TagItSmart
Smart tags driven service platform for enabling ecosystems of connected objects

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DuraTag
D3 Trial execution and validation report

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Extension title:	**Durability Tag Pilot for Work Conditions Assessment of Heavy Duty Mechanical Parts in Machinery Industry**
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Introduction

In this document, results from the executed trial and evaluation are provided. Beta testing is first done separately for the different components, e.g. SmartTags are first encoded without the sensors, with the replica looking as the sensor, and tested in lab conditions before the execution of the actual trial in the field. The outcomes of the beta testing of the platform was used to employ corrective measures and to apply modifications of particular modules that was not working as specified. Finally, the trial was executed with company BankPro as actor, which provided their human resources and their machines during different operations and platform processes.

The field trial was executed during first 2 weeks of December 2018 and included testing at 2 different sites:

- Belgrade Waste Processing Plant in Vinča (03.12.2018. – 14.12.2018.)
- BankPro Factory in Kraljevo (10.12.2018. – 14.12.2018.)

The number of involved users was 5 during this 2-weeks trial, including 2 full-time operators working on the waste briquetting machines, with total number of 31 deployed tags on 21 independent machine parts. Platform was validated using processes and KPIs identified in WP1, conforming to end user requirements and platform functionalities.

Section 1 - Platform evaluation

Monitoring of overheating process was done on 21 elements and total 31 tags were deployed. First day of testing on both pilot locations (Belgrade and Kraljevo), machine elements were identified by BankPro and Belgrade Waste Plant staff and the area was prepared for the DuraTag team members to tag the parts and initialize the machine parts within the DuraTag platform. In Kraljevo, some machines needed to be opened in partial, to be able to place the tags on the critical parts.

On the first day of field testing, scanning was evaluated on different mobile devices collecting significant number of logs of the machine elements. Each function was iteratively tested, step by step on every device, and by different user profiles. Trial was following user stories described in D1 deliverable. Administrator of the platform was first creating users with "company" permissions. User with this permission then created machine operator accounts with credentials for using the FC-scanner. Personel involved in the trial were 5 people, out of which 3 were formally trained to use the FC-scanner.

After the initialization of the machines, further evaluation was done following user stories:

1. Machine operator (company) was scanning all deployed tags in the morning and in the afternoon, at the beginning and at the end of work hours, respectively. Working shifts at location in Vinča were 06:00 – 14:00 and at location in Kraljevo 08:00 – 16:00, as regulated by the facilitator (company). Machine operator was in charge for scanning tags every work day, excluding weekend, following this agreed scenario.
2. Additional validation was done by DuraTag team which was also scanning the tags and checking statuses in some random periods of time, checking the overall set of functionalities of the platform, mobile applications and web services.
3. BankPro (stakeholder) was involved in monitoring the status of the machine remotely over the platform, as well as on the field, being present on the initial tags deployment and at the formal end of the trial testing. BankPro was also controlling logs being transferred into statistics about machine usage, for both operators working habits as well as general machine operations.
4. The only missing user profile was service inspection. For the purpose of the trial, this role was covered by DuraTag team, being present at both locations and replacing activated tags.

BankPro as a producer of the machines, was deciding about tagging the crucial machine parts (electric motors – AC motors, bearings and geared motors). The first initial scan of the each tag via mobile application was done to pair the machine part with its belonging QR code. When the machine operator (company) scanned the QR code, they were actually activating the tracking of the machine status, logging data which is used to build the product passport together with the manual feedback, logs of overheating and general usage. Operation of the machine is tracked with the manual scanning using version of adapted FC-scanner.

User stories

1. Admin – master administrator who has all permissions and control over every part and entity in system.
2. Stakeholder – machine manufacturer.

- Admin – purpose of this role is to manage stakeholder operators, machines and product passports.
- Operator – purpose of this role is to register previously added product passports by scanning them with FC-scanner.

3. Company – end user of the machines and product passports.
   - Admin – purpose of this role is to manage company operators.
   - Operator – purpose of this role is to scan tags in order to keep track and log product passport lifespan.

1.1 FC-scanner evaluation

For the evaluation, two FC-scanner modules was used, adapted from the original TagItSmart module, one deployed for the automatical scanning and the second one used by end users. The automatic camera module feasibility was evaluated by scanning the tags from distance to 10cm and it showed good results. The main drawback was the inability to use the camera without additional flashlight and lack of user friendly setup – one tag required one camera. Nevertheless, during the field testing the smart tags needed to be placed inside of the machine, within very dirty, moist and rigid environment, including some dangerous rotational parts, so the camera approach would never be possible. With deployed camera and light, tags were read normally and there were no deviations in laboratory conditions.

The manual scanning was used to generate information for the product passport and we succeeded to extract data about when the machine is being used and for how many working hours, as well as to provide additional services, such as shift monitoring for the workers, etc.

