Fraunhofer IPA

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17. ANWENDERFORUM 19. September 2012
RAPID PRODUCT DEVELOPMENT

Additive Manufacturing mit SLS - Qualitätsmanagement und Kostenfaktoren

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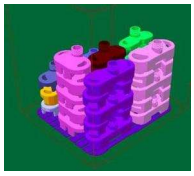
Agenda



- Inspire, irpd
- DirectSpare (DS) ein europäisches Projekt (FP 7)
- DS: Business model und Qualitätsmanagement AM
- SLS Prozess und Elemente der Qualität
- Kostenabschätzung von Qualitätsmassnahmen
- Zusammenfassung



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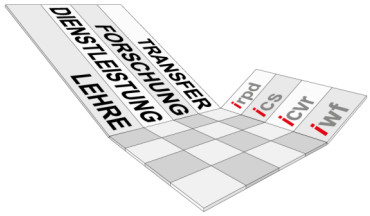
Einführung: inspire



inspire
AG für mechatronische Produktionssysteme und Fertigungstechnik

inspire iwf Werkzeugmaschinen & Fertigung
inspire icvr innovation center virtual reality
inspire ics innovative composite structures
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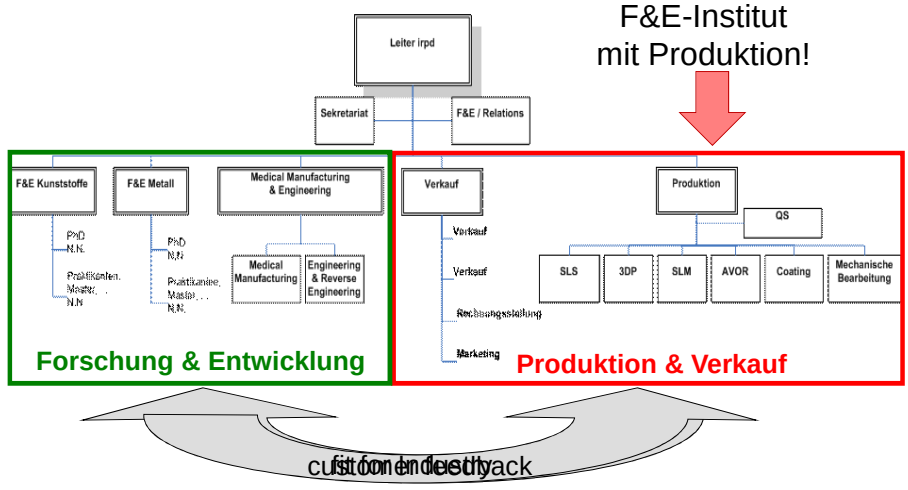
Einführung: irpd

F&E-Institut
mit Produktion!



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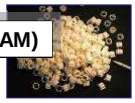
Kernkompetenzen - irpd

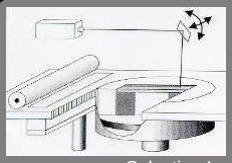
Produktion, F&E, Technologietransfer

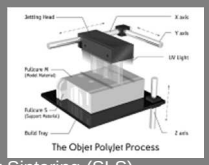
Additive Manufacturing (AM)



Rapid Prototyping (RP)

Technologien





Selective Laser Sintering (SLS)

LaserCUSING® (SLM)

Conformal Cooling

Medical Manufacturing

Reverse Engineering

Prozess und Material Entwicklung

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DirectSpare an European Approach for Spare Parts on Demand

SEVENTH FRAMEWORK PROGRAMME

(Grant Number: 213'424)

Berenschot · Flying Cam · EOS e-Manufacturing Solutions · inspire · +9O · Hexagon studio · TNO · Evonik Industries · BMW · Eurocopter An EADS Company · Materialise driving your innovations · Siemens · Fraunhofer · BPO

16 Partners from 7 (European) Country

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DirectSpare an European Approach for Spare Parts on Demand

SEVENTH FRAMEWORK PROGRAMME

Objective of DirectSpare

Strengthening the industries competitive position by development of a logistical and technological system for 'high added value spare parts' that is based on on-demand production.

