Thermal degradation of High-Density Polyethylene Containing Cobalt Stearate as Oxidant Additive

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Abstract. Cobalt stearate can be used as an oxidant additive into High Density Polyethylene (HDPE). HDPE with the addition of 0.075% (w/w) of cobalt stearate was printed with a hot press. SEM results showed damage to the membrane surface which had been thermally degradation at 75 °C for 10 days. The TGA results also showed that the film had a weight loss of 75.99%. This decrease in weight indicated that an oxide compound had been formed due to the degradation of HDPE. The oxide compound is a chemical compound containing oxygen. With this oxygen, the degradation process of polyethylene will be easier and faster.

1. Introduction
In recent years, plastic has become a useful material with a wide range of applications. Unfortunately, the properties of plastic that make it so valuable also make its disposal problematic, such as its durability, light weight, and low cost. In many cases, plastics are thrown away after one use, especially packaging and sheeting, but because they are durable, they persist in the environment [1-3]. Based on data obtained from the Central Agency on Statistic of Indonesia, the amount of plastic waste produced in Indonesia reaches 64 million tons/year. Now, Plastic waste is an environmental problem faced by the world community, including the people of Indonesia.

To solve this problem, an effort is needed to improve the degradation capability of plastic. One attempt is to add an oxidant additive to polyethylene [4]. According to Copol International, an institution that is engaged in creating a green or environmentally friendly environment, additives used in this process are multivalent transition metals which are combined into an organic compound ligand [5]. Transition metal which suitable for this purpose are cerium, manganese, iron, and cobalt [6-7]. This study presents an investigation of the effects of addition cobalt stearate as an additive oxidant for High-Density Polyethylene and test the oxidation degradation through heat treatment.

2. Materials and methods

2.1 Preparation of films
The homogeneous High-Density Polyethylene with cobalt stearate (CoSt) 0.075% (w/w) of the total mass. The mixture was ground and then casted by hot press at temperature 120 °C for 5 minutes [8].
2.2 Thermal degradation process
Thermal degradation of HDPE containing cobalt Stearate 0.075% (w/w) is carried out in a vacuum oven on temperature variations 25 °C and 75 °C for 10 days. Films that has been degraded thermally characterized by Thermal Gravimetric Analysis, Scanning electron microscopy, and tensile tester.

3. Result and Discussion

3.1 Thermal properties of films
TGA analysis was used to determine the thermal properties of HDPE films which were added with 0.075% (w/w) of cobalt stearate (CoSt) and thermally degraded through a heating process at 75 °C for 10 days. Based on the thermogravimetric trace above shows that the film has a mass loss is 75.99 % in the temperature range around 218-550 °C. The occurrence of this decrease in mass indicates that the formation of an oxide compound due to the degradation of HDPE has been added to cobalt stearate [9]. The oxide compound is a chemical compound containing oxygen. With this oxygen, the degradation process of polyethylene will be easier and faster [2].

![TGA curve for HDPE + CoSt 0.075% (w/w)](image)

**Figure 1.** TGA curve for HDPE + CoSt 0.075% (w/w)

3.2 Mechanical properties of films
Mechanical test aims to determine the mechanical properties of membrane or film, with parameters such as strain and stress. The tensile stress is the strength of a membrane when given pressure, while strain is the extension of the membrane when withdrawal carried out. Comparison of strain and stress expresses the level of elasticity or stiffness of a material, known as Young's modulus.

| Films                        | Strain (MPa) | Stress (%) | Young’s Modulus (Mpa) |
|------------------------------|--------------|------------|-----------------------|
| HDPE (25 °C)                 | 2.073        | 7.98       | 25.97                 |
| HDPE + CoSt 0.075% (25 °C)   | 1.005        | 2.47       | 40.68                 |
| HDPE + CoSt 0.075% (75 °C)   | 0.820        | 1.47       | 55.78                 |
In general, pure HDPE films and HDPE + CoSt 0.075% (w/w) have a high Young’s modulus. Because HDPE is a type of polymer that is thermoplastic and has a very strong intermolecular force generated from a very tight array of polymer chains. Tensile tester was used to determine Young’s modulus value so that the value of the mechanical strength of the HDPE + CoSt 0.075% (w/w) film was heated at 25 °C and 75 °C. Young’s modulus has increased with increasing temperature of the treatment given. Films that have a higher Young modulus value indicate the properties of increasingly stiff and brittle films because they have been degraded due to additive additives and as a result of the oxidation reduction reaction during thermal treatment.

3.3 SEM results
Membrane morphology analysis was carried out using SEM. The results of SEM analysis can be seen in Figure 2. Figure 2 is the surface of HDPE film without the addition of cobalt stearate, the surface properties are smoother and homogeneous. Figure B is a HDPE + CoSt 0.075% (w/w) film that has been thermally degraded for 10 at a temperature of 75 °C. In this picture, there is damage to the surface of the film. The SEM results indicate that the catalytic properties of the addition of cobalt stearate are active as an oxidant additive in an HDPE film [2]. With the activation of these catalytic properties, the polymer degradation process is accelerate.

![Figure 2. Surface morphology of HDPE + CoSt 0.075% (w/w)](image)

HDPE + CoSt 0.075% (w/w) film which was thermally degraded at 75 °C for 10 days there was a weight loss is 1.68%. This shows the breakdown of chains from HDPE polymers faster after being given heating at higher temperatures [10]. This is because cobalt stearate would become more reactive if given heat treatment.

4. Conclusion
Cobalt stearate (CoSt) is effectively used as an oxidant additive in HDPE films if it is treated with heating (thermal degradation). The results of thermal degradation at a temperature of 75 °C in HDPE + CoSt 0.075% film (w/w) were able to reduce HDPE weight by 75.99%. This proves that thermal degradation in HDPE films that have been added to cobalt stearate will accelerate the degradation rate of HDPE polymers

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