南京航空航天大学

论文集

（一九九九年）

第20册

（十四系）

南京航空航天大学科技部编

二○○○年三月

十四系

20

目　录

智能材料结构研究所(18篇)

测控技术教研室(22篇)

材料力学教研室(7 篇)

第17卷 第1期 1999年3月
应用科学学报 JOURNAL OF APPLIED SCIENCES
Vol. 17, No. 1 March 1999

自诊断自适应智能复合材料结构系统的研究*

陶宝祺 石立华 熊 克 梁大开 袁慎芳
(南京航空航天大学)

摘 要 在复合材料中埋入传感和驱动元件并与外部处理器结合，构成了自诊断、自适应智能复合材料结构系统. 传感器网络由光纤和压电传感元件构成，驱动器采用特殊设计的形状记忆合金框架，该系统采用人工神经网络可识别结构的载荷与损伤状况，并可根据诊断结果激励相应位置的形状记忆合金实现大面积结构局部应力分布的自适应调整.

关键词 复合材料 智能结构 传感器 驱动器

智能结构将具有仿生命功能的材料耦合或集成于基体材料中，使制成的构件具有人们所期望的智能功能[1]. 智能结构不仅具有承受载荷的能力，还具有识别、分析、判断及动作等一系列体现智能特点的功能，它代表着21世纪先进材料发展的一个方向，被誉为新材料时代的曙光[2].

设计师们一直希望在飞行器和航天器中更广泛地采用复合材料结构，但是复合材料在生产过程中工艺不稳定，缺陷无法完全检查，它的横向承载与抗剪能力较低，在冲击或疲劳等载荷的作用下极易发生损伤直至最终破坏，因此复合材料结构的强度诊断和控制成为一个迫切需要解决的问题. 智能复合材料结构的出现为这一问题的解决提供了途径[3~5]. 本文在损伤监测的基础上进而提出了强度自适应的构想，在复合材料结构中同时埋入传感器和驱动器阵列，与外部信号处理器相结合，构成了强度自诊断、自适应智能复合材料结构系统.

1 强度自诊断系统

强度自诊断的基本思想是利用结构中埋入的传感网络实时监测由于意外载荷作用或损伤造成的结构中应力应变分布的变化，并采用神经网络识别载荷或损伤的位置. 在这一系统中主要研究了光纤和压电两种传感网络.

光纤具有电绝缘、耐腐蚀、无辐射、抗电磁干扰以及与复合材料耦合良好等独特的优点，将其埋入结构时可以连续监测其内部的应变、应力等物理量的变化. 偏振型光纤应变传感器结构简单、埋置方便、灵敏度适中，因此，本文首先采用它构成传感网络. 实验结构选用典型的平板结构，传感器排列方式为图1a所示的纵横排列式布局. 当传感器的敏感

收稿日期：1997-10-11

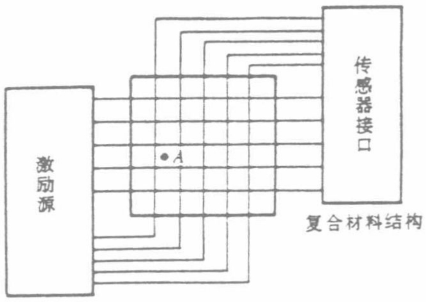
第一作者陶宝祺：男，1935年生，教授，博导，南京航空航天大学智能材料与结构航空科技重点实验室，南京 210016

* 国家自然科学基金、航空科学基金及高校博士点基金资助项目

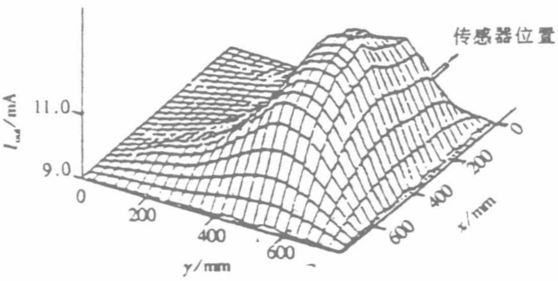
光纤受到应变 ε 作用时，一小段长 ΔL 的光纤中传输光的偏振态的变化为

$$\Delta\Phi=\{\beta-\beta n^2[P_{12}-\mu(P_{21}-P_{12})]/2\}\Delta L\varepsilon \tag{1}$$

