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# A STUDY OF THE DEVELOPMENT, CHARACTERIZATION AND DEGRADABILITY OF LUFFA GOURD FIBRE FILLED UNSATURATED POLYESTER COMPOSITES

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***ABSTRACT***

*The composites were produced using several percentage fibre loadings (0, 10, 20, 30, 40 and 50 weight percent). Luffa gourd fibre was used as the reinforcing fibre in unsaturated Polyester resin; composites sheets were prepared through hand mixing method using a fabricated glass mould. Tensile, flexural, impact tests and degradability of luffa gourd fibre filled unsaturated polyester composites were determined. The results attained for mechanical tests indicated that the optimum values and significant improvement were at 30 wt % fibre loading. The modulus of luffa gourd fibre filled unsaturated polyester composite reached maximum and minimum values at 50 wt % and 10 wt % fibre loadings respectively, however, the tensile strength of luffa gourd fibre filled unsaturated polyester composites were at maximum and minimum values at 30 wt % fibre loading and 50 wt % fibre loading with 18.2 MPa and 11.9 MPa respectively, and flexural strength test shows that the maximum and minimum values were also at 30 wt % and 50 wt % fibre loading with 25.14 MPa and 15.85 MPa respectively. The results of the impact strength indicated that increase in fibre loading from 10 wt % fibre loading to 30 wt % fibre loading produced maximum strength at 30 wt % fibre loading with 3.9 MPa. The results for soil burial show the weight loss of luffa gourd fibre composites at varying fibre loading as a function of degradation time, the results signify that sample weight loss increases with increase in fibre loading from 10 wt % to 50 wt % fibre loading and also indicating increase in biodegradability with increase in the number of days for soil burial.*

***Keywords***: Composite, Luffa Gourd Fibre, Scanning Electron Micrograph, Soil Burial, Unsaturated Polyester

## 1.0 INTRODUCTION

There are many potential natural resources. Most of it comes from agriculture or forest. The fruit of the Luffa gourd plant (genus: Luffa gourd, species: Luffa gourd aegyptiaca) a forest product which is of the Curcubitacea family (Mazali and Alves, 2005). Dried Luffa gourd fruits are shown in Plate 1. Common sponges vary in length from around 15–25 cm to 1.20–1.50 m (Boynard and d'Almeida, 2000). The Luffa gourd is a subtropical plant in large amounts available in China, Japan, India and other countries in Asia as well as in Central and South America (Oboh and Aluyor, 2009). The sponge guard are being used as component of shock absorbers, sound proof linings, utensils cleaning sponge, packing materials, for making crafts, filters in factories and part of soles of shoes (Bal *et al*., 2004). Very limited scientific information is available on this fruit in literature specially related to its structure and properties. The fruit is also of medicinal value. It also has cleansing property and is used for dropsy, nephritis, chronic bronchitis and lung complaints (Partap *et al*., 2012). The dried Luffa gourd fruit fibres are used as coarse sponges in skin care, to remove dead skin and to stimulate the circulation. The fruit of Luffa gourd has ligneous netting System in which the fibrous cords are disposed in a multidirectional array forming a natural mat. This fibrous vascular system is made up of fibrils glued together with natural resinous materials of plant tissue (Niharika, 2016).

The importance of the Luffa gourd sponge material is increasing in our society because of the search for sustainable solutions using new materials. In a recent study, authors discovered that under quasi-static loading the Luffa gourd sponge material exhibits remarkable stiffness, strength and energy absorption capacities that are comparable to those of a variety of metallic cellular materials (Shen *et al*., 2012). It is interesting to note that this fibre contains cellulose 55-90%, hemicelluloses 8-22 %, lignin 10-23 %, and extractives 3.2 % and ash 0.4 % (Shen *et al*., 2012). This makes it suitable for reinforcing material in polymer matrix (Siqueira *et al*., 2010; Seki *et al*., 2012).

