PRODUCTIONALIZATION OF A PREDICTIVE MAINTENANCE SYSTEM FOR RAILWAYS
01. INTRODUCTION

02. DEFINITION OF CONDITION BASED MAINTENANCE (CBM)

03. CBM IMPLEMENTATION

04. CONCLUSION
01. INTRODUCTION

+ DISTINCT MAINTENANCE TYPES
+ MAINTENANCE REALITY PROCESS
+ MAINTENANCE OPTIMIZATION
3 DISTINCT MAINTENANCE TYPES

MAINTENANCE TYPE: REACTIVE, SCHEDULED AND PREDICTIVE

- **Maintenance**
  - Preventive
  - Reactive
  - Scheduled
  - Predictive

- **Reliability**
  - "up time" and safety increase

- **Ownership cost**
  - Minimize maintenance costs

- **Customers reputations**
  - Up of availability and quality
MAINTENANCE REALITY PROCESS

TODAY’S MAINTENANCE PROCESS IS 100% PREVENTIVE AND CAN BE IMPROVED.

Preventive Maintenance
- Delivery
- Inspection 1
- ...
- Inspection i
- ...
- Inspection n
- Decommission

Visit i
- Preparation
- Task 1
- ...
- Task i
- ...
- Task n
- Exit checking

Task i
- Check
- OK?
- Repair
- End

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- TUESDAY, JUNE 19, 2018
HOW TO OPTIMIZE MAINTENANCE PROCESS WHEN MAINTENANCE IS BASED ON TASK

Task i

Check

OK ?

Repair

End

Is it possible to perform this check with real time monitoring

Yes

Predictive maintenance

No

Scheduled maintenance

Optimization by CBM

Optimization by RCM

Optimized Maintenance

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02. DEFINITION OF CBM

+ MAINTENANCE OPTIMIZATION PROCESS WITH CBM
+ CBM SYSTEM
+ CBM DATA WORKFLOW
+ CBM DETAILED ARCHITECTURE
MAINTENANCE OPTIMIZATION WITH CBM

CBM SYSTEM GIVE ORDERS TO MAINTENANCE CENTER. THIS ORDER MUST BE INTEGRATED IN THE MAINTENANCE WORKFLOW PROCESS.

In rolling stock railway maintenance, it is almost impossible to completely replace a preventive inspection by a predictive maintenance inspection.

To overcome this issue, predictive maintenance is integrated to preventive and corrective maintenance workflow process.

Diagram:
- **Predictive maintenance process**
  - Real time monitoring
  - CBM
  - Repair order
  - Maintenance order

- **Preventive maintenance process**
  - Preventive scheduled
  - Preventive inspection

- **Corrective maintenance process**
  - Corrective scheduled
  - Repair

- Operation return
CBM SYSTEM

CBM system is a software tool created to organize predictive maintenance task. It is composed by several function:

- Gather data from on board train systems and sub-systems
- Order and link data from studied systems
- Analyze data
- Translate data from analyzed data to obtain maintenance orders
- Display results in industrial tools
CBM DATA WORKFLOW

AN ARCHITECTURE SPLITED IN 7 LAYERS

1. Import
   - Sensor data
   - Data files
   - External database

2. Data mining
   - Preprocessing
     - Decoding
     - Noise removing
     - Filtering
     - Sampling
   - Indicator data fusion
     - Performance indicator
     - Diagnosis indicator
     - Failure indicator

3. Storage

4. Indicator Analyse
   - Time based analysis
   - Distribution analysis

5. Prognostic
   - Knowledge based prognosis
   - Physical rules engine
   - Rules engine

6. Decision support
   - Maintenance orders
   - Health monitoring
   - Rolling stock monitoring

7. Presentation
   - Web interface
   - CMMS

MATLAB and Compiler SDK TBX

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**CBM – DATA IMPORT**

**DATA IMPORT VS ROLLING STOCK TYPE**

**Connected train (native sensors and network)**

- **RER-NG**
  - Native data file:
    - Sub system data file
    - Passengers access
    - HVAC
    - Train data file

- **R2N**
- **NAT**

**Data type:**

- Boolean data
- Analog data
- Context data
- Maintenance and operation data

**Additional sensors:**

- IoT
- Data acquisition card

**Unconnected train (integrate sensors and network)**

- **TGV**
- **Z2N**

**Transmission type:**

- Volumetry

**CBM off-board server**

**Wired data**
CBM – DATA PREPROCESSING
IMPORTATION, CLASSIFICATION, DECODING, FILTERING AND RE-SAMPLING

Off-board server

Import:
- FTP
- Web Service
- API

Decode:
- Context data
- Boolean data
- Analog data

Preprocessing:
- Cycles identification
- Invalid cycle filtering system

Data Cleaning:
- Noise removing
- Re-sampling

Order:
- Train type 1
  - System 1
  - System n
- Train type n

MATLAB and Parallel Computing TBX

CBM server

MATLAB and Statistics & Machine Learning TBX
Battery current intensity (2 hours)

Cycle 1
Too short

Cycle 2
Cycle 3
Expansible cycle

discharge
charge in floating mode
charge in boost mode
CBM – DATA PROCESSING
FROM TRAIN SIGNAL TO INDICATORS DATA

Clean data → « Low level » indicator → Σ → Performance indicators → Indicator DBSM recording

MATLAB, Statistics and Machine Learning TBX + Database TBX
Indicator definition:
An indicator is a “simple” calculated value extracted from a time data sensor.