The concept creates an AM (Additive Manufacturing) driven solution for companies to:

- *Maximize warehousing efficiencies by balancing spare parts' end-of-stock*
- *Elongate product life time by continously improve products with each new and improved spare parts*
- *Create economic and environmental advantages by on-demand and on-location spare part manufacturing*

→ www.directspare.eu http://www.youtube.com/watch?v=n4iivjVOv_Y

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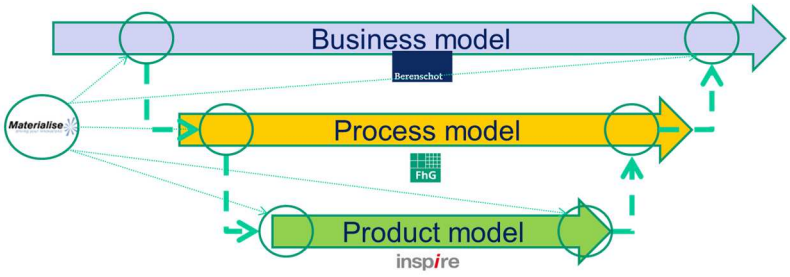
Work package 5 (WP5): Business model, ICT and TQM



- Berenschot is responsible for the business model
- Fraunhofer is responsible for the process quality model
- **Inspire is responsible for the product quality model (manufacturing processes)**
- Materialise is responsible for the interlinkages and connections between and shell (user interface) around these three models

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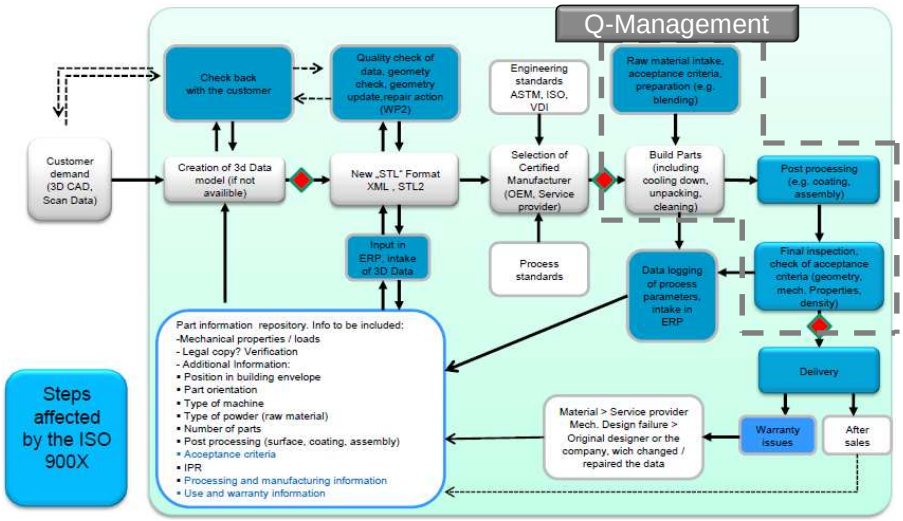
Work package 5 (WP5): Business model, ICT and TQM