Limited research has been carried out in the past on this (Luffa gourd sponge) fibre as a potential reinforcement in composites. Those research findings indicated that it is a potential alternative material for packaging (Mazali and Alves, 2005), water absorption (Bal *et al*., 2004; Partap *et al*., 2012; Shen *et al*., 2012; Siqueira *et al*., 2010; Seki *et al*., 2012; Demir *et al.,* 2006) and waste water treatment (Laidani *et al*., 2011; Oboh *et al*., 2011). The Luffa gourd fibres were also used as reinforcement fibre for other materials (Ghali *et al*., 2009; Paglicawan *et al*., 2005; Tanobe *et al*., 2005) and cell immobilization for biotechnology (Chen and Lin, 2005; Zampieri *et al*., 2006; De Sousa *et al*., 2008). From these findings it was concluded that the full potential of Luffa gourd fibre is yet to be explored. Therefore, this research work is aimed at exploring the possibility of using luffa gourd fibre as filler in unsaturated polyester resin matrix to improve their strength, dimensional stability and moisture absorption characteristics, and produce composites for industrial applications.

Plate 1: Dried Luffa gourd fruits

## 1.0 MATERIALS AND METHODS

The luffa gourd fibre used in this study was obtained from Auta farm in Chukun Local government area in Kaduna State, Nigeria. The fibres were cleaned to remove contaminants, sundried for 12 hours and prepared for pulverization. The pulverizing machine (Thomas-Wiley Laboratory Mill Model: 4) was used to grind the luffa gourd into short fibre length.

### 1.1 Preparation of composites

The composites were fabricated with 0 wt % - 50 wt % fibre loading at interval of 10 wt % fibre loading. This was prepared by mixing the various ratios of the prepared fibres with the unsaturated polyester (UPE) resin made up of 100 % of each as in weight fraction using electronic weighing balance. The components of each composite sample were obtained using the preparation in Table i and combination was done in wt % fibre loading. The mixing was achieved via manual stirring method. 2 ml of cobalt naphthenate (accelerator) and 2 ml of methyl ethyl ketone peroxide (hardener) were mixed with unsaturated polyester resin prior to mixing with the varying weight fractions of luffa gourd fibre. The mixture was poured into glass mould previously covered with aluminum foil serving as realizing agent. The composite sheets produced were post cured at 60°C. The produced composites were thereafter machined into various dimensions according to American Society for Testing and Materials (ASTM) standards for various polymer tests.

**Table i:** Percentage combination of Luffa gourd fibre and unsaturated polyester matrix

| Fibre (wt %) | 0 | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|---|
| Matrix(wt%) | 100 | 90 | 80 | 70 | 60 | 50 |

## 2.2 Sample cutting

The sheets of unsaturated polyester and its composites were cut into specimens, by using a circular iron saw, pluses from the samples were removed by using the iron rasp, and the samples were polished by using coarse emery papers of grade 400. The shape and measurement of the samples cut for tensile test, impact test, flexural test and sample required for soil biodegradation were in accordance to the required ASTM international standards.

## 2.3 Tensile strength test

The tensile test was carried out on a universal testing machine (Universal Instron Testing Machine Model 3369, Number 3369k1781, Capacity 50 KN, Weight 141 Kg, Maximum Speed 500 mm/min.) with maximum load of 10 KN in accordance with ASTM D-638. A cross speed of 2 mm/min was used. Five specimens for each composite were tested and statistical averages for each set of results were recorded.

## 2.4 Flexural strength test

The test was carried out on a universal testing machine (Norwood Instruments Ltd. Serial Number Cat. Nr 261, 100 KN capacity) and a cross head speed of 5 mm/min were maintained in accordance with ASTM D790-03 to measure the flexural strength and flexural modulus of the composites using Equations i and ii respectively

$$Flexural\ Strength\,(F_S) = 3PL/2bt^2 \ldots\ldots\ldots\ldots(i)$$

$$Flexural\ Modulus\ (F_M) = PL^3/4bwh^3 \ldots\ldots\ldots(ii)$$

Where L is the span length of the sample in mm, P is the load applied in Newton or Pascal (pa), b and t are the width and the thickness of the specimen respectively in mm, while h is the specimen thickness (mm) and w indicates the depth of the deflection (mm).

## 2.5 Impact strength test

The impact tests was done according to ASTM D256 standard using impact testing machine (Charpy Impact Testing Machine, Capacity 15 J and 25 J, Serial Number 412-07-15269c,manufactured by Norwood Instruments Limited, Great Britain). The specimens were held as a cantilever beam, thereafter broken by a blow delivered at a fixed distance from the edge of the specimen.

