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# Intelligent control station for improved quality management in flat steel production ⋆

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**Abstract:** Reaching the maximum yield of produced stainless flat products is an important aim to be successful in the competitive market. This paper describes a solution to optimise the allocation of orders to coils taking into account the actual product quality as well as the quality expected by the customer. In opposite to already available solutions also the appearance of over-quality products is taken into account. Especially for high quality stainless flat products the re-allocation of over-quality products to orders with higher demands can increase the added value distinctly. Another topic is the processing of Manufacturing Specifications (MS). A concept for the digitization of usually freely formulated MS is presented as well as a systematic monitoring, if the MS are really considered by the plant operators. The shown use cases were implemented at the German sites of Outokumpu Oyj, the Finnish producer of stainless flat products sited in Espoo.



*Keywords:* decision support system, optimisation, product quality, manufacturing specifications, yield improvement, surface quality, stainless, flat products

## 1. INTRODUCTION

The European flat steel industry is being forced by its customers to enhance product quality as well as to reduce production costs. This leads to the demand to detect and react to product quality deviations as soon as possible. Therefore steel producers have to observe and grade the products along the production chain to be able to make early decisions regarding the further handling of the products according to their quality. These steps are part of the Quality Control.

Quality Control (QC) represents a huge and complex task involving fundamental concepts such as quality monitoring and defect detection and identification, process control and optimization, dynamical scheduling and production planning as well as human factors such as personnel training and continuous education. In the most advanced approaches, all these components should interact on one hand by exploiting the ever increasing amount of data that are collected in the plants, and on the other hand by keeping the human personnel "in the loop", in order to preserve, increase and possibly store the know-how on the production processes, which is one of the most important resources for every kind of industry.

To this aim, Decision Support Systems (DSS) can have a fundamental role in assisting plant operators and managers in the complex task of taking into account all the factors affecting product quality by also following the evolution of the products and the changing demands from the customers.

DSSs have been applied since some years in the steel sector. In most cases DSS are used to support operators in scheduling or production planning problems. For instance, in Fedáková and Marek (2003) a DSS called OKO is presented supporting decision making of business processes in a steel work basing on statistical system SAS.

Other publications describe applications at specific process steps, like a DSS for hot rolling mill scheduling Cowling (2003); in Gao and Tang (2008) a former manual scheduling is compared to an applied DSS for scheduling problems at a colour coating line of galvanised coils[1]. In Tang and Wang (2008) an application of DSS for production planning is described related to the problem of arranging ordered slabs to heats, and the heats to casting sequences.

More recently in Porzio et al. (2013) and Porzio et al. (2014) a DSS exploiting process modelling and multi-objective optimization techniques has been applied to off-gas management within an integrated steelwork.

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[1] A coil is a rolled-up flat steel strip


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Concerning process control the application of DSS has encountered some difficulties, due to the lack of confidence from the industrial side and the constraints imposed by real-time implementation. A first example can be found in Saxén and Sillanpää (1994) a DSS applied to the monitoring and control of steel temperature at the tundish is described.

In Jacobi et al. (2007) a DSS has been applied to an online job scheduling problem and an online planning problem concerning the ladles, while in Gao et al. (2003) a scheduling problem in slab continuous casting is solved through a multi-agent DSS. DSSs have been applied also to primary steel-making; for instance in Zhang et al. (2011) DSS architecture based on multi-role is applied to obtaining the lowest-cost optimal solution for BF ore blending.

The work developed in Jiang et al. (2010) is closely related to the application described in the present paper: the problems of monitoring dynamic quality variations, diagnosing the abnormal variations and adjusting the process quality are addressed through a DSS that exploits multi-agent system modelling. The proposed system is suitable to multi-type and small batch production enterprises, but no specific application is described.

The paper is organised as follows: The first chapter describes the background of the present work by means of the motivation and the general concept. The next chapter describes the problem definition for three of the processed use cases. In the following chapter 4 the technical solution is shown, followed by a description of the field implementation. Finally some numerical results are presented.

## 2. BACKGROUND OF THE PRESENT WORK

### 2.1 Motivations

A first relevant example of a DSS for quality control in flat steel production is provided in Holzknecht et al. (2009), where a DSS was developed and implemented to the aim of supporting the personnel through the application of quality rules. Process and quality data were gathered at all rolling and finishing mills and assigned to the coil in terms of length. A set of quality rules is defined by the quality and process engineers and is applied after each production step to the relevant process and quality data. The significant difference between such DSS and traditional systems, which are only piece oriented, is that all high resolution data like results of surface inspection systems, flatness, etc. can be handled properly and in real-time. Therefore these high resolution data can be aggregated (the kind of aggregation can be defined by the user) to transform the length-oriented data to a scalar value, on which the decision making process can work. If the rule system detects deviations from the required product quality or process conditions, the operators are alerted to the rule violation and can take the final decision about the further treatment of the product.

This system has been running for some years with good results and by allowing to gain the necessary experiences to develop a second generation DSS, the **Intelligent Control Station (ICS)**, with the following improvements compared to the previous one:

- Currently quality deviations are detected only if the product quality is worse than defined in the quality rules, but the opposite problem (i.e. the so–called **over-quality**) is not addressed. However, a product with better quality features than required represent a waste of resources, if not reallocated, as it can have a higher added value by satisfying more demanding customer specifications. Having that information available an **optimisation** for the coil allocation according to the actual product quality can be developed.
- The application and adaptation of **Manufacturing Specifications** (MS) has not yet been investigated. The manufacturing specifications of the product have to be compared to the process parameters that are actually applied and the quality of the produced material must also be evaluated, in order to draw conclusions on a possible adaptation of the manufacturing specifications for this product. Reminders can also be issued for the operator in order to apply the given specifications. If adaptation is necessary, it has to be done manually because the background knowledge of the plant personnel is essential. Furthermore, the rule base can be adapted by using the above information.

### 2.2 Overall concept

The aim of the research project, from which several results are presented in this paper, was to describe the product quality and use that information together with process data as input for a DSS. Together with the customers order information over-quality products can be identified and a re-allocation to orders with higher demands lead to and increased added value. Furthermore is this information used to optimise the allocation of orders to coils, considering the detected surface quality. The general concept is depicted in the following Fig 1 [2]

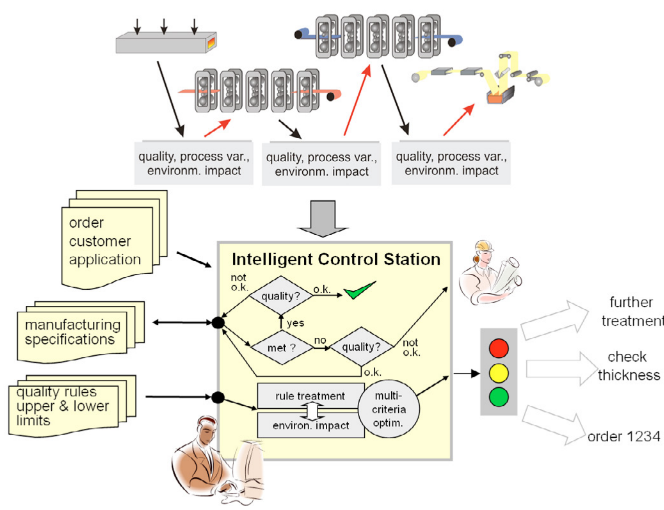


Fig. 1. General concept

This paper describes the application of the use cases in the industrial environment of Outokumpu Oyj, a Finnish stainless steel producer located in Espoo. The investigations were processed at the German sites Krefeld, Benrath, Dillenburg and Bochum.

[2] The environmