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INVESTIGATION OF MECHANICAL PROPERTIES AND ADHESION BEHAVIOUR OF BIO-PLASTIC SHEET MATERIAL

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الملخص

هدف علماء البيئة هو إيجاد حل لمشكلة البيئة ويبدو أن البوليمر القابل للتحلل هو أحد هذه الحلول. البلاستيك الحيوي قابل للتحلل. يختلف عن غيره من البلاستيك غير القابل للتحلل. يوفر حلًا للصناعة كمواد ذكية وقدرة على التحلل البيولوجي في نهاية دورة حياة المنتج وباستخدام مادة البلاستيك الحيوي يمكن إعادة استخدام ورق النفايات وهذا سيساعد على التخلص من الحاجة إلى إعادة التدوير وتقليل انبعاث الغاز (CO_2).

أشارت مراجعة الأدبيات إلى أن مادة البلاستيك الحيوي عبارة عن بوليمر، منتج بلاستيكي حيوي من خليط من المكونات (بوليمرات قابلة للتحلل) ويتم إنتاج هذه المادة بتقنية القولبة بالحقن ، ويتم استخدام القولبة بالحقن في إنتاج قطع من المواد المرنة مثل البلاستيك وهي طريقة سريعة لإنتاج أنواع مختلفة من المواد البلاستيكية بجودة عالية وبصورة دقيقة. ومن الممكن خلال هذا البحث تطوير نماذج ثلاثية الأبعاد باستخدام مادة البلاستيك الحيوي التي توفر آلية تتضمن سهولة القطع والالتصاق حتى يستفيد ويتعلم الأطفال من هذه المادة ، والبلاستيك الحيوي مثل أي مادة أخرى له مزايا وعيوب.

يبحث هذا البحث في الخواص الميكانيكية لمادة البلاستيك الحيوي عن طريق اختبار الشد في المختبر واستخدام القطع بالليزر ، وقياس خشونة السطح ، وقدم البحث توصيات لتطبيق مادة البلاستيك الحيوي.

Abstract

The aim of environmental scientists is to find solution of environment problem and is appears that biodegradable polymer is one of these solutions. Bio-Plastic is biodegradable; it differs from other plastic which are non-degradable. It provide solution for industry as a smart material and ability to biodegrade in the end of life cycle for product and by use Bio-Plastic material can reuse waste paper and this will help to eliminate need for recycling and reduction of the emission of gas.

Literature review has indicated that Bio-Plastic material is a smart polymer, Bio-Plastic produce from a mixture of components (Biodegradable polymers) and this material is generated by injection molding technique, and injection molding is used in the production of pieces of elastic material such as plastic and it is rapid way of producing varieties of plastic materials in a high quality precision manner. It has been possible during this research to develop 3D models using Bio-Plastic material which offers automata including easy cutting and sticking so children learning will benefit from this material, Bio-Plastic like any other material has its advantages and disadvantages.

The research has looked into mechanical properties of Bio-Plastic material via tensile testing in the lab and using laser cutting, and Measurement of Surface Roughness. The research has made recommendation for application of Bio-Plastic material.

***Keywords**: heat shape mould, biodegradable polymers, Computer Numerical Control (CNC), plastic sheet material, Mechanical properties of plastic, Waste Management, Adhesives behavior, Surface roughness, Tensile Test, Laser Cutting.*

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1. Introduction

The policies and new legislation that being implemented, with respect to environmental issues shows that landfills are being eliminated in European Union. Up to now main recovery method is via incineration with energy recovery comprising of gasification pyrolysis and composition, separating, reusing the waste are being applied as a second option. Many government recently published new strategy for innovation, this identify relation between innovation and environment [1,2].

To protect environment and regulate the use of natural sources therefore respective countries have introduced policies. UK introduced a new generation of policy tools and this for trading system and environmental tax and voluntary agreements, the program for major of companies for waste reduction should be reducing the waste paper and cardboard. The most material in the commercial from Paper, cardboard and we can collect Papers and cardboard easily and industrial waste in United Kingdom, can be reduce, reuse and recycling of resources easily [3,4,5,6].

A new material has developed , and we can use Bio-Plastic material for reuse paper and cardboard and this would create to reuse waste paper for example, paper to create 3D objects and boxes and This research trying to demonstrate Bio-Plastic technology and also to find solution for environmental problems and potential effects [7,8,9].

Bio-Plastic produce from a mixture of components polylactide (PLA), Poly-3 hydroxybutyrate (PHB), Starch ($C_6H_{10}O_5$), and cellulose, these components are available in large quantities from the natural sources and have the feature of being ability to absorb humidity, we will get biodegradable adhesives and also when wet by water, it shows novel adhesion behaviour and it has no harmful impacts on the environment and is indeed friendly for the environment. a smart polymer come in the shape of thin plastic sheet which release its adhesion behaviour when it wet by water and stick for card, paper and wood, such as glue and can be fragmented into any form or any size. It is a non-toxic biodegradable product. it is a low melting point thermo plastic which starts to soften at 60 °C, material stays mouldable for up to two minutes before hardening and can be reheated continuously to continue shaping. It helps to increase creativity and makes learning fun for everyone and suitable for 3D and 2D model, it has many uses from home application to creative for example, prototyping, jewellery making, toys, moulds, etc. [10,11,12,13].

