Technical solution of the under locomotives visual inspection system

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Abstract. In recent years, liberalisation of rail cargo operators market brought to the position of a number of small rail operators that are operating on rail infrastructure. Most of them are relatively small with specific cargo transport products, limited number of locomotives and wagons and with limited service resources. Independently of the cargo operator size, they are also obligated to have regular inspections according to the railway regulations. Inspections are frequent and in normal cases they need special depot with inspection pit that small operators do not possess. In the paper are given technical solutions that can be found in the market as well as developed and proposed equipment solution with different concepts for the under locomotives visual inspection without using inspection pit. In the paper is also carried out evaluation and choice of proposed solutions as part of regular product development process.

1. Introduction

Product development implies the whole process from the idea to the launch of the product on the market. It consists of number of steps.

In reality, product development depends from an investor while investor is defining starting and final point in the process of product development. Important steps in product development process are generating idea, developing concepts and their evaluation, development in details and manufacturing of prototype. Product development engineer has to follow these steps in order to solve task without losing possible partial solution or basic principle some into final solution [1].

Private rail cargo operators are operating in the market but they have limited inspection capacities. Independently of the cargo operator size, they are obligated to have regular inspections according to the railways regulations. Inspections are frequent and in normal cases they need special depot with inspection pit that small operators do not possess.

In the paper are given technical solutions that can be found in the market as well as developed and proposed equipment solution with different concepts for the under locomotives visual inspection without using inspection pit. In the paper is also carried out evaluation and choice of proposed solutions as part of regular product development process.

2. Product development task

According to railway regulations, railway vehicles, primarily locomotives, should be inspected relatively frequently, and inspections differ from those in which the visual inspection is sufficient to those for which it is necessary to measure something or open a part of the vehicle [2, 3, 4, 5].
Level of inspections depends from locomotive series and time or passed miles. Railway regulations prescribe “service inspections”, P0, P1, P3, P6 and P12. Service inspection has to be done ones a week and others depending from series:

- P0 - 5000 - 7500 km
- P1 - 10000 - 15000 km
- P3 - 30000 - 45000 km
- P6 - 60000 - 90000 km
- P12 - 120000 - 180000 km

Smaller inspections like “service inspection” of electric locomotives includes:

- Visual control (from inspection pit and exterior) of boxes and equipment on it
- Visual inspection of handrails, axle assemblies, wheel rims, traction motor, primary and secondary suspension, winding springs and hydraulic shock absorbers.

Based on the described list of inspections, visual inspection from the pit, ie, the bottom view prescribes that an overview is performed:

- Wheelsets
- Traction motors
- Transverse coupling
- Nuts and bolts of transverse coupling
- Brake rigging
- Brake cylinders and
- Brake rigging regulator

![Figure 1. Visual inspection of rail vehicle in the pit by rail inspector.](image)

Normally, this overview is done from a pit by a rail inspector (Figure 1) who uses a hand lamp for lighting. However, very often a workshop (depot) equipped with a pit is distant, so it is advisable that the check is carried out on the ground, ie, on a secondary or industrial track. In order to visualize the vehicle from the bottom of the pit without a pit, a request was made to develop a visual control system that should be placed at the level of the thresholds between the rails and to allow the overview of the vehicle's running gear while the vehicle is standing or moving at a low speed (up to 5 km/h).

On the basis of the requirements set out by inspections regulations and the assessment of the potential positions of the camera from which the visual control of the partial (individual) parts of the
running gear, in the Figure 1, a motion is proposed to position the camera in order to perform visual control of the locomotive.

Within the framework of visual inspection of the craft stand, as part of the service inspection, it is necessary to carry out the inspection and pay attention to the following:

• Wheelsets (see if there are any damage / drawings on the axles, wheels, wheel bars, gearboxes, and whether there is a leak from the gear unit)
• Traction motors (see if there are damage to the traction motor trains, coupling elements, gearbox, traction motor)
• Transverse coupling (see if there are damage to the transverse coupling, whether there are screws and nuts of the transverse coupling, see if there is damage / crack on the frame of bogey)
• Brake rigging (see if there are damage on three-way lever, brake controls, brake lugs-screw connections)
• Brake cylinders (see if there is damage to the brake cylinders and on the piston and brake links)

3. Existing and possible solutions on the market

In order to develop the appropriate system for visual inspection of the railway vehicle from the bottom on a track without inspection pit, research of technical solutions has been carried out, which can be applied with specific requirements on the railway.

