Flexural Properties of Tropical Natural Fibres Reinforced Epoxy Composites Prepared Using Vacuum Bagging Method

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Flexural Properties of Tropical Natural Fibres Reinforced Epoxy Composites Prepared Using Vacuum Bagging Method

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Abstract

This paper discusses the results of experimental investigation on the flexural properties of natural fibre composites prepared using vacuum bagging method. The reinforcement fibres were derived from tropical grown natural fibers which include jute, sisal, hemp and bamboo fibre that reinforced epoxy polymer resin. The flexural properties of each laminate were tested and assessed thoroughly. The results showed that all composite laminates have fairly comparable flexural strength which varied from 47.17 MPa for hemp fibre composite to 62.72 MPa for jute fiber composite. Natural fiber composites based on sisal and bamboo fibre provided almost comparable flexural strength, which was 54.35 MPa and 53.34 MPa, respectively. The flexural modulus properties differs by a significant amount. Jute fibre composite has the highest flexural modulus (3459 MPa), which is approximately 73 percent higher than bamboo fibre composite (2001 MPa), the lowest value reached in this study. Meanwhile, sisal and hemp fibre composite reached a slightly different flexural strength of 2322 MPa and 2489 MPa, respectively. In general, the results are comparable to the results of the previous studies. The stress-strain curves for all the tested laminates presented a linear elastic behaviour up to the final failure. Some specimens showed a slight strengthening beyond the ultimate load, and then collapsed in a sudden motion. Most of the specimens failed due to fracture at the bottom part under the loading point, which is a common failure mechanism of natural fiber composite tested under three point bending load.

Keywords: Natural fiber composites, flexural properties, vacuum bagging method

1. Introduction

Over the past two decades, extensive researches have been conducted to investigate the use of natural fibers as reinforcement in polymeric and cementitious matrices. As reported by Salit (2014), most of the commonly used natural fibers are native in tropical areas including pineapple, banana, sisal, hemp, jute, bamboo, cotton, abaca and many more. The most common fabrication process reported in literatures is a hand lay up method, especially in a preliminary works. In this method, the composite is formed by manually mixing and placing layers of reinforcement fibers and resin matrix onto an open mold surface until the desired thickness is achieved (Kaynak and Akgul, 2001; Akovali, 2001). Today, hand lay up method is still extensively used especially for large components but in lower quantities. The disadvantages of this method is that the quality of products is mostly depended on the skill of the workers. It seems that a similar shortcomings also encountered in laboratory works which causes a large discrepancies of the testing results. Actually, there are a lot choices of fabrication process that can be used in the production of natural fibre composites (NFCs). Among those options, vacuum bagging method may be used as an alternative to meet the quality while maintaining affordable cost. This method combines a manual method using hand-layup or spray-up on the open mold to produce a laminated component with a vacuum process after covering the laminated using polymeric sheet (Kaynak and Akgul, 2001; Akovali, 2001).

As already indicated earlier, there are a large differences in reported literatures about the properties of NFCs including their flexural properties. Few important works dealing with the flexural properties of NFCs are listed in Table 1. A quick impression given by the obtained data in the table is that there has a widely fluctuated data of flexural strength within the reported studies. The flexural strength ranges from 47.82 MPa for gomuti/polyester composite to a maximum of 128.5 MPa for bamboo/polyester composite. The highest value almost two and half times of the least. While the flexural modulus lies between 2490 MPa for sisal/polyester composite and 5020 MPa for hemp/polyester composite.

Table 1. Flexural properties of natural fibre composites obtained from several literatures

No	Fibre	Matrix	Flexural Properties		References
			Flexural Strength (MPa)	Flexural Modulus (MPa)	
1	Jute	PVC	62.6	3200	Khan et al. (2011)
2	Banana	Polyester	65	-	Pothan et al. (2002)
3	Gomuti	Epoxy	64.71	3150	Sastra et al. (2005)
4	Gomuti	Polyester	47.82	3400	Ticoalu et al. (2010)
5	Jute	Vinylester	128	-	Ray et al. (2001)
6	Sisal	Polyester	99.5	2490	Prasad and Rao (2011)
7	Bamboo	Polyester	128.5	3700	Prasad and Rao (2011)
8	Hemp	Polyester	54	5020	Rouison et al. (2006)

