Original Article

Conceptual design of multi-operation outdoor flexural creep test rig using hybrid concurrent engineering approach

M.R.M. Asyraf\textsuperscript{a,*}, M.R. Ishak\textsuperscript{a,b,c,*}, S.M. Sapuan\textsuperscript{d}, N. Yidris\textsuperscript{a,b}

\textsuperscript{a} Department of Aerospace Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
\textsuperscript{b} Aerospace Malaysia Research Centre (AMRC), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
\textsuperscript{c} Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
\textsuperscript{d} Advanced Engineering Materials and Composites Research Centre, Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

\textbf{A R T I C L E  I N F O}

Article history:
Received 19 September 2019
Accepted 20 December 2019
Available online 3 January 2020

Keywords:
Conceptual design
TRIZ
Morphological chart
Analytic Network Process
Flexural creep
Test rig

\textbf{A B S T R A C T}

The hybridisation of conceptual design methods is presented in the development of multi-operations creep flexural test rig. The paper explains the integration of theory of inventive problem solving (TRIZ), Morphological chart, and Analytic Network Process (ANP) method to ensure the quality function is fulfilled with the essential requirements. The objective of this project is to produce and choose the best design concept for the product development depending on the product design specifications (PDS). In the early stage of product development, the TRIZ contradiction principles and 40 TRIZ inventive solutions were applied as the guidance tools. To refine the specification of the product design, the principle solution parameters were detailed systematically with the aid of morphological chart. In this article, four innovative conceptual designs of the multi-operations creep flexural test rig were produced and the selection process was conducted using ANP method to perform the multi-criteria decision making process in selecting the best concept design.

© 2019 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Cross arm is one of the main component in transmission tower to lift the electric cable along the transmission line. In the middle of 1963, a wooden cross arm had been introduced in the Malaysian electrical system to accommodate 132 kV of power transmission [1]. The installation of Chengal or Neobalanocarpus heimii wood as a cross arm in the transmission tower was due to the high quality of mechanical and arch quenching properties. Still and all, the matured Chengal wood showed a severe deformation after more than 20 years of service due to the effect of the natural wood defect [2]. This can be seen because of natural-based material, especially wooden material and natural fibre exposed to creep loading in a prolonged time [3–7]. As a solution, several researchers had been urged...
Design concepts were proposed based on the current parking brake lever mechanism and application used for automotive vehicles. Apart from that, ANP and technique for order preference by similarity to ideal solution (TOPSIS) are commonly applied in the conceptual design selection for product development [20–22]. These methods are crucial in decision making process where multiple proposed attributes and design alternatives are being analysed simultaneously. These selection techniques are suited for the targeted design specification and can be implemented in combination selection process. Table 1 exhibits the list of recent studies to develop product based on concurrent engineering processes.

To the best of our knowledge, no design and study have been found in the literature regarding test rig to accommodate three-point flexural creep test in the open tropical climate. Thus the purpose of this manuscript is to present a new multi-operation flexural creep test rig, which can be accommodated in extreme tropical climate to evaluate the creep behaviour of composite material. In this paper, the conceptual design of the multi-operation creep test rig is developed to establish a standard machine in order to conduct three points flexural creep test for viscoelastic material such as composite. On top of that, the proposed design is ensured to produce a machine with specific required structural strength for safety and functionality performance. Based on the project requirements, a new concurrent engineering approach, which implements the combination of TRIZ, morphological chart and ANP, employs the conceptual design of the multi-operation test rig. Using this approach, four stages of design development were executed, such as idea generation, idea refinement, concept development, and design selection. At the end of the study, four new concept designs were created, and the best concept design was selected according to the product design specification (PDS).

2. Applications of TRIZ in concurrent engineering for new product development

TRIZ is an inventive concurrent engineering principle used to solve problems experienced by the user and valuable for design solutions [29]. The TRIZ aids to eliminate any problem arising from the solution in conjunction to the product goal. Generally, the TRIZ focuses on the root cause of a problem for a specific situation before solving the problem. The TRIZ method solution can be implemented by using four approaches to solutions depending on the problem complexity. These approaches are divided into Su-field modelling and 76 Standard Inventive Solutions, 40 TRIZ inventive principles, Prediction of Technology Trends, and Algorithms of Inventive Problem Solving (ARIZ) [30]. The TRIZ provides a systematic opportunity by evaluating the innovation approach to identify the problem unlike the conventional brainstorming method, which highly depends on luck [26].

