Non linear modal rolling tyre model for dynamic simulation with ADAMS

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PURPOSES

- Description of a new non linear Rolling Tyre
- ADAMS implementation of the full model
- Validation of the model (Static, Modal, Cleat tests)
- Road interaction

Non linear modal rolling tyre model for simulation with Adams

SUMMARY

- ❒ *Overview on the Pirelli tyre modeling*
- ❒ *Non linear modal Pirelli rolling tyre*
- ❒ *ADAMS implementation*
- ❒ *Validation*
- ❒ *Road description*

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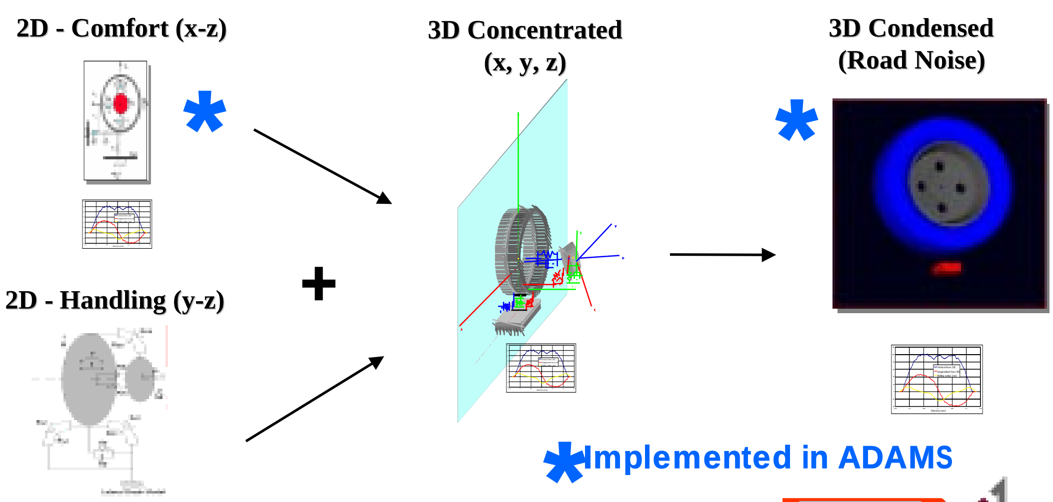
Overview on the Pirelli tyre modeling

Pirelli model history



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Overview on the Pirelli tyre modeling

Our point of view on tyre modeling

The models should be:

- validated and documented
- shared with the vehicle partner
- simple in the use (although difficult in the concept)
- physical meaning of the parameter (if possible)
- easy to be interfaced with various scientific software

The exploitation of the models requires always new competence

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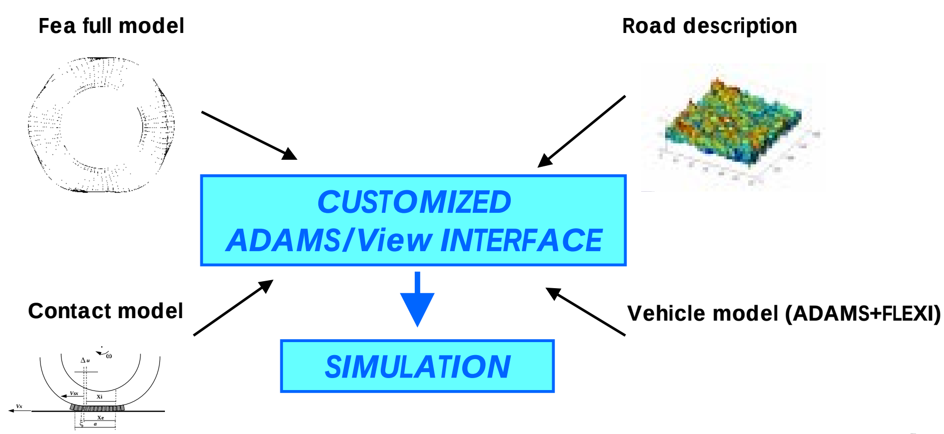
Overview on the Pirelli tyre modeling