Flexural and tensile properties are the most common mechanical properties examined in developing natural fiber composites. Other mechanical properties such as shear and compressive properties are slightly less attracted the researchers. The results of both tests provide extremely important properties, which are the elastic modulus and the stiffness of the material. The flexural test is commonly used to select a suitable material that support loads without flexing. As the intended used of NFCs is largely for material that supporting flexural loads, examining this property is extremely important during the development process. This paper reports the results of experimental investigation on the flexural properties of natural fibre composites prepared using vacuum bagging method. The reinforcement fibres were derived from tropical grown natural fibers which include jute, sisal, hemp and bamboo fibre that reinforced epoxy polymer resin.

2. Materials and Methods

2.1. Materials and Sample Preparation

The fibres which includes jute, sisal, hemp and bamboo were collected from various sources and also in different form. Jute fibers were in the form of woven with a commercial name of Hessian jute, while sisal fiber was in the form of unidirectional long fibers. The mechanical properties of sisal fiber reinforced epoxy composite were actually reported previously (Fajrin, 2016). In this paper, the flexural properties are presented again to compare with others. Hemp fiber was already in the form of hemp mat, while bamboo were randomly chopped. The natural fiber composites were prepared using a vacuum bagging process as shown in Figure 1.

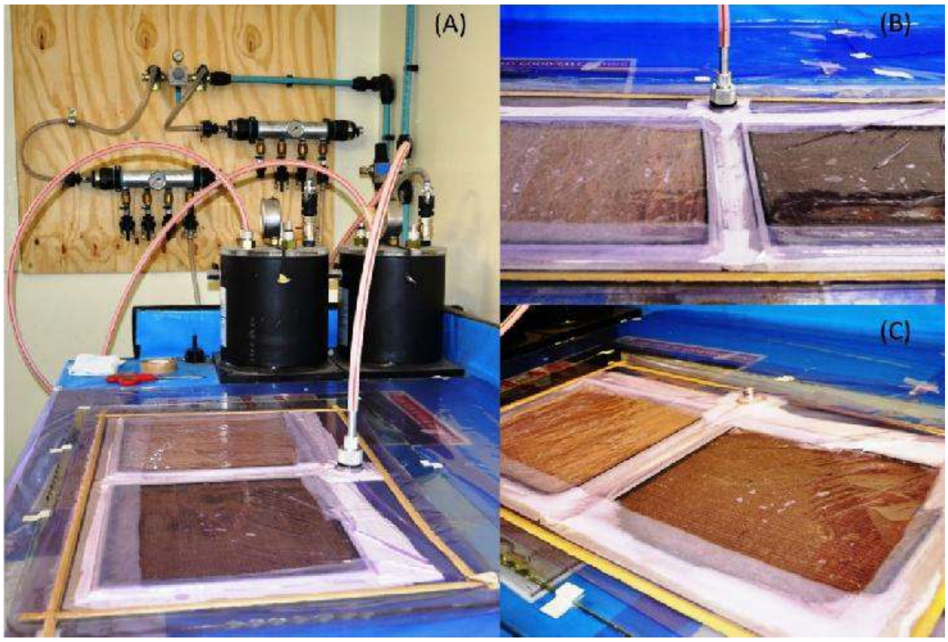

Figure 1. Sample fabrication using vacuum bagging method. (A) Vacuum bagging equipment, (B) Applying the pressure, and (C) Curing the laminates.

2.2. Experimental Procedure

The flexural test was conducted as per ISO standard, which is ISO 14125 (British Standard, 1998); a standard test for the determination of flexural properties of fibre-reinforced plastic composites. A flexural test is typically carried out on simply supported beams where the test specimen is deflected at a constant rate until the specimen fractures or until deformation reached some pre-determined value. The test was carried out using a MTS machine with a maximum load capacity of 10 kN. The testing speed applied was 2 mm/min, as recommended by the standard. Five specimens of recommended dimensions were prepared for each natural fiber composite laminate. The specimen was in a flat rectangular shape and supported close to the ends and centrally loaded in three-point bending. In order to minimize membrane stress, a typical roller and pin support was used allowing the specimen to rotate. The testing program for flexural testing of laminate in this work is presented in Figure 2.