In the concurrent engineering, the implementation of TRIZ among designers and engineers in the product development is gaining attention day by day. Azammi et al. [24] reported on the conceptual design development of automobile engine rubber mounting composite using the integration of TRIZ-Morphological chart-ANP method. In the study, four design
concepts were developed using the TRIZ contradiction matrix and the best design concept was selected using ANP method based on the performance efficiency requirements. The same approach was also used by Mazani et al. [31] to develop kenaf fibre reinforced unsaturated polyester composite shoe shelf. The TRIZ method can also be applied by hybridising this principle with a four-phase quality function deployment (QFD) method, which was applied by Yeh et al. [27] to produce a new notebook casing product. The QFD method is another important concurrent engineering approach to satisfy customer's needs with respect to product development. The QFD approach is made up of design characteristic, operational process, components/modules, and production, which was integrated with the 40 TRIZ inventive solution principles to achieve the design goal. Hence, this hybrid method was implemented to ensure the product is fulfilling the safety and performance aspects.

3. Application of TRIZ-Morphological Chart-ANP method in conceptual design

Fig. 1 shows the current creep flexural test rig assembly. The previous creep test machines design was developed according to the fundamental and theories of creep. Theoretically, creep is divided into three stages: primary, secondary, and tertiary. Fig. 2 shows the general and typical creep behaviour for viscoelastic material such as woods and composite material. Based on the trend in Fig. 2, a viscoelastic material is experienced, constant stress would cause a gradual deformation on the coupon strip. In some cases, an extreme deformation is occurred and expedite the failure of material with a shorter duration. This can be seen due to a material, which is lacking water barrier properties, such as virgin wood [4], and the surrounding condition is exposed to elevated temperature [32]. This led the material to be exposed to an unusual behaviour, which caused the material to be less predictable at the breaking point [33].

To further understand the creep phenomenon, the creep test is divided into three modes of tests including flexural, compression, and tensile. Generally, flexural test is more preferred over tensile and compression tests because it creates concentrated high stress only in the small region of test specimen surface [5]. This is because, a localised effect on the specimen is more accurate to examine mechanical changes on the specific specimen. Additionally, the flexural creep test exhibit three failure mechanisms: tensile, compressive, and shear [15,16]. In contrast, the tensile test produces concentrated maximum stress on the whole test specimen, which is needed for mechanical inspection process. Hence, it requires more complex sensors to observe the changes to the test specimen, which will require higher experimental cost.

These creep testing modes must follow several basic designs to develop a conducive and operational testing
machine. The basic design of the machine should comply the following criteria [35]:

1. Load platform or load hanger is where the object will endure pressure at a constant rate.
2. Grips/fittings are used to hold the material tested in a specific position. The position is essential because misalignment will cause inaccurate creep readings of the material.
3. Strain measurement instrument is used to measure the strain. It captures the movement of the object in the machine. The load beam transfers the movement from the grip to the dial gauge.

In this study, the integration of TRIZ-Morphological chart-ANP method was used to discover the best solutions for the existing creep test rig problems. The TRIZ solution principle was used to generate idea and conceptualise the expected designs. Later, the selection process of proposed designs using the Morphological chart was implemented as an ideal refinement tool based on the TRIZ recommended solutions. Lastly, the ANP principle was executed in the design selection to determine the final decision for the design concepts depending on the PDS. Fig. 3 depicts the comprehensive concurrent engineering method used to develop a multi-operation outdoor flexural creep test rig for this project.

