An attempt to introduce a resuspension model in MELCOR 1.8.6 for fusion applications

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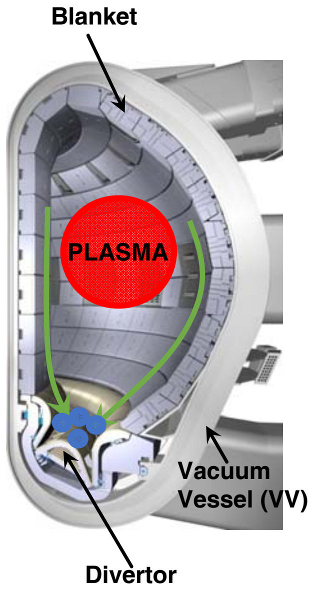
Content of the presentation

- Introduction – The problem;
- Selection of a resuspension model;
- The "ECART model";
- Implementation in MELCOR - Limitations;
- Validation;
- Conclusions & Future perspectives.

Introduction – The problem

- During normal plasma operation the ***erosion*** of the "plasma facing components" occurs;
- The ***dusts*** formed tend to ***deposit onto the divertor surface***;
- In case of an ***In-vessel LOCA***, these dusts may resuspend;
- ***Resuspended dusts may be transported*** to the VV Pressure Suppression System (VVPSS);
- Define the ***maximum amount of mobilized dust*** is an issue of main concern;
- ***MELCOR v1.8.6 for fusion applications hasn't a resuspension model***;
- ***In MELCOR v2.2 for LWRs a resuspension is implemented (Force Balance Model);***
- ***An attempt to introduce a resuspension model in MELCOR was performed***.



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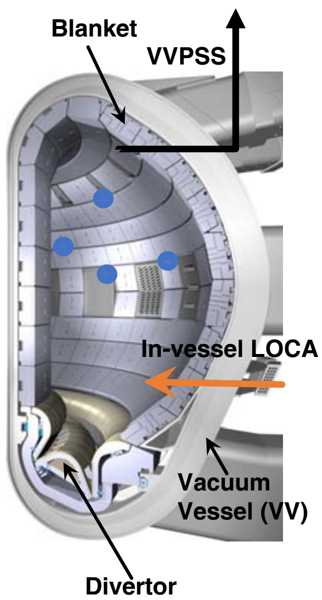


Selection of a resuspension model

Different models are available in literature, but they can be all subdivided into

TWO CATEGORIES

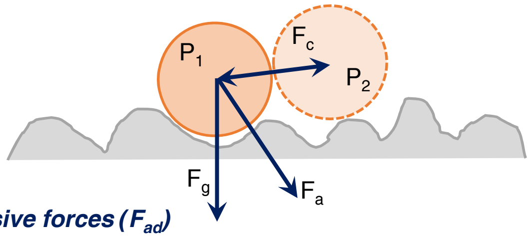
FORCE BALANCE models
↓
The particles resuspend if the aerodynamic forces exceed the adhesion forces
- *ASTEC model*
- *MELCOR V2.2 model*
- *ECART model*

ENERGY TRANSFER models
↓
The particles resuspend if enough rotational energy is transferred by the fluid motion
↓
Reeks, Reed & Hall model
↓
Rock & Roll model and derivates

The "ECART model"

- Why the ***ECART model***?
  - It is ***simple***;
  - It was ***already validated*** for fusion applications.
- How it works?

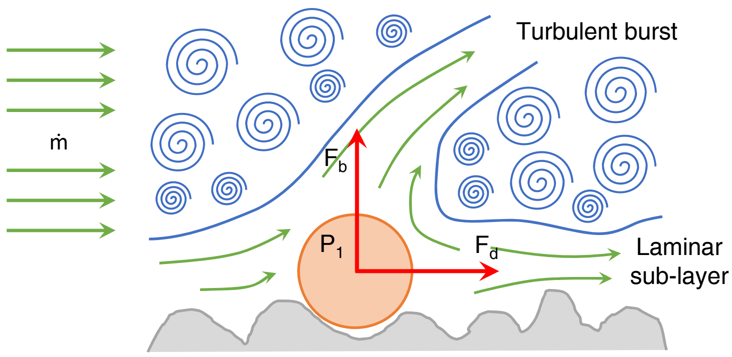
The "ECART model"



Adhesive forces (F_ad)

F_g	Gravitational
F_c	Cohesive (intermolecular attraction)
F_a	Friction adhesive (sliding and rolling resistance)

The "ECART model"



Adhesive forces (F_ad)