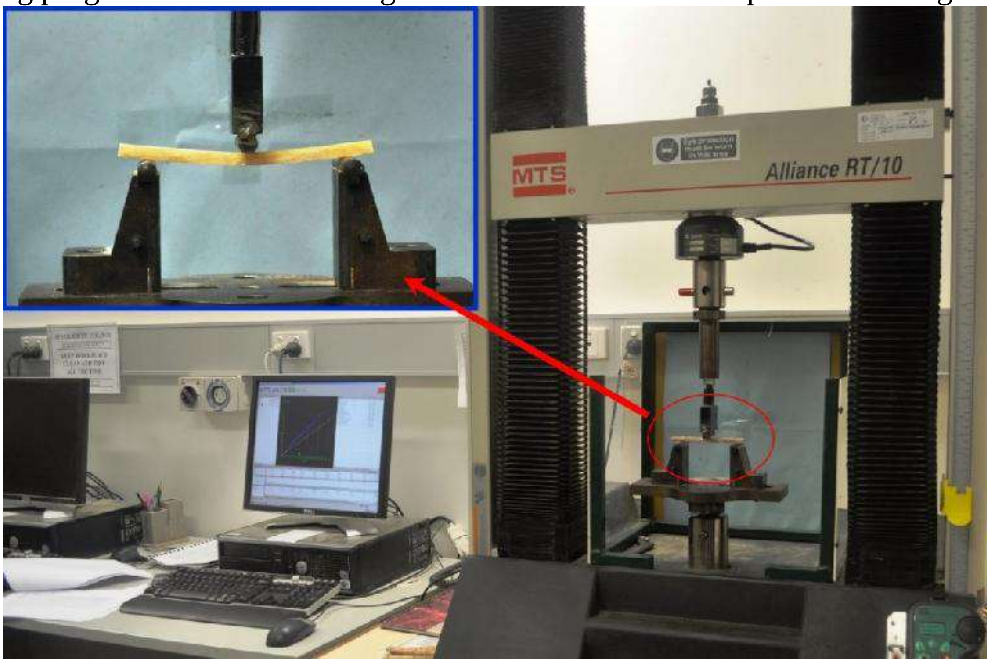

Figure 2. Setting-up testing machine for the flexural test

3. Results and Discussions

As stated in EN ISO 14125 (British Standard, 1998), the referred standard for flexural test in this work, flexural stress is the nominal stress in the outer surface of the test specimen at mid span, while flexural modulus isthe modulus of elasticity in flexure which is the ratio of stress difference divided by correspond strain difference. The results of tensile testing are tabulated in Table 2, which include some important parameters such as flexural strength, flexural modulus and deflection at peak load. In natural fibre composites researches, it is well understood that there has a lot of variations in their properties. It is therefore, checking the consistency of the provided data is very important prior to further analyze them. The distribution of coefficient of variations (CV) might provide some important information relates to the quality of the fabrication or testing process. As it can be seen in Table 2, the CV values ranges from 9.24 to 62.52 percent, which can be considered as high. The high values of CV indicates the inconsistency in the quality of samples.

In more general values, the average of CV values was approximately 15 to 20 percent, with the exception for the CV value of the flexural modulus data of BFC. The CV value for this data was 62.52 percent which may be contributed by one or two peculiar observed data among the specimens. However, the variation of the data which is called as noise is, to some extent, also normal. The noise is usually called as experimental errors that may arise from various factors (Montgomery, 2009).