## 2.6 Soil burial

The biodegradability of Luffa gourd fibre filled unsaturated polyester resin composites were carried out by soil burial method. The samples were buried in the soil at a depth of 20 cm from the surface of the soil for 75 days. One set of samples were carefully taken out of the soil for testing every 15 days and then washed with distilled water to remove the sand from the surface of the samples and oven dried at 55 °C until their weights become constant ($W_2$). The percentage of weight loss (% WL) was calculated using Equation iii.

$$\%WL = [(W_1 - W_2)/W_1] \times 100 \ldots\ldots\ldots(iii)$$

Where, $W_1$ and $W_2$ is the initial and final weight of the samples respectively.

## 3.0 RESULTS AND DISCUSSION

The factors which determine the physical and mechanical properties of polymer composites depends on the extent of fibre adhesion, fibre dispersion, interfacial interaction between fibre and matrix and degree of degradation of composites etc. The results of the tensile strength, tensile modulus and flexural strength, flexural modulus properties are shown in figures 1 and 2 respectively while Figures 3 and iv depicts the impact strength and soil burial results respectively.

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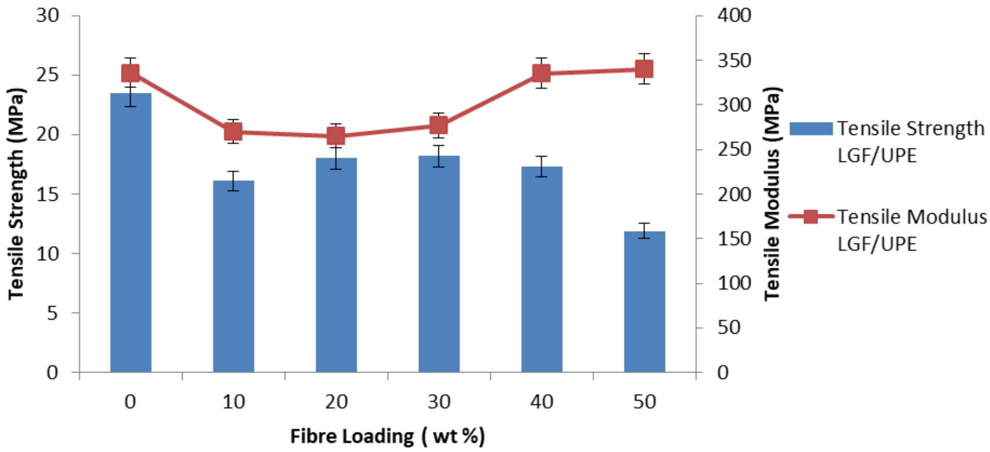


Figure 1: Effect of fibre loading on the tensile strength and modulus of Luffa gourd fibre/unsaturated polyester (LGF/UPE) composites.

## 3.1 Tensile properties

The results of the effect of fibre loading on the tensile strength and modulus of luffa gourd filled unsaturated polyester composites are shown in Figure 1. The results reveal that there is an increase in tensile strength from 10 wt % fibre loading to 30 wt % fibre loading and further incorporation of fibre results to a decrease in tensile strength beyond 30 wt % fibre loading to 50 wt % fibre loading with 18.2 MPa and 11.9 MPa respectively, while the unfilled unsaturated polyester serving as the control, has a high tensile strength of 23.5 MPa. Similar work was carried out by Imoisili et al., (2012) which also shows a decrease in tensile strength as the fibre loading increases beyond 30 wt %.

Results in Figure 1, equally shows that tensile modulus increases as the fibre loading increase which was also in agreement with several previous reports on the effects of lignocellulosic fibre loading on the modulus of polymeric composite. It has been observed by many researchers that the modulus increases as the fibre loading increases (Raju *et al*., 2012). Incorporation of luffa gourd improves the stiffness. The modulus of luffa gourd fibre/unsaturated polyester composite was at maximum and minimum values at 50 wt % and 10 wt % fibre loading with 340 MPa and 270 MPa respectively as against 336 MPa for the unfilled unsaturated polyester composite.