By examining visual control in various areas of the technique, especially for parts that are less accessible, the following conceptual technical solutions that could (partially or completely) have been observed, will be applied in the conditions that we have explored:

• Manually operated inspection camera
• Under vehicle inspection system (UVIS)
• Industrial camera for inspection and mapping of pipes

3.1. Manually operated inspection camera

Figure 2 shows a hand-held inspection camera for inspecting road vehicles from the bottom that consists of a camera, which is fixed to a special holder, and a monitor.

![Parking Security Undercarriage Inspection Camera SA920](image)

Solutions like this are widely used in inspections of cars and trucks on the borders or security points. It is easy to use and it needs flat surface.

3.2. Under vehicle inspection system (UVIS)

Under vehicle inspection system is a system used to inspect primarily road vehicles from below.

Figure 3 shows the under vehicle inspection system that is used to inspect the road vehicles from below (without the inspection pit). There are a number of producers for this solution that can be made to be fix in the ground or mobile so that can be easily moved from one place to another. It consist mostly with at least two cameras that are creating one picture. Pictures generated by cameras are
processed by software and they are generating one picture from more pictures. Mostly these cameras are linear and they make it possible to create as long picture as the vehicle is long.

**Figure 3.** Visual inspection system for road vehicles [Westminster International Ltd].

Figure 4 represents one picture made by this system. It is a single picture that contain whole undercarriage of vehicle.

**Figure 4.** Picture made by visual inspection system for road vehicles.

Company Westminster International made UVIS system for railway vehicles (Fig. 5). Device with cameras has to be put between rail trucks and visual inspection is carried out when train goes over the device. System is mobile with two cameras and it can make inspection possible when train is running up to 40 km/h.

**Figure 5.** System UVIS for rail vehicles [Westminster International Ltd].
Figure 6 represents pictures made by such a system. It is a single picture that contain whole undercarriage of vehicle.

![Figure 6](image)

**Figure 6.** Picture of railway vehicle made by UVIS.

### 3.3. Industrial camera for inspection and mapping of pipes

In different areas, robots are often used to view hidden ones, hardly accessible spaces / parts. Figure 7 show examples of such robots. They are connected to the operator by wire and they are create to explore space up to 200 meters.

![Figure 7](image)

**Figure 7.** Robot for visual inspection.

### 4. Development of possible solutions - concepts

The conceptual solutions of the system are elaborated on the basis of two initial conditions:
- The system is mobile (mobile) and the locomotive is static (without moving) or vice versa
- At the location where the visual control is carried out, it is possible to set the appropriate surface

Four conceptual technical solutions have been developed in total:
- „Rod“
- „Tray“
- „Runway“
- „Trolley“

#### 4.1. „Rod“

The technical solution "rod" is based on similar products used for inspection and control of passenger vehicles and trucks at border crossings, where the solution is adapted to the needs of inspection of railway vehicles and on-line inspections. The transverse and longitudinal movement, reliance on a single line around which the rod can be rotated, and all manipulation possible by one operator, is
designed. The power supply of the camera can be solved through a separate power supply, and a laptop can be viewed by another operator.

**Figure 8.** Concept of technical solution „rod“.

Advantages:
- Low price
- Solution for which no additional installation of the structure and laying of the substrate is required
- Easily portable from vehicle to vehicle
- Low weight
- Quick setup

Disadvantages:
- Large operator manipulation is required
- Danger of damage to the camera
- Limited autonomy in work

**Figure 9.** Concept of technical solution „tray“.
4.2. "Tray"
Technical solution "tray" is an improved technical solution "rod" based on the installation of the entire device on the rails. Transverse and longitudinal movement is accomplished manually by one operator and the movement of the device is much easier than compared to the "rod". Longitudinal movement is achieved through the bearings, which greatly facilitates and accelerates the manipulation, and a special leverage would be the launch of cameras inside the device.

