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

Laverne Floriane[1]; Bottacini. E[2]; Segonds. F[1]; Perry. N[3]; D'Antonio. G[2] and Chiabert. P[2]

[1] LCPI, ENSAM Paris, 151 bd de l'Hôpital, 75013 Paris, France
[2] DIGEP, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy
[3] I2M, ENSAM Bordeaux, Esplanade des Arts & Métiers 33405 Talence, France

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 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 & Product design

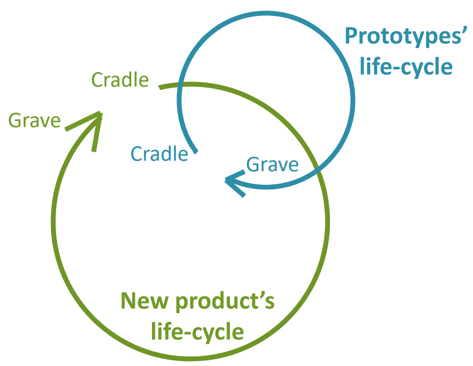
AM upsets the design paradigm and offers wide possibilities for product innovation
(Laverne, Segonds, Anwer, & Le Coq, 2015)

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

AM & Product life-cycle

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 & Zavattiery, 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?

1. Literature Review

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 :

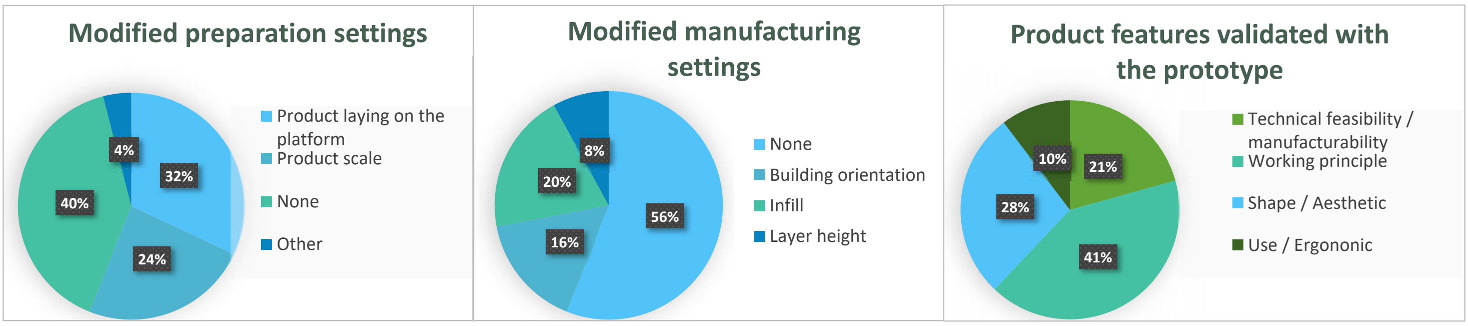
(Laverne, Segonds, D'Antonio, & Le Coq 2017)

- 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

2. TEAM: Tool for Eco Additive Manufacturing 2.A. Requirements specifications

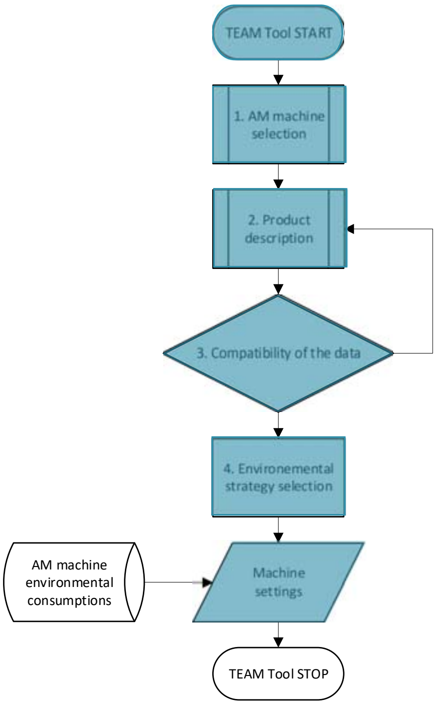
A 3-months study to understand the use of AM machines during the EDS of innovation projects