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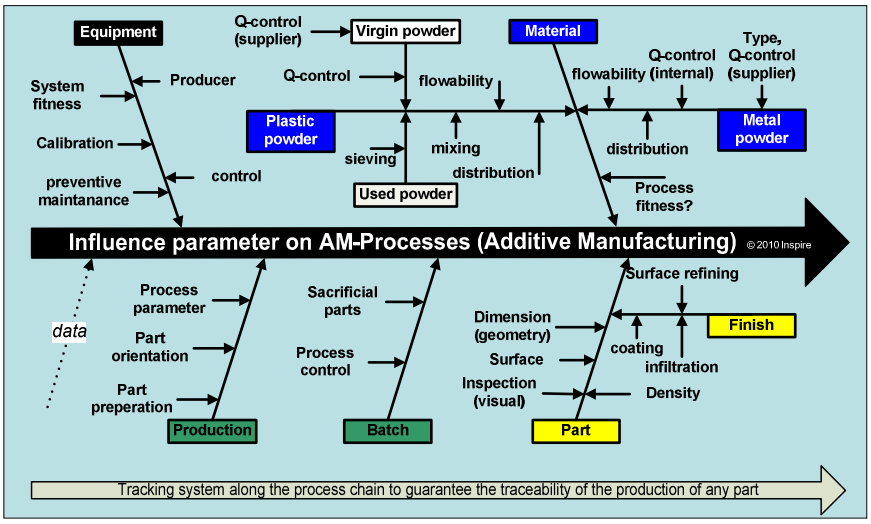
Identification of most important quality parameter along the production chain



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→ Questionnaire to partners involved in AM processing or material production

Quality of SLS-Material (what are the main parameter to guarantee sufficient material quality?)

Regarding SLS-Material (polymeric material) there are some specialities regarding QS as the material is commonly not used in a virgin state. Virgin SLS powder will be usually used to refresh already used powder in order to generate a medium quality (Refreshed Material). So there are different levels of Q-control along the material flow of SLS powder (see flow chart). At the different Q-points there will be different demands regarding data to be generated. Regarding 'Direct Spare' project Q-aspects are of relevance when the material is delivered to the part producer (service bureau).

Please answer the following question connected to the different Q-levels:

Please answer the following questions and/or comment	Yes	No	Don't know	--> Comments
data 1: Virgin Plastic Powder				
Assumption: The quality of the virgin plastic powder must be mainly guaranteed by the supplier (powder confectioner); is this correct regarding to your opinion?	F, M, +, C, S, B			C: supposed, we only are end customer B: For new powders (batch controls regarding the process requirements): powder confectioner, supplier; for mixtures (new:old) in the production: Part Producer
if 'Yes' in 'line 11': - should (analytical) data be provided to the part producer ('service bureau') and if 'Yes' which data should be provided?	M, +, S; B			S: powder spec, chemistry B: Material supplier should know what kind of analytical data is necessary to know for constant powder quality and constant processes.
- a production identification (e.g. Charge)	E, F, +, S, B	M		-->M: In fact you don't need the data, as long as the powder quality is consistent between certain specs that allow you to run the machine, it's ok.
- date of production	+, S, B	E, M		-->M: see above
- Powder distribution (e.g. d10 / d50 / d90)	E, F, S, B	M	F, +	-->F: so far I know this is fix?! M: see above

→ Example of a 7 page questionnaire with mainly **Yes / No** answers

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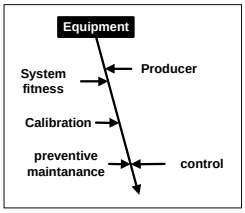
Q-activities for Equipment and System



The system fitness and performance and all connected aspects regarding equipment are under the responsibility of the part producer

Action	Documentation	Comments	Fre.*
conduct a equipment logbook; and a machine checklist (eventually integrated in e-RP)	any relevant Q-activity (see below) and any machine problem and maintenance	a logbook/checklist has to be conducted for every production equipment (SLS, SLM);	⋮
Cleanliness: maintain constant cleaning sustain overall cleanness check clarity of laser window (after every build)	any activity must be confirmed at a machine checklist (like done ✓)	for cleaning activities see also specification of equipment supplier	daily
System fitness: Periodical complete machine service (preferably every three month - service contract)	check of laser and optical system, temperature control, inert gas supply, replacement of wear parts (filter, scraper,…);	Service should be performed by special skilled people (e.g. machine supplier service or service companies (e.g. LSS GmbH, Germany))	quaterly
System performance: A specially designed reference part (benchmark) must be built and analysed	benchmark part to be analysed regarding: - Weight (density) - Scaling - Tolerances - Beam offset - Surface roughness (R_a, R_z and different orientation) ??	producer without analytical equipment should have a contract with a service laboratory (surface roughnesses); Retain samples must be stored for the whole production period of the machine.	monthly