Advantages:
• A solution that does not require additional laying of the structure and handling of the surface
• Increased reliability and speed of longitudinal and transverse movement

Disadvantages:
• Great operator manipulation
• It takes more time to set up and more time to transfer the system between the rails
• Greater mass in relation to the "rod"

4.3. "Runway"
The technical solution of the "runway" is designed as a solution in which it is possible to easily position the camera to the desired location below the locomotive. For this purpose, a frame was constructed that would be placed between the rails and would be placed on the surface. The frame is projected at 3.6 meters which is limited by individual construction elements and 18 meters as estimated length is needed to suddenly perform visual control of the whole locomotive.

- Runway 3.6
Longitudinal and transverse suspension, guidance and drive system of the camera at a length of 3.6 m with automated visual control system; The locomotive need to be moved 5 times for complete visual control.

- Runway 18
Longitudinal and transverse suspension, guidance and drive system of the camera at a length of 18 meters with an automated visual control system (without movement of the locomotive).

![Figure 10. Concept of technical solution „runway“](image)
Advantages:
• Solution for which no additional installation of the structure and laying of the surface is required
• Increased reliability and speed of longitudinal and sub-movements (possibility of automation of transverse motion)

Disadvantages:
• Complex construction - complete assembly of parts, it is necessary to foresee the possibility of permanent construction of the structure
• A lot of work and time spent before the start of the inspection - the total inspection time is extended

4.4. "Trolley"
The technical solution of the "trolley" is designed as a solution where the camera with the device would move on the profiles back and forth and thus allow for longitudinal movement, and for the transverse movement on the device there are motors that allow the remote control to position the camera to the desired place. For this solution it is necessary to mount the path, ie. profiles (pipes) before inspection and it would be designed to quickly mount two tracks.

![Concept of technical solution „trolley“](image)

Figure 11. Concept of technical solution „trolley“.

Advantages:
• Full automation and ease of operation, the operator is completely free to focus on the inspection

Disadvantages:
• It is necessary to mount the profile, which increases the time of preparation of the inspection

5. Evaluation
Evaluation of the concepts has been done according to following criteria:
• Price – this is the most important factor for investor
• User friendliness. It is also important since the operators of this device can be people that has low education and awareness.
• Degree of automatization. It is important since higher degree of automatization will make whole inspection process easier.
• Inspection speed. It is important that the inspection is going to be done in some normal period.
• Mass. This should be more movable device and lower mass makes the whole process easier.
Weight coefficients are chosen in agreement with investor and experts in field of railway vehicles inspection.

**Table 1.** Evaluation according to criteria and weight coefficient.

| Criteria                  | weight coefficient | Rod | Tray | Runway 3.6 | Runway 18 | Trolley |
|---------------------------|--------------------|-----|------|------------|-----------|---------|
| Price                     | 0.4                | 10  | 8    | 3          | 1         | 6       |
| User-friendliness         | 0.3                | 4   | 5    | 2          | 3         | 9       |
| Degree of automatization  | 0.1                | 1   | 6    | 7          | 10        | 8       |
| Inspection speed          | 0.1                | 2   | 7    | 6          | 10        | 8       |
| Mass                      | 0.1                | 9   | 6    | 4          | 3         | 6       |
| Sum                       | 1                  | 6.4 | 6.6  | 3.5        | 3.6       | 7.3     |

According to Table 1, the best grade has concept Trolley. The lowest grades have concepts Runway due to their price. Concepts Rod and Tray are having a little lower Sum of grades than Trolley.

6. **Conclusion**

In the paper is shown case study of product development for under rail vehicle visual inspection system. For the development of under rail vehicle visual inspection system are presented steps of idea generation, concept development and evaluation.

First step in cases like this is to define product profile and to generate ideas. Product profile is given by investor. In the paper are presented three products that can be found on the market and they are solving similar problems which basic idea could be use in case of under rail vehicle visual inspection system. Basic ideas are generated on the base of existing products as well as authors give their own concepts for this specific problem. In the case of under rail vehicle inspection system are developed four different concepts and for every case are given advantages and disadvantages.

On the end is carried out evaluation which gives conclusion which concept has to be further developed in detail and manufactured.

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