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

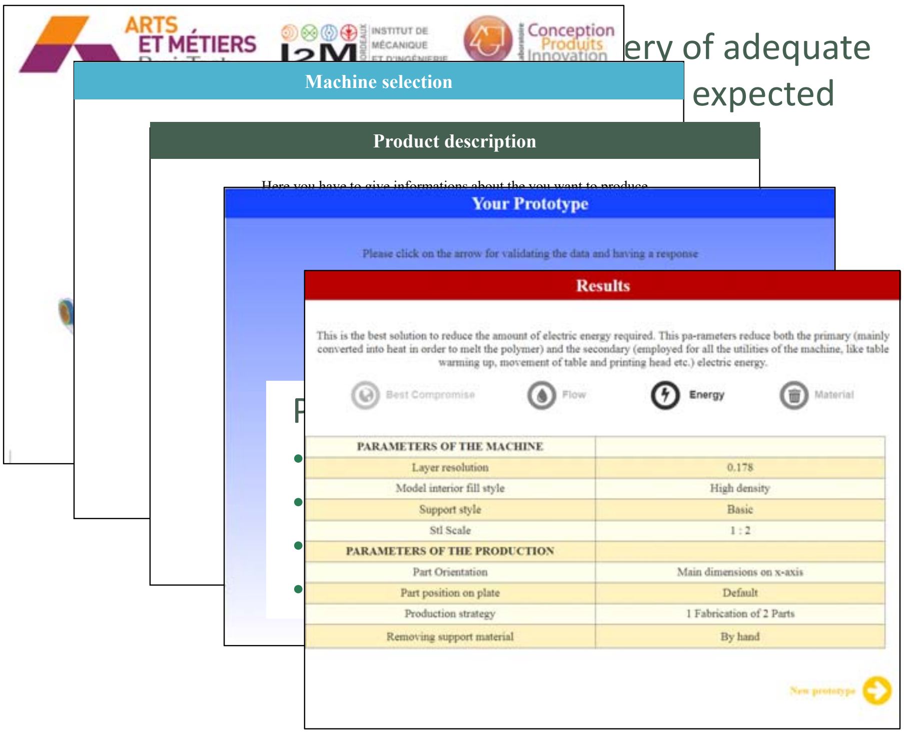
TEAM specification:

- **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

ery of adequate
expected



Objective:

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

Panel:

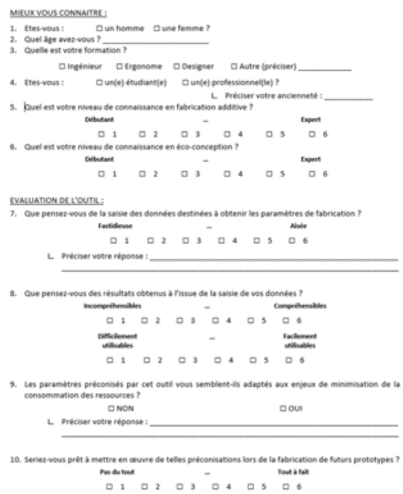
28 participants working in EDS of new product development
Pluridisciplinary profils

Protocol:

TEAM handling (≈ 15min)

+

Questionnaire



MIEUX VOUS CONNAITRE :

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

EVALUATION DE L'OUTIL :

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

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**

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

Laverne Floriane[1]; Bottacini. E[2]; Segonds. F[1]; Perry. N[3]; D'Antonio. G[2] and Chiabert. P[2]

[1] LCPI, ENSAM Paris, 151 bd de l'Hôpital, 75013 Paris, France

[2] DIGEP, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

[3] I2M, ENSAM Bordeaux, Esplanade des Arts & Métiers 33405 Talence, France