2. Techniques and Methods:

2.1. Tensile test

Tensile test is used widely to provide background information for the design about the resistance of materials. Tensile test is a method used to determine of mechanical properties and the behaviors of material when an axial load is stretching, we will cut the specimen for plastic sheet by laser cutting in order to use it in tensile test. Tensile test gauge the force involved to break a specimen and the extent to which the specimen stretches or elongates to that breaking point, the specimen has constant rate of expands and limited Load. Therefore could calculate the stress (σ) from the load and calculate the strain (ε) form the extension, in addition to can either is plotted as nominal stress against nominal strain, or as true stress against true Strain and these cases will be differing in each graph [14,15,16].

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Fig. 1 Bio-Plastic material disk The Square shapes for Bio-Plastic

Tensile testing machine is able to apply loads on the specimen and tensile forces, than its ends. It is controlled by the computer, the software controls the machine and record the result. The home screen appears which has different function's buttons, where the user can choose a test method to load test parameters to give name to the sample and to select the location in where data will be saved [16,17].

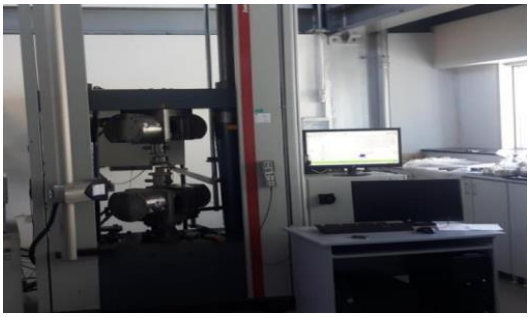

Fig. 2 A typical Tensile Testing machine

2.2. Laser cutting

Also we will use Laser cutting, it is a technology which used laser to cut many materials. The cutting of materials by laser technology involves exposing it to the heat which come from the laser beam. The laser cutting machine is driven by Corel Draw program (software).The Laser cutting is used in this research to perform for identifying the best setting to cut plastic sheet to create many shapes and cut in different setting [18,19].

Fig. 3 Laser cutting machine

2.3. Surface roughness measurement

After cut plastic sheet by laser cutting and CNC Milling Machine we will measurement of surface roughness, and surface roughness measurement is a measure of the texture of a surface and roughness play an important role for determining how objects will be interact with its environment and good predictor for performance of a mechanical component, as well as roughness is usually undesirable, and surface performance closely connected with surface roughness and very important in ensuring the wanted quality of machined parts [20,21].

The aims to be familiar with surface roughness, for surface of plastic sheet which is cut by milling machine and laser cutting and compared between the results. The measurement of surface form, Texture in the lab controlled by the computer, soft were for measurement of surface roughness for 3D which driven by computer, this used to measure the centre-line average (CLA) or Roughness average (Ra), this method using a surface profilometer with a contact stylus, and this method is accurate and effective, when analyzing surface finish, there many different parameters which measures average roughness by comparing all the peaks and valleys to the mean line [22,23,24].

Fig. 4 Surface roughness measurement Machine

3. Results in the lab:

3.1. Results of tensile testing for specimens from bio plastic material

In the lab we need to specimens from Bio-Plastic, and by using CorelDraw to drawing the specimen and cut by laser cutting to be used this specimen in the tensile testing in the lab to test plastic properties such as the mechanical and adhesion property, next figures shows the specimens from Bio-Plastic.

Fig. 5 Specimens from plastic disk by laser cutting

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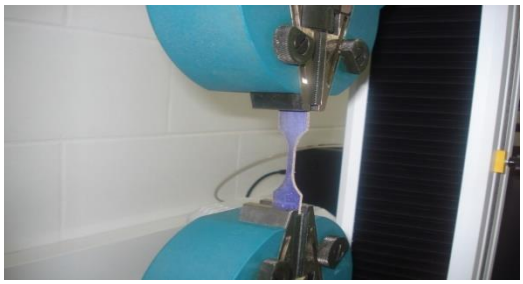

Fig. 6 the specimen extended in machine

First result shows the stress and strain curve and Mechanical Properties of Specimen for plastic disk, which cut by laser cutting, as per next table and also next graph.

Table 1: Dimensions and Mechanical Properties of Specimen for plastic disk.

