Digital model and training simulator charging crane Tata Steel IJmuiden.

Dennis Berkvens, Cees Brockhus, Sander Willemsen, Hans Pronk

BOS plant , Tata Steel Nederlands, Wenckebachstraat 1, 1951 JZ Velsen-Noord, Nederlands

Corresponding author

Hans Pronk

Tel: +31-(0)610880934

Email: hans.pronk@tatasteeleurope.com

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Summery:

The automation of processes in steel production is difficult and risky because of the high potential risks if programming errors are made. In order to ensure safe and stable automation, time-consuming testing of the equipment/machines involved is required.

In the case of automation on production-critical equipment, the testing time results in loss of production. In Tata Steel Ijmuiden BOS plant, the central charging crane for hot metal or scrap is the most production critical compared to other cranes, so we decided to build a digital model of this crane to speed up the automation.

This digital model behaves like the real crane and is connected to a backup PLC of the crane with the same software as in the real crane. With this digital model, we can test new software in a 3D environment before implementing it on the real crane. The automation of these cranes can be accelerated without loss of production.

Figure 1 - loading hot metal in converter

Automation and operator skills are linked.
If the automation task stops due to an abnormality, the operator needs the skills to continue the task manually. For simple tasks this isn't a problem, but for complex tasks such as loading hot metal into a vessel without creating fumes or spilling hot metal, it is a difficult task.

Another problem is getting operators to work in a steel plant and training them on the job with a mentor.

The work done to create a digital model for software development and testing is the basis for the next step, a charging crane simulator for operator training.

A simulator is already in operation at Tata Steel Port Talbot and other steelworks (non-Tata) have also started using Steel Sim VR to train crane operators.

Keywords: Steel plant, charging crane, Digital twin, digital model, training simulator, crane automation.

1. Introduction:

The steel industry is not the best in class when it comes to automation, it is a traditional heavy industry with enormous weights and high temperatures. A high-risk area with many skilled operators to keep the steel flowing. The presence of skilled operators is not so normal anymore, for safety reasons you want to minimize the presence of people in risky areas. Steel making is not so sexy anymore for young people to start their career there and stay in the job for decades.

So automation in the steel industry is the key to survival in terms of safety, process control and operator availability. The first steps were taken a long time ago, where simple processes were automated, such as water treatment stations, flux filling from the train to the bins, and linking level 1 and 2 systems so that models feed the PLC to avoid manual input and possible errors.

These days the more complex processes are under construction for further automation such as

- Hot metal pouring from torpedo to ladle.
- LD vessel operations such as charging, blowing, tapping, refractory maintenance , etc.
- Casting such as start and stop casting, flying tundish, etc.
- Crane movements such as Go-To, hot metal charging and ladle on turret.

These incremental improvements require a lot of dry testing and reprogramming on vessels, cranes and casters to gain confidence to go live. These dry test periods on bottleneck equipment such as vessels and some cranes have an impact on production and are not easy to schedule, slowing down the automation process.

2. Starting with a crane simulator at Port Talbot:

Tata Steel's Port Talbot steelworks used a Steel Sim VR simulator to train crane operators on a new charging crane. This new charging crane was to be installed a year after the simulator was introduced to train the operators on the new controls and behavior of the newly built modern crane. The simulator was built with an original crane chair and a dummy crane cabin with multiple LCD screens. The experiences with this simulator were positive and it really helped them to avoid problems during the startup of this new crane related operator skills.

