# Mechanical Properties of Tin Slag filled Polyester Composites

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**Abstract**

The mixture of tin slag (TS) powder and polyester (PE) along with Methyl Ethyl Ketone Peroxide (MEKP) as the catalyst were studied in this paper. This study is about the properties of PE alone and the addition of TS as the filler. Three formulations are prepared which are 5 wt%, 10 wt% and 15 wt%. The MEKP is used to harden the mixture. The objective of this study to determine the mechanical properties of the mixture. The samples obtained are tested with two different types of testing which are tensile and flexural. As the wt% increases it will cause the mixture of TS and PE result in a poor structure rather than PE alone. The 5% of addition gives the best results in the flexural testing and the pure PE has better tensile properties compared to the other formulations.

*Keywords:* Polyester; MEKP; Tin slag; Mechanical testing

## 1.0 Introduction

Today the term polymer usually used in plastics and composites industry. It is used to replace the meaning of plastic or resin. The polymer is a chemical compound where molecules are bonded together in long repeating chain. The polymers have their own unique properties and can be alter depending on their intended purpose. Polyester (PE) is the example of the synthetic polymer that is produced from polymerization process. PE is flammable and very durable means that the substance resist to most chemicals. The substance also has a quick drying effect. PE are commonly used in the manufacturing industry to produce car tire reinforcements, safety belts and insulating materials in pillows.

Tin slag (TS) is a very common waste product in Malaysia as this country is one the biggest tin producers in the world. However, the waste product of tin or known as TS are not being used in any sector. TS have a very small percentage of radioactive which chromium in it. This component is quite dangerous towards the environment. However, the addition of TS as a filler to a polymer will reduce the percentage of radioactive substance in the TS, thus effect to the environment can be reduced significantly. The addition of TS and PE will produce a component with new properties.

From past research, they used Pineapple Leaf Fibre-polyester composite with glass fibre. It is proven that the composite has improved tensile strength by 66%. The ultimate tensile strength is achieved when it was added by about 8.6 wt% of glass fibre. Unfortunately, the tensile strength was decreased by about 10% when 12.9% of glass fibre was added (Mishra et al., 2003). Other than that, another research on natural fibres showed that hemp composites have the best flexural strength properties (54 MPa) compared to glass mat composites (60 MPa). However, the specific flexural strength (flexural strength divided by density) of hemp composites which was 36.5 were higher than the specific flexural strength for glass mat composites which were about 24 (Wambua, Ivens, & Verpoest, 2003).

The current investigation is centralized on the properties of PE and the addition of TS with PE. The mixture is then added with the catalyst Methyl Ethyl Ketone Peroxide (MEKP). MEKP is a flammable substance, so only small percentage is needed to speed up the curing time. Curing process of polyester is very critical has a very complicated mechanism. For the cure process to be studied successfully by mechanical methods, the dynamic torsional vibration method (DTVM) was used. (Cheng, Y., Chen, D., Wang, C., & He, P 2005)

The interest of study is to explore the possibility of using TS and PE to produce a very complex polymer in term of mechanical properties. Besides, it will decrease the amount of environmental pollution because the usage of waste product of tin instead of just disposing it to the environment. In the previous research, paddy's husk is used to replace tr in producing paper rather than disposing it. So, this example is used to be applied in this study.

## 2.0 Material and methods

### *2.1 Materials*

Material used are TS, PE and MEKP. TS, which was supplied by Universiti Teknologi Malaysia (UTM) in powder form and the average size of each particle is below 1mm. To achieve the average size of less than 1mm per particle. T is sieved using 125μm electronic sieve after blended to achieve the size of fine particles. PE has a density of 1. 7 g/cm$^3$, and a melting point of 250°C. The hardener used with PE is Methyl Ethyl Ketone Peroxide (MEKP which has a density of 1.17 g/cm$^3$ and a melting point of 110°C.

### *2.2 Methods for preparing the sample*

Table 1: Tin slag, polyester resin and MEKP were weighed according to the assigned ratios:

| PE (wt% | TS wt%) | (MEKP) wt% |
|---|---|---|
| 100 | 0 | 4 |
| 95 | 5 | 4 |
| 90 | 10 | 4 |
| 85 | 15 | 4 |

The ratio range for catalyst to PE is 1 or 2 percent hardener to the total volume of PE. Four drops of harden r will be 1 percent of 28.4g of PE. The speed of the curing time is affected by the amount of catalyst agent. Nevertheless, adding less or more than the ratio range will cause the PE to cure improperly and mending to fail. It also includes the study of the composites formed when the mixture was being mixed with different formulations.