Pirelli approach: one system more sub-models



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Non linear Pirelli modal rolling-tyre

MAIN PROBLEMS

- ❒ **The tyre is a NON-LINEAR system (both in terms of material and load)**
- ❒ **The finite element model of the tyre represents the NON-ROLLING tyre (it is unable to be used for time domain simulations)**
- ❒ **Our goal is a fully VIRTUAL APPROACH FOR ROLLING TYRE**

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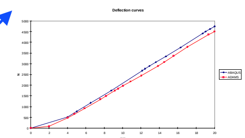
Flow chart

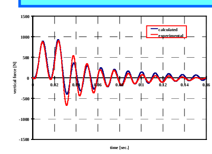
FEA analysis → CMS approach → Customized ADAMS interface

Contact Model → Customized ADAMS interface

Customized ADAMS interface → Validation



Customized ADAMS interface → Simulation



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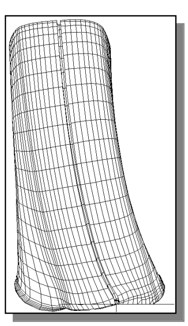
FEA Analysis: flow chart



STATIC PREANALYSES

❶ Mounting

❷ Inflation

❸ Loading

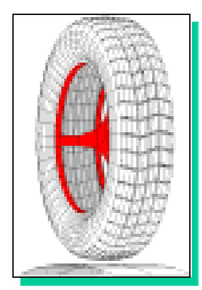
MODAL REDUCTION

❹ Stiffness matrix reduction

❺ Mass matrix reduction

❺ ***ABAQUS/ SUPERELEMENT***

❻***STATIC MODES Computation***



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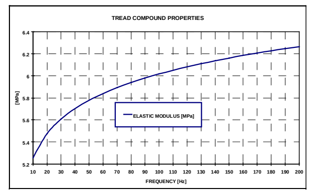
FEA Analysis: notes

- The typical full FEM model is made up of about 20 thousands of brick elements, that give like 80 thousand degree of freedoms
- It is fundamental a good characterization of the compound properties, the reinforcing materials , etc..



- It has been developed an automatic procedure for the computation of the static modes (necessary for the CMS approach)

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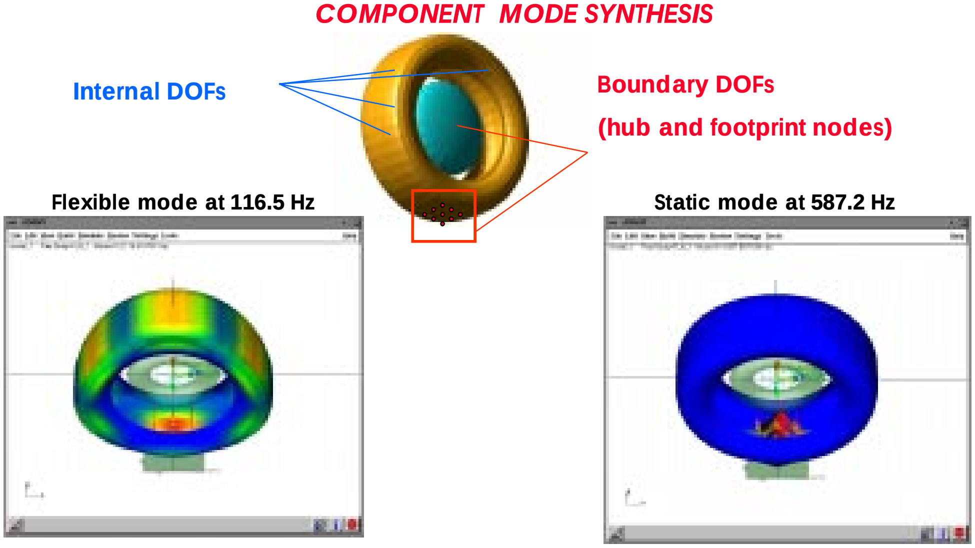
COMPONENT MODE SYNTHESIS