F_g	Gravitational
F_c	Cohesive (intermolecular attraction)
F_a	Friction adhesive (sliding and rolling resistance)

Aerodynamic forces (F_ae)

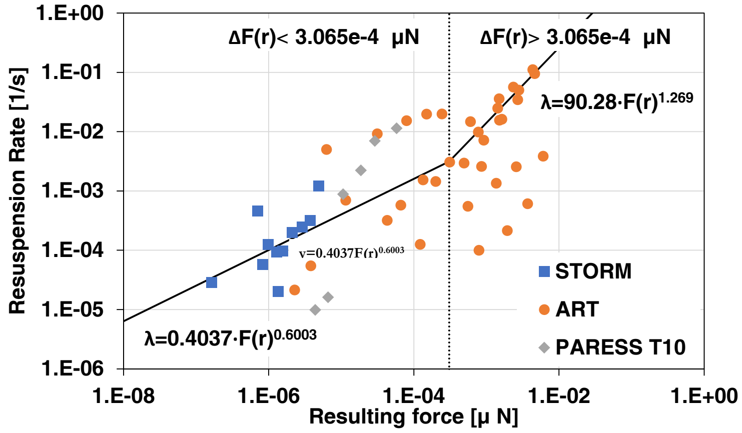
F_d	Drag (shear stress on wall)
F_c	Burst (breaking of laminar sub-layer)

The “ECART model”

Resuspension occurs when:

Adhesive forces (F_{ad}) < ***Aerodynamic forces*** (F_{ae})

If $\Delta F(r) = F_{ae} - F_{ad}$, the resuspension rate (λ) can be expressed as shown



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Implementation in MELCOR - Limitations

- The model was implemented through ***Control Functions (CFs)***;
- About ***200 CFs*** are needed for each CV;
- The model is ***not identical to the ECART one*** because correlations needing iterative calculations were substituted with explicit correlations;
- The aerosol population is subdivided into only ***5 groups***;
- ***The CFs calculate only the resuspension rate for each group, and the resuspended mass is computed at the end of the calculation through a dedicated Microsoft Excel ® file***;
- The model runs ***independently from the RN package***;
- Only the total amount of resuspended mass is computed. ***The fate of the resuspended particles is not tracked***.

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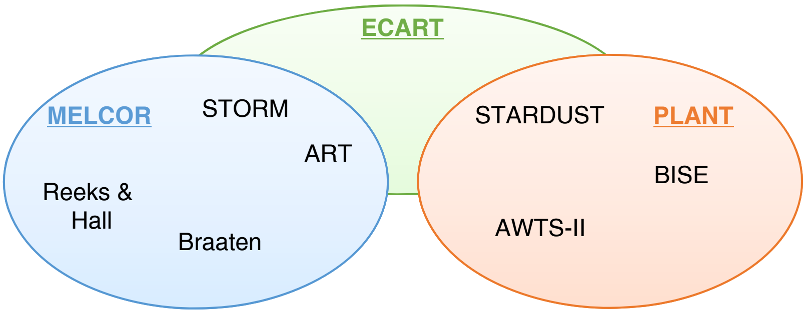
Validation

Several tests were selected to be part of the validation matrix. The selection was based on:

- Tests employed to validate the model implemented in ***ECART***;
- Tests employed to validate the model implemented in ***MELCOR v2.2***;
- Tests referring to the peculiar "***plant conditions***".