Specimen label	Thickness (mm)	Width (mm)
plastic disk	20.53000	20.00000
Length (mm)	Area (cm^2)	Maximum Extension (mm)
40.00000	4.12400	1.23000
Tensile stress at Maximum Extension (MPa)	Maximum Load (N)	Extension at Maximum Load (mm)
0. 61485	322.10584	1.20358

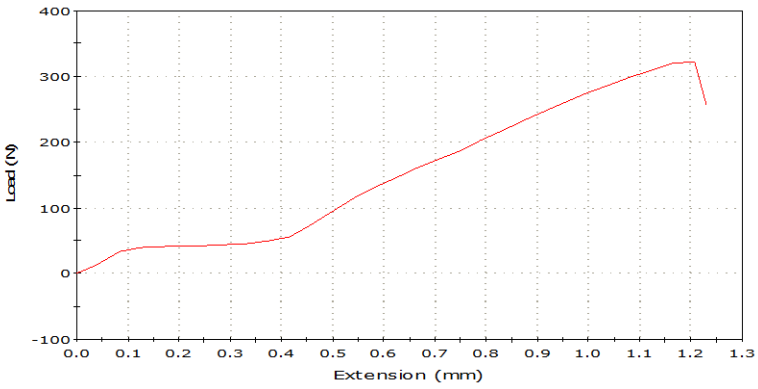

Fig. 7 stress and strain curve for plastic disk

Next figures shows the specimen of plastic sheet, when sticking with cardboard, and after the tensile testing was performed, and this will show adhesion property for plastic sheet, because the break occurred in cardboard but plastic sheet did not broken.

. **Fig. 8** wetting plastic to Sticking with cardboard

Fig. 9 Specimen for plastic with cardboard in machine Adhesion property for bio plastic

Next result show the stress and strain curve, and adhesion properties of specimen for plastic sheet which sticking with cardboard, as well as this show us plastic is more stronger than cardboard, if improvement plastic material will become very strong as a result, more usage and application, and the dimensions of specimen for plastic sheet which sticking with cardboard and used in tensile test as per next table:

Table 2: Dimensions and Mechanical Properties of Specimen for plastic sheet with cardboard

Specimen label	Thickness (mm)	Width (mm)
plastic material	19.62000	20.00000
Length (mm)	Area (cm^2)	Maximum Extension (mm)
40.00000	3.92400	0.62490
Tensile stress at Maximum Extension (MPa)	Maximum Load (N)	(mm) Extension at Maximum Load
0.22572	109.10123	0.68240

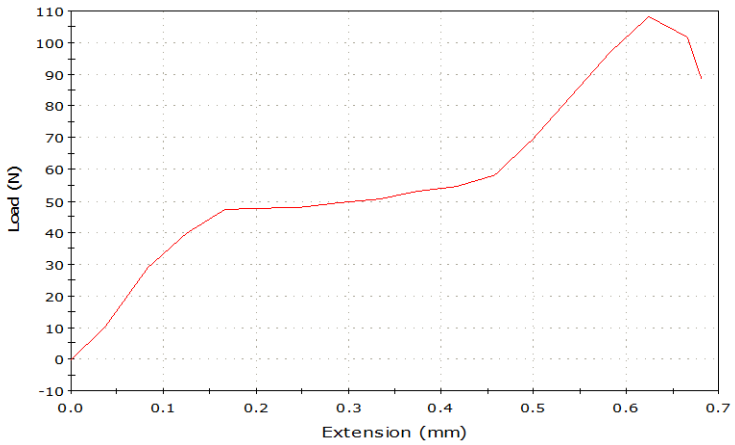

Fig. 10 stress and strain curve for plastic sheet with cardboard

3.2. Results of Laser Cutting on bio plastic material:

By using laser cutting, different setting has been done to determine the best setting to cut plastic material. It is been observed that the best speed to cut is 5% and the power is 80%, but when it was tested for its manufacturability it was found that the material was getting melted or fusion. Since laser cutting process operates on the principle of focusing high density laser beam on to the work piece to make cuts. It will produce enormous amount of heat the contact point of the laser beam and work piece.

The next figures show some Shapes which are cut by laser cutting using different setting.

Fig. 11 Result for laser cutting to bio Plastic material

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Fig. 12 two gears from bio plastic material by laser cutting

Fig. 13 Toy from Square Shapes by using the adhesion behavior

3.3. Results of Surface Roughness Measurement:

In the lab we measure many points for the surface of bio plastic material after cutting by laser cutting, and the procedure to measure surface roughness with a stylus-type surface roughness measuring instrument in order to a measure of the texture of a surface, and this method is accurate and effective. The next figures show us the stylus measurement the points for laser cutting.