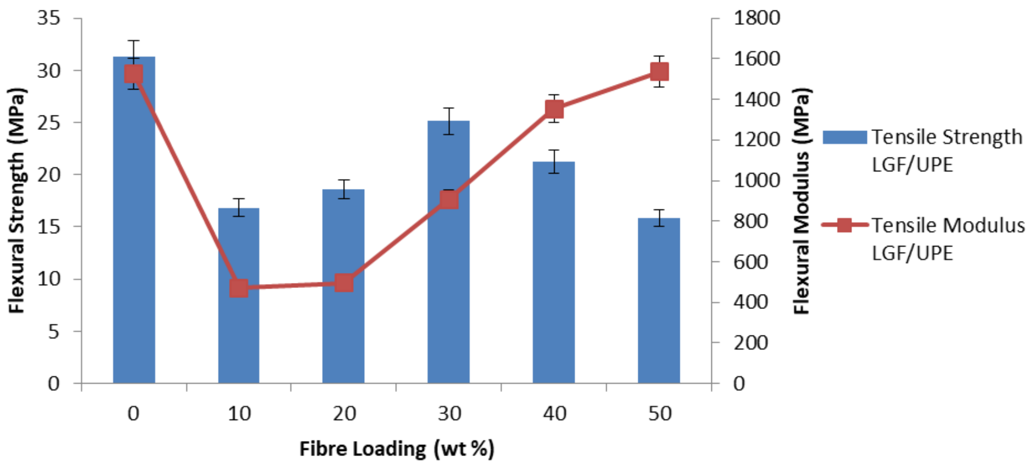


Figure 2: Effect of fibre loading on the flexural strength and modulus of Luffa gourd fibre/Unsaturated polyester (LGF/UPE) composites.

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### 3.2 Flexural properties

The results of the effect of fibre loading on the flexural strength and modulus of luffa gourd fibre filled unsaturated polyester composites are shown in Figure 2. It can be observed that flexural strength increases from 10 wt % to 30 wt % fibre loading after which the strength decreases as the fibre loading increases from 40 wt % fibre loading to 50 wt % fibre loading. From the results, it was observed that the flexural strength of the unfilled unsaturated polyester resin was reduced by 46 % on addition of 10 wt % fibre loading and further increase in the fibre loading at 30 wt % fibre loading, the unfilled UPE resin was observed to be reduced by 19 %, fibre loading, beyond 30 wt % shows a decrease in strength from

25.14 MPa to 21.25 MPa as presented in Figure 2. On the other hand, the flexural modulus increases as the fibre loading increases which is in agreement with several previous reports on the effect of lignocellulosic fibre content on the modulus of polymetric composite. It has been observed by many researchers that the modulus increases with increase in fibre loading (Raju *et al.,* 2012). The flexural modulus of luffa gourd fibre/unsaturated polyester (LGF/UPE) composite was at maximum and minimum values at 50 wt % and 10 wt % fibre loading with 1534.8 MPa and 469.2 MPa respectively. While, that of the unfilled unsaturated polyester resin is 1525.2 MPa. The modulus of the unfilled unsaturated polyester resin (0%), fibre loadings at 10 wt %, 20 wt % 30 wt %, 40 wt % and 50 wt % were obtained as 1525.2 MPa, 469.2 MPa, 495.6 MPa, 906.5MPa, 1352 MPa and 1534.8 MPa respectively.