式中，P_{21}、P_{12} 为光纤芯的弹光常数，n、μ 为纤芯的折射率及泊松比，β 为光在光纤中的传播常数. 通过传感器系统中的检偏镜及光敏管可把 $\Delta\Phi$ 的变化转换成输出电压的变化，从而得到要检测的应变. 图 1b 为 1.0m×1.0m 四边固支平板上 0.6m 处的 0.6328μm 偏振式单模光纤的输出随载荷作用位置的变化情况. 可见当加载位置靠近该光纤时，传感器输出较大，并且输出随加载点沿光纤纵向的位置变化而不同.



a)传感器布局



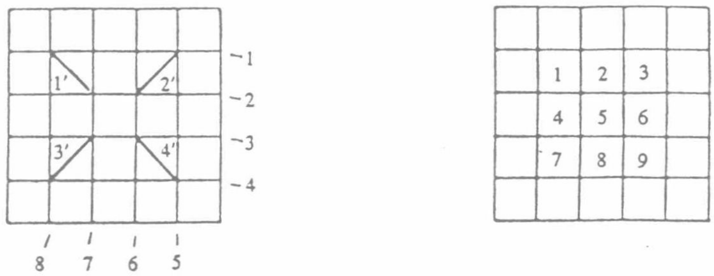
b)单根光纤的输出

图1 纵横排列式光纤传感网络

若板上 A 处由于载荷作用或损伤造成一大应变区域，则 A 附近的四根传感元件感受的应变较大、输出也较大，而其他各处传感元件输出均较小. 这样，就可以从不同位置传感元件的输出大小分布情况判别载荷或损伤的位置.

由于传感元件沿平板结构的纵向或横向连续分布，传感器检测的实际上是板上敏感部分的积分应变. 对四边固支平板的应变分析表明，在平板的边缘部分存在负应变区，传感元件贯穿正、负交替的应变区，使传感器输出结果中存在正、负抵消，降低了传感器灵敏度和位置分辨能力. 为避免这种正、负抵消，又采用了在板件的适当位置局部埋入少量传感器的点式传感方案. 图 2a 是以四点式布局传感元件(标号为 1′,2′,3′,4′)替代原来纵横排列的 8 根传感元件(标号为 1～8)的示意图. 图 2b 为实验时采用的 9 种加载位置. 表 1 和表 2 分别是两种传感方案的传感器输出情况. 可见点式布局的传感器输出随加载位置的变化明显，例如，在 7 号位置加载，纵横方案的 2、3、6、7、8 号传感器输出都大，加载位置的判别困难，而点式布局方案中 3 号传感器输出显著大于其他，很容易区别出加载的位置. 试验表明，采用点式布局方案对载荷大小的分辨力为 0.1kg，而采用纵横方案的则在 10kg 以上. 因此，点式布局的传感方案比纵横排列布局的传感方案区分载荷位置的能力强，并且有较高的分辨力.

鉴于目前光纤传感器还存在成本高、设备复杂的问题，我们进一步研究了采用压电传感元件和点式传感器布局的传感方案. 压电元件具有很高的灵敏度和响应带宽，尤其是压电薄膜材料和复合材料结构结合而成的压电复合材料层板结构是目前最受关注的一种智能复合材料结构形式. 根据压电元件的本构方程，可得到埋入复合材料结构中的压电元件的输出电荷 q 为



a)传感器布局　　b)加载位置

图 2　两种传感器布局方案的比较

表 1　纵横法应变输出(ε×10⁻⁶)