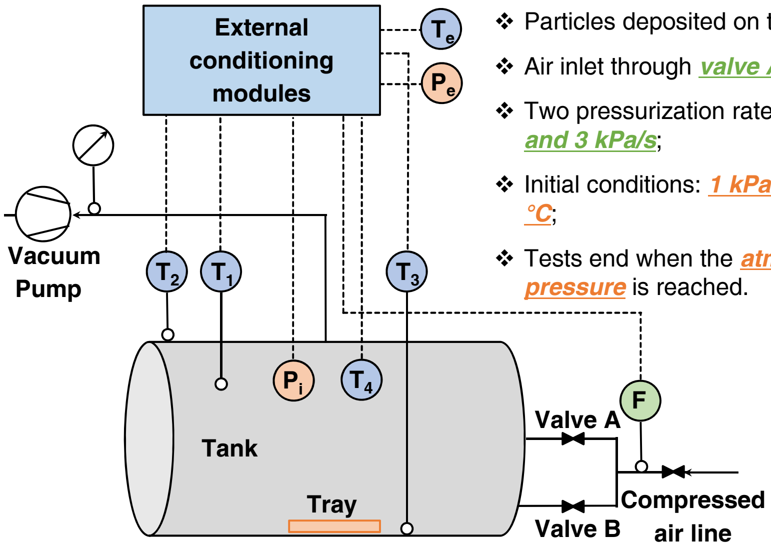


Validation

	EC.	*MEL.*	*PL.*	*N° of tests*	*Tests characteristics*	*Ref.*
STORM	✓	✓		*5*	- *Atmospheric pressure* - *Multi-layer deposit*	[1] [2] [3]
ART	✓	✓		*7*	- *Atmospheric pressure* - *Multi-layer deposit*	[1] [4]
Reeks & Hall		✓		*7*	- *Atmospheric pressure* - *Monolayer deposit*	[1] [5]
Braaten		✓		*141**	- *Atmospheric pressure* - *Monolayer deposit*	[1] [5]
STARDUST	✓		✓	*41**	- *Pressure increasing from 1 kPa to 100 kPa* - *Multi-layer deposit*	[6] [7]
AWTS-II			✓	*5*	- *Pressure below atmospheric one (constant)* - *Multi-layer deposit*	[8]
BISE			✓	*30*	- *Atmospheric pressure* - *Mono-layer deposit (?)*	[9]
			TOTAL	***236***		

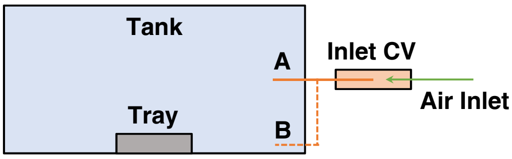
* Several tests were executed with the same boundary conditions.

Validation – STARDUST tests



- ***W***, ***C***, or ***SS*** particles;
- Particles deposited on the ***tray***;
- Air inlet through ***valve A or B***;
- Two pressurization rates: ***0.3 kPa/s and 3 kPa/s***;
- Initial conditions: ***1 kPa*** and ***110 °C***;
- Tests end when the ***atmospheric pressure*** is reached.

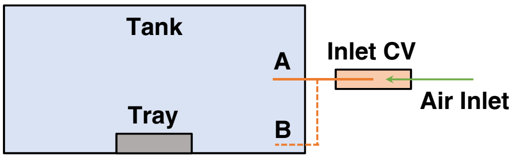
Validation – STARDUST tests



- ***Simple nodalization***;
- Tank is ***adiabatic***;
- Range of ***velocities*** impacting the tray calculated through ***CFD calculations***;
- Flow velocity tuned through the ***hydraulic diameter of the tank***.

Inlet	*Pressurization rate [kPa/s]*	*Range of velocities impacting the tray [m/s]*	*Velocities investigated [m/s]*
A	0.3	1 – 5	1 – 2.5 – 5
A	3	5 – 10	5 – 7.5 – 10
B	0.3	50 – 100	50 – 75 – 100
B	3	200 – 300	200 – 250 – 300

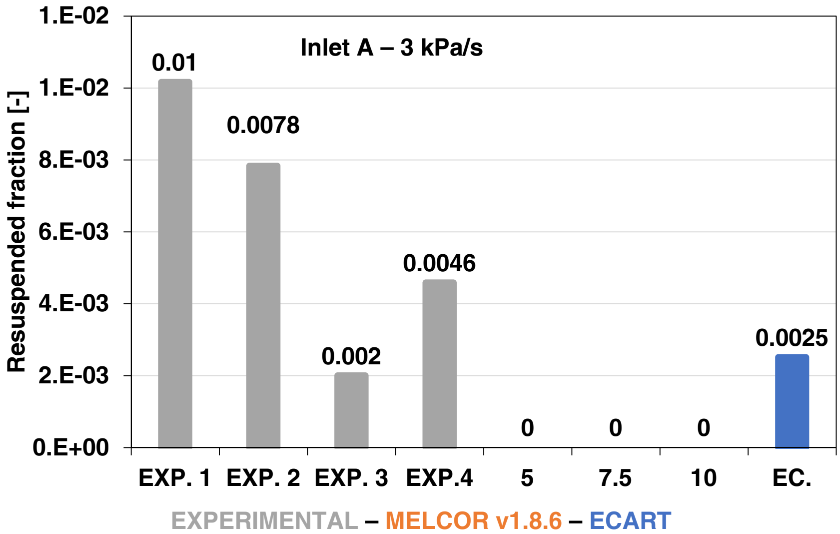
Validation – STARDUST tests



- ***Simple nodalization***;
- Tank is ***adiabatic***;
- Range of ***velocities*** impacting the tray calculated through ***CFD calculations***;
- Flow velocity tuned through the ***hydraulic diameter***.

