EUROfusion

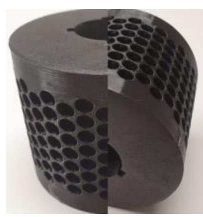
HKP in the Simoloyer®
Media Reload Processing (MRP)

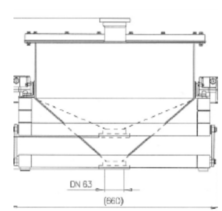
JÜLICH Forschungszentrum

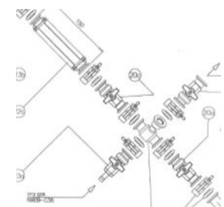
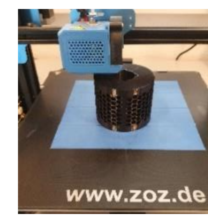
Rotary Vane Feeders (ZS*-GM), Media Product Separator (MPR) & DispersoidChargingUnit (DCU) for commercial SMART PM2020

In High Kinetic Processing (MA/HEM/RM) towards commercial large scale manufacturing of nuclear materials, here ODS/NFA/SMART, heat-control represents a major challenge since available cooling surface does not expand simultaneously with enlarging processing vessels. Grinding Media (GM) however does store huge heat at low heat transfer-level to the inner processing vessel surface. Thus continuously replacing e.g. hot GM by e.g. cold GM might offer an economic option to keep temp. significantly lower enhancing quality at lower manufacturing cost. Forto SMART-PM2020, another challenge is the Yttrium-Metal contributing in only very small fractions to the total composition, requiring an all automatic small, highly precise charging unit.







At Media Reload Processing (MRP), Rotary Vane Feeders (ZS*-GM) allow precise transfer of GM, Media Product Separator (MPR) economically separates GM from powder material and the Dispersoid Charging Unit (DCU) offers the required precise charging, all fully automatic under inert/vacuum condition, proven on lab-scale within this EUROfusion project. Next step: set-up of CM20-CM100 scale manufacturing unit, durability of vane feeders particularly under GM-deformation as well as potential self-coating/crusting still to be addressed.

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HKP in the Simoloyer®

Media Reload Processing (MRP)

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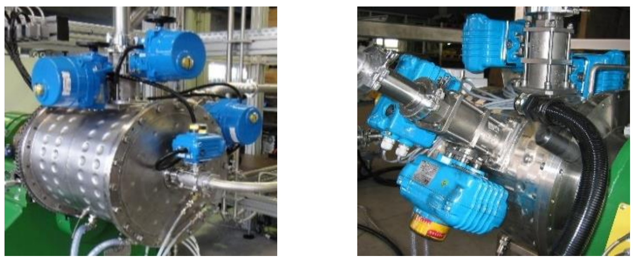
High Kinetic Processing (HKP) in the Simoloyer® represents the most advanced technique for Mechanical Alloying (MA), High Energy (HEM) and Reactive Milling (RM) for making Nanostructures. Three general processing modes are addressed, namely the common batch-process (01), auto-batch (02) with automatic loading and unloading as well as the semi-continuous processing route (03) for insitu separation/classification by the adapted carrier-gas/multiphase flow circuit.



[1a] draingratings Ask0820 (left) and Askm0820 (charging) & Bskm0820 (discharging) at Simoloyer® CM20 auto-batch (on right)

[1b] draingratings Ask100 (left) and Askm100 (charging) & Bskm100 (discharging) at Simoloyer® CM100 auto-batch (on right)

Media Reload Processing (MRP)

HKP at industrial manufacturing (repeated and fast processing) may require complete discharging/charging of product including GM in order to increase discharging efficiency (time and yield, economic) and to extract all heat that is stored by GM (heat-break, process technical) from the flow chart.

Complete discharging may also improve product access for CMB materials, such as highly ductile metals and composites.

Media Reload Processing (MRP), as a variant to batch- or auto-batch mode, also allows to discharge through a fixed main-port at 6 o`clock position [2-10b] without turning the grinding unit from charging- to discharging position. Thus auto-batch without carrier-gas becomes possible and carrier-gas assisted discharging can be replaced to some extent.