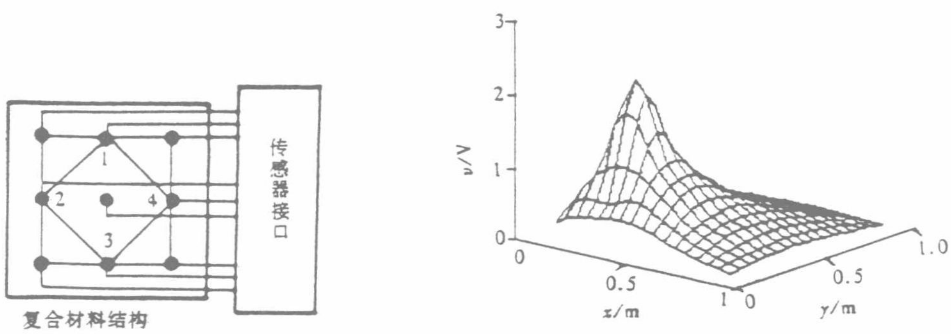
区域 \ 标号	1	2	3	4	5	6	7	8
1	92	127	125	62	116	150	125	64
2	1128	144	159	88	104	142	126	59
3	75	105	155	103	113	201	115	73
4	244	140	140	72	99	158	202	100
5	142	150	162	98	99	148	174	103
6	90	113	163	102	92	158	170	98
7	165	134	125	65	65	196	165	140
8	152	173	192	114	82	136	177	153
9	96	126	192	135	73	126	176	160

表 2　四点法应变输出(ε×10⁻⁶)

区域 \ 标号	1	2	3	4
1	-412	50	74	5
2	123	127	5	50
3	78	369	19	25
4	148	40	203	25
5	100	97	95	90
6	45	178	25	215
7	42	202	515	50
8	46	55	112	125
9	22	81	73	357

$$q=\iint_A (e_{31}S_1+e_{32}S_2+e_{33}S_3)\mathrm{d}x\mathrm{d}y \qquad (2)$$

其中 A 为传感元件的面积，S_1,S_2,S_3 为沿 x,y,z 方向的应变. 图 3a 是压电元件采用点式布置的平板实验结构示意图，图 3b 是 1.0m×1.0m 四边简支平板上不同位置受集中载荷作用时，采用数值模拟得到的(0.3m，0.3m)处 1cm×1cm 的压电薄膜的输出电压同加载位置的对应关系.



a)传感器布局　　b)传感器输出

图 3　点阵式布置的压电传感系统

若采用人工神经网络模型，使其通过训练逼近传感器组的输出与载荷位置间的复杂映射关系，则可使传感阵列信号得到简单、直接、快速的处理，从而完成载荷位置的识别. 图4是利用神经网络对九个加载位置上30组测量数据的定位实验结果. 图中，"＊"代表实际加载位置，"○"代表神经网络判别位置，除左下角一点误差稍大外，其余8个位置的判别结果均集中在对应的实际加载位置，神经网络的识别平均距离误差为9.4cm. 数值模拟实验进一步表明[6]，若增加参与训练的样本数目，减小样本之间的距离，则神经网络的定位精度还可进一步提高，并具有较好的内插能力.

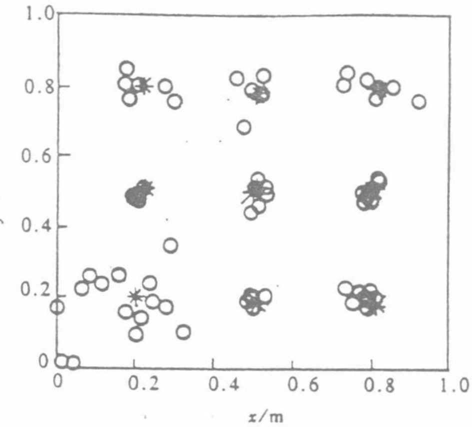
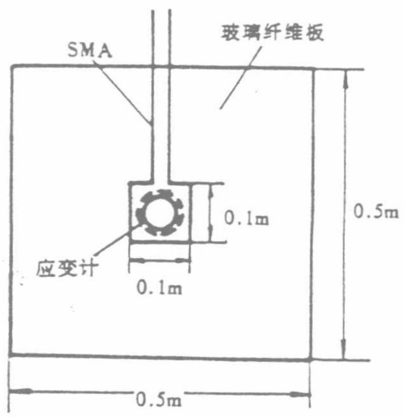