The modified FC-scanner module was tested with SmartTags in different conditions outside and inside, where temperature ranges were spanning between 0-20 degrees. This module usability was evaluated on different mobile phones, where we have notices only slight deviation in scanning time, depending on the hardware computational power, but the accuracy was 100%.

1.2 SmartTags evaluation

Requirements for the SmartTags in this use case and depicted sensors were not as specified originally. After feedback from VTT that the highest possible temperature **for reversible inks is 65°C** as reversible pigments do not survive high temperatures, we decided to order 90°C irreversible tags, as they were only available at the moment. Accordingly, we have used SmartTags with these features in the pilot project to signal if overheating of the certain element has occurred.

SmartTags feature set:

- The physical dimensions of the QR code was 24x24 millimeters, the overall dimension of the tag with the reactive bar above the QR code was 30x30 millimeters.
- The physical dimensions of the reactive bar printed with thermochromic ink was 4x24 millimeters (height x width) with 2 millimeters distance from the QR code.
- Paper based label substrate was used that can survive the surface temperature of 90°C
- The magenta ink was used for the reactive bar over QR code.
- 50 QR codes with the reactive bar was produced.

Table 1 Components monitored with SmartTags

No	Component	Monitoring temperature	Tag size	Evaluation
1	Electric motors	90°C	3x3 cm	Corresponding to operational temperature of majority of elements, but not for failure overheating.
2	Geared motors	90°C	3x3 cm	Corresponding to operational temperature of majority of elements, but not for failure overheating.
3	Bearings	90°C	3x3 cm	Not appropriate for monitoring operational temperature, but useful for overheating detection.

Trial testing of the SmartTags was intentionally done on 2 very different sites and on variety of different machines, to cover the widest possible range of applications for this specific use case. Testing site in Vinča considered the relatively new machinery installation, that has not been in use for substantial time for the parts to deteriorate. In addition, the installation in Vinča is outside and heavily exposed to weather conditions and affected by outside temperature. Testing site in Kraljevo included machines that are in use for several decades, being also of very different type, intended for metal processing with rotational elements that involves much friction. Factory in Kraljevo is within industrial facility, so machines are places inside and are not affected by weather conditions.

Considering the usage of 90°C tags on electric motors and geared motors, it has proven to be useful for monitoring operational temperature of those elements, since in practice it is around 95°C so we have had activated tags on those elements. On location in Vinča, only one motor has been reaching the threshold to activate the tag, due to the fact that all monitored elements were outside and affected by low winter temperatures, so probably weather acted as natural cooling force for all motors involved in the testing. In contrary, on location in Kraljevo, all monitored motors were triggering the SmartTags, as motors were regularly reaching their operational temperatures which is substantial for activating the tags, especially after several hours of exploitation during work shifts. On the other side, the usage of 90°C tags for the purpose of overheating detections is not appropriate, since the declared temperature for overheating of motors is 120°C.

Bearings overheating can be monitored with 90°C tags, actually providing even more stern condition, thus predicting the total failure of the element that happens on higher temperature ranges (110-120°C). Considering the operational temperature of bearings it is lower than 80°C in practice, so during the trial testing we haven't had any positive activation of bearings tags on either location. Every tag deployed on bearings remained in the initial state, witnessing the stable condition of all monitored machines and serving as confirmation for good and timely maintenance.

Figure 2 depicts SmartTag final design as provided, showing one of the tags that reacted during the trial testing. SmartTags magenta color line was appearing if thermochromic ink reach threshold higher then predefined (90°C). Size of the tags that were used to label mechanical parts was just 3x3 cm, but it did not influence accuracy of the scanning.

Figure 1 DuraTag SmartTag [activated]

