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TEAM : a Tool for Eco Additive Manufacturing to optimize environmental impact in early design stages

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1. Literature Review
2. TEAM: Tool for Eco Additive Manufacturing
 - A. Requirements specifications
 - B. TEAM development
3. Experiment
 - A. Protocol
 - B. Results

AM & Sustainability

AM & Product design

AM & Product life-cycle

AM is promising for sustainable manufacturing and sustainable design
 (Despeisse & Ford, 2015)

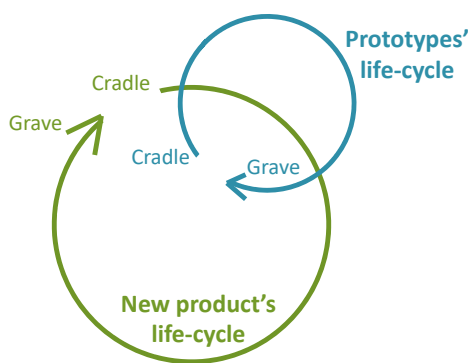
Using AM to produce near net shape workpieces can substantially reduce lead time, cost, and material waste.
 (Thompson, Moroni, Vaneker, Fadel, Campbell, Gibson, Bernard, Schulz, Graf, Ahuja, & Martina, 2016)

AM upsets the design paradigm and offers wide possibilities for product innovation
 (Laverne, Segonds, Anwer, & Le Coq, 2015)

AM offers a high design freedom due to four possible complexities available in a same product
 (Gibson, Rosen, & Stucker, 2015)

The production phase of a product manufactured with AM is the most influential on the environmental impact
 (Barros, Mansur, & Zwolinski, 2017)

Designers often waste material due to the multiple trial-and-error iterations required for fixing unqualified feature requirements
 (Gao, Zhang, Ramanujan, Ramani, Chen, Williams, Wang, Shin, Zhang & Zavattieri, 2015)



Inter-twined life-cycles

Dilemma during Early Design Stages !

⇒ Focus on the new product sustainability but no consideration for the prototype's one!

⇒ Using AM for prototyping has an impact on the new product life-cycle!

How to make the environmental impact of AM use for prototyping as low as possible in the life-cycle of a new product?

How to make the environmental impact of AM use for prototyping as low as possible in the life-cycle of a new product?

The **Design to Environment approach** requires:

(Rio, Reyes, & Roucoules, 2013)

- ⇒ Increasing the **eco-efficiency of the product manufacturing**
- ⇒ Improving the **eco-effectiveness of the design**

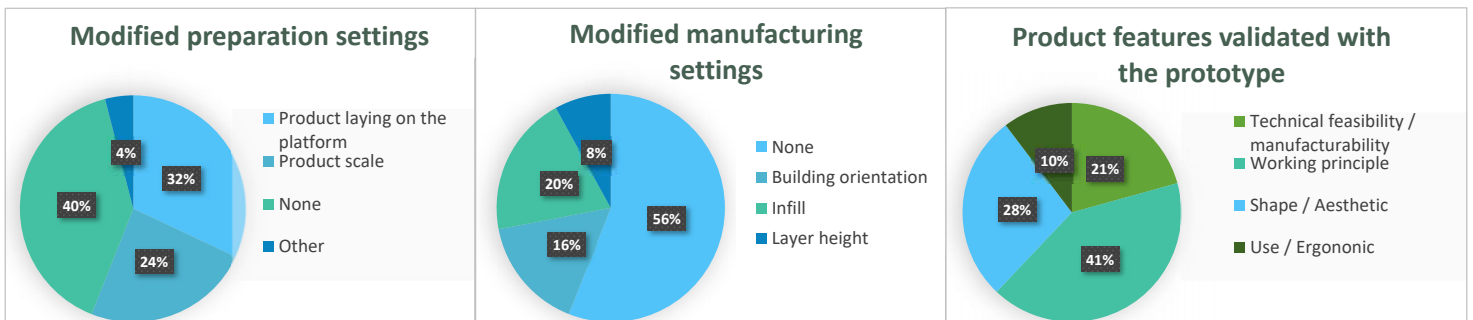
Two possibilities for integrating DTE considerations :

(Laverne, Segonds, D'Antonio, & Le Coq 2017)

- Involving AM experts during the EDS >> **sometimes impossible**
- Supporting the designer with specific tools

By assisting designers with a Tool for Eco Additive Manufacturing dedicated to an eco-efficient use of AM and an eco-effectiveness of the prototype design

