rolled.

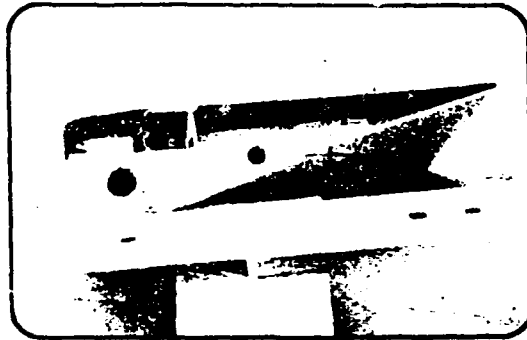


ILLUSTRATION SEVEN: CONTROL SURFACE CROSS SECTION

During installation, the wing supports and the skin are glued together at the edges. This process allows the control surfaces to withstand more than 3,750 kg/m even under during yawing tension.

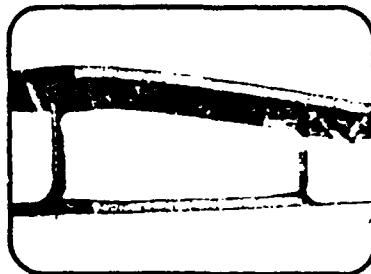


ILLUSTRATION FIVE: FORWARD WING CROSS SECTION

AIRWORTHINESS CERTIFICATION AND TESTING OF THE "STARSHIP"

For airworthiness certification, the "Starship" must satisfy the universal Article 34 of FAR23 as well as several special articles applied to individual aspects of aircraft structure. The testing and analysis stipulated in these articles for composite material structure include:

- Use destruction tolerance methods in place of destruction safety fatigue life methods.

- Use post impact destruction residual strength as the standard for allowing a material to be used.

- Environmental impact assessment.

- Adhesion failure assessment.

- Do lightning testing on the same piece of composite material before and after repair.

Material testing of the "STARSHIP" was conducted using the matrices and statistical methods stipulated in MIL-HDBK-17. For each piece of material, testing must be done for several different layer properties for each environmental condition. For just the initial material assessment tests, more than 8,000 pieces of data were collected.

Prior to testing, engineers had to document the extreme environmental conditions to which the structure could be exposed. For example, Anderson Air Force Base on Guam was determined to be the area with the highest humidity. The relatively humidity during

most of the wet months there is 85.3 degrees. During static testing, a humidity of 87 degrees was used. The humidity could be somewhat less for fatigue and crack expansion testing. California's Death Valley was determined to be the hottest area. During the heat of summer, the ambient temperature there can be as much as 47 degrees Celsius. The upper surfaces of an aircraft can be exposed to solar radiation as high as 980 watts per square meter.

In the testing process, more than 1,200 pieces of layered plate were used. They were used for strength and rigidity tests under conditions of tension, compression and shear and under conditions of cold and dry, room temperature and dry, room temperature and humid, and hot and humid. The adjustment of the experimental conditions was done by rapidly raising the experimental temperature (layered plate experiments raised the temperature to 71 degrees Celsius and the component tests raise the temperature to 60 degrees Celsius). Various types of destructive testing had to be conducted on the samples, including testing from no observable damage to punching of a series of holes, in order to determine threshold value of each type of layered plate while measuring the different degrees of damage.

Engineers point out that structural analysis uses layer pressure analysis techniques which were already demonstrated during layered plate testing, while considering the internal loading of each composite material part. It is required that they use corresponding environmental conditions and lamination properties. Internal loading can be calculated by limited element analysis. Its accuracy is reviewed by comparing it with the full scale static test data under laboratory conditions.

The FAA is very concerned about the effect of temperature and humidity before mechanical loading. They are also concerned about the precision of limited element estimation of the composite effects of environment and mechanical loading on complex three dimensional structure. To resolve these concerns, they have established two regulations: (1), There can be no more than a ten percent error between the estimated variable and experimental results. This can be achieved through more detailed simulation of experimental structures with internal reinforcements, experimental loading and capture and constraint simulation during the experiments. (2), in large models, complex load transfer parts must be adjusted to saturation humidity, temperature of 71 degrees Celsius and loaded to a suitable internal pressure and bending load. When the data indicates that the temperature and humidity do not alter the overall loading effect, the estimates are finally accurate.

At a high percentage of maximum strength, the samples underwent a cyclical loading fatigue test to obtain data on when cracking was produced. The cyclical loading used in the destruction tolerance testing included wind gusts, engine, cockpit pressure, landing, engine torque, propulsion and minimum surface loading. The load distribution coefficient was 1.15, allowing for a statistical use life to be represented by two laboratory experiment lives. All flight parts underwent full scale safety testing, including leading edge and its installation cross member, the wings and its fuselage connection, the pressurized cabin, vertical stabilizer and control surfaces.

After initial life tests of prefabricated structures, each sample was subjected to several mechanical destruction tests including impact destruction, lighting, rivet loosening or loss,

connection ungluing, delamination and piercing of composite material parts and cracking and damage of metal parts.

Residual strength testing was the final item in destructive tolerance testing. This testing demonstrated that the load bearing properties of the "STARSHIP" structure were at least capable of maintaining design load tolerance. The strain and distortion records demonstrate that changes in overall structural rigidity do not extend to the range of flight vibration tolerances.

The glued connections were demonstrated to have extremely high fatigue and loading resistance properties and very high resistance to cracking (ungluing) properties. However, additional analysis also indicates that more load transfer channels or supplementary mechanical fastener connections are necessary to meet FAA requirements. For such areas which are extremely sensitive to weight and are fairly thin, such as control surfaces, product verification was selected and not the addition of rivets.

Just as indicated in the "STARSHIP" plan, through careful planning and coordination (especially series, explanations, test criterion, test planning and test verification), a total composite material aircraft structures has completely passed FAA certification.

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