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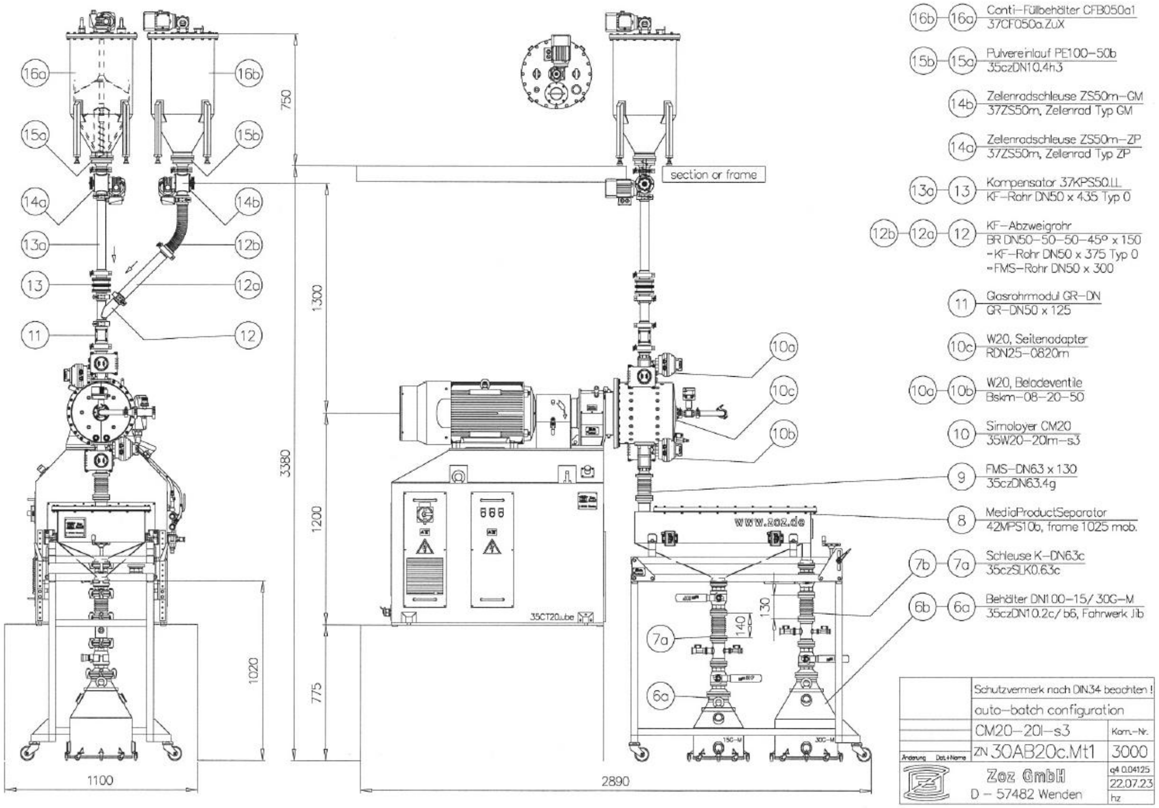
2024-01 Media Reload Processing, EUROfusion & FZJ

[2] Simoloyer® CM20 in MRP auto-batch, technical survey and flow-chart



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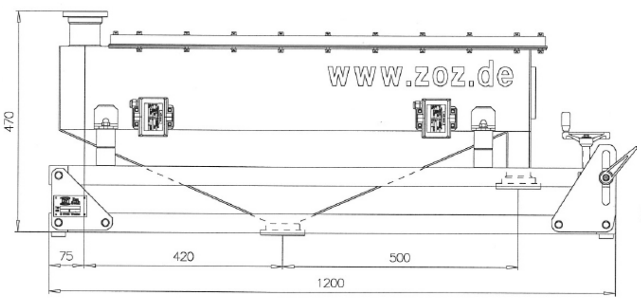
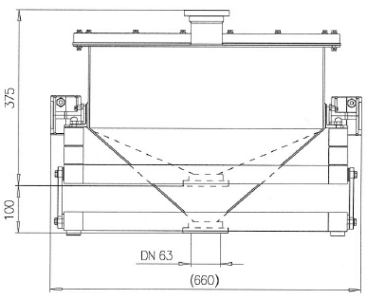
MediaProductSeparator MPS10b

after HKP in the Simoloyer® during auto-batch at Media Reload Processing

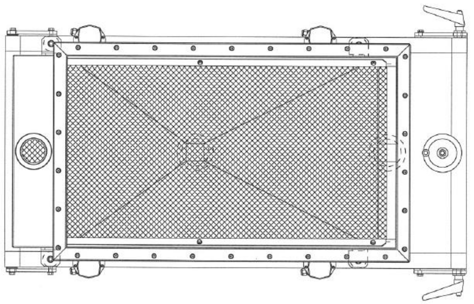
MediaProductSeparator MPS* is made to collect and separate the full multi-phase flow (grinding media + powder product) particularly from the Simoloyer® processing chamber during auto-batch operation. Material flows in via the KF loading port DN63 on upper left [3a] onto the converter-driven vibrating pan [3a]. Grinding media (GM) will pass over towards the smaller collector-compartment on right while powder product is passing through into the larger collector-compartment on left [3a].

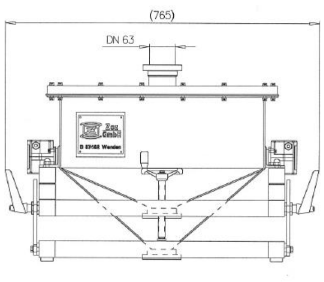


[3a] MPS10b, side-view with 2 compartments (powder/GM) and shift-angel-setting



[3b] rear-view, main dimensions


[3b] rear-view, main dimensions



[3d] front-view, shift-angel-setting

MRP – major advantages

MediaReloadProcessing for industrial manufacturing provides significant saving of discharging time at the Simoloyer®, which can easily become 20 times faster. By relocating the powder product separation from the complex Simoloyer® to the comparably simple MediaProductSeparator, cost reduction is achieved (a) in investment, (b) in operating cost and (c) in maintenance cost. Advantages not only relevant to large scale and auto-batch operation are described by practically eliminating the unavoidable impact by shear/friction/collision during common Simoloyer® discharging. This improves (d) the product quality also since the important powder/ball weight ratio is significantly changing with ongoing Simoloyer® discharging progress. If applicable, then MRP is less harmful to the powder product.