Table 2. Flexural properties of natural fiber composites

Natural Fibre Composites	Flexural Strength		Flexural Modulus		Deflection at Peak	
	Average (MPa)	CV (%)	Average (MPa)	CV (%)	Average (MPa)	CV (%)
Jute Fiber Composite (JFC)	62.72	16.02	3459	9.24	4.74	15.61
Sisal Fiber Composite (SFC)	54.23	16.96	2322	24.98	6.40	19.69
Hemp Fiber Composite (HFC)	47.17	21.88	2489	19.12	7.41	11.07
Bamboo Fiber Composite (BFC)	53.34	18.12	2001	62.52	4.57	21.23

3.1. Flexural Strength

The flexural strength of various NFCs examined in this study is presented in Figure 3 (A). It is clearly demonstrated in the figure that JFC has the highest value of flexural strength, which is around 62.72 MPa. While in contrast, HFC has the lowest value with the flexural strength of 47.17 MPa; approximately 32.9 percent lower than JFC. In addition, SFC and BFC provided almost comparable flexural strength, which was 54.35 MPa and 53.34 MPa, respectively. The difference between the two NFCs is only about 2 percent. Further, the performance of JFC obtained in this study almost similar to the work reported by Khan et al. (2011), where jute reinforced polyvinyl chloride (PVC) has the flexural strength of 62.6 MPa. The result also parallel to the flexural strength of banana/polyester composite (Pothan et al., 2002) and gomuti/epoxy composite (Sastra et al., 2005), which is 65 MPa and 64.71 MPa, respectively. In addition, sisal fiber composite obtained in this study has a significant lower value (54.35 MPa) compared to the flexural strength of sisal/polyester composite examined by Prassad and Rao (2011) which reached the value of 99.5 MPa. Bamboo/epoxy composite studied in this work also has a pretty lower flexural strength compared to the bamboo/polyester composite reported by Prassad and Rao (2011). The flexural strength of BFC (53.34 MPa) was only approximately half of the previous work, which is and 128.5 MPa. Similarly, the flexural strength of HFC (47.17 MPa) is also lower than hemp/polyester reported by Rouosin et al. (2006), which reached the value of 54 MPa. Although the difference it is not greatly significant, which is around 15%, the strength of composite using epoxy should be theoretically stronger than composite using polyester matrix. However, the variations in the properties of natural fibre composites have been well understood which may arise from many factors related to the material and manufacturing process.

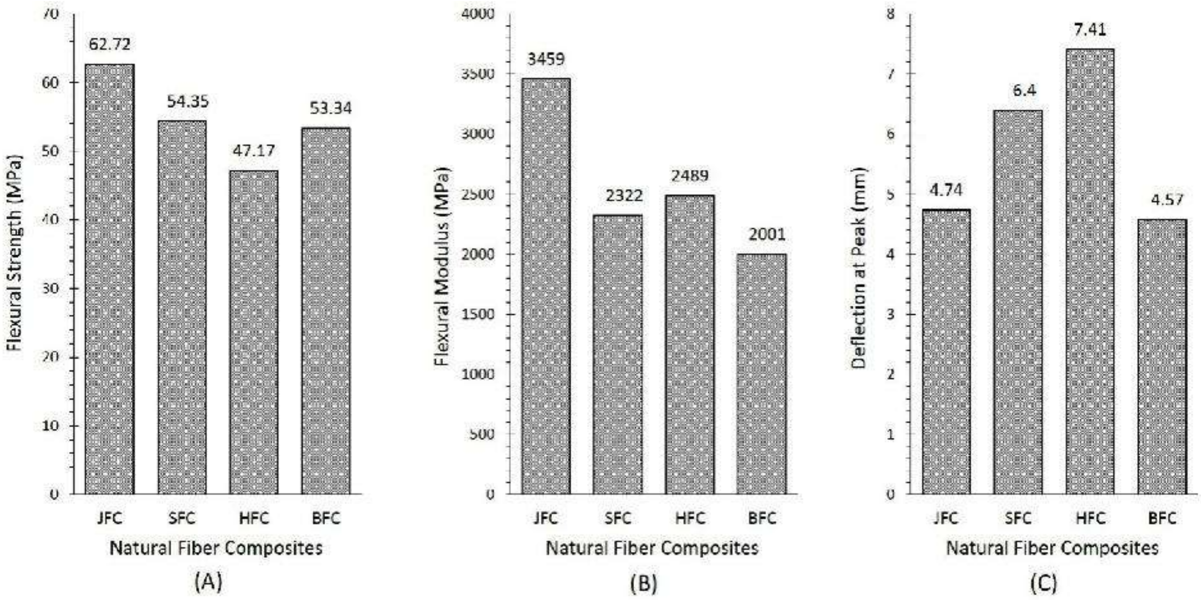

Figure 3. Flexural properties of lignocellulosic composites; (A) Flexural strength, (B) Flexural Modulus, and (C) Deflection at peak load