Figure 2 - Training simulator Port Talbot

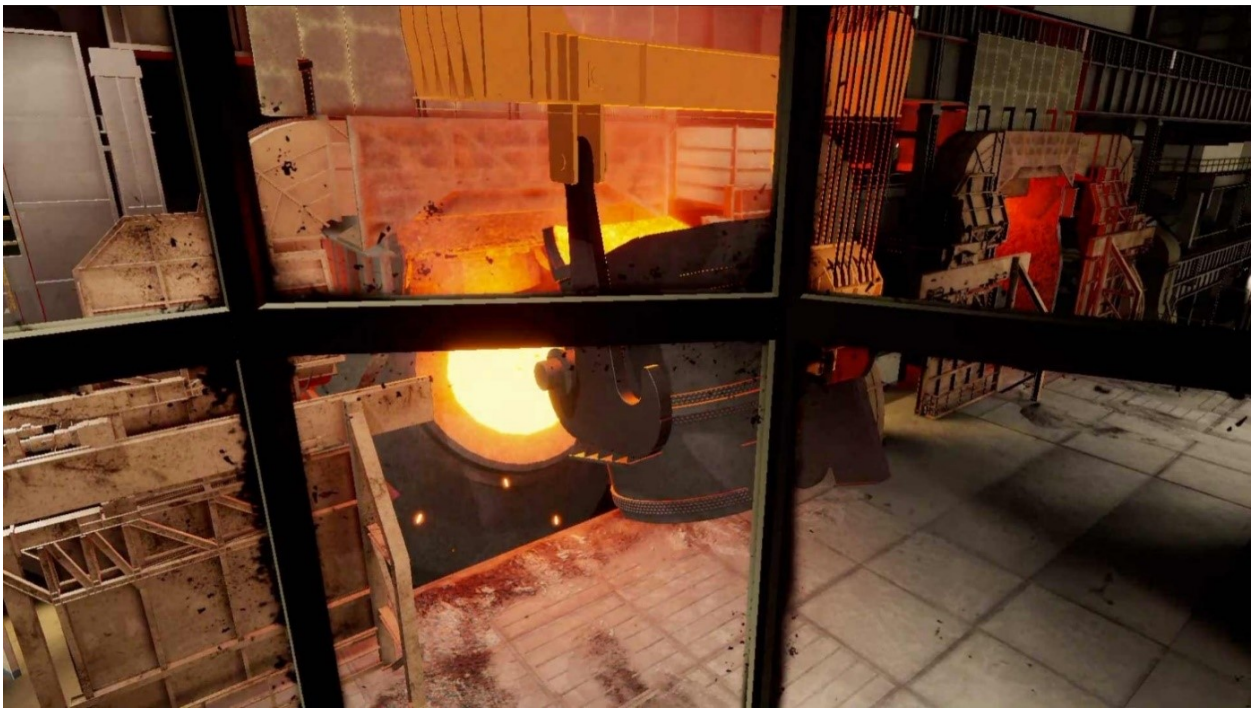

Figure 3 – Operator view simulator Port Talbot.

3. Can a training simulator be useful in our case ?

In IJmuiden we started discussing how a training simulator like Port Talbot could help us train new operators. During this discussion we came up with the idea of having a similar 3D environment for testing software, and the work done for this project could later be used for a simulator.

We discussed this idea with Steel Sim VR and came to the conclusion that Controllab Products BV was the best place to start this development.

This company does all the programming of the natural behavior and the exact simulation of the technical behavior of the equipment for the simulations of Steel Sim VR.

The second step was to select a crane to copy into a digital model. We decided to take the most critical crane we have, with the added advantage that this crane can load hot metal and scrap, so that all the handling in the loading bay can be simulated.

4. What is the best crane to start ?

In the charging bay of our 7 million tls/year steel plant we have three cranes, two for handling hot metal and one (lighter) crane for scrap handling and charging. The two hot metal cranes can also pick up scrap and load it into a vessel.

If the middle charging crane has a maintenance stop, problems or is out of production for software testing, it will also block the scrap loading crane. You end up with only one crane and production slows down to 50%.

It is also the crane that automates the most difficult handling "loading the hot metal into the vessel". This process step is extremely important in our steel plant for environmental reasons. Using Advanced Analytics on a signal from a dust collector related to process parameters, we found that the roof emission was mainly caused by

- Too fast charging of the ladle.
- Gap between hot metal ladle and ladle mouth too wide.
- Dust from the empty ladle after charging the ladle.

Because of this criticality, we have automated this task and it can now be activated by the crane operator at the push of a button. We started this automation with a fixed vessel angle, but now it is done with a tilting vessel (also automated) and wireless communication between different PLCs.

For safety reasons, this crane is also the most critical one in the steel plant, as it is in the impact zone when hot metal is poured into a vessel with more and more (possibly wet) scrap. Keeping this crane operator out of harm's way is the wish of many steelmakers, but it takes a lot of automation and new methods of machine protection to make this dream come true.

Reason enough to start with a digital model of this crane, and the lessons learned can be applied to simpler cranes.

5. Digital model the Hil Simulator:

The process between Tata and Controllab began and was divided into 3 phases:

1. Assessment.
2. Basic model.
3. Extending the model.

The start was to explore what is available, what are the connections to PLC's and other data etc. This step is needed to find out if it is possible to build a digital model and to get a feeling about the hours to spend.

After this successful assessment, Controllab started to build the basic model with an already existing 3D point cloud of the area, adding extra details for cranes, cars and ladles for a better representation and exact dimensions for this equipment.

All the weights, speeds and other physics of the crane and equipment are included in this model to have the same behavior as in reality.