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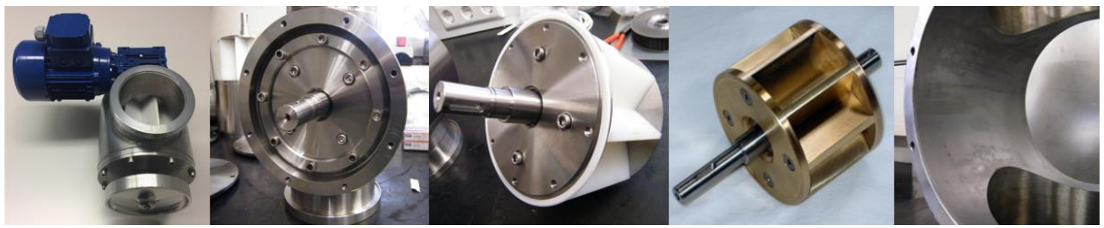
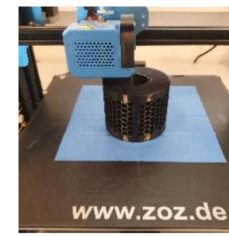
Rotary Vane Feeder ZS**-GM*

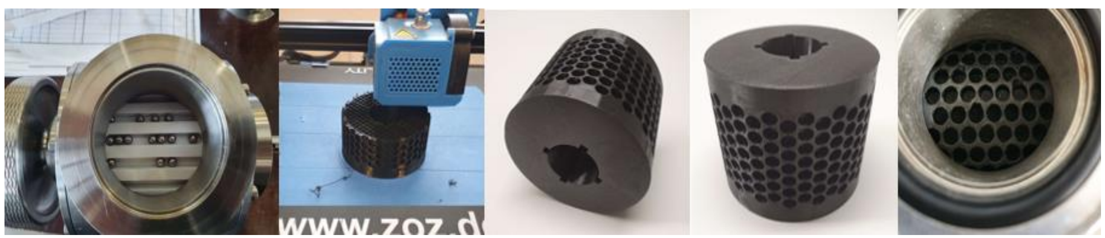
precise auto-batch feeding of grinding media at Media Reload Processing

Media Reload Processing in auto-batch requires precise feeding not only of starting powder material but also of grinding media (GM) for each processing run. Rotary Vane Feeder ZS do represent to outside vacuum-tight cycle locks that to some limited extent can be used for packaging/portioning of processing components. Common star-feeders cannot transfer GM, resulting frequent blocking does harm equipment and process. Thus, a new feed-wheel strategy had to be developed.



[4] star-feeders 37ZS50.ZR1 utilized in Zoz ZS Rotary Vane Feeders, adjusted mainly in material, seals & surface, in geometry only slightly





[5] feed-wheels, zebra-type (left) and 3D-printed STS-type, installed at ZS50m (on right)

The working-volume of ZS50m with common star-feeder 37ZS50.ZR1 is 96,99cm³, feed-wheel STS-50-GM06 at full load carries 245 steel-balls D4,762mm each 0,44g weight and 56,5414 mm³ volume.
In case of STS-feeder, the working volume should describe the “transfer-volume”, which equals to the volume of the 245 steel-balls, thus 13,85 cm³ at Σ107,8g. In result, the star-feeder transfer rate is 7x (7,003) higher compared to the STS-wheel.

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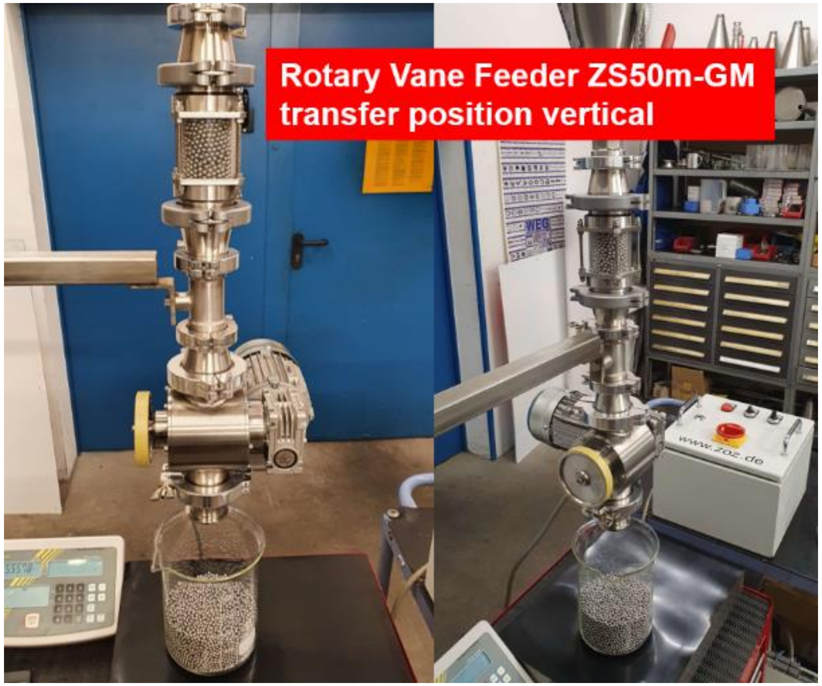
Rotary Vane Feeder ZS**-GM*