*Fre. = Frequency;

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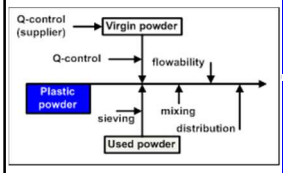
Q-activities for plastic materials (new and used)

A suitable quality of new SLS material must be guaranteed by the material supplier (powder confectioner);



The quality of the (refreshed) production material must be guaranteed by the producer

Action	Documentation	Comments	Fre.*
conduct a material logbook	collect any material documentation	no particular Q-check of virgin plastic powder	⋮
check delivered material data sheet regarding guaranteed value (according to agreement with material supplier)	Following data to be given at least for new batch: Production identification (e.g. chargen number) - Bulk density - Melting point (T_m) - Recrystallization (T_c) - Powder distribution (e.g. d10 / d50 / d90)	Preferebly further data are disclosed by supplier: - molecular weight distriburtion (M_w, M_n) - residual monomer - BET surface - flowability (e.g. Hausner Ratio)	as needed
material blending: 3D: virgin / overflow / part cake material EOS: virgin / used material	amount of fresh and used material, mixing time and technique	control and documentation for every production batch (material logbook); refresh rate see also specification of equipment supplier	every batch
sieving	type and mesh size of sieve	see above; prefered mesh size 140 µm	
optional: check quality by MFI measurements	MFI value for every batch	MFI value support quality assurance but need to be adjusted to any specific system and material; no common recommendation for target MFI definable	weekly

*Fre. = Frequency;

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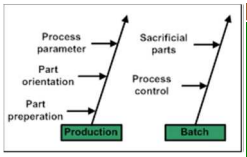
Q-activities for production and batch



The part production process is under the responsibility of the part producer;

Action	Documentation	Comments	Fre.*
record relevant production/batch parameter for every single part	part orientation within build; build parameter: laser power, scan spacing, temperature profile, scan strategy, layer thickness, laser exposure style, scan speed, hatch distance scan vector length, atmosphere	the recording and storing of these data should be preferably realised with specialized production software; e.g. eRP-System of Materialise (partially developed within this project); or EOSTAT of EOS;	daily
comment: no standardised production of test bars for every build		in contradiction to the results of questionnaire no production of special test bars is forseen for DirectSpare (effort and costs);	⋮

*Fre. = Frequency;

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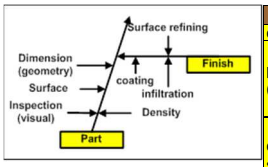
Q-activities for part and finishing



Action	Documentation	Comments	Fre.*
conduct a part protocol	collect any part specification		---
perform quality check (qualitative)	- optical inspection & dimension check - surface control (roughness) - weight (density)		as needed
check comparison to order specification	- part quantity - on time delivery - special requirements - pre-assambly		
perform defined finishing	- infiltration (which infiltrate) - coating (e.g. colour) - surface optimization (vibratory grinding)		

The final part quality and the desired finishing is under the responsibility of the part producer;

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SLS production machine (newest generation)

➢Turnover (fully loaded)
•80 builds/Year
•50 parts/build = 4000 P/Y
•average part price 200 €
→ 800'000 €

➢Fixed Quality costs:
• analytical equipment (DSC, MFI)
• equipment for finishing (vib. grind.)