3.2. Flexural Modulus

Figure 3 (B) shows the flexural modulus of the natural fiber composites obtained in this study. JFC has the highest flexural modulus (3459 MPa), which is approximately 73 percent higher than BFC (2001 MPa), the lowest value reached in this study. Meanwhile, SFC and HFC reached a slightly different flexural strength of 2322 MPa and 2489 MPa, respectively. The difference between the two composites is only around 7 percent, while their differences with JFC is considered as significant which is approximately 50 percent for SFC and 40 percent for HFC. The difference is most likely due to the nature of each fiber used in this study. In general, the values of flexural modulus of composites provided in this works are comparable to the previous reported works as shown in Table 1. As clearly shown in the table, the flexural modulus lies between 2490 MPa to 3700 MPa, except for hemp/polyester composite (5020 MPa). The flexural modulus of Jute/PVC composite (Khan et al., 2011), gomuti epoxy composite (Sastra et al., 2005) and gomuti/polyester composite (Ticoalu et al., 2010) was 3200 MPa, 3150 MPa and 3400 MPa, respectively. While polyester reinforced with sisal fiber (Prassad and Rao, 2011), bamboo fiber (Prassad and Rao, 2011) and hemp fiber (Rouosin et al., 2006) has the flexural modulus of 2490 MPa, 3700 MPa and 5020 MPa, respectively.

3.3. Deflection at Peak

In relation to the stiffness of a material, deflection is also an important parameter that needs to be evaluated. A stiff material only slightly changes under elastic loads. Figure 3 (C) shows the deflection of the natural fiber composites obtained in this study under the peak load. Regarding their deflection at peak load, JFC and BFC may be categorized in the same cluster where they reached almost the same values of 4.74 and 4.57 mm, respectively. While in slightly higher values, SFC and HFC provided a deflection of 6.4 and 7.41 mm, respectively. It can be assumed that, in regards to the scope of this study, JFC and HFC are much stiffer than SFC and HFC.

3.4. Mode of Failures and Stress-Strain Graphs

The failure pattern of different natural fibre composites investigated in this research is shown in Figure 4. Some specimens collapsed in a sudden motion and displayed a slight strengthening beyond the point of ultimate load. All natural fibre composites examined in this work, regardless of their nature of fibers, failed due to fracture at the bottom part which acted a tension region of the specimen under the loading point. This failure mechanism is commonly observed for specimens tested under a three point bending test. The typical stress-strain graphs of different natural fibre composites tested under flexure in this study are presented in Figure 5. As shown in the figure, the stress-strain curves showed a linear elastic behaviour up to a final failure.