3.1. Defining the design intends and determine the 39 engineering parameters of TRIZ principles

To generate an efficient product design, the improving factors and worsening parameters should be defined in the new engineering system. The aim is to fix the design intends and consequent effect would be issued when fulfilling the requirements. In this project, the reliability of the testing machine to execute in outdoor condition and the additional number of operations for the testing were introduced to compensate reliable and faster data generation for creep test on material. This is because the tropical climate (hot and rainy seasons throughout the year) in Malaysia can eventually damage the test rig if it was not properly designed [36]. In this case, it is worth to note that an improved design with higher durability, strength, and operability to ease the testing operation should be developed to comprehend this problem. According to the previous statement, a multi-operation outdoor flexural creep test rig was chosen. The improving parameters involved were the reliability and availability of multi-operations test, while the worsening parameters were the depletion of the product durability, temperature, and easiness of operation. Later, all improving and worsening parameters were classified and paired with the lists of 39 engineering parameters available inside the TRIZ solution method.

3.2. Implementing TRIZ contradiction matrix method

In the TRIZ contradiction matrix principle, two general engineering parameters (improving and worsening parameters) were set and linked together in the results analysis to attain the design goal. The specific 39 engineering parameters, in the form of TRIZ contradiction matrix technique, aid the researchers and designers to find the contradiction between the improving and worsening factors during the preliminary stage of design development. Finally, an appropriate solution principle to identify the complication was determined using the TRIZ 40 inventive principles technique. Table 2 displays the project contradiction matrix produced based on the design goal.
Table 2 – TRIZ contradiction matrix for multi-operations flexural creep test rig.

<table>
<thead>
<tr>
<th>Improving features</th>
<th>Worsening features</th>
<th>TRIZ solution principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>39 Engineering parameters #27 Reliability</td>
<td>39 Engineering parameters #14 Temperature</td>
<td>40 Inventive principles #3 Local quality #28 Parameter changes #10 Preliminary action</td>
</tr>
<tr>
<td>#16 Durability of non-moving object</td>
<td></td>
<td>#34 Discarding and recovering</td>
</tr>
<tr>
<td>#33 Ease of operation</td>
<td></td>
<td>#27 Cheap short-living objects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#6 Universality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#40 Composite material</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#17 Another dimension</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#10 Parameter changes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#14 Use of less sophisticated objects</td>
</tr>
</tbody>
</table>

Table 3 – Design strategy based on identified TRIZ solution principles.

<table>
<thead>
<tr>
<th>TRIZ solution principles</th>
<th>Solution descriptions</th>
<th>Design strategy descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3 Local quality</td>
<td>Change an object’s structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform. Make each part of an object function in conditions most suitable for its operation. Make each part of an object fulfil a different and useful function. Make a part or object perform multiple functions; eliminate the need for other parts.</td>
<td>Vary the thickness of the component according to the stress concentration value. Thicker component at higher stress location points</td>
</tr>
<tr>
<td>#6 Universality</td>
<td>To move an object in tw- or three-dimensional space. Use a multi-story arrangement of objects instead of a single-story arrangement. Tilt or re-orient the object, lay it on its side. Use ‘another side’ of a given area.</td>
<td>Make two level of testing area to allow more number of operation can be run simultaneously. Make a netting cage for the testing area to avoid from animal such as birds to disturb during the reading measurement</td>
</tr>
</tbody>
</table>

3.3. Developing solutions using 40 inventive principles method

Based on the results obtained from the TRIZ contradiction matrix principles, the suitable solution principles were selected based on the existing flexural creep test rig mechanisms. Local quality (#3), universality (#6), and another dimension (#17) were the selected inventive principles to improve the reliability and avoid stress loss in the multi-operation outdoor creep flexural test rig as well as enhance the durability of the stationary object and ease the operation. Table 3 summarises the design strategy used in producing the new multi-operation outdoor flexural creep test rig based on the TRIZ solution principles.

3.4. Refining the selected solution principles with relevant alternative design product

At this stage, a Morphological chart approach was performed using the identified TRIZ solution principles to further refine into several relevant alternative system elements. Generally, the Morphological chart was constructed with respect to the functional analysis in order to deliver ideas for design characteristics in the idea generation process. The method also helps engineers and designers to classify the sub-solution for each sub-function of the design. Hence, a new total design solution for a product can be created using this method, which links and combines the individual solution idea for each function [37,38].