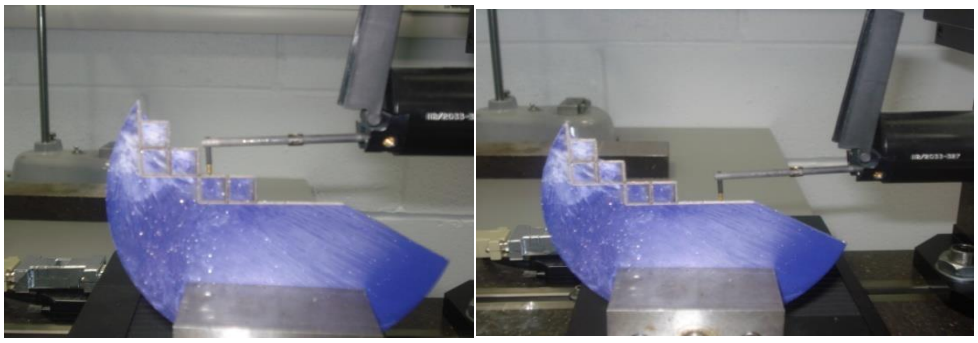

Fig. 14 measurement of stylus for laser cutting

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There was Parameters for this method and Parameters description as per below:

- Rmax: Maximum peak-to-valley height
- Rt:Vertical height between max/min
- Ry: Maximum roughness depth
- Rq: RMS of roughness average
- Rp: Maximum peak height
- Rz: (DIN) Mean peak-to-valley height
- Rz: (ISO) Ten point height

We can get the results from the graphs by calculation, in the lab No need for calculation because the results can be obtained from computer.
Next graphs show us how measure many points for surface of bio plastic material.

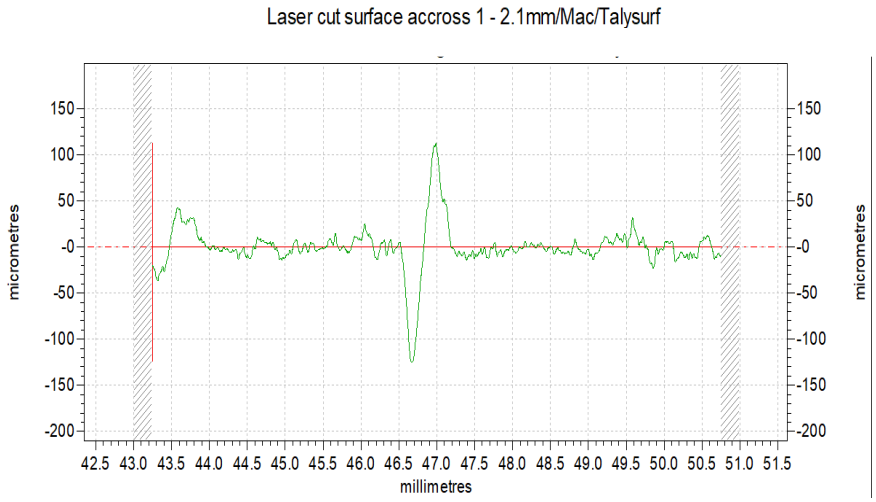

Fig. 15 Surface Roughness at first point for laser cutting

Ra 12.8188 µm	Rp1max 112.3125 µm	Rv1max 124.9599 µm
Rt 237.2724 µm	Rp 62.2664 µm	Rv 61.6774 µm
Rz(DIN) 123.9437 µm	RS 211.59 µ	RSm 1456.05 µm

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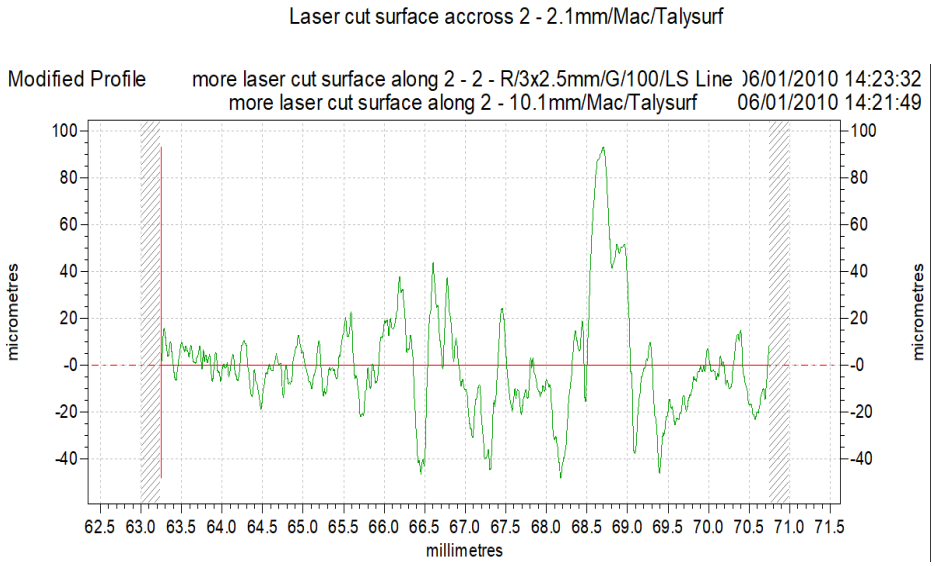