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COMPONENT MODE SYNTHESIS

❒ a beta release of the translator from Abaqus results to Adams format is available (fil2mnf). It carries out the orthogonalization procedure

❒ further reduction of the mnf file using an ADAMS executable file (mnf2mtx)

file .FIL —(fil2mnf.exe)→ **file . MNF** —(mnf2mtx.exe)→ **reduced_file . MNF**

≈ 140 Mbyte ≈ 10 Mbyte ≈ 2,5 Mbyte

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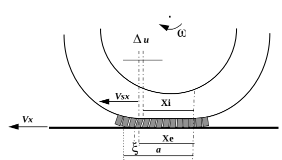
Non linear Pirelli modal rolling-tyre
Third step: CONTACT MODEL

❒ The discrete brush model is modeled as individual elastic elements radial linked to the tyre belt

❒ The maximum deformation of the tread elements is limited by the friction coefficient between the tyre and the road

❒ The contact model is implemented in ADAMS using an **user subroutine (VARSUB)**



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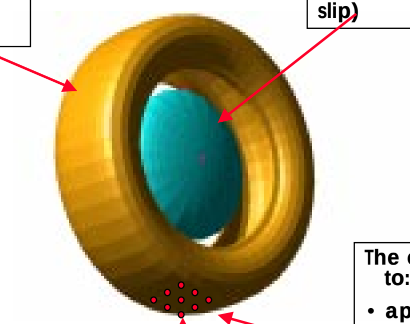
Further details

The flexible body takes into account the structural information of the non-rolling tyre

The rigid part needs to simulate the rotation of the tyre (The angular speed is necessary for the computation of the slip)



The contact nodes can be used to:

- application of the slip forces
- application of the basis curves
- apply impact function for the interface with the road

Contact Model for the evaluation of the longitudinal slip force

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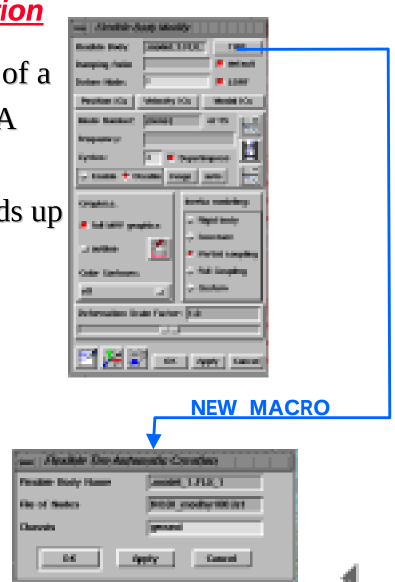
ADAMS implementation

❒ It has been developed a first release of a customized ADAMS/View interface. A macro reads an external file (.lst) containing the "hard-points" and builds up automatically the marker on the nodes

❒ A modified Flexible Body dialog box permits the user to select the Node list file and where to attach the tyre (ground, chassis, etc.)



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ADAMS implementation

❒ Moreover, the implemented macro creates all the objects for Road-Tyre interface: motions, impact forces, dummy part, state variables, etc.

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VALIDATIONS

Overview

❒ It has been modeled a 195/65 R15 tire size.