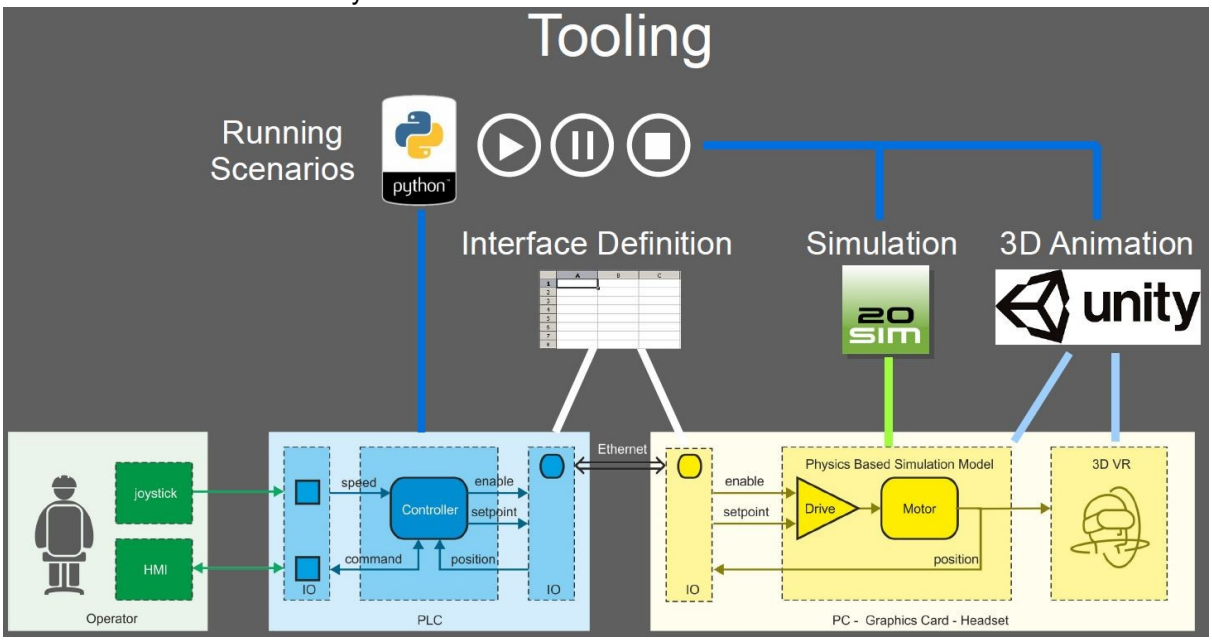

Figure 4 - schematic representation HIL-test components

As mentioned earlier, the model interacts with a real Programmable Logic Controller (PLC), comparable to the PLC of the loading crane. Data is exchanged between the PLC and the digital model (PC) via Ethernet packets containing data that conforms to a customized interface definition.

Independently of the PLC data, the model also runs user-specific scenarios created by scripting in Python. The movement of a vessel or a ladle heater are examples of such scenarios.

The PC cyclically receives consistent data and processes it with the 20-Sim modelling and simulation software. For a realistic and real-time experience, the processed data is then output with Unity.

After a successful initial basic model and testing of the software on this model, the need for expansion began to grow. Interaction with the vessel movement and the transfer cars is introduced with a status monitor.

6. The result.

The HIL simulator (digital model) is now an important tool for testing and adjusting new software. It is used not only for the medium loading crane, but also for the initial testing of new software for other cranes in this area. Instead of understanding complicated software rules and parameters, it is easy to see the result of changing a rule or parameter. New software engineers can be trained on the job and are allowed to make mistakes without serious consequences.

Difficult movements, such as loading hot metal into a vessel, were already automated but improved by using this model.

Figure 5 - HIL-test charging crane in action

7. Next step: Training simulator:

As automation progresses, it becomes difficult to keep operators skilled without practicing the most difficult movements. In our case, loading the vessel with hot metal in manual mode is the most critical. If it is done wrong, it ends with a roof emission. Incidents become rare and crane operators for live also become rare. The COVID period also had the effect that 2 people in a crane cabin for training was no longer desirable. The need to train using a Simulator began to grow. Discussions with Port Talbot and AM Gent made it clear that a simulator would be helpful. The company Steel Sim VR was approached to build a training simulator.

Instead of a real crane cabin, Steel Sim VR optimized the trainer to a fully digital one with a 3D VR headset, based on the experience gained with the Port Talbot and Arcelor Mittal simulators.

This allows easy switching between simulators because it is a fully digital environment.

The Steel sim VR platform is designed so that an operator can train completely autonomously. At Tata Steel, we have 15 scenarios that are in line with our process in the plant. These scenarios range from basic operations to emergencies such as a ladle break outs.

All data from the trainees is collected for business intelligence. The data can be used to optimize our processes and adjust training where necessary. Our expectation is for faster and safer training of our operators through the use of the simulator.

Figure 6 - Realistic graphics training simulator

8. Conclusion:

The digital model (twin) of our most critical charging crane has become an essential part of the automation of other cranes in this area or ladle cranes in other areas.

For the automation department, it makes it easier to implement and test new software and to train new automation people on the job. Operators can also test the model to find bugs before installing it on the crane itself, reducing the downtime of that crane.

The crane simulator will help to train new crane operators and existing operators to obtain their certificate. Crane operators can also be trained for emergency scenarios such as breakdowns or other disasters that Hopley will never have to deal with in real life.

The simulator is also a great way to get people excited about the job at a steelworks, during school visits or special days such as recruitment. They can virtually experience what it is like to work in a steel plant.