Fig. 16 Surface Roughness at second point for laser cutting

Ra 15.5361 µm Rp1max 93.1414 µm Rv1max 48.3243 µm
Rt 141.4656 µm Rp 53.1605 µm Rv 38.8669 µm
Rz(DIN) 92.0274 µm RS 175.96 µm RSm 623.27 µm

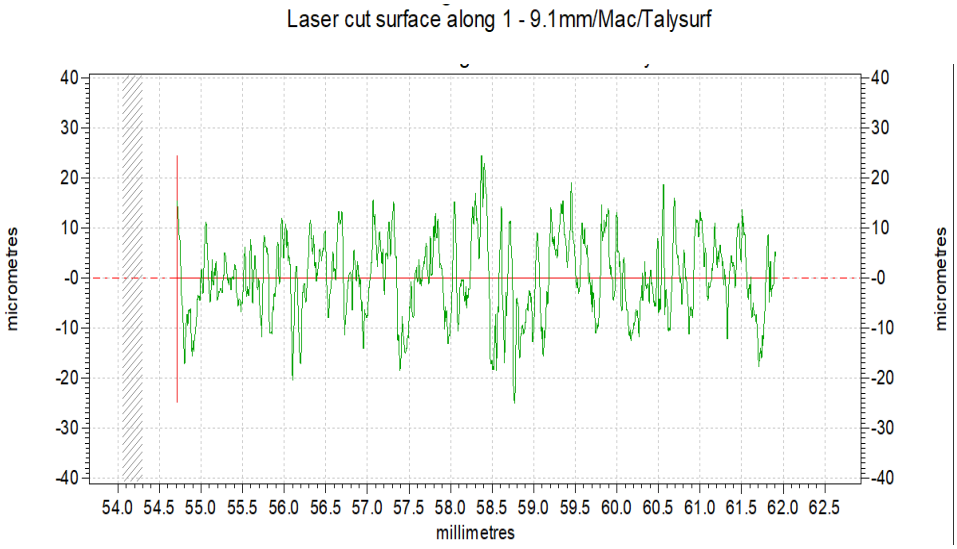

Fig. 17 Surface Roughness at third point for laser cutting

Ra 6.4027 µm Rp1max 24.5653 µm Rv1max 24.9980 µm
Rt 49.5632 µm Rp 16.6199 µm Rv 17.2226 µm

Rz(DIN) 33.8425 µm RS 63.79 µm RSm 205.00 µm

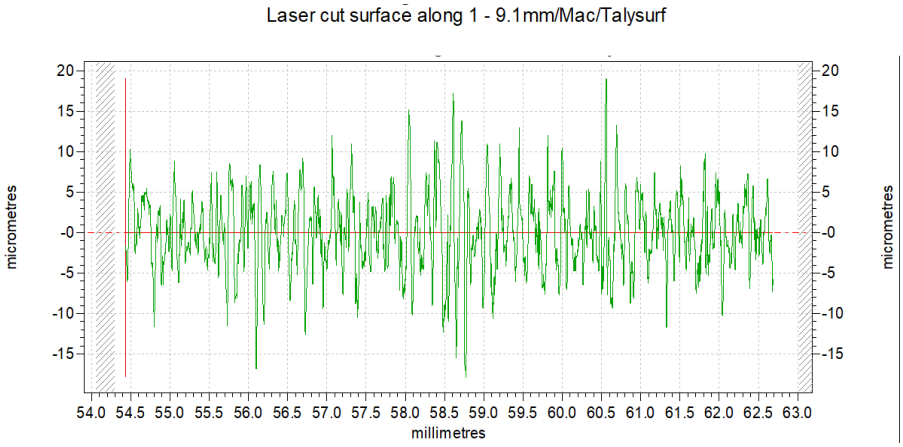

Fig. 18 Surface Roughness at fourth point for laser cutting

Ra 3.6898 µm Rp1max 19.0524 µm Rv1max 17.8679 µm
Rt 36.9203 µm Rp 9.6137 µm Rv 8.9860 µm
Rz(DIN) 18.5997 µm RS 40.05 µm RSm 106.69 µm

From the results we can get the average maximum profile which is the difference between the heights of the ten highest peaks and the ten deepest valleys, and this show us evaluating to surface texture on limited-access surfaces where the presence of high peaks or low valleys.

A datum marked on the surface allowed the precise location of surface 3D maps and 2D surface profiles to be accurately known thus allowing comparison of parent Surface and replica. Next figures show us meshed axonometric and photo simulation and pseudo colour Image for the surface of bio plastic material after cutting by laser Cutting.