precise auto-batch feeding of grinding media at Media Reload Processing

[6a] test configuration 45°, ZS50m-G06, feed-wheel STS-01



[6b] test configuration 90°, ZS50m-G06, feed-wheel STS-02

A rotary vane feeder ZS50m is fixed in adjustable transfer angel position [6a/b], grinding media is fed from a KF-Container DN40-G1-3l through KFA-Adapter DN50-DN40x45 and a Transparent Pipe Module GR-DN50x125. At 45°-test [6a], additionally a pipe-bend RBA-DN50-22.5° was installed at the ZSm flow-out port. Grinding media was collected in a 2.000ml glass-bin (Schott) continuously weighted on a high precision balance (Kern KFS-T).

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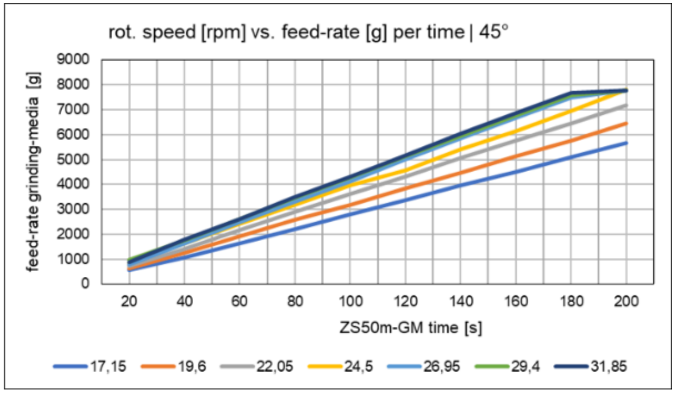
Rotary Vane Feeder ZS**-GM*

precise auto-batch feeding of grinding media at Media Reload Processing

140 measures during 14 runs with 2 new STS-wheels in 2 transfer positions (45° and 90°) have been carried out. Each measure was taken after 20s, thus the total run-time was 1.400s/wheel equals to 23min20s, total test-time 46min40s. Rotational speed of the feed-wheel was varied from nominal 100% (24,5rpm) to 70, 80, 90, 110, 120 and 130% for each transfer position. Total transferred grinding media was 105,494kg equals to 239.759 steel balls.

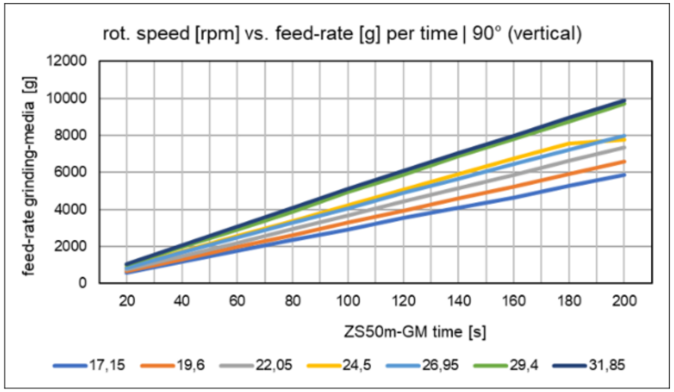


Rotary Vane Feeder ZS50m-GM **pos. 45°**

- **8kg grinding media in 200s**

charging time CM20-20lm (20kg) > 500s > 8-9min

[7a] 45°-test, 7 runs at 70-130% rotational speed (100% = 24,5 rpm) ea. 10x 20s, ZS50m-G06, feed-wheel STS-01



Rotary Vane Feeder ZS50m-GM **pos. 90°**

- **10kg grinding media in 200s**

charging time CM20-20lm (20kg) > 400s > 6-7min

[7b] 90°-test, 7 runs at 70-130% rotational speed (100% = 24,5 rpm) ea. 10x 20s, ZS50m-G06, feed-wheel STS-01

Best results with respect to transfer load are achieved at 90° transfer position [7b], all 7 curves/lines are higher than the corresponding ones at 45° transfer position. The feed-rate is increasing with the rotational speed of the STS-wheel increasing.

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Rotary Vane Feeder ZS**-GM*

precise auto-batch feeding of grinding media at Media Reload Processing

Best results with respect to transfer load are achieved at 90° transfer position [7b], all 7 curves/lines are higher than the corresponding ones at 45° transfer position. The feed-rate is increasing with the rotational speed of the STS-wheel increasing.

	transfer position	Σ time [s]	Σ transfer [kg]	feed-rate [kg/h]	feed-rate [Δ-%]	feed-rate max. [kg/h]	feed-rate max. [Δ-%]	runs	data obtained	% N-speed deviation
a	45°	1.400	50,382	129,554	+/-0	139,806	+/-0	7	ea. 20s	70-130%
b	**90°**	1.400	55,112	**141,717**	+9,14	178,002	+27,32[x1]	7	ea. 20s	70-130%
Σ	a+b	2.800	105,494	135,635	-	14	14	14	-	-

T2, mass transfer, feed-rate average and max.