Each ratio of tin slag is heated beforehand at the temperature of 60°C for 10 minutes and mixed together with 100 ml of polyester weighed to approximately 100 g. After the TS is heated it is then mixed with the PE. The mixture was stirred well while adding 4 wt% of MEKP. The formation was then poured into two different types of molding structure shaped of dog bone or dumbbell and a simple rectangle to prepare 5 specimens for each type and each ratio. It took about 20 minutes to cure and hardened.

## 3.0 Mechanical testing

### *3.1 Tensile testing*

Tensile testing was performed under ambient condition on any Hounsfield H5KS universal tester at a cross-head speed of 5mm $min^{-1}$. The specimens of dumbbell shape (gauge by length 113mm, width 18mm, thickness 3mm) and rectangular shape (gauge by length 125mm, width 13mm, thickness 3mm) were prepared. 5 samples per formation and 5 samples per types were analyzed and the average and standard aviation values were recorded.

### *3.2 Flexural testing*

Flexural testing was conducted using the same sample from tensile testing but different equipment which is Autograph AGS-XSeries – Shimadzu Scientific Instruments. The sample is gripped and test jig in the upper and lower gripping head respectively. The sample is located so that the upper surface to the side and centered in the loading assembly. The machine was operated until the loading block was brought into contact with the sample. Full contact between the load surface and the sample is ensured to secure. The load recorder was adjusted on the front panel controller to zero to read load applied. The start button was pushed. The sample was observed as the load was gradually applied. The maximum load is recorded, and loading was continued until complete failure.

## 4.0 Results and discussion

### *4.1 Flexural and tensile strengths*

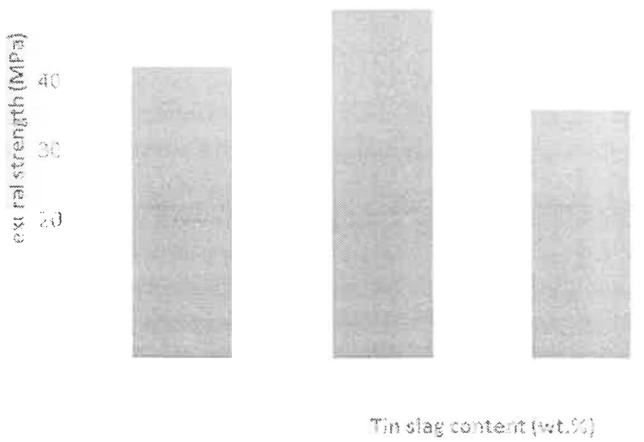


Fig. 1. Flexural strength of different weight percentage of tin slag


Fig. 2. Tensile strength of different weight percentage of tin slag

Figure 1 illustrates the measured flexural strength of the pure PE and different weight percentage of TS. The material with 5 wt% TS content displayed the best flexural strength properties (50.3 MPa) since it has the maximum stress while 15 wt% TS content shows the lowest (32.4 MPa). The pure PE has the flexural strength of 42 MPa and 10 wt% TS content has 35.7 MPa.

The mechanical properties of the PE with the addition of TS such as initial modulus and ultimate tensile stress, are related not only to the chemical composition of the different addition weight percentage of the TS but also to its internal structure (Wambua et al., 2003). From the Figure 1, with the small addition of TS which is 5 wt% gives the best result of flexural properties since more forces is applied to bend the material. Moreover, the addition of 5 wt% TS content increases the stiffness of the material.

In flexural testing various mechanisms such as tension, compression, shearing etc. (Mishra et al., 2003) take plac simultaneously. When a specimen is placed under flexural loading all three fundamental stresses are presented so the flexural properties of a specimen are the result of the combined effect of all three stresses. As the increasing addition of TS, it makes the structure of the polymer become more brittle and the best formulation is 5 wt% since it gives the highest maximum stress compared to the pure PE, 10 wt% and 15 wt%.

Tensile strength results of the pure PE and different addition weight percentage of the TS can be observed in the Figure 2 as pure PE gives the highest (20.4 MPa) tensile strength while 15 wt% of TS showed the lowest (about 10 MPa). Next, for the 5 wt% and 10 wt% TS content were approximately 16 MPa.

