Computational simulation in compactor components for plate product of palm slag composites

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ABSTRACT
Computational simulation of compactor components for plate product of palm slag composites has been investigated. The plate product of palm slag composites was compacted on a compression molding machinery using jig and fixture. Jig and fixture were modeled by finite element simulation to determine stress distributions of a jig and fixture. An advantage of having a finite element model of a compression molding machinery is that it can be quickly altered by designers. Further improvement of plate product compactness can be tested through a manufacturing simulation. The influence of geometric shapes under static compression of compactor components was studied in detail. The results show that the geometric shapes of jig need to be improved against the stress concentration area. The length of fixture plate from supported location must be reduced against the maximum deflection at the end of fixture plate.

KEY WORDS: Computational simulation, plate product, palm slag composites, jig and fixture

1.0 INTRODUCTION
The simulation of jig and fixture subjected to compaction pressure is a complex problem due to interaction between jig and plate product of palm slag composite. A computational approximation has been developed for the jig and fixture interaction. In view of stress distribution and displacement of jig and fixture in compactor components for plate product is employed in this study. The objective of this study is to simulate a jig and fixture subjected to compaction pressure. The plate product of palm slag composite was compacted experimentally in hot static pressure in order to achieve more uniform compaction. The computations of the pressure response are carried out using finite element codes. Information of stress distributions and displacement response of jig and fixture to compaction pressure is useful in manufacturing design to enhance their response to compaction pressure. Several simulations modeling, stress distributions and displacement of jig and fixture have been performed.

Consider the same 3D solid structure whose domain is divided in a proper manner into a number of tetrahedron elements with four nodes and four surfaces, as shown in Figure 1. A tetrahedron element has four nodes, each having three DOFs [1].

Figure 1: A tetrahedron element
(u, v and w), making the total DOFs in a tetrahedron element twelve, as shown in Figure 1. The nodes are numbered 1, 2, 3 and 4 by the right-hand rule. The local Cartesian coordinate system for a tetrahedron element can usually be the same as the global coordinate system, as there are no advantages in having a separate local Cartesian coordinate system. In an element, the displacement vector $U$ is a function of the coordinate $x$, $y$ and $z$, and is interpolated by shape functions in the following form,
which should by now be shown to be part and parcel of the finite element method:

\[ U^H(x, y, z) = N(x, y, z)D_e \]  

(1)

It was mentioned that there are six stresses in a 3D element in total. The stress components are \( \{\sigma_{xx}, \sigma_{yy}, \sigma_{zz}, \sigma_{xy}, \sigma_{xz}, \sigma_{yz}\} \). To get the corresponding strains, \( \{\varepsilon_{xx}, \varepsilon_{yy}, \varepsilon_{zz}, \varepsilon_{xy}, \varepsilon_{xz}, \varepsilon_{yz}\} \):

\[ \varepsilon = LU = LNde = Bde \]  

(2)

where the strain matrix \( B \) is given by

\[
B = LN = \begin{bmatrix}
\frac{\partial}{\partial x} & 0 & 0 \\
0 & \frac{\partial}{\partial y} & 0 \\
0 & 0 & \frac{\partial}{\partial z} \\
0 & \frac{\partial}{\partial z} & \frac{\partial}{\partial y} \\
\frac{\partial}{\partial y} & 0 & \frac{\partial}{\partial x} \\
\frac{\partial}{\partial z} & \frac{\partial}{\partial x} & 0
\end{bmatrix} N
\]  

(3)

2.0 COMPUTATIONAL SIMULATION

Figure 1 shows the compressive molding pressure, \( p \) that has been measured using pressure gauge during compaction process. The finite element model for compactor as shown in Fig. 2 was creating using Autodesk Inventor [2]. In FEM model creation, compactor divided into two components: jig and fixture. The static compaction pressure was 59 MPa, the sintering temperature was 150 °C [3]. The material properties of steel alloy were determined [4]. Jig and fixture volume were 1.64 mm\(^3\) and 1.16 mm\(^3\), the compactor is comprised entirely of tetrahedral elements.

![Figure 1: Jig and fixture for plate product of palm slag composites under investigation](image1)

Jig and fixture were subjected to constant displacement, the loading type was taken, instead of using constant compaction pressure as shown in Fig. 2.

![Figure 2: Finite element mesh of jig and fixture](image2)

3.0 RESULTS AND DISCUSSION

3.1 Stress distribution

The analysis of computational simulation in manufacturing components focuses on determination and estimation of the stress distribution and displacement during compaction process, which regarded as the critical location of the compactor components. In the case of stress distribution approach, it is assumed that a critical stress at the surface distributes on a preferred plane which the normal stress-strain reaches its maximum.

Figure 3 shows Von Mises stress distribution of jig and fixture components. Computational simulation identifies the critical jig element was occurred at the bottom of the jig plates.
The critical fixture element was occurred at the contacting plate part direct with the plate product.

A comparison of the stress response for jig and fixture shows that at the bottom of plate is only 2.47% higher than that for fixture plate. The maximum stress for the centre of the bottom fixture is 67.37% higher than that the top plate of fixture. This indicates the contact location of fixture to the plate product has significant effect on the manufacturing process of palm slag composites whereas relatively less influences on the jig plate.

3.2 Displacement

In order to have a clear view of stress distribution of jig and fixture as shown in Fig. 3, let us observed the displacement of jig and fixture presented in Fig. 4. Computational simulation identifies the critical jig element was occurred at top of the jig plates. It is observed that the displacement response in fixture side exhibits much higher value than those other parts of fixture. It is due to the fact that the stress distribution influence displacement which causes a prediction of resulting response in fixture components. It is also observed that the values of displacement response for the jig components are lower than that of fixture components. The maximum value of displacement was not occurred at stress concentration area, whereas the maximum displacement occurred at the end of fixture plate. This is because the maximum displacement corresponds to the length of fixture plate from supported location.

Finally, it is considered important to evaluate a quantitative comparison among displacement of jig and fixture. A comparison of displacement response for jig and fixture shows that at the top of jig plate is 16.84% higher than that at the end of fixture plate. The maximum displacement for the end of fixture plate is only 2.1% higher than the maximum displacement at the jig plate.
4.0 CONCLUSION

In this paper, computational simulation of compactor components for plate product of palm slag composites was analyzed. The influences of geometric shapes on the static compression of compactor components were studied detailed and results show that the geometric shapes of jig must be improved against the stress concentration area. The length of fixture plate from supported location must be reduced against the maximum deflection at the end of fixture plate.

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REFERENCE