[x1] > see mismatch M02

Due to mismatches M01-M04, the general increase 45° to 90° can only be estimated. With regard to the total transferred mass in both angels (50,382kg vs. 55,112kg), it should be higher than (+9,14%) and lower than the measured max. value of (+27,32%). In any case it is significant, feeding angel, which describes particularly the flow-in angel at ZSm is to be recognized [T2].

M	mismatch	% N-speed [%]	speed [rpm]	curve	time	
01	45°	120	29,40	green	180s ff.	significant change of slope (-)
02	45°	130	31,85	black	180s ff.	significant change of slope (-)
03	90°	100	24,50	orange	180s ff.	significant change of slope (-)
04	90°	110	26,95	blue	all	blue lower than orange, should be vice versa

T3, mismatches with respect to [1a] and [1b]

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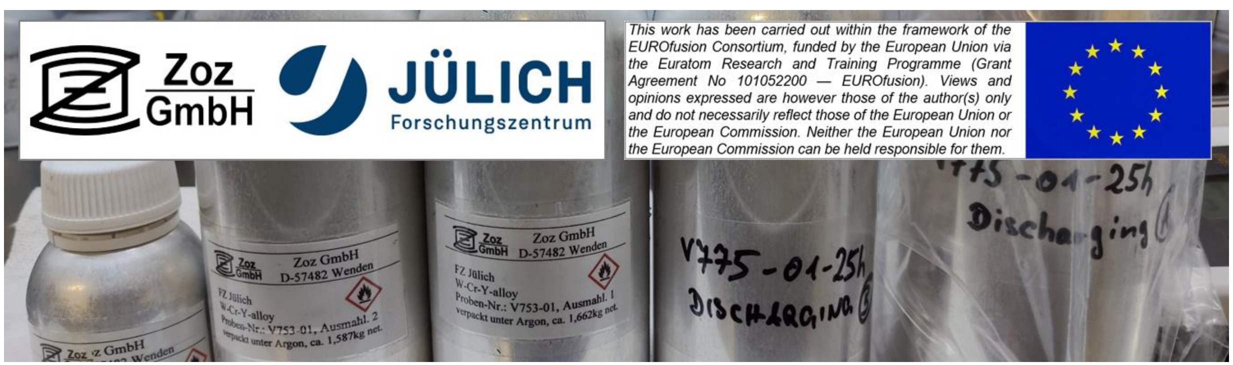
Rotary Vane Feeder ZS50m-GM06 pilot + next gen.

filament damage at prototype, predicted next gen. commercial performance

Even the working/transfer volume of STS-wheels is comparably small, the transfer capacity is impressive where at present status commercial success can only be predicted since strength and stability of the filament-printed structure is not at all acceptable for commercialization. However, weak material in this case is resulting in wear and damage determining lifetime but geometry is determining performance. STS-wheel-speed and transfer position are determining performance, too and should be further investigated, highest applied 130% of nominal speed at 90°-position seems not to be the limit. However, achieved transfer-performance parameters are more than good enough for commercialization.

After geometric performance of STS-type feed wheels is confirmed, commercial product availability can now be predicted. The next generation STS-wheels will be made by stainless steel which should solve the given wear/damage problems of the weak filament-structure. Following the common star feeder experience where each of the star heads represents a tube-stripper, STS-wheel (ZS50-scale) in V2A/V4A will be equipped with 6 tube-strippers made from PTFE. These provide pressure-shock resistance as well as wheel-in-tube wear, transfer tube/case will be chromium-plated which also represents an option at decades experience.



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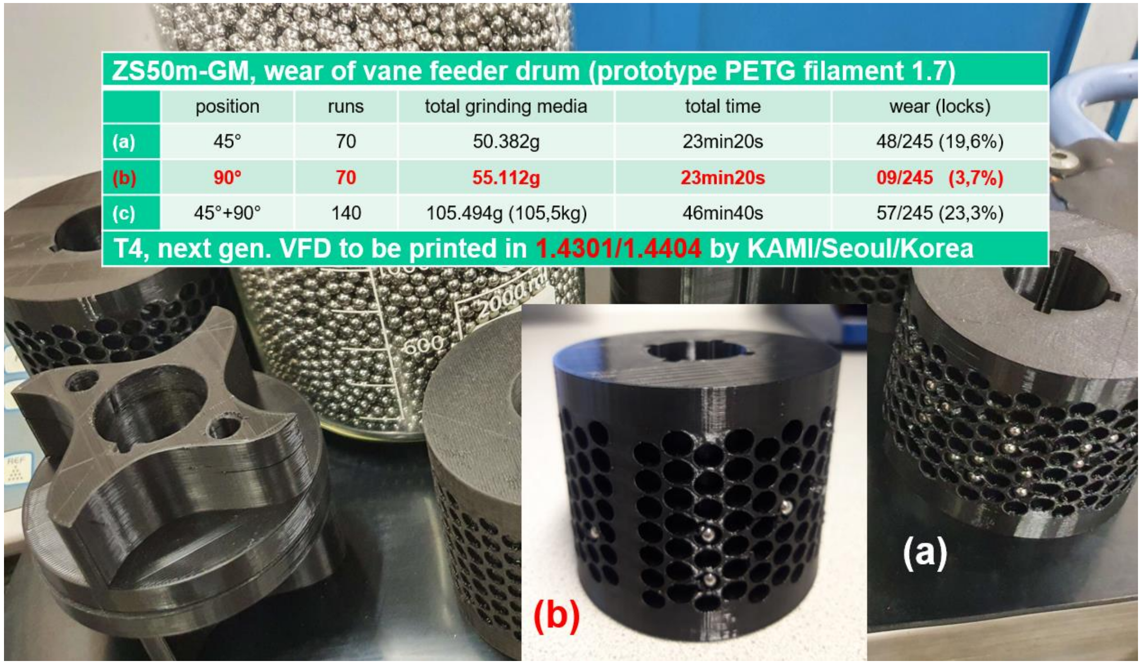
Rotary Vane Feeder ZS50m-GM06 pilot + next gen.