The application of Morphological chart and TRIZ was conducted to further improve the TRIZ method to discover the specifications of design characteristics with TRIZ solution. As discussed earlier, the TRIZ solution is in abstract in nature, which is not clearly explained the design specification, hence it requires subsequent explanation by converting the general solution into specific design features. This allows the designers to develop concept designs from the results of elimination of contradiction of improving and worsening during problem solving process using the TRIZ inventive method. Thus, the success of TRIZ method was significantly based on the designer’s ability and knowledge to visualise the image and build the specific features according to the proposed solutions.

For instance, according to the universality (#6) solution principle, there is a description on how it can be applied. This includes to produce either a part or object perform multiple functions or eliminate the need for other parts. The general solution recommended is very wide scope, which needs further clarification to be executed on the design. Therefore, the hybridization of TRIZ and Morphological chart allows designers to quickly convert the general solution to a systematic and ordered method. Fig. 4 depicts the Morphological chart.
for TRIZ and design features of the multi-operation outdoor creep flexural test rig.

3.5. Developing the multi-operation outdoor flexural creep test rig based on integration of the expected system elements

Four concept designs of a new multi-operation outdoor flexural creep test rig were developed using the design strategy adopted from the TRIZ solution principles and Morphological chart as shown in Fig. 5. The design concepts were modelled into 3D CAD models in an actual scale size to have a better view of the product design characteristics. In general, the proposed design concepts considered features as follows:

1. Shell-like feature was used for the structural design to reduce the weight of the test rig and subsequently lower the cost of raw material.
2. Bracing system was adopted in the creep test rig to improve structural stability and integrity to support high lateral loading dead weight when test operation [39,40]. The strengthening mechanism is contributed by the frames, which is one of the effective ways to reduce deformation as the application of bracing support in a structure increases moment resisting [41].
3. Welding was used to build the product because the joining of two members using high temperature to melt the end joints reduces the mechanical failure at the joining points and provides better surface finish [42].
4. Mild steel was used because it is excellent in weldability and provides good appearance in the connection between structure members. It also provides a uniform and harder shell in developing tall structures. Recent findings also show that mild steel has better machinability than other forms of steel and higher Brinell hardness because it is produced from hot-rolled steel [43,44].
5. A dial gauge with magnetic holder was implemented instead of strain gauge, which is fixed directly on the specimen.
6. Tubes with square profile cross section design were adopted in the test rig to provide higher strength since greater bending forces acted on the structure compared to the U-profile and double-T profile cross-section design [45].
7. A-shaped structure was implemented due to its higher base area, which lower the centre of gravity causing the structure to have higher stability when it is operated. Fur-
thermore, it can be equipped with two storey of test area and protected by BRC meshing steel, which can increase the number and effectiveness of creep testing operations.

The significant difference between all proposed concept designs is the design of bracing. These concept designs are distinguished based on four basic bracing types: chevron bracing, cross-bracing, triangle bracing, and I-bracing. According to Fig. 5, the chevron bracing and triangle bracing were implemented in Concept Design 2 and Concept Design 3, respectively. Meanwhile, the cross bracing was applied in Concept Design 4 and the I-bracing was utilised in Concept Design 1 to reinforce the structure.

3.6. Executing final design concept selection using ANP method based in the product design specification

In the designing stage, the ANP is one of the most comprehensive and reliable to select the method of design [46,47]. The ANP assists designers to provide a systematic and overall multi-criteria decision making process via a pair-wise comparison technique [48]. The method implements the generalisation of analytical hierarchy process (AHP) in dealing with dependence and response in the decision making process [49]. According to AHP approach, the method highlights the customer’s needs. The project utilised the ANP method in the final concept design selection among the five developed conceptual designs. The selection process was done according to the PDS for the new multi-operation outdoor flexural creep test rig as displayed in Fig. 6. Based on the overall PDS document, three elements and nine sub-elements were chosen for the selection purposes. For the sub-elements, they were adopted into equivalent design indicators as tabulated in Table 4.