图4　神经网络载荷定位结果

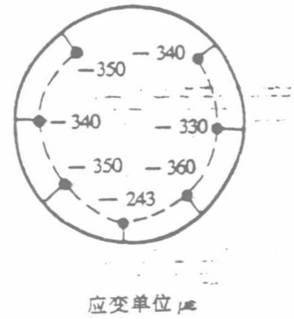
2　强度自适应系统

强度自适应系统的功能是在结构自诊断基础上，通过逻辑控制触发相应的驱动元件动作，改善结构中的应力应变分布，降低最大应力，防止损伤的扩展. 研究中采用形状记忆合金(SMA)作为智能结构中的驱动元件. 实验中采用的NiTi SMA在自由状态，可使6%～8%的塑性变形完全恢复；若形状回复受到约束，则可产生高达690MPa的回复应力.

将含有预变形的SMA丝埋入复合材料，拉伸、弯曲和扭转实验表明：(1) 激励SMA丝，可以大大地提高试件的承载能力；(2) 利用SMA丝可以使含孔试件的孔边产生压应变，并可明显地延长试件的疲劳寿命. 图5是利用SMA改善孔边应力的实验结果. 采用复合材料试件，开孔模拟结构局部被枪弹击穿的情况，在孔四周埋入SMA框架，孔边粘贴电阻应变片监测SMA激励后的孔边应变，可见SMA激励后使孔边产生了较大的压应变，这有利于增强结构强度，防止损伤扩展.



a)试件尺寸



b)孔边应变

图5　SMA改善孔边应力分布试验

表3 对应不同损伤位置图6中引出线的连接情况

序号	损伤位置	形状记忆合金丝造成的压应力区域	引出线的连接情况
1	[1]～[16]中间，但合金丝不断	包围损伤处的一格	1与2；或3与2；或13与14；或15与14等接电源
	例如[1]中损伤或穿孔	激励(1)-(2)-(10)-(9)4根合金丝	3与2两端接电源
2	一个单元中两格之间，一根合金丝断	一个单元中与合金丝有关的两格	根据损伤位置确定1与3或4与6等接电源
	例如在合金丝(9)处有损伤并断丝	激励(1)-(2)-(10)-(12)-(7)-(8)6根合金丝	1与3两端接电源
	又如在合金丝(10)处有损伤并断丝	激励(1)-(9)-(11)-(4)-(3)-(2)6根合金丝	4与5短接，2与3接电源
3	一个单元中间的4根合金丝处损伤或穿孔，4根合金丝断	包围损伤或穿孔的一个单元中的4格	根据损伤位置，将一端引出线的两根线短接，组成包围一个单元的封闭线
	例如在合金丝(9)、(10)、(11)、(12)处损伤并断丝	激励(1)-(2)-(3)-(4)-(5)-(6)-(7)-(8)8根线	短接引出线4与6；并在1与3两端接电源
4	两个单元之间相邻6根合金丝处损伤或穿孔，6根合金丝断	包围损伤或穿孔的两个单元中的各一格	根据损伤位置将两个单元各自一根引出线短接，组成包围两个单元中各一格的封闭线
	例如[3]中(4)及[9]中(25)合金丝处有损伤并断丝	激励(11)-(10)-(3)-(26)-(34)-(33)6根线	短接33和34，并在5与8两端接电源
5	两个单元之间相邻6根合金丝处损伤或穿孔，6根合金丝断	包围损伤或穿孔的两个单元中的各两格	根据损伤位置将两个单元中的两处、及每个单元中3处短接，组成包围两个单元中各两格的封闭线
	例如(7)、(14)、(6)、(15)、(12)、(22)合金丝处有损伤并断丝	激励(8)-(9)-(11)-(5)-(16)-(23)-(21)-(13)8根线	两个单元之间引出线25与26及27与28分别短接；单元中的13与14、18与17、6与5分别短接；1与2两端接电源
6	4个单元之间相邻8根合金丝处损伤或穿孔，8根合金丝断	包围损伤或穿孔的4个单元中的各一格	将4个单元的边缘线短接及每个单元中3处短接，组成包围4个单元中各一格的封闭线
	例如(6)、(5)、(32)、(31)、(38)、(37)、(16)、(15)合金丝处损伤并断丝	激励(11)-(33)-(36)-(46)-(45)-(23)-(22)-(12)8根线	4个单元之间的引出线27与28、31与32分别短接，17与5、20与8之间接电源