filament damage at prototype, predicted next gen. commercial performance

ZS50m-GM, wear of vane feeder drum (prototype PETG filament 1.7)

	position	runs	total grinding media	total time	wear (locks)
(a)	45°	70	50.382g	23min20s	48/245 (19,6%)
(b)	**90°**	**70**	**55.112g**	**23min20s**	**09/245 (3,7%)**
(c)	45°+90°	140	105.494g (105,5kg)	46min40s	57/245 (23,3%)

T4, next gen. VFD to be printed in 1.4301/1.4404 by KAMI/Seoul/Korea



[8] components & test-wheels, (b) STS-wheel after all test-runs in 90°-position, (a) STS-wheel from 45°-position testing correspondingly

unit-size ZS	ZS25	**ZS40m-GM**	**ZS50m-GM**	**ZS63m-GM**	**ZS100m-GM**
access surface E/A Δ-%	24	66,6	100	165,3	416,4
type GM est. minima	0,7 kg/min	2 kg/min	3kg/min	5kg/min	12,5 kg/min
for Simoloyer®	CM01 (2kg)	**CM08** (8kg)	**CM20** (20kg)	**CM20** (20kg)	**CM100** (100kg)
charging time (standard GU-size)	(3min) **too small**	**4min**	**6-7min**	**4min**	**8min**
T5, prediction of automatic GM loading time for Simoloyer® CM08 - CM100. ZS25 is too small, CM01 may be charged with ZS40 in 1min. For CM400 & CM900, ZS130 and ZS160 (KF-DN130/DN160) will be introduced.					

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HKP in the Simoloyer®

Media Reload Processing (MRP) for SMART PM2020 DispersoidChargingUnit (DCU)

High Kinetic Processing (HKP) in the Simoloyer® represents the most advanced technique for Mechanical Alloying (MA), High Energy (HEM) and Reactive Milling (RM) for making Nanostructures. General processing modes are the common batch-process (01), auto-batch (02) with automatic loading and unloading as well as the semi-continuous processing route (03) for insitu separation/classification by the adapted carrier-gas/multiphase flow circuit.

Media Reload Processing (MRP)

On route to automatic processing at industrial importance at best economic condition, Media Reload Processing (MRP) was developed in 2023 as a variant to batch- and/or auto-batch mode.

MPR allows entirely discharging of processed material (PM) including grinding media (GM) utilizing MediaProductSeparator (MPS) for PM/GM-separation outside Simoloyer® under continued atmosphere control. Different RotaryVaneFeeder (RVF) allow reloading GM (RVF ZS-GM) and charging starting powder material (RVF ZS-ZP).

MPR can substantially improve cooling efficiency (heat-storage GM), significantly reduce total processing time (discharging time towards zero) and by the latter may improve product quality due to constant PM/GM wt-ratio at all time. The former process-bottleneck, namely the draingrating for discharging under controlled atmosphere at the absence of dead-zones as well as discharging itself under severe alteration of PM/GM wt-ratio, can be eliminated [1].

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HKP in the Simoloyer®

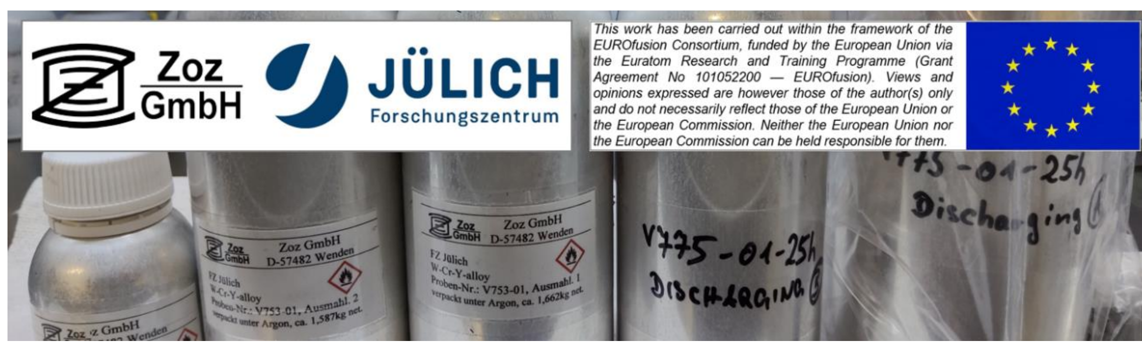
Media Reload Processing (MRP) for SMART PM2020 DispersoidChargingUnit (DCU)

Simoloyer® automatic loading/charging

At auto-batch and so at MRP, Simoloyer® is automatically loaded from one or more ChargingContainer CFB. Portioning is provided by RVF ZS-ZP at appropriate precision over its rotation number. To some extent, portioning precision can be increased by decreasing mass-transportation per rotation at the rotary vane feeder.