Plate 2: Universal material testing machine

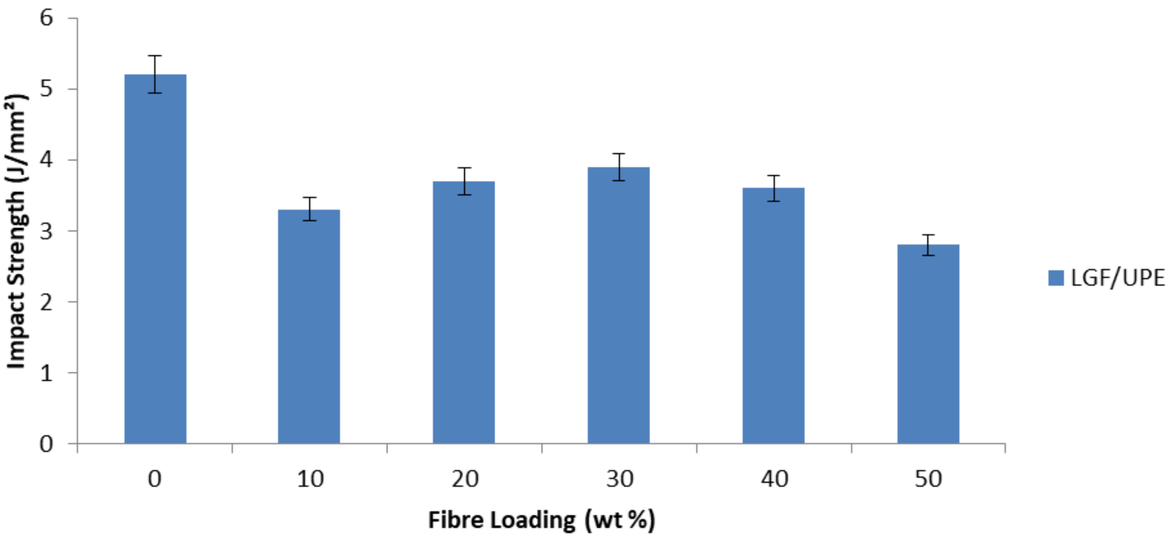


Figure 3: Effect of fibre loading on the Impact strength of Luffa gourd fibre/Unsaturated polyester (LGF/UPE) composites.

### 3.3 Impact strength

The results of the effect of the impact strength of luffa gourd fibre filled unsaturated polyester composites are shown in Figure 3. The results show a progressive increase in their impact strength as the fibre loading increases from 10 wt % to 30 wt % fibre loading. However, there was a gradual decrease in the strength at 40 wt % fibre loading. The impact strength of luffa gourd fibre filled polyester composites at 0 wt %, 10 wt %, 20 wt %, 30 wt %, 40 wt %, and 50 wt % fibre loading are 5.2 $Jmm^{-2}$, 3.3 $Jmm^{-2}$, 3.7 $Jmm^{-2}$, 3.9 $Jmm^{-2}$, 3.6 $Jmm^{-2}$ and 2.8 $Jmm^{-2}$ respectively.

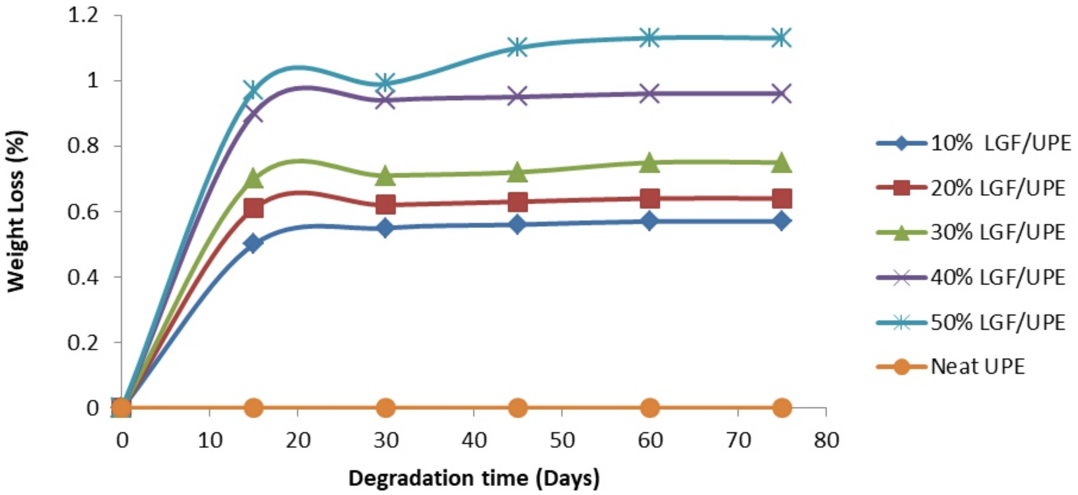


Figure 4: Soil burial on the weight loss of luffa gourd fibre/UPE composites at varying fibre loadings as a function of degradation time