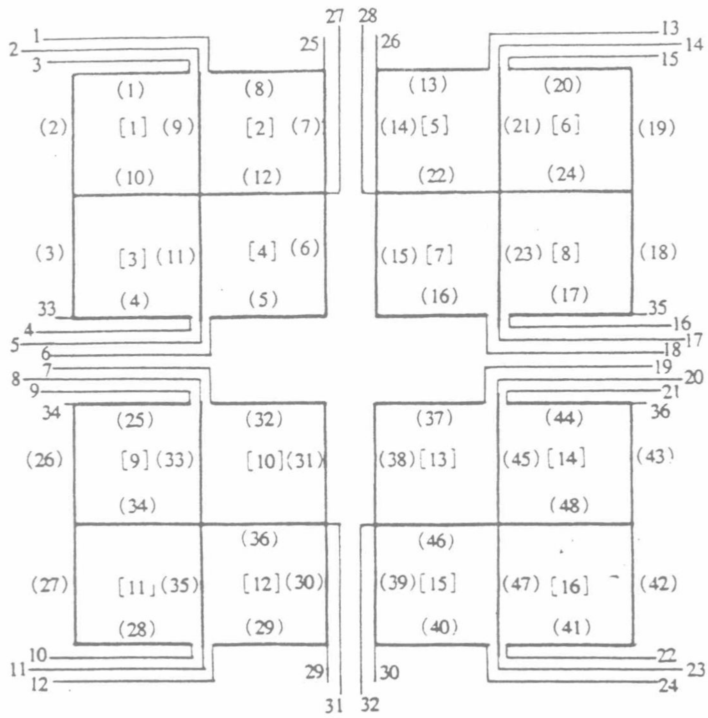


图6 组合式SMA驱动器

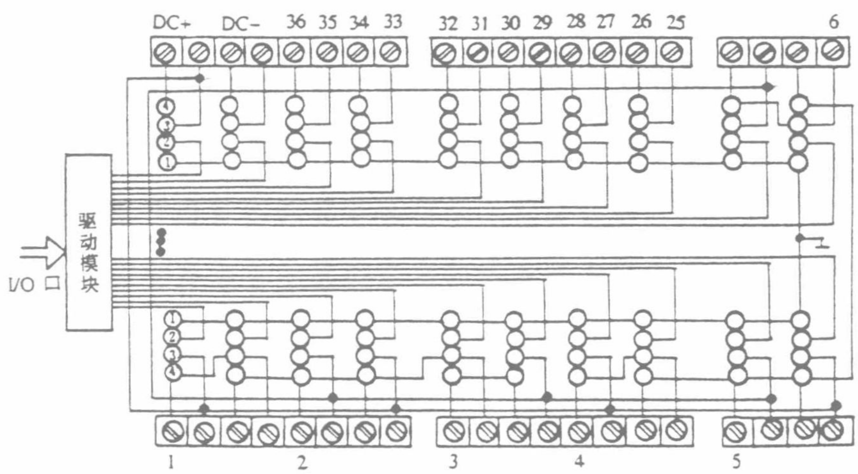


图7 SMA控制单元

为了实现结构大面积强度自适应，我们提出了SMA在平板结构中的一种组合式布置方案．图6是组合式SMA驱动器，不论损伤处于什么位置，都可以根据损伤识别的结果，通过控制电路改变SMA单元的连接方式，激励相应的SMA动作，在损伤周围形成压应力区域，防止损伤的进一步发展．表3是考虑了不同区域出现损伤时的SMA引线连接

情况．图 7 是与组合驱动器中左上角一个单元有关的 SMA 控制电路．其中，1～6 及 25～36对应于 SMA 的引线端，DC_+、DC_-接恒流源；①～④为固态继电器模块的引脚，①、②为控制端，③、④接负载，各继电器根据测控系统的控制信号动作，使 SMA 构成不同的回路．

