

# **Carbon Accounting and Sustainable Designs in Product Lifecycle Management**

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**Week 08**

**Lecture 36**

**Carbon Accounting Model (Part-3)**

Welcome to the third part of the lecture on Carbon Accounting Model. We are in the course Carbon Accounting and Sustainable Designs in Lifecycle Management. I am Dr. Amadeep Singh Oberoi. I am teaching this course along with Professor Deepu Philip and Dr. Prabal Pratap Singh. We have discussed about the carbon accounting models in the last lectures.

And we have discussed about the different layers of AML flexing facility. And I have talked about the model in a facility umbrella. That is the total model for a workshop or a facility in which I talked about the carbon emissions in product, in distribution, in inventory, in auxiliary and in working medium. Now, I will talk about the product layer and part layer majorly in this lecture. When we have seen the different systems, you call it distribution, inventory, auxiliary and medium.

These are all supporting systems to the major product that is developed in the facility. Now, for a product, how do we put the carbon emissions?

# Carbon Accounting Model

- manufacturing facility (Product layer)

$$CE_{product} = \sum_{i=1}^n CE_{part}^i + \sum_{j=1}^m (CE_{equip-p}^j + CE_{equip-wait}^j + CE_{transfer}^j)$$

Part
Assembled

*n*: Part number of product  
*m*: Assembly process number of product  
 $CE_{part}^i$ : Carbon Emissions of a part *i*  
 $CE_{equip-p}^j$ : Carbon Emissions for the assembly process *j*  
 $CE_{equip-wait}^j$ : " " " " " " " " when it is idle  
 $CE_{transfer}^j$ : " " " " " " " " transport (transportation energy consumption)  
predecessor → successor  
(j-1)            (j)

Therefore, the carbon emissions of a product are:

$$CE_{product} = \sum_{i=1}^n CE_{part}^i + \sum_{j=1}^m (CE_{equip-p}^j + CE_{equip-wait}^j + CE_{transfer}^j) \quad (49)$$

where

- *n* - part number of the product
- *m* - assembly process number of product
- $CE_{equip-wait}^j$  - represents the carbon emissions of the equipment idle energy consumption during the assembly process *j*
- $CE_{equip-p}^j$  - represents the carbon emissions of the assembly process *j*
- $CE_{transfer}^j$  - transfer represents the carbon emissions from transportation energy consumption of the workpiece from assembly process *j-1* to assembly process *j*

We are transferring the part from one equipment to other equipment. I will show you a video in the end of this lecture, where we will try to see how different machining operations are there and different components of that machining system. Components means I showed you the graph when the machine is running idle, when the spindle is rotating, when the actual machining is happening and how do we set up the machines. So, those all are part of the carbon emission for a product that is we have. Carbon emission for the equipment\_P, which is carbon emission for the assembly process.

Previously, in the last week, I was majorly talking about my facility And this was also about facility umbrella where we talked about the distribution systems. We talked about

the overall workshop or facility in the facility umbrella only. So, in the product layer, we have talked about carbon emission for parts.

## Carbon Accounting Model

- manufacturing facility (Part layer)

$$CE_{part} = \sum_{k=1}^{ip} (CE_{equip-p}^i + CE_{equip-wait}^i + CE_{transfer}^i)$$

$ip$ : Number of processing steps

$CE_{equip-p}^i$ : Carbon Emissions for  $i$ th process execution

$CE_{equip-wait}^i$ : " " " " when it is idle (still energy being consumed)

$CE_{transfer}^i$ : " " " " energy consumed for transferring ( $i$ th process)

$$CE_{equip-wait}^i = CEF_e \cdot P_s^i (t_{i, batch}^i / N_{batch} + t_w^i)$$

(Handling vehicle)

(Conveyor Belt)

$$CE_{transfer}^i = (EC_{conve-p} \cdot CEF_{energy}) / N_{batch} = (EC_{conve-p} \cdot t_i \cdot CEF_{energy}) / N_{batch}$$

$P_s^i$ : Standby power of the device

$t_{i, batch}^i$ : idle time waiting for the batch of parts

$t_w^i$ : switching time for adjacent parts

$N_{batch}$ : number of parts in the batch

$CE_{transfer}^i$ : Carbon Emissions for EC for transfer to  $i$ th process

$EC_{conve-p}$ : EC of the handling vehicle ( $i$ th process)

$CEF_{energy}$ :

$EC_{conve-pt}$ : EC per unit time of handling vehicle

$t_i$ : transfer time

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We come from the part layer. Let me try to put that as well. So in the part layer as I have already discussed that manufacturing of a part exactly corresponding to a process flow. Therefore, carbon emissions in the part layer would also include the equipment layer would also include logistics and activities. So, carbon emissions in manufacturing equipment layer that could be caused due to process execution, due to the standby power or many other small power inputs which are there.

For conveyor belt, what is there? The belt has to take the material or whatever the equipment system or the car from one place to another and in between the assembly is happening. Here the carbon emission factor would be energy convention for the conveyor belt for the arc process multiplied by the carbon emission factor for that energy. That could be electrical energy only. So, these energy consumptions would be then the sum of the power to run the motor multiplied by time for which the motor is run.

So, that also could be put down here. So, similarly, different energy consumption systems are there. So, I have talked about the assembly. I have talked about majorly some about the part and in the part. The energy consumption in the equipment during process, this is something I will talk in detail.

In the coming lecture, and here I am taking a break and I will talk about the machining, the sand casting, the forging, majorly about the machining.

I will talk about in the next lecture and we will also start that with a demonstration video on how the machine runs and how the power consumption at the different levels of the machines are there.

Thank you.