![Fig. 5 – Multi-operation outdoor flexural creep test rig design concepts.](image)

![Table 4 – Multi-operation outdoor flexural creep test rig PDS elements and their equivalent design indicator.](table)

<table>
<thead>
<tr>
<th>PDS main elements</th>
<th>PDS sub-elements</th>
<th>Equivalent design indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Strength</td>
<td>Von Mises stress (N/m²)</td>
</tr>
<tr>
<td>Weight</td>
<td>Tensile properties</td>
<td>Deformation (mm)</td>
</tr>
<tr>
<td>Cost</td>
<td>Mass</td>
<td>Mass (kg)</td>
</tr>
<tr>
<td></td>
<td>Volume</td>
<td>Volume (m³)</td>
</tr>
<tr>
<td></td>
<td>Raw material cost</td>
<td>Raw material prices (RM)</td>
</tr>
<tr>
<td></td>
<td>Manufacturing cost</td>
<td>Shape complexity</td>
</tr>
</tbody>
</table>

![Fig. 6 – Multi-operation outdoor flexural creep test rig product design specifications.](image)

In the overall PDS elements, disposal and weight were not incorporated in the concept design selection because both are related to the material selection requirement, which adopts the mild steel for the test rig’s material. The standard PDS element in the design follows international standard, ASTM D2990, test requirements for flexural creep test operation using the conventional approach. This criterion was also not considered in the design selection process because the standard is common for the creep test.

The PDS elements, as displayed in Table 4, were further interpreted into main criteria and sub-criteria in the ANP network framework. In detail, four levels of hierarchy were formed based on the information depicted in Fig. 7. At the beginning, the goal was set at the Level 1 of the project and later continued by design selection based on the criteria and sub-criteria at the corresponding Levels 2 and 3. To sum up,
these four design concepts produced for the multi-operation outdoor flexural creep test rig were listed as alternatives at Level 4 in the ANP method.

According to ANP approach, the decision process among the concept designs were carried out using the pair-wise comparison technique. Numerical values were attributed to each of concept design in order to establish the relative importance comparison as shown in Table 5. Fig. 8 shows the evaluation of each concept design for the multi-operation outdoor creep test rig. Every design concept was translated into 3D CAD models and a comprehensive examination was conducted on their attributes based on their performance selection criteria to compare each design made using the sketch method. From this, a finite element analysis was carried out on each model to estimate their structural performance when the stress is applied causing the formation of deformation on the product. Furthermore, the weight criteria was determined by the mass value from CAD models, which later used to estimate the raw material cost for each concept. To predict the manufacturing cost, the shape complexity design was assigned as one of the criteria in the PDS document. In the manufacturing cost attribute, the evaluation was defined into low, medium and high complexity values. Fig. 9 shows the example of the pair-wise judgment process between the concept designs with respect to the weight and cost criteria.

Based on the ANP result using Super Decision 2.1 software, the key objective of the design selection is the performance of multi-operation outdoor of creep flexural test rig. Subsequently, the weight and cost attributes were considered equally, for which the weight criteria influence the cost of the design. Fig. 10 displayed the result of the simulated scenarios based on ANP analysis. For the test rig design selection process, the performance criteria was put as a vital attribute because the product should adapt higher loading capacity, which contributes when the experiments are operated simultaneously.

According to the overall sensitivity in Fig. 10, Concept Design 3 has the highest sensitivity value among the design concepts based on three (3) simulated conditions: performance, weight and cost criterion. According to the ANP selection process, Concept Design 3 permitted the overall and best results. The overall synthesised alternatives in Table 6 depicts the ranking of the design.

From the beginning, Fig. 10(a) explained numerical rankings of all proposed concept designs via ANP selection approach based on performance criteria. Concept Design 3 exhibits the highest performance value comparing to the other designs. This was due to the fact that the Concept Design 3 experiences the lowest Von Mises stress value at the critical point in the structure. Moreover, it also emits the least value of deformation, which indicates that the chevron bracing allows to resist applied force from the dead weighs better as compared to other bracing types. Aside from that, Concept Design 3 was a lightweight structure as compared to other designs, which is associated with lesser material to construct the product. This was proven, as in Fig. 10(b). In the fabrication point of view, Concept Design 3 permits the most uncomplicated structural design, which reduced the manufacturing process time. Afterwards, it helps to reduce the production price. Thus Fig. 10(c) reveals that the Concept Design 3 has the highest cost attributes due to lower raw material and manufacturing cost. In the end, Concept Design 3 was the best concept design to be chosen due to the lowest weight among the designs with lower raw material and manufacturing cost without compromising the strength and stiffness of the structure.