❒ For the static and modal validations there are the comparisons between the results obtained with ADAMS and Abaqus (with different boundary conditions)

❒ For the cleat test simulation with fixed hub the comparison is between the ADAMS results and the experimental data

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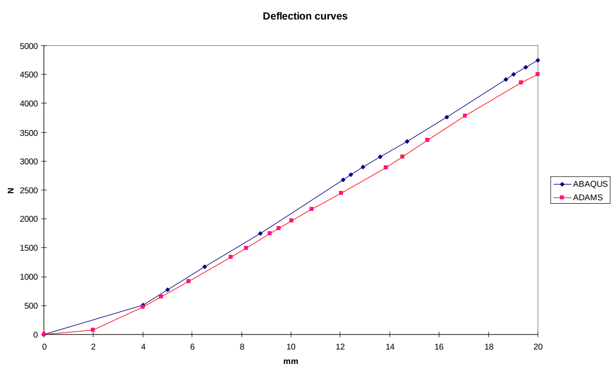
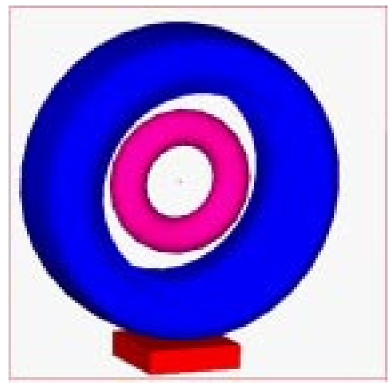
VALIDATIONS

Static analysis - Comparison between Abaqus and ADAMS





PIRELLI

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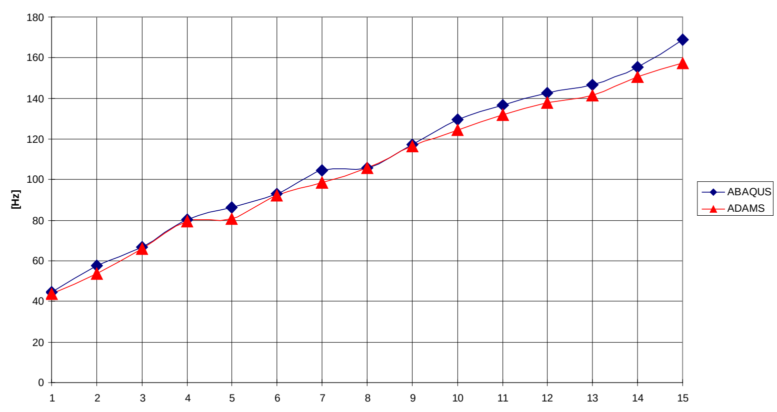
VALIDATIONS

Frequency analysis - Comparison between Abaqus and ADAMS

- Fixed hub

- Fixed nodes in footprint area



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VALIDATIONS

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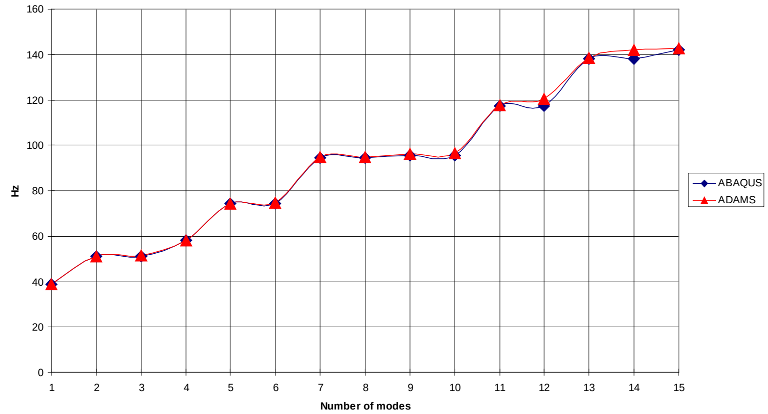

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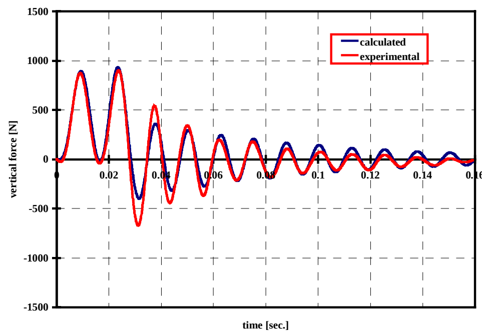
VALIDATIONS