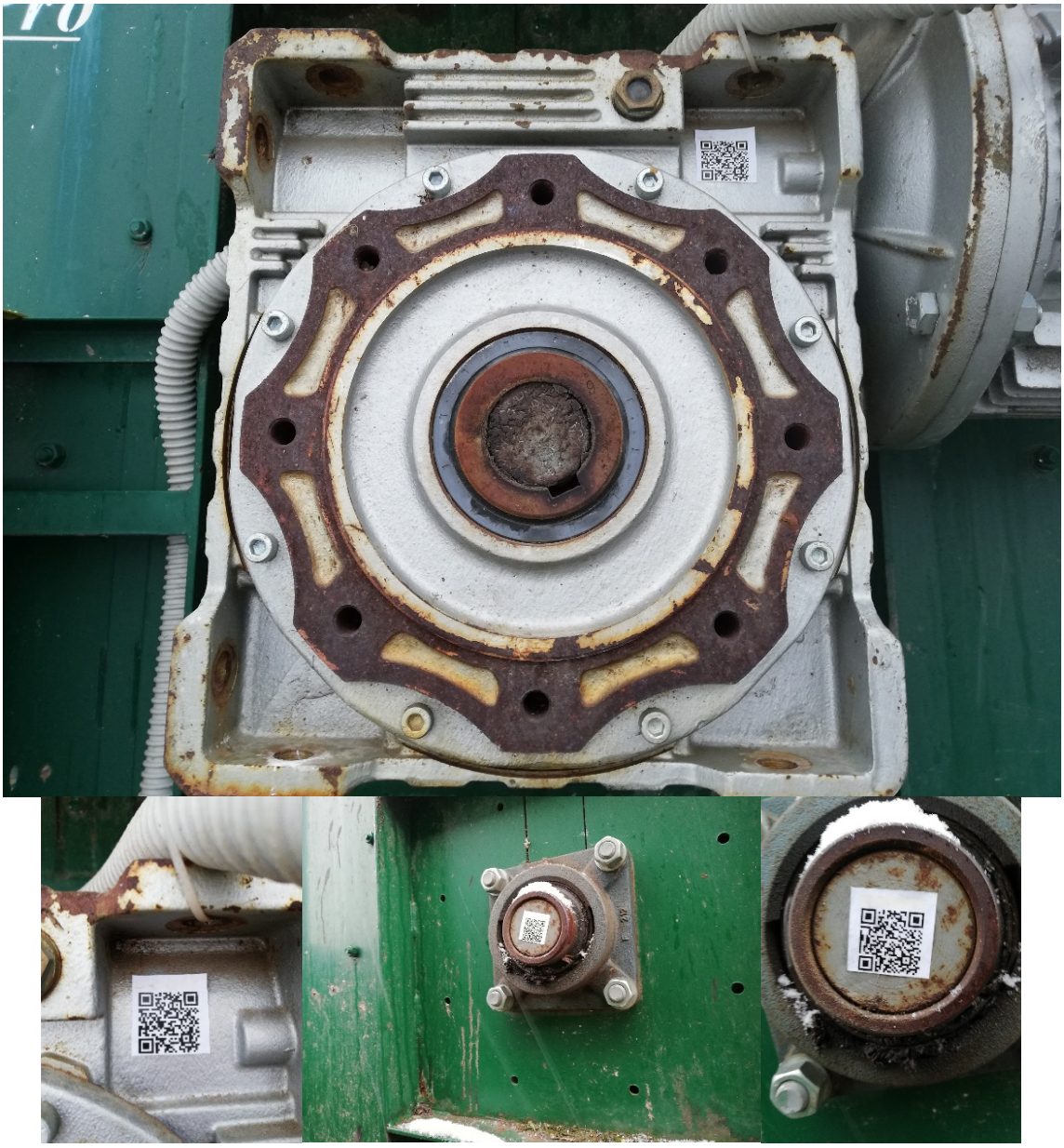
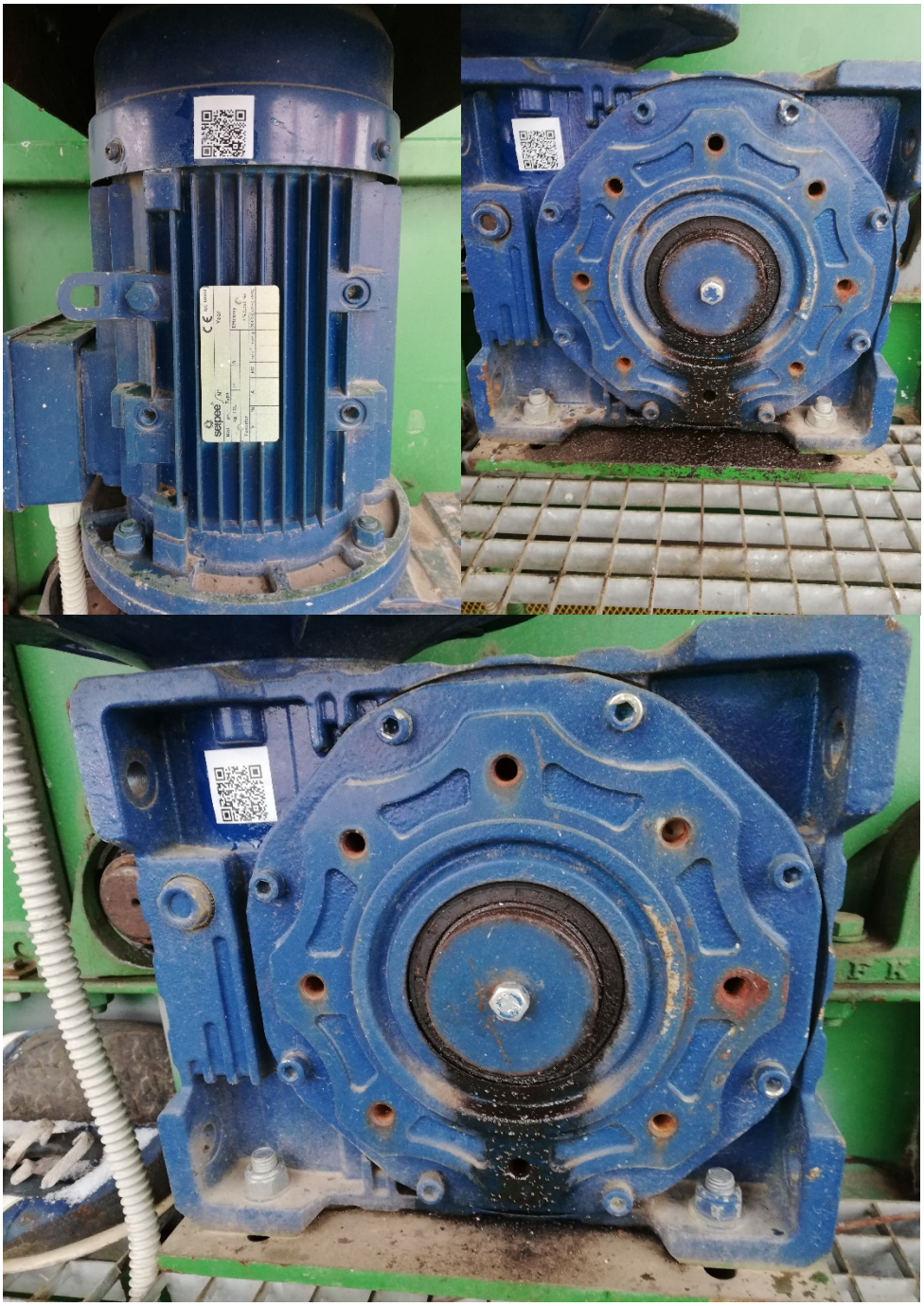
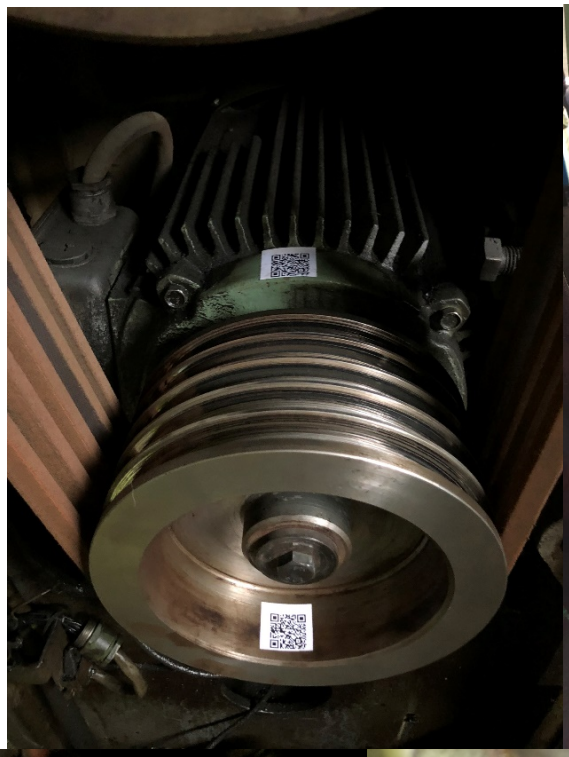
Section 2 - Key Performance Indicators (KPIs)

The previously identified KPIs were completely satisfied during the trial execution with all predefined numbers met, as presented in the table:

KPI	Target value	Achived value	Comment
SmartTags data feedback	>= 100	>750	More then 750 logs from SmartTags made by 5 different users in the system.
Product Passports	2	21	Marketplace is developed with 21 product passports. 5 machines for waste processing and 5 machines for metal processing were included in the trial.

Section 3 - Results / Conclusions

The results of the trial shows that tags can be efficiently used for such use case were it is necessearry to monitor temperature above 90°C. The drawback was inability to have reversible thermochromic tags for temperatures higher then 65°C as they cannot be manufactured; making it difficult to implement full spectrum of envisioned features. Anyway, the forseen functionalities performed very well and the logged utilization of the machines and its parts was adopted in this iteration by the stakeholders. Automatic scanning of the tags with camera was not user friendly, it was working only for short distances, meaning one camera per tag and in some situations it requires manual light installation to ensure that scanning is efficiently done within closed machines and dark areas. Marketplace can be used by different stakeholders to search and preview parts of the machine and the machine product passport on the platform.

Section 4 - Annex

BankPro