3　结论

强度自诊断、自适应智能结构是材料与结构领域的一项重大变革，这一研究在国防及民用结构领域都具有广阔的应用前景．本研究在复合材料中埋入光纤和压电传感网络及形状记忆合金驱动元件，成功地实现了大面积结构的载荷监测和损伤在线诊断，并能够根据损伤诊断结果自适应控制相应区域的应力状态使其产生改变，使结构处于有利于抑制损伤扩展的应力状态．

参 考 文 献

[1] 陶宝祺，熊克．智能结构的定义及应用前景．中国科学基金，1995，(2)：40～46
[2] Rogers C A. Smart material systems—The dawn of new materials ages. J Intelligent Material Systems and Structures，1993，4(1)：4～12
[3] Miller G E. Fiber optic sensors for aircraft. SPIE Fiber Optic Smart Structures and Skins IV，1991，1538：178～181
[4] Lee C K. Theory of laminated piezoelectric plates for the design of distributed sensors/actuators. Part I：Governing equations and reciprocal relationships. J Acoust Soc. Am，1990，87(3)：1144～1158
[5] Salzano T B，Calder C A. Vibration measurement in composite members using embedded constantan wire. J of Intelligent Materials and Structures，1992，3(3)：536～546
[6] 石立华．基于压电元件的损伤自诊断自适应智能结构研究：[学位论文]．南京：南京航空航天大学，1996

A Smart Composite Structure System of Self-Diagnostic and Self-Adaptive Strength

TAO BAOQI　SHI LIHUA　XIONG KE　LIANG DAKAI　YUAN SHENFANG
(Research Institute of Smart Material and Structure Nanjing University of Aeronautics and Astronautics，Nanjing 210016)

Abstract　A smart composite structure system with embedded sensors and actuators is developed to realize the function of self-diagnostic and self-adaptive strength. Sensory systems employing optic fibers and piezoelectric elements are investigated. A frame type Shape Memory Allory(SMA) actuator is designed. The smart system can identify loads and damages of the structure by using artificial neural networks and initiate adaptive control to the embedded SMA to improve the structural strength.

Key words　composites，smart structure，sensor，actuator

The Second International Conference on Structural Health Monitoring.
September 6-8, 1999, Stanford, USA

Research on Some Problems about Optic Fiber Embedded in Carbon Fiber Smart Structure

L. DAKAI, H. MINGSHUN, T. BAOQI and Q. HAO

ABSTRACT

The carbon fiber composite which is provided with the characteristics of high intensity and light weight is wildly used in the aeronautics and astronautis industries. The research of the change of optic characteristics of optic fiber after being embedded in carbon fiber composite structure is introduced in the paper. In the manufacturing process of carbon composite structure, the optic fiber embedded in structure will endure high pressure and high temperature. The harsh environment will effect the optic characteristics of optic fiber. The stability of optic fiber sensors in smart composite structures will be effected. In the second part of the paper, the research of a kind of optic fiber self-repair composite structure is introduced. In the structure, the adhesive liquid core optical fibers are used to made up the self-repair system and the shape memory alloy network is embedded in the structure, it is good to improve structure's strength and quantity of self-repair.

INTRODUCTION

Carbon fiber composite which possess characteristics of high strength and modulus, lightweight and high resistance to fatigue are widely used in aeronautics industry. In military planes, the weight ratio of carbon fiber composite in whole aircraft structure has increased from 2% (American's F-15 fighter) in 1970's to 35% (American F-22 fighter and European EFA fighter)[1]. At present, the carbon fiber smart composite in which the functional components such as optic fiber, shape memory alloy, piezoelectric crystal, were embedded is one of the important research areas of the "Smart Material and Structure".

In order to put carbon fiber composite into use, we have made some preliminary researches on it in this paper..