Group	*GMD [m]*	*W mass distribution*
1	2.15e-7	0.009
2	3.22e-7	0.104
3	4.30e-7	0.257
4	5.37e-7	0.329
5	6.45e-7	0.300

Validation – STARDUST tests



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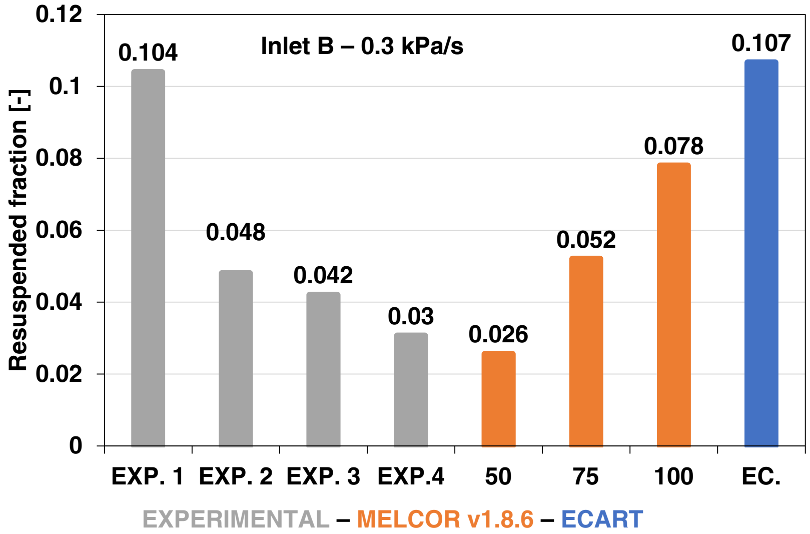
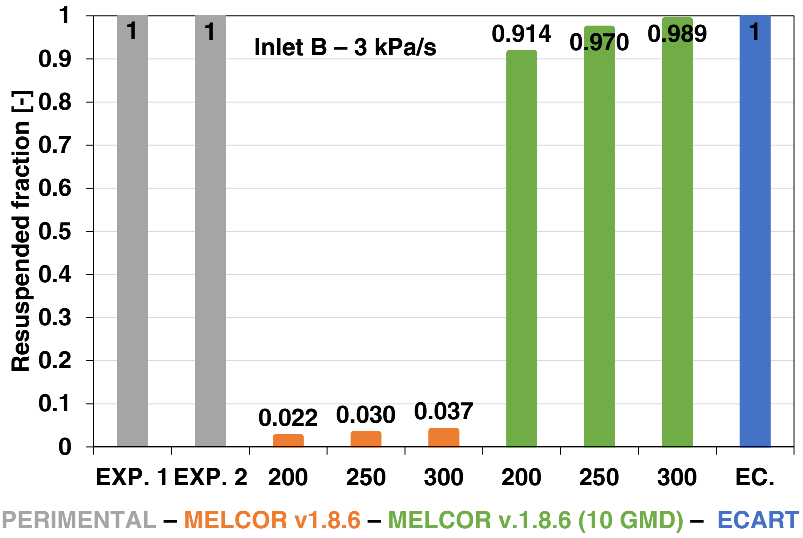


Validation – STARDUST tests



- At the end of the tests, large tungsten agglomerates were found;
- Probably, tungsten agglomerates while rolling onto the tray;
- Increasing the tungsten size of 10 times improves the MELCOR predictions.

Conclusions & Future perspectives

- An attempt to introduce a ***resuspension model in MELCOR 1.8.6*** for fusion applications was shown;
- The model was derived from the model implemented in the ***ECART code***;
- The model was implemented by mean of ***CFs***;
- Small variations were introduced to ***avoid iterative calculations***;
- The model was ***validated*** against several tests;
- For the ***STARDUST tests***, the model showed a ***good agreement*** with the experimental data ***if only more than the 5% of initial mass is resuspended***;
- For almost all the ***other validation tests***, the model showed ***conservative estimations***.

Conclusions & Future perspectives

- ***Improve the model***:
  - Reduce the ***CFs*** needed. Some CFs are now employed for diagnostic purposes;
  - Introduce an ***agglomeration model*** in function of the "Drag-Burst forces" ratio;
  - Increase the ***aerosol groups number to 10*** (instead of 5);
  - Create CFs for the ***calculation of the resuspended mass*** (avoid Microsoft Excel ® file);
  - ***Coupling with the RN package***: ***Inject the resuspended mass*** during the time step Δt_n as an aerosol source during the time step Δt_{n+1};
  - If needed, further expand the ***validation matrix***.