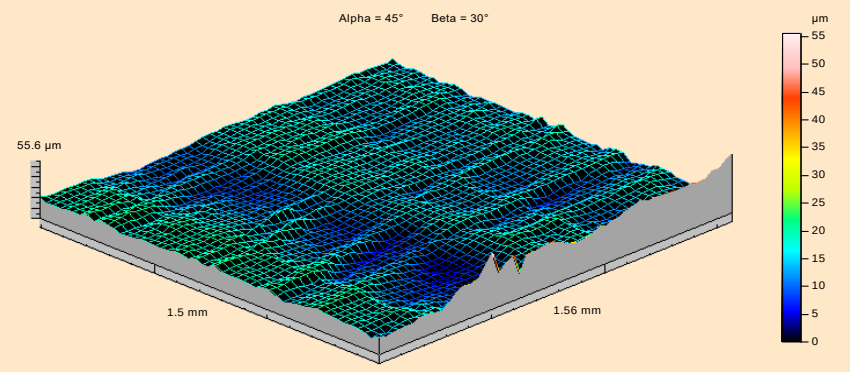

Fig. 19 Meshed axonometric at point for laser cutting

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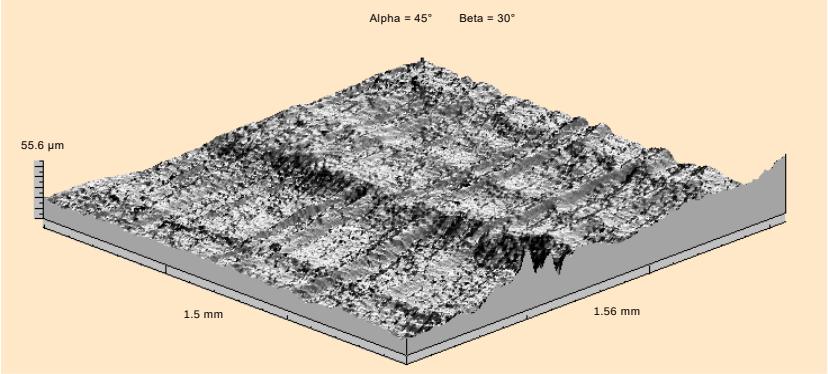