Liang Dakai. The Key Laboratory for Smart Materials & Structures. Nanjing University of Aeronautics & Astronautics,#29Yudao Street, Nanjing 210016, P.R. China.
e-mail:tbqemt@public1.ptt.js.cn

1. CHANGE OF OPTIC FIBER'S OPTIC PERFORMANCES AFTER IT WAS EMBEDDED INTO CARBON FIBER COMPOSITE.

The optic fiber can be used and reserved at temperature range from 45℃ to 80℃ and at ordinary pressure. But, in the curing process, the carbon fiber composite must endure the 0.4-0.5Mpa's pressure and 100-200℃'s temperature, which would make some influence to the optic fiber's optic performance when it is embedded in the carbon fiber composite. In order to study this influence, we have done some experiments to research on the optic performances' change of optic fiber embedded in carbon fiber composite before and after the curing.

1.1 Selecting of optic fiber's type and testing parameters

There are several optic fiber sensors which can be used in carbon composite structures, and we can make these sensors with many kinds of optic fiber as singe mode optic fiber, multiple mode optic fiber and polarity keeping optic fiber. For the multiple mode optic fiber the curing of carbon fiber composite has almost no influence on its optic performance because it is usually used for transmission light. Therefore, we select the single mode optic fiber and polarity keeping optic fiber as research objects and do some experiments to study the changes of their optic parameters before and after the carbon fiber composite structure cure.

The single mode optic fiber and polarity keeping optic fiber have many optical parameters such as attenuation, dispersion, cutoff wavelength (λ_c), mode field diameter (MFD), numerical aperture(N.A), section shape, extinction ratio (η). Among these parameters, the attenuation and dispersion mean depression of light intensity and development of wide light pulse after the light transmits a long way along optic fiber. Because the length of fiber-optic used in smart composite structure is relatively short, we select λ_c , MFD, N.A and η as test parameters[2].

λ_c is one of the intrinsic parameters and the most elementary parameter of the single mode optic fiber. From the fiber-optic transmission theory, we know the number of conducting mode is related to the value of the normalized frequency V. In order to guarantee the single mode transmission, we should make the value of V small enough to reach one value which just cuts off the high-order mode LP_{11} to transmit the fundamental made in optic fiber. The value V_c mentioned above is called normalized cutoff wave length of LP_{11} and defined as:

$$V_c = \frac{2\pi}{\lambda_c} n_1 a \sqrt{2\Delta} \qquad (1)$$

where, λ_c is called λ_c of optic fiber. Only when the value of working wavelength is greater than that of λ_c, the single mode transmission can be guaranteed. Thus, the λ_c determines the ranges of light wave length which can transmit as single mode. The value V_c and the refractive index distribution are related each other. When the refractive index distributions are different, the values V_c are different too. For instance, the value V_c of the step optic fiber is 2.405.

The light field strength of the basal mode in single mode optic fiber has a certain distribution in fiber-optic section and the light power is restrained in a certain range in fiber-optic section. MFD is a physical parameter which is used to evaluate this range. From MFD, we can get the parameter of equivalent step fiber and estimate the connecting losing, bending losing, micro-bending losing and dispersion of single mode optic fiber. So, MFD is a very important parameter of single mode optic fiber.

The N.A of optic fiber is a parameter which expresses whether the optic fiber is easily to be excited and the optic beam is easily to be coupled with optic fiber. It and the computation of optic fiber's transmitting coefficient are related intimately and the width of fiber-optic transmitting strip is influenced greatly by N.A. Meanwhile, it is an important parameter of multiple mode optic fiber. We can evaluate the influence which multiple mode optic fiber undertakes in the process of carbon fiber composite curing by experiment it.

Polarity keeping optic fiber is a special single mode optic fiber. It only allows the polarized mode which is identical with the main axle direction to transmit through it. Thus, what determine the optic characteristics of optic fiber are not only the parameters identical with the ordinary single mode optic fiber such as MFD, λ_c., but also the parameters which determine optic characteristic of polarity keeping optic fiber such as birefringence, beat length, extinction ratio(η). Among all of these parameters, the extinction ratio is simple to be tested and can well reflect the optic fiber 's capability of polarity keeping. Thus, in experiments, we test this parameter, too.