From the results obtained, the relationship between the tensile strength of the pure PE and the increasing addition of the TS content result in decreasing of tensile strength as the addition of the TS will decrease the elasticity properties of the pure PE. The maximum load was applied on the pure PE as it elongates over some distance to its breaking point. It is clearly shown that the pure PE has the highest tension and elasticity properties.

The flexural strength would be the same as the tensile strength if the material were homogeneous (Ashby, 2005). Material have small or large defects in them which act to concentrate the stress locally. When a material is bent only th extreme fibre has the largest stress (Hodgkinson, 2000). From the results, for both flexural and tensile strength testing, pure is more better than the addition of 5 wt% TS.

However, if the same material was subjected to only tensile forces then it has the same stress and failure will initiate when the weakest fibre reaches its limiting tensile stress (Hodgkinson, 2000). The addition of 15 wt% TS content is the weakest polymer. Therefore, it is common for flexural strength to be higher than tensile strength for the same material.

*4. Flexural and tensile moduli*

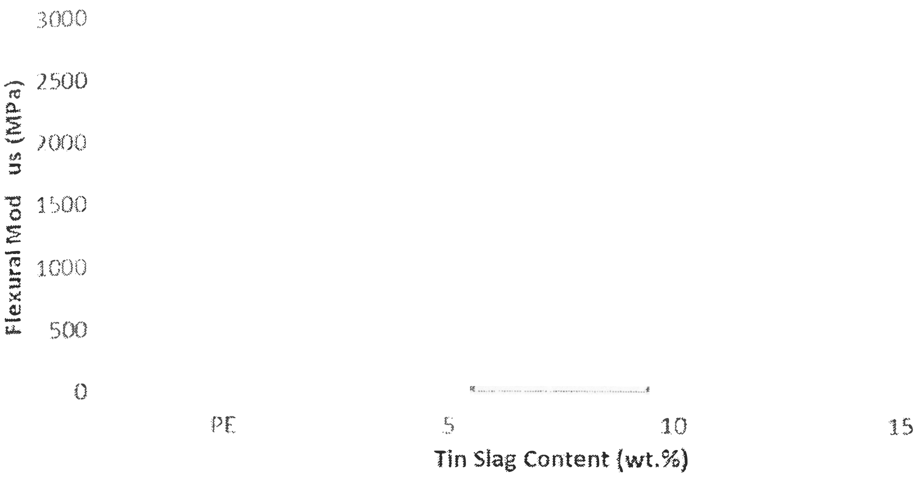


Fig. 3. Flexural modulus of different weight percentage of tin slag.

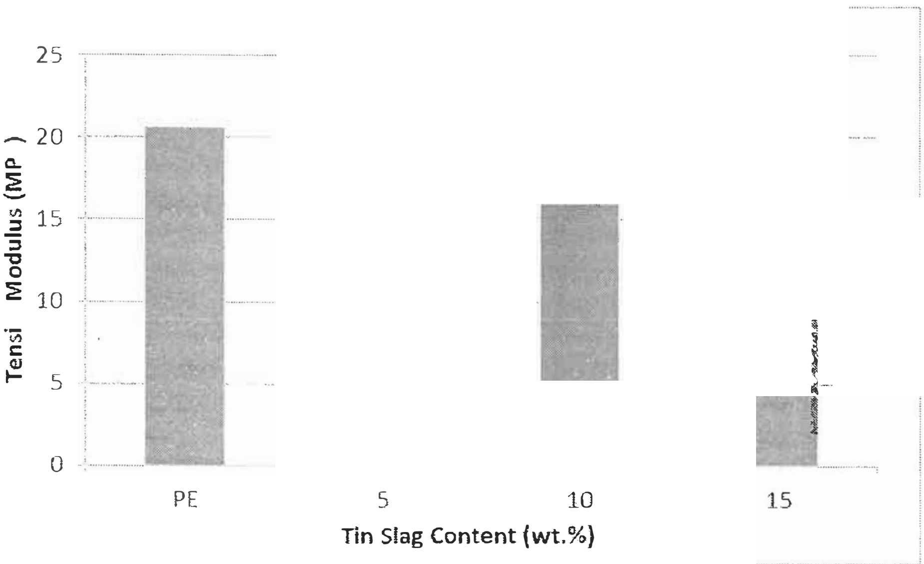


Fig. 4. Tensile modulus of different weight percentage of tin slag.