Fig. 20 photo simulation at point for laser cutting

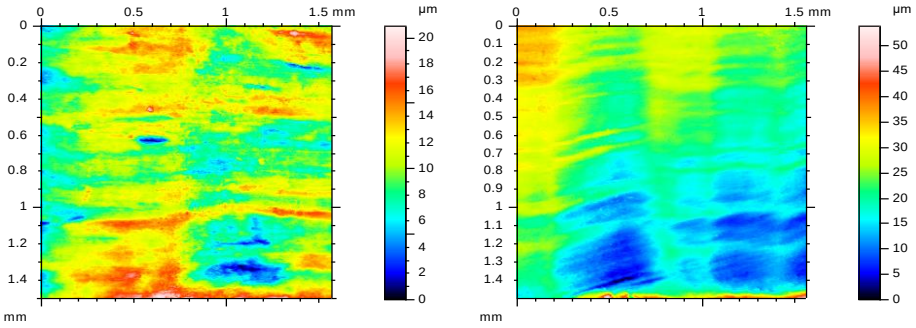

Fig. 21 pseudo color image at point for laser cutting

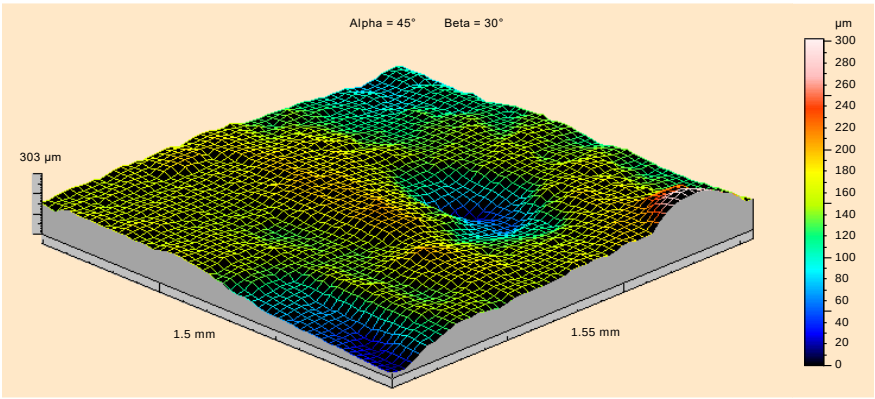

Fig. 22 Meshed axonometric at another point for laser cutting

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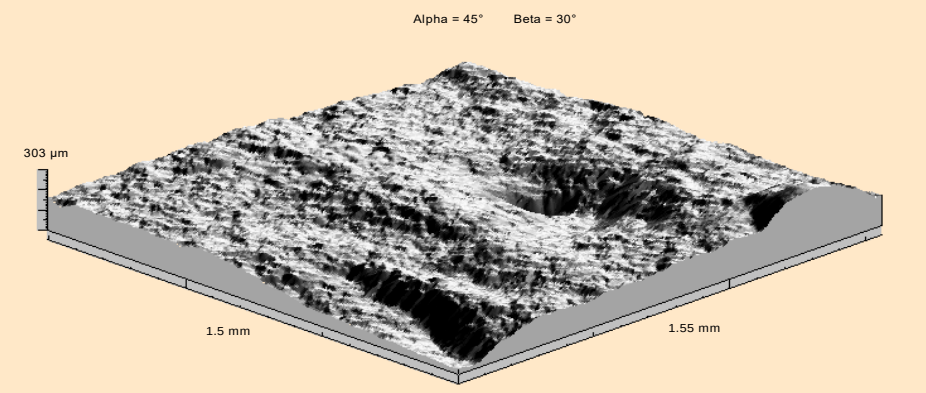

Fig. 23 photo simulation at another point for laser cutting

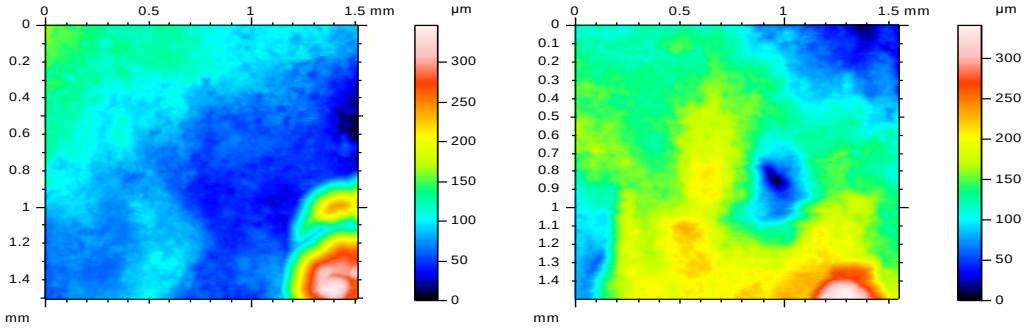

Fig. 24 pseudo color image at another point for laser cutting

Parameters calculated on the surface lasercut 2 > Levelled (LS)

Amplitude Parameters

Sa	=	32.5 µm
Sq	=	48.2 µm
Sp	=	257 µm
Sv	=	89.5 µm
St	=	347 µm
Ssk	=	2.26
Sku	=	10
Sz	=	94.8 µm

Parameters calculated on the surface lasercut 3 > Levelled (LS)

Amplitude Parameters

Sa	=	26.7 µm
Sq	=	36.8 µm
Sp	=	158 µm
Sv	=	145 µm
St	=	303 µm
Ssk	=	-0.495
Sku	=	5.21
Sz	=	135 µm

These figures show us the effects for cut processes which done by laser cutting , the surface for laser cutting show the effect for heating from laser on the surface, melting for strength joint of surface.

4. Discussion

4.1. Analysis of results obtained during tensile test:

In graphs of tensile test all the specimens have relatively good bonding strength. Bio plastic is an adhesive material and to determine the adhesion properties many types of testing can be done. Such as, peel test is the best way to examine the adhesive material properties. The bonding strength between the bio polymers of the different blends with cardboard offers very good resistance for stress and hence it fails a little late. From the curves in the graphs we can see different properties because plastic sheet have high modulus of elasticity and plastic disk have low modulus of elasticity and this depend on flexibility for the materials and also different in the collapse, this help us in select appropriate materials for engineering applications.

4.2. Analysis of results obtained by laser cutting:

It is important to bring to the attention that use of laser cutting is not the proper way to cut bio plastic materials, the substrate material gets burnt and the bio plastic edges need to be cleaned for applications. The plastic sheet is more susceptible to heat and it melts very fast. So it was not possible to get the good accuracy of the dimensions to be cut on the work piece. Even thought it was very easy to cut but the materials was getting melted there by making it more difficult to machine.

It was also tested for less power laser beam but the results were still the same. If the power of laser beam is reduced too much low then it would be difficult to cut the material. So it is very difficult to decide about permanent and constant settings for laser machine to cut this material. For plastic disk the results were satisfactory with this sample material when compared with the other plastic sheet samples. Plastic disk also shown burns but the resistance more than from plastic sheet. It was easy to cut with laser cutting machine, manufacturing time was also less due to the fact that it was fast to cut the required profiles. Even though it was learned that the plastic disk gave some good results because the particle distribution and bonding between them was very good and uniform throughout the sample when compared with plastic sheet sample. The most important thing observed during the cutting with bio plastic by laser cutting is that there was no production of dust after cut and also can be cutting easily, tool was stable even at high and low speeds, this enables the operator to handle the material safely.