When the polarized light is coupling into polarity keeping optic fiber with the direction of polarized mode HE_{11}^{y}, and transmit along the fiber, the HE_{11}^{x} mode will appear at the outlet end, which means the polarized state changes in the transmitting process. The η is used to express the change extent of polarized state, and is defined as

*1) The first and second tests are tested before and after composite was cured.
2) The roots of sample 5,7,9 break after the carbon fiber composite sample is solidified.
3) Cutoff wavelength tested range from 0.4 to 1.6um

Table 2: Experimental Results Of Polarity Keeping Optic Fibers

Number	Type(μm)	Testing Time	λ_c (μm)	MFD(μm) x, y	η (dB)
1	1.3	First Second	1.1156 Don't get	6.66 6.58 6.68 6.65	39.6 36.6
2	1.3	First Second	1.117 Don't get	6.65 6.59 6.65 6.60	39.3 37.8
3	1.3	First Second	1.1157 Don't get	6.39 6.33 6.40 6.37	39.2 37.0
4	0.85	First Second	0.789 Don't get	5.84 4.35 4.77 4.64	25.6 25.1
5	0.85	First Second	0.8158 Don't get	4.26 4.23 4.34 4.34	27.1 25.6
6	0.85	First Second	0.789 /	4.20 4.58 / /	29.5 /

*1) The first and second tests are tested before and after composite was cured.
2) Cutoff wavelength tested range from 0.4 to 1.6um
3) After the sample is solidified, the root of fiber-optic sample 6 breaks. Other fiber-optic samples all break at different positions, which makes the length of fiber-optic samples vary from 1.2m to 1.8m.

Table 3. Experimental Date

Number	Type(μm)	Testing Time	λ_c(μm)
1	0.85	First Second	0.8175 1.510
2	0.85	First Second	0.8173 1.558

*The first and second tests are tested before and after composite was cured.

From Table 1, we know that the single mode optic fiber's λ_c change greatly after carbon fiber composite is cured. In order to study it further, we take two single mode optic fibers of the type 0.85um and lay them in a hot-press pot to endure the curing process with the carbon fiber composite together. The optic fibers endure the high temperature and pressure during the curing process, but they are not embedded in the carbon fiber composite. After the curing is completed, we test them again. The results are shown in Table 3.

1.3 Discussion

From the limited experimental date, we find that after the carbon fiber composite is cured some of the optical parameters of optic fiber have changed. Now we discuss them by turns:

1. Cutoff wavelength (λ_c): λ_c is a parameter which changes most among all the parameters. After the sample is cured, we scan it in the range from 0.6 μ m to 1.6 μ m, but can not get this parameter for any samples. There are only two possibilities. Firstly, it is possible that great additional dying out has been made in the forming process, which make LP_{11} mode cut off already. We observe the output faculae radiated by the laser of 0.6328 μ m and found dark lines in the faculae which are the multiple mode faculae. So this suppose is wrong. The other possible is that the cutoff wavelength deflects, which converts the single mode transmission to multiple mode transmission and leads to the instability of sensor performance. The reason why cutoff wavelength changes is the mutation of fiber-optic coating's performance under the high pressure and the temperature. The environment soften and then reshape coating layer, which will generate great internal stress in coating and fiber core. Thus, great additional losing is generated, which leads to the change of cutoff wavelength.

2. Mode field diameter (MFD): This parameter has a little change before and after the test sample is formed. But the mutation amplitude is small and has no order. So, the process of carbon fiber composite has little influence on this parameter for this optic fiber.

3. Numerical aperture (N.A): From the test results, this parameter almost has no change at all.

4. Polarity keeping optic fiber: The test results of polarity keeping optic fiber and those of single mode optic fiber are similar. Because polarity keeping optic fiber is a kind of special single mode optic fiber, what we research on the performances of single mode optic fiber is suitable for polarity keeping optic fiber. The extinction ratio η changes decline in different extent before and after carbon fiber composite is cured. The η is in reverse proportion to the length, that is, the optic fiber is longer, the η is smaller. After the composite is cured, the length of the optic fibers is shorter. So the decoration of the η is more badly than what the experiment results have shown. That is said the curing of the carbon fiber composite will influence the polarity keeping optic fiber's optic performance.