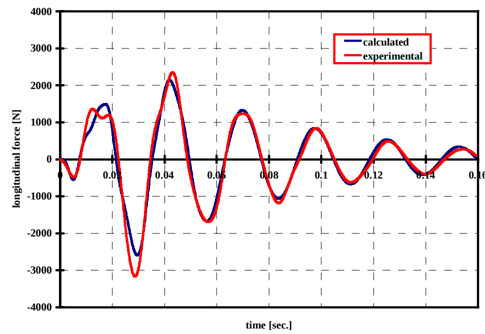
Cleat tests simulations - Comparison between ADAMS an experimental data

Triangular obstacle 15X20 mm

Vertical force at 30 km/h



Longitudinal force at 30 km/h



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CONCLUSIONS AND FUTURE WORKS

- ***An automatic procedure to create the flexible tyre model (markers, motions, forces, etc.) is available***
- ***The model has been validated for the static, modal and cleat test simulations; it has to be fully validated for the road noise simulation***
- ***Improvement in MNF format which must take into account the the generalized forces associated with the deformed configuration. The ADAMS/Solver must be enhanced to account for this preload***

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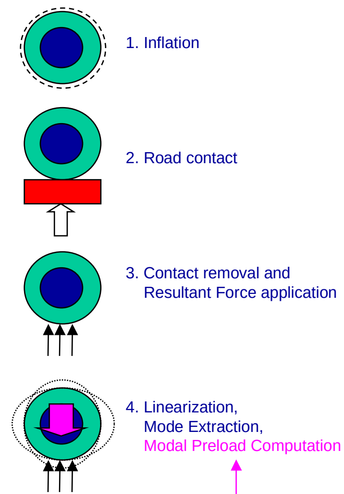
Consideration on Pre-Stressed configuration for Mode Extraction - 1

- **Deformations in a FlexBody are described via a superposition of Mode Shapes**
- **Modes are assumed to have been obtained by linearization about an unstressed configuration**
- **A linearization about a stressed state contains an associated Modal Preload which currently the MNF format does not accomodate and ADAMS/Solver does not account for**
- **ABAQUS must export node locations to the MNF that correspond to the deformed locations of the nodes**
- **The MNF format will be enhanced so that it can account for Generalized Forces associated with the deformed configuration**



$$M_i \ddot{q}_i + C_i \dot{q}_i + K_i q_i = F_{qi}$$

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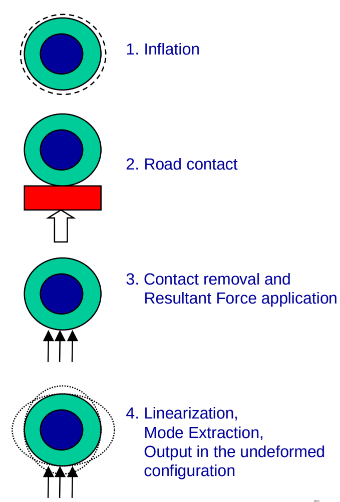
Consideration on Pre-Stressed configuration for Mode Extraction - 2

- **To overcome the absence of Modal Preload the current simulation in ABAQUS is done accordingly to the following sequence of calculation steps:**
  - **inflation at the nominal pressure**
  - **squeezing against a rigid surface which represents the road**
  - **contact removal and static concentrated loads on contacting nodes based on resultant forces**
  - **linearization and Mode Extraction**
- **The model is ouput in the undeformed configuration shape, with a linearized stiffness corresponding to the one at the end of road-contact simulation**



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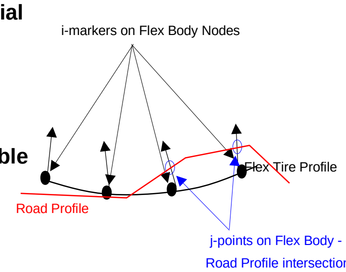
Flexible Tire / Road Contact Algorithm - current implementation