When any organization decides to go for bulk production to make any products of biodegradable material it becomes necessary to take initial investment and operational cost in consideration so that a correct price or cost per product can be determined. The Laser cutting machines are normally highly expensive when compared to the conventional cutting machine. But depending upon the budget available, production targets and availability of skilled labor along with resources one will be able take those critical decisions about to choose which type of manufacturing facility is suitable for the organization.

The quality of product is also important in deciding the fate of the organization and the product, it was possible to make better quality product from bio plastic material. The samples made during the research were found to be having good surface finish and pleasant in looks. Most important the time taken to make these products was very less when compared with other materials. So it

will be possible to make better product in very short time using bio plastic blended with calcium carbonate.

4.3. Analysis of results obtained during Surface Roughness Measurement:

Investigated the effect of the cutting on the surface for bio plastic material, it lead to details study of surface roughness which has been carried out at different points on the specimens using surface roughness measuring machine. The surface roughness of specimen was found to be different at different locations. As we saw from the graphs, the surface roughness value different from point to point.

For instance, the surface roughness value at first point 12.81 µm and at second Point 15.53 µm. when compared the results at these points, and we can also compared between the averages for value of surface roughness at these points.

The average for laser cutting = $\frac{12.81+15.53+6.40+3.68}{4} = 9.60\mu m$

These results confirm for the surface which cut by laser cutting is rough. As well as from meshed axonometric and photo simulation and pseudo color image for the surface of laser cutting show us melting for strength joint of surface. It can be concluded that burns by laser cutting on the surface of bio plastic material need to improving the surface quality and this because strength of the surface is low. Surface roughness model is based on mechanical analysis, as well as the hardness and surface deformation depend on material.

Surface roughness is useful in determining the quality of the bond of the polymer with other materials. The type of bonding is an essential factor that influences the physical, mechanical and aesthetics of the substance, and makes each class of materials unique. The exception may be composites, which are not homogeneous materials. A composite is a kind of engineered material that consists of particular fillers in a soft matrix.

In this study the matrix material is bio plastic and fillers are calcium carbonate. We found that the quality of the bond improves with decrease in the filler material. The reason behind this improvement is the covalent and secondary type of bonding that takes between the chain of molecules of bio degradable polymer and material molecules when they come into contact.

In most of applications the basic criteria during the selection of adhesive is by knowing how it can with stand against mechanical loading conditions and quality of bond. Another important issue during the adhesion is preparing surfaces that come into contact.

Etching, Priming & Grinding is done to avoid irregularities, dirt, grease accumulated on the surfaces which directly measure the bond strength. These processes are time consuming and need usage of other resources [21].

Since the biodegradable polymer is partially engineered to be water soluble, the free molecules in the polymer firmly adhere with other molecules when they dry up. So it can be as adhesive in some applications. A thin film of this polymer could offer very good resistance to axial stress developed in case of tensile and compressive loading. Another advantage of using bio degradable polymer is we can get the best bonding as most of the surface area will come into contact avoiding pore and air gaps which make the bonding weak. The smooth surface areas consist of more free

molecules than rough surfaces and these free molecules are responsible to get good adhesive bond [22].

5. Conclusion

It is paramountly important to state as part of the conclusion that, there are some companies who are striving to provide the solutions to reduce waste material for environmental benefits. Typically, the waste paper and cardboard are materials for reuse rather than to throw them for the waste. This research has found that bio plastic material could be the solution of reusing paper and cardboard and no energy or natural resources would be consumed. Using bio plastic to reuse paper and cardboard waste would benefit the world environmentally and economically.

There are some of countries that regulated laws which aim reduce the waste, (CO_2) emission, and to encourage re-use and recycling of waste. bio plastic material can participate in the efforts which are being made by the governments and the environmental groups to overcome the environment problems, the degradability of bio plastic is accounting it as the one of the environmental solution.

6. Recommendation

It can be strongly stated that bio plastic material has many novel applications including many benefits to innovation, creativity of Shapes. The followings may be recommended depend on this research:

- The industrial companies should product packing boxes that are eco-friendly for environment so that able reuse them and decrease the waste;
- Using bio plastic material for building 3D models in designing novel products and create many new shapes;
- Bio plastic material has the ability of being cut and stick easily without of using any glue, so we can used in automata;
- Concentrate on case studies which target to reduce the waste and promotion case study, where create some of shapes which are assist of reduce the waste, as a result aimed to reduce the waste of paper and cardboard;
- The innovative product development needs support the development of knowledge transfer capacity and skills in public research organisations, and measures to raise the awareness and skills of students;
- Knowledge transfer activities between the communities and development of integrated plans between the public and private entities with expertise in management; and
- Collaborate between the manufacturing companies and universities to create the solutions that target improving the products, and which decrease the environmental impacts, such as the waste and heat emission.

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