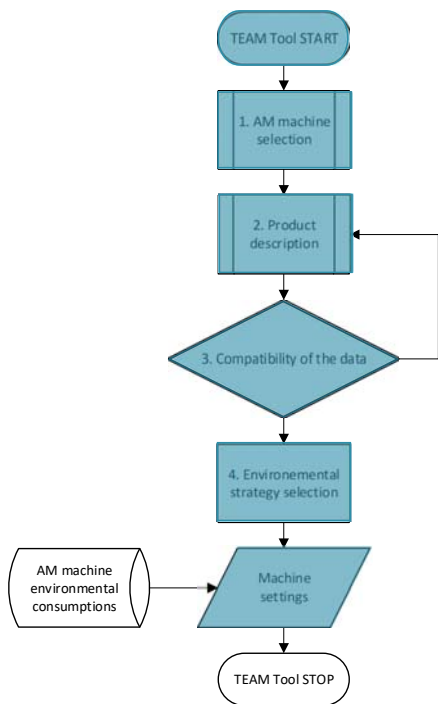
A 3-months study to understand the use of AM machines during the EDS of innovation projects



Default settings are frequently selected whatever the prototype's use is

TEAM specification:

- **Delivering adequate settings** compatible with a **validation of the expected features** and with a **sustainable manufacturing**
- **Delivering design rules** for the adaptation of the concept CAD into a feature CAD



TEAM V1 Flowchart

Machine selection

Product description

Here you have to give informations about the you want to produce

Your Prototype

Please click on the arrow for validating the data and having a response

Results

This is the best solution to reduce the amount of electric energy required. This pa-rameters reduce both the primary (mainly converted into heat in order to melt the polymer) and the secondary (employed for all the utilities of the machine, like table warming up, movement of table and printing head etc.) electric energy.

Best Compromise Flow Energy Material

PARAMETERS OF THE MACHINE	
Layer resolution	0.178
Model interior fill style	High density
Support style	Basic
Stl Scale	1 : 2
PARAMETERS OF THE PRODUCTION	
Part Orientation	Main dimensions on x-axis
Part position on plate	Default
Production strategy	1 Fabrication of 2 Parts
Removing support material	By hand

New prototype

ery of adequate expected

Objective:

TEAM user experience + Influence of AM and Eco-design knowledge

Panel:

28 participants working in EDS of new product development
Pluridisciplinary profiles

Protocol:

TEAM handling (≈ 15min)



Questionnaire



MIEUX VOUS CONNAÎTRE :

- Êtes-vous : un homme une femme ?
- Quel âge avez-vous ? _____
- Quelle est votre formation ?
 Ingénieur Ergonome Designer Autre (préciser) _____
- Êtes-vous : un(e) étudiant(e) un(e) professionnel(le) ?
L. Préciser votre ancienneté : _____
- Quel est votre niveau de connaissance en fabrication additive ?
Débutant 1 2 3 4 5 6 Expert
- Quel est votre niveau de connaissance en éco-conception ?
Débutant 1 2 3 4 5 6 Expert

EVALUATION DE L'OUTIL :

- Que pensez-vous de la saisie des données destinées à obtenir les paramètres de fabrication ?
Facilité 1 2 3 4 5 6 Abide
L. Préciser votre réponse : _____
- Que pensez-vous des résultats obtenus à l'issue de la saisie de vos données ?
Incompréhensibles 1 2 3 4 5 6 Compréhensibles
Difficilement utilisables 1 2 3 4 5 6 Facilement utilisables
- Les paramètres préconisés par cet outil vous semblent-ils adaptés aux enjeux de minimisation de la consommation des ressources ?
 NON OUI
L. Préciser votre réponse : _____
- Seriez-vous prêt à mettre en oeuvre de telles préconisations lors de la fabrication de futurs prototypes ?
Pas du tout 1 2 3 4 5 6 Tout à fait

Subjective evaluation:

Nielsen criteria: (Nielsen 1994)
Usability : Learnability + Satisfaction
Utility
Acceptability

6-points Likert scale
+
Non-mandatory open answers

Results:

	Learnability	Satisfaction	Utility	Acceptability
Mean on the 6points Likert scale	4.14	4,71	4.53	5,05
Standard Deviation	0,93	0,91	0,92	1,03

Intermediate to high satisfaction level for the 4 criteria

⇒ **TEAM is well accepted by users**

Mann–Whitney U test for the grouping criterion “AM knowledge level”

	Usability Learnability	Usability Satisfaction	Utility	Acceptability
U de Mann-Whitney	47,5	63	45	75,5
W de Wilcoxon	257,5	273	255	111,5
Z	-1,77	-0,911	-1,87	-0,245
Asymptotic significance (bilateral)	,077	,363	,062	,806
Exact significance	,099	,409	,079	,823

Mann–Whitney U test for the grouping criterion “Eco-design knowledge level”

	Usability Learnability	Usability Satisfaction	Utility	Acceptability
U de Mann-Whitney	76,5	48,5	80,5	63
W de Wilcoxon	266,5	93,5	270,5	253
Z	-,474	-1,912	-,259	-1,186
Asymptotic significance (bilateral)	,635	,056	,796	,236
Exact significance	,664	,068	,809	,285

No significant difference between groups (with or without AMK or EDK)

⇒ **Skills don't influence the answers**

⇒ **TEAM use doesn't require skills**

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