➢Flexible Quality costs:
• quarterly equipment service;
• monthly benchmark with analysis (retain sample)

➢Finishing costs:
• no finishing,
• handmade or automatic finishing;

With material analysis	1 machine (4000 parts/year; average part price 200€)							
	handmade finishing				automatic finishing			
	fixed	flexible costs			fixed	flexible costs		
	k€	lot	50 €/h	k€/a	k€	lot	50 €/h	k€/a
Equipment (Performance & Fitness)								
Regular performance check (maintenance contract 'regular')				35				35
Monthly Benchmark (Production & Evaluation)		12	8	4,8		12	8	4,8
Material								
Analytical Equipment (DSC, MFI)	50				50			
consumables				5				5
Material control (DSC/MFI)		80	2	8		80	2	8
Production & Batch								
Build setup & process control		80	1	4		80	1	4
Part & Finish								
Final Inspection		4000	0.1	20		4000	0.1	20
Post processing (assump.: half of parts to be finished)		2000	0.5	50		2000	0.05	5
Machine for vibratory grinding					50			
consumables (vibratory grinding)								5
sum fixed costs - depreciation (10 y)	50			5	100			10
Q-costs per anno				131,8				96.8
Parts		4000				4000		
Q-costs €/part				33				24
Estimated turnover per anno				800				800
Q-cost percentage per anno				16%				12%

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Finishing

		handmade finish	automatic finish	
1 machine half	Q-costs/anno	88'300	73'300	
	Parts	2000	2000	
	Q-costs/part (€)	44.2	36.7	
	Estimated turnover/anno (€)	400'000	400'000	
	Q-cost percentage/anno	22%	18%	- 4%
1 machine full	Q-costs/anno	131'800	96'800	
	Parts	4000	4000	
	Q-costs/part (€)	33.0	24.2	
	Estimated turnover/anno (€)	800'000	800'000	
	Q-cost percentage/anno	16%	12%	- 4%
2 machine	Q-costs/anno	241'100	157'100	
	Parts	8000	8000	
	Q-costs/part (€)	30.1	19.6	
	Estimated turnover/anno (€)	1'600'000	1'600'000	
	Q-cost percentage/anno	15%	10%	- 5%
4 machine	Q-costs/anno	446'200	269'200	
	Parts	16000	16000	
	Q-costs/part (€)	27.9	16.8	
	Estimated turnover/anno (€)	3'200'000	3'200'000	
	Q-cost percentage/anno	14%	8%	- 6%

cost reduction: about 5 %

Analyses

		with analyses	without analyses	
1 machine half	Q-costs/anno	88'300	76'800	
	Parts	2000	2000	
	Q-costs/part (€)	44.2	38.4	
	Estimated turnover/anno (€)	400'000	400'000	
	Q-cost percentage/anno	22%	19%	+ 3%
1 machine full	Q-costs/anno	131'800	113'800	
	Parts	4000	4000	
	Q-costs/part (€)	33.0	28.5	
	Estimated turnover/anno (€)	800'000	800'000	
	Q-cost percentage/anno	16%	14%	+2%
2 machine	Q-costs/anno	241'100	215'100	
	Parts	8000	8000	
	Q-costs/part (€)	30.1	26.9	
	Estimated turnover/anno (€)	1'600'000	1'600'000	
	Q-cost percentage/anno	15%	13%	+ 2%
4 machine	Q-costs/anno	446'200	404'200	
	Parts	16000	16000	
	Q-costs/part (€)	27.9	25.3	
	Estimated turnover/anno (€)	3'200'000	3'200'000	
	Q-cost percentage/anno	14%	13%	+ 1%

cost increase: about 2 %

Summary

- Q-Modell erarbeitet als Teil des ‘AM business models’ von ‘DirectSpare’;
- Identifizierung der Haupteinflu… …er einzelnen Prozessschritte;
- Analyse des Q-Fragebo… …ptionen;
- Eine umfassende ‚Ac… …konnte erstellt werden;
- Abschätzung der Q…

  Anzahl Maschinen, …and

Danke!

Fragen?

Acknowledgement

Diese Arbeit war Teil des EU Projekts ‘DirectSpare’ (Grant Number: 213424)
- Wir danken der Europäischen Kommission (EC) für die finanzielle Unterstützung;
- Wir danken allen Projektbeteiligten für die Unterstützung mit wertvollen Inputs;