- Flex Tire Model is sliding on the uneven surface
- An auxiliary part is subjected to rolling by means of the tangential forces generated at the Tire-Ground interface
- An high speed searching algorithm finds potential road contact elements, described as triangular polygons
- A vector line along the Z-axis of a Marker belonging to the Flexible Body is drawn
- The intersection Point where the Z-axis and the Road Surface intersect is computed (j-point)
- dz(i,j,i) and vz(i,j,i) are then computed (j=road contact point)
- Forces are applied along directions normal to the external Tire Surface
- A SFOSUB routine generates a force on i-Marker based on dz and vz



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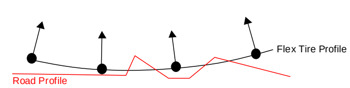
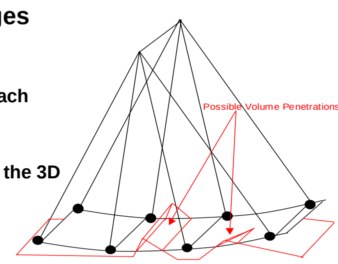
Flexible Tire / Road Contact Algorithm - on going development

- To avoid situations like those presented on the left, a new algorithm to detect compenetration between ground irregularities and Flex Tire needs to be introduced
- The Flex Tire model is ideally divided into several wedges
  - Each wedge has a base constituted by i-markers belonging to the deformable tire surface, with its volume subjected to changes at each iteration step
  - At every iteration, the intersecting volume between the wedge and the 3D road profile is computed
  - By means of a look-up table derived from FE, the resulting load is proportionally lumped to the nodes that constitute the base of the wedge





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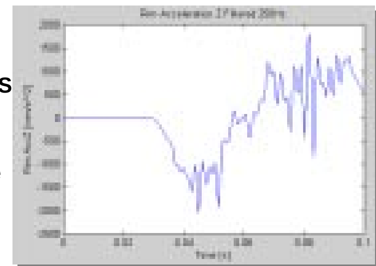
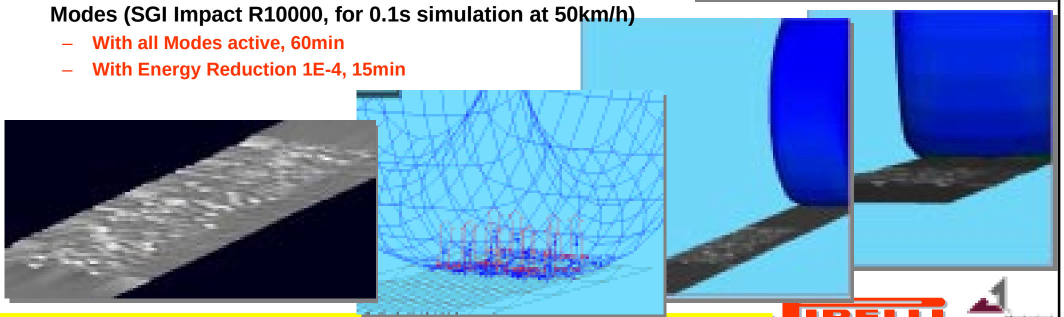
Flexible Tire / Road Contact Algorithm - some result



- **Contact surface description is entirely compatible with ADAMS Durability Tire Data Files**
- **It is possible to define Stiffness and Damping for the contact**
- **12 possible contact points identified on the Tire surface in the present model, and 15 Normal Modes**
  - **Total of 57 initial DOFs**
- **Simulation speed is influenced by the Number of retaines Modes (SGI Impact R10000, for 0.1s simulation at 50km/h)**
  - **With all Modes active, 60min**
  - **With Energy Reduction 1E-4, 15min**



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