For verification of the final design, a computational simulation analysis was conducted using ANSYS R14.5 to indicate the deformation behaviour of the design in full capacity. Fig. 11 shows that the Chevron bracing incorporated in Concept Design 3 generated the lowest deformation value on the product. In this case, the material applied in the test rig’s structure during the computational simulation was mild steel with a yield strength of 250 MPa and modulus of elasticity of 202 GPa [50,51]. As described above, the mild steel can be well performed as a body frame for the test rig. It permits high performance mechanical properties and subsequently contributes to higher durability. From the simulation results, as depicted Fig. 11(a) and (b), the primary stress regions are
Design | Weightage evaluation
--- | ---
Concept design 1 | ![Concept design 1](image1.png)
Concept design 2 | ![Concept design 2](image2.png)
Concept design 3 | ![Concept design 3](image3.png)
Concept design 4 | ![Concept design 4](image4.png)

**Fig. 8** – Conceptual design evaluation data.

**Fig. 9** – Pair wise comparison among alternatives in design selection process.
located in contact areas beside the bracing midpoint at the top and bottom surface of the component. As mentioned earlier, the maximum deformation is seen at the red regions, which probably might bend the steel frame into U-shape. Moreover, the midpoint region of chevron bracing is indicated as yellow colour. This additional bracing allows easing the buckling effect and tension yield capacity from the applied loads [23,52,53]. Thus the simulation results indicate that the design shape of the chevron bracing can withstand the highest applied force in full capacity of flexural creep loadings. Hence, the addition of bracing in the proposed design allows more flexibility, higher durability, and permits the least bending in horizontal members. The new concept design encompasses chevron bracing with two storey test areas using A-shaped structure. This selection probably improves the structural strength and stiffness of the product in safety and functional operation while reducing the product weight to have economical raw material and fabrication cost.

4. Conclusions

As a conclusion, a new conceptual design for the multi-operation outdoor flexural creep test rig was developed. The design was selected from four proposed design concepts. A combination of systematic concurrent engineering principles, including the TRIZ, Morphological chart, and ANP principles, was implemented to develop the product concepts. The integration of TRIZ-Morphological chart-ANP method was able to perform a preliminary product development including idea generation, idea refinement, concept design development, and concept design selection. To identify the required specification for product installation, three TRIZ inventive solutions were made up from the TRIZ contradiction matrix: local quality (#3), universality (#6), and another dimension (#17). Concept Design 3 was chosen as the final product design using the ANP method due to its highest normalised value compared to the other design alternatives. The sensitivity analysis shows that Concept Design 3 was ranked first among all four simulated scenarios. On top of that, computational simulation results verified that the Concept 3 design has the lowest deformation values compared to other design when fully operated with maximum loading. The addition of chevron bracing assist the distribution of load evenly without compromising the cost, stability and safety features of the test rig. Thus, the integrated concurrent engineering method does provide a holistic view in term of concurrent engineering to attain the desired solutions, which focusing on the development of multi-operation outdoor flexural creep test rig for outdoor areas.

Conflict of interest

The authors declare no conflicts of interest.
Acknowledgements

The authors would like to thank Universiti Putra Malaysia (UPM) for the financial support provided through Geran Putra, UPM with VOT no. 9634000. The authors are very thankful to Department of Aerospace Engineering, Faculty of Engineering, UPM for providing space and facilities for the project. Moreover, all authors are very appreciate and thankful to Jabatan Perkhidmatan Awam (JPA) and Kursi Rahmah Nawawi for providing scholarship award and financial aids to the first author to carry out this research project.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://doi.org/10.1016/j.jmrt.2019.12.067.

REFERENCES