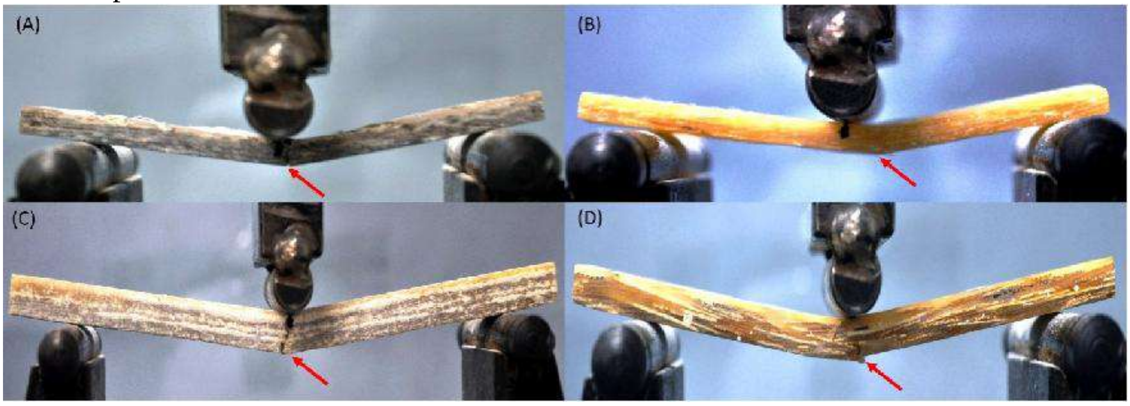

Figure 4. Failure mode of natural fiber composites under flexural load; (A) Jute fiber composite, (B) Sisal fiber composite, (C) Hemp fiber composite, and (D) Bamboo fiber composite

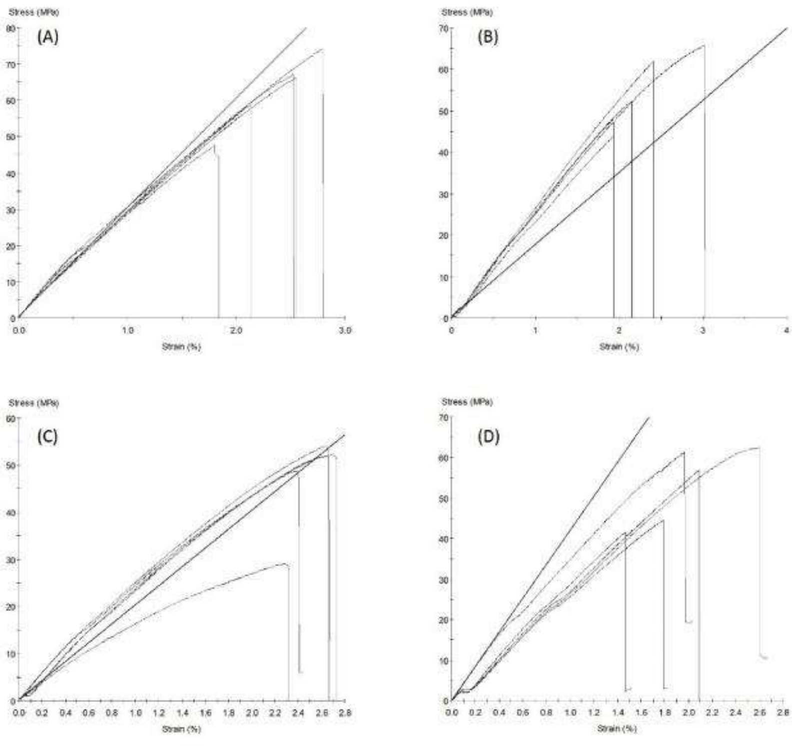

Figure 5. Stress-strain graphs of natural fiber composites under flexural load; (A) Jute fiber composite, (B) Sisal fiber composite, (C) Hemp fiber composite, and (D) Bamboo fiber composite

4. Conclusion

A comparison study on the flexural properties of natural fiber composites derived from tropical grown natural fibres and prepared using vacuum bagging method has been investigated comprehensively. The results show that the flexural properties of the composites are comparable to the previousstudies. More specific findings are as follow:

1) All composite laminates have fairly comparable flexural strength which varied from 47.17 MPa for hemp fibre composite to 62.72 MPa for jute fiber composite. Natural fiber composites based on sisal and bamboo fibre provided almost comparable flexural strength, which was 54.35 MPa and 53.34 MPa, respectively.
2) The flexural modulus properties differs by a significant amount. Jute fibre composite has the highest flexural modulus (3459 MPa), which is approximately 73 percent higher than bamboo fibre composite (2001 MPa), the lowest value reached in this study. Meanwhile, Sisal and hemp fibre composite reached a slightly different flexural strength of 2322 MPa and 2489 MPa, respectively.
3) The stress-strain curves for all the tested laminates presented a linear elastic behaviour up to the final failure. Some specimens showed a slight strengthening beyond the ultimate load, and then collapsed in a sudden motion. Most of the specimens failed due to fracture at the bottom part under the loading point, which is a common failure mechanism of natural fiber composite tested under three point bending load.