SMART material for NuclearFusionReactor 1st wall

SMART describes a safety-issue material W-Cr-Yttrium for the 1st wall plasma facing side at the Fusion Power Plant. In NuclearFusion (NF) operation, SMART behaves like Tungsten. In case of severe accident e.g. at a loss of coolant at first wall temperatures >1000°C, SMART forms a self-propagating protective surface layer [2]. In early stage, utilizing Simoloyer® CM20, processing times were reduced from 60h (lab, g-scale) to 20h (kg-scale). The composition at present is W-11.4Cr-0.6Y (wt%), once commercialized, SMART shall become PM2020 [3].



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HKP in the Simoloyer®

Media Reload Processing (MRP) for SMART PM2020

DispersoidChargingUnit (DCU)

Charging small component fraction, insitu portioning

Due to its small dispersoid-fraction (Yttrium), SMART describes another challenge towards HKP at industrial manufacturing. Precise portioning/vessel-loading now becomes a strict requirement that in auto-batch processing could not have been provided under the technical state of the art. In NF, ODS/NFA structural materials for the plasma face-away side at 1st wall, undergo identical relevance.

In batch processing, any component fraction by weight can be loaded one by one using given airlocks, if necessary then premixed and then processed. To achieve a precise composition in auto-batch, pre-mixing of final composite is not acceptable due to the potential of subsequent de-mixing in the ChargingContainer CFB and/or piping and interconnections enroute to the processing chamber.

DispersoidChargingUnit (DCU)

A new device shall allow charging small but precise amounts of powder material into the processing vessel. General requirements are low cost and maintenance, no moving parts and no wear. Charging port shall be located utmost close to processing chamber, given support such as gravity shall be utilized.

The DispersoidChargingUnit (12s) is adapted at CalmingPipe (12) as a part of the airlock for charging right at the vessel. DCU is assembled in 45° angel, thus gravity supports in transfer direction. Entry-port is right where starting powder and GM from ChargingContainer (16b) and (16a) res. come straight down inside (12). Uptake of small fraction by two large fractions is suggested.

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HKP in the Simoloyer®

Media Reload Processing (MRP) for SMART PM2020 DispersoidChargingUnit (DCU)

DCU is equipped with its independent airlock (21) with vacuum- and inert-ports assembled under 70° thus here gravity supports solids-flow in desired direction hindering the opposite/exhaust. The Dispersoid (here Yttrium) comes as the precise portion in the sealed glass-tube (22) to be connected at airlock (21).

(a) after clearing atmosphere and opening transfer valves (20a+c), Dispersoid flows into the vessel supported by gravity;

(b) simultaneously to (a), GM and starting powder from ChargingContainer (16b+16a) may flow in supporting (a);

(c) optionally, vessel and pipe-system can be set under preceding vacuum, supporting Dispersoid-flow by depression mode. Evacuation may be pulled via CFB (16b+16a), side adapter (10c), MPR-unit (8) or via airlocks (7a+b) whatever evacuable volume is required for depression;

(d) once (a-c) would not provide appropriate result, which may be visually controlled at glass-tube (22a) and glass-tube module (11), ventilation valve (23a) may be connected to an inert gas source and subsequently opened for expansion and/or used for pulsed pressure into the comparably multiple times larger vessel/pipe-volume.

The Dispersoid, here Yttrium, is precisely loaded into the vessel after an estimated handling time below 3min at discontinuous operation during auto-batch processing.