Example:

Indicator 1: Current discharge quantity
Coding: current discharge area

Indicator 2: Current charge quantity in boost mode
Coding: current charge area

Performance indicator: discharge/charge ratio

MATLAB, Statistics and Machine Learning TBX + Database TBX

CBM Server

SGBD Recording

CBM – INDICATORS PROCESSING EXAMPLE

INDICATOR CREATION FOR BATTERY SYSTEM

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CBM – MAINTENANCE DATA PROCESSING
FROM INDICATORS DATA TO MAINTENANCE DATA

Prognostic:
• Expert system
• Machine learning

Criticism estimator system

MATLAB, Statistics and Machine Learning TBX + Database TBX

Use of Predictive Maintenance TBX in study
CBM – PROGNOSTIC

INDICATOR ANALYSIS (TIME AND DISTRIBUTION)

Time analysis: how evolve an indicator during time

Distribution analysis: how indicator values are distributed among rolling stock fleet

CBM Server

Time analysis:
- Indicators value
- Optimum
- Average
- Abnormal behavior

Distribution analysis:
- Indicators value
- Fleet indicators distribution
- Optimum
- Average
- Abnormal behavior
CBM – VISUALIZATION
FROM MAINTENANCE DATA TO MAINTENANCE ORDERS GMAO SYSTEM

Visualization of maintenance orders and maintenance data in maintenance factory

CBM server

Maintenance DBSM

Train criticism estimator

TM
STF
CBM – VISUALIZATION TOOLS

VISUALIZATION TOOLS FOR CONDITION-BASED MAINTENANCE
## CBM – VISUALIZATION TOOLS

**VISUALIZATION TOOLS FOR CONDITION BASED MAINTENANCE**

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### Operation Tracabilité CBM MIT 12/13/14/15 Porte sur rame 13H 50025

Tracabilité éditée le 2018-03-30 08:29:55

---

#### Communication train

---

#### Tâches validées par CBM

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<th>V2 501025</th>
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## CBM – VISUALIZATION TOOLS

### VISUALIZATION TOOLS FOR CONDITION BASED MAINTENANCE

### Accès voyageurs

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### DCU

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05. USE CASES

+ ALL OUR USE CASES
+ DOORS USE CASE
+ HVAC USE CASE
+ PANTOGRAPH USE CASE
ALL OUR USE CASES

FEW EXAMPLES OF OUR USE CASES

Compressor
Performance

Battery
Capacity ratio

Pantograph
Taring and up/down time

HVAC
Performance

Doors and Steps
Performance and adjustment

Traction
Engine performance

Brake
Brake performance

Toilette
Reservoir levels
DOORS USE CASE

Problem with the door seal

Current (A)

Deviation

Time (CS)

Temps (cs)

Current

Problem with the door seal

CBM server
HVAC USE CASE

Temperature (°C)

Time (CS)

CLOUD

CBM server
06. CONCLUSION

+ OUR LIFE CYCLE
+ OUR PRODUCT
CONCLUSION : OUR LIFE CYCLE

TRANSMISSION PROTOCOL

SERVERS

ANALYZE
(data scientist + train expert)

VISUALIZATION TOOLS

DATA

DATA PROCESSING

GMAO

4G

Maintenance process

Without a single step, our maintenance is not optimized

Connected train

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– TUESDAY, JUNE 19, 2018
CONCLUSION : OUR PRODUCT

A SOLUTION IN ADEQUACY WITH ROLLING STOCK FLEET CONSTRAINTS

A new maintenance process, centered on data

Our solution is a complete turnkey for SNCF. It optimizes the whole maintenance process without breaking the existent process. Our product use native train sensors when it’s possible and replace already existing maintenance task.

Data analysis
Understand and process data from train

Scheduling helper
Give information based on data to schedule maintenance center operation.

Native connected rolling stock fleet
All train with on board / off board communication systems and sensors

Maintenance helper
Give tool to optimize maintenance process
CONCLUSION : PROSPECTS
MAINTENANCE 4.0 FROM CBM TO THE WHOLE MAINTENANCE PROCESS CENTERED ON DATA

New train
Standardize and expand our CBM system to all rolling stock

Connect resources
Connect stock availability maintenance order and human resources to find the best possible maintenance order

Connect schedule
Use operational data to optimize the callback of rolling stock in maintenance center accordingly with connected resources

Technology
Always move forward with new tech BigData, AI, new algorithm...

Industrialize
Even if our system is in production we have to study how to grow our tech to absorb and compute always more data

Reactive Maintenance
Speed up (real-time data) data process to optimize reactive maintenance