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PREFACE

Bismillaahirrahmaanirrahiim
Assalaamu'alaikumwarahmatullaahwabarakaatuh.
Peace be upon us.

Praise always we pray to God Almighty for giving us the abundance of grace, guidance and inayah, so that we all can meet here in the "2nd International Conference on Science and Technology (ICST) 2017". The theme of this conference is "The Emergence of Science for Human Prosperity and Health" where this conference is joint international conference between Mataram and Malaya University.

First of all, I would like to welcome you all to West Nusa Tenggara Province specially Lombok Island, "the Island of Thousand Mosques", which is famous to its many natural resource and beautiful tourism destinations where you can enjoy them while attending the conference. This conference will be held for two days, from 23rd to 24th August 2017, and took place in campus of the University of Mataram.

So far, we received one hundred fifty papers from various universities and research institutions in Indonesia and from overseas. The paper have been selected and grouped based on the similarity of the research field, which then are presented and discussed. Presentation of the papers will be held in seven parallel classes and poster presentation. The Selected papers will be published in Malaysian Journal of Science (Special Issue) which index by Scopus, and the rest will be published in the Conference Proceedings. Additionally, selected paper in aquaculture have the opportunity to be published in Jurnal Akuakultur Indonesia.

At this moment, the organizing committee would like to express our gratitude to all of you for your participation on this conference, especially to the all keynote speakers, presenters who have submitted for both oral and posters presentations and also to all participants. Our special gratitude also goes to the Rector of the University of Mataram and Vice Chancellor of Malaya University, who have been highly supporting this conference. Critics and suggestions on the implementation of this conference will be appreciated and as much as possible we will improve the next ICST. Last but not least, the organizing committee would like to thank to all of you who have supported this conference.

Have an enjoyable conference.
Wassalamu'alaikum warohmatullahi wabarakatuh.

Chairman of 2nd ICST 2017

Dr.rer.nat. Lalu Rudyat Telly Savalas, M.Si.

OPENING SPEECH - RECTOR THE UNIVERSITY OF MATARAM
The 2nd International Conference on Science and Technology 2017

Joint International Conference on Science and Technology in The Tropic Beetwen Mataram and Malaya Universiti

Respected Guests,
Keynote speakers,
Conference participants,
and all other participants.

On Behalf of all staffs of the University of Mataram, I welcome you all to Lombok, a beautiful island in West Nusa Tenggara Province, where the University of Mataram is located. Lombok is known for its natural and cultural diversity where you can enjoy traditional cuisines, beaches, waterfalls, mountain, traditional villages and handicraft of many ethnics including Sasak, Samawa, Mbojo, Balinese, Chinese, Arabic, and many others.

As the Rector of the University of Mataram, it is a great honour for me to address the opening of “The 2nd International Conference on Science and Technology” here at the University of Mataram, which will be held from 23rd to 24th August 2017, with a theme “The Emergence of Science for Human Prosperity and Health”. The main aim of this seminar is to gather scientist from all over the world to share their ideas, knowledge and experiences and to build network for possible future collaboration.

As we are aware that sharing knowledge and experiences from speakers are extremely valuable in a conference, therefore I would like to express my high appreciation, first, to the keynote speakers from overseas and from Indonesia for their willingness to come to Lombok to share their acknowledged works. Your effort and contribution to this conference are absolutely valuable. Second, my high appreciation also goes to the national speakers and all other participants, including the speakers from University of Mataram and local universities in West Nusa Tenggara Province, your participation in this conference not only will give incredible share of ideas, skills and knowledge that you have, but also will improve the academic environment that we are developing in this university. I hope this conference will be a good forum, not only for communicating and sharing ideas, knowledge and experiences, but also for building networking for future collaboration.

I would also like to take this opportunity to express my appreciation to the sponsors which have given some contribution to this conference. Last but not least, I would like to thank the organizing committee as well as all other supporters and participants, without their effort, commitment and hard work, this conference will not run well.

Finally, I wish you most successful conference, enjoy Lombok Island and hope to see you again in other forum here at the University of Mataram.

Rector of the University of Mataram

Prof. Ir. Sunarpi, Ph.D

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