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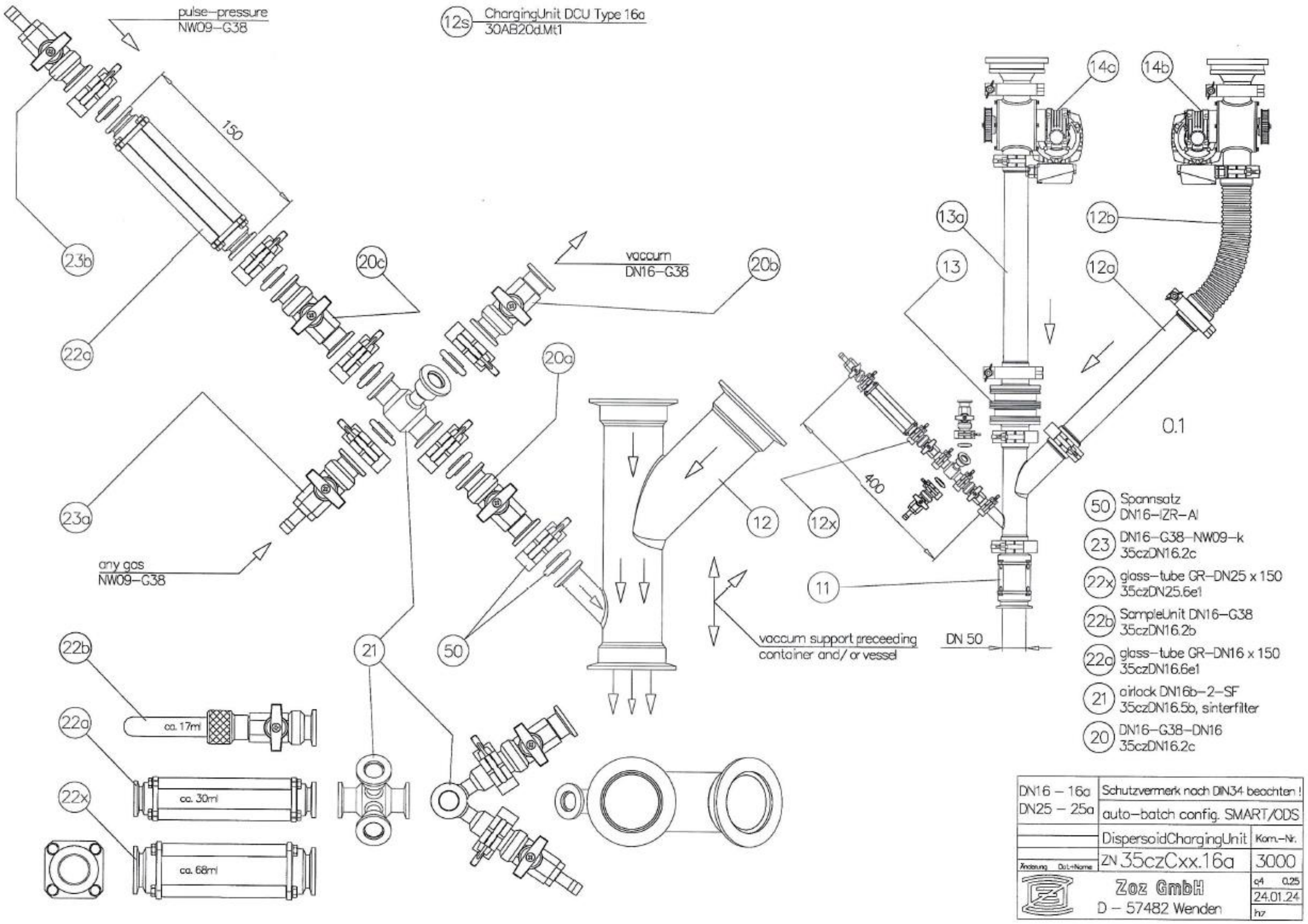
HKP in the Simoloyer®

Media Reload Processing (MRP) for SMART PM2020



[2] Simoloyer® CM20 in MRP auto-batch including ChargingUnit DCU (12s), technical survey and flow-chart

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Media Reload Processing (MRP) for SMART PM2020

DispersoidChargingUnit (DCU)

pos.¤	unit-definition¤	what·for·?¤
12x¤	DispersoidChargingUnit¤	loading·small·fraction,·e.g.·dispersoid·ODS/NFA/SMART¤
20a¤	KF-Adapter·DN16-G38-DN16¤	airlock·transfer-valve·intra·locking·CalmingPipe·(12)¤
20b¤	dito¤	airlock·evacuation·valve·extra·locking¤
20c¤	dito¤	closing·(22a)¤
21¤	DN16a-2-SF·airlock¤	transfer·small·fraction·under·controlled·atmosphere¤
22a¤	Glass-tube·GR-DN16·x·150,·30·ml·approx.¤	carry·precise·small·powder·fraction¤
22b¤	DN16·SampleUnit,·17·ml·approx.¤	alternative·for·smaller·small·fraction·to·be·loaded¤
22x¤	Glass-tube·GR-DN25·x·150,·68·ml·approx.¤	alternative·for·larger·small·fraction·to·be·loaded¤
23a¤	DN16-G38-NW09¤	airlock·gas·flow-in·valve¤
23b¤	dito¤	closing·(22a),·depr.·gas·supply·and/or·pulse·pressure·valve¤
50¤	clamp·set·DN16-IZR-Al·(ISO)¤	seals·all·components¤
[T1]·DCU16a·at·Simoloyer®·CM20·in·MRP·auto-batch,·main·component·list¤		

Glass-tubes (22a) or (22x) are utilized as Dispersoid charging container. During further realization, the closing valves 23b + 23c may be directly connected via inner-thread in order to saving 2x clamping (50) and total DCU-lengths at now 400mm.

Such connector design is realized at the SampleUnit (22b) for smaller Dispersoid volume up to 17ml. For larger volume up to 68 ml, DCU-scale can be altered from DN16 to DN20 (ISO). Optionally, Glass-tube (22a) can be extended in length from now 150mm up to 200mm resulting in about 40ml Dispersoid-capacity.

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Media Reload Processing (MRP) for SMART PM2020 DispersoidChargingUnit (DCU)

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