### 3.4 Soil burial

Results in Figure 4 show the effect of weight loss of luffa gourd fibre/unsaturated polyester composites at varying fibre loading as a function of degradation time. It was found that the initial rate of percentage weight loss and maximum percentage weight loss increases as the fibre loading increases from 10 wt % fibre loading to 50 wt % fibre loading. This may be due to the presence of micro voids in the matrix, water molecules start diffusing into the micro voids till saturation state occurs. The luffa gourd fibre/unsaturated polyester composite at 50 wt % fibre loading shows higher water absorption as degradation time increases which is due to the hydrophilic nature of the fibre and the presence of greater interfacial area between the fibre and the matrix. On increasing the luffa gourd fibre content, causes an increase in the amount of cellulose, micro voids and interface surface area. The percentage weight loss for luffa gourd fibre/unsaturated polyester composites at degradation time of 30, 45, 60 and 75 days gave 0.55 %, 0.56 %, 0.57 % and 0.57 % percentage weight loss respectively.

### 3.5 Morphology

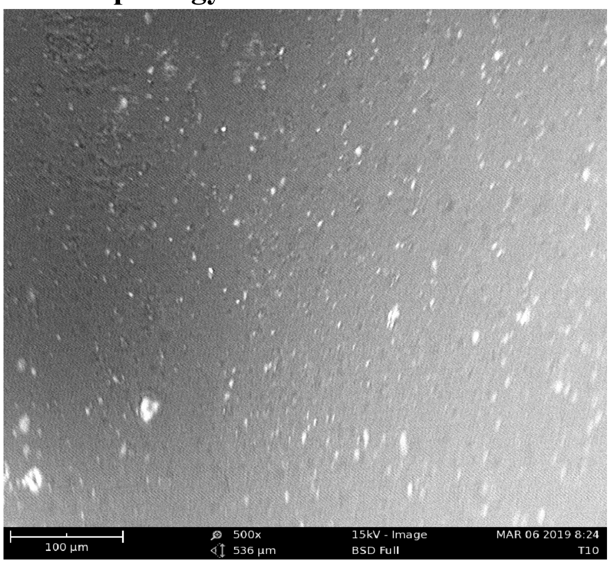


Plate 3: Scanning electron micrograph of fractured cross-section of Luffa gourd fibre/UPE composite at 50 wt % fibre loading before degradation (magnification of 500x).


Plate 4: Scanning electron micrograph of fractured cross-section of Luffa gourd fibre/UPE composite at 50 wt % fibre loading after degradation over 75 days (magnification of 500x).

Plate's 3 and 4, shows the Scanning electron micrographs of surfaces of Luffa gourd fibre/unsaturated polyester composite before and after degradation respectively on exposure to soil burial for 75 days. The microbial attack which has taken place on the sample surface either by bio-deterioration, bio-fragmentation or assimilation is accompanied by loss in weight leading to an eroded surface, micro voids have been formed after the microbial attack as shown in plate 4, the effects of biodegradation was more pronounce, this observations were further evidence by the increase in surface roughness and in addition to the formation of cracks and micro voids on the sample surface.

## 3.0 CONCLUSION

The results of this study revealed that useful composites could be successfully developed using luffa gourd fibre as reinforcing fibre in thermoset resin such as unsaturated polyester resins. The incorporation of pulverized luffa gourd fibre into unsaturated polyester resin matrix enhanced the stiffness and impact behavior of the composites such as tensile strength, flexural strength and impact behavior of the composites system.

The results indicated that tensile strength of luffa gourd fibre/unsaturated polyester composite has its maximum and minimum strength at 30 wt % fibre loading and 50 wt % fibre loading respectively with 18.2 MPa and 11.9 MPa respectively with unfilled unsaturated polyester resin having tensile strength of 23.5 MPa. The strength of the unfilled unsaturated polyester resin was reduced by 5.3 MPa indicating 28.02 % reduction on incorporation of 30 wt % fibre loading of luffa gourd fibre into unsaturated polyester resin matrix. The modulus of luffa gourd fibre/unsaturated polyester composite produced maximum and minimum values at 50 wt % and 10 wt % fibre loading with 340 MPa and 270 MPa respectively

Results show that optimum values and significant improvement were at 30 wt % fibre loading. The study provides fundamental data for the composite material and their degradation thereby shows that it is possible to control the degradation of the polymer composites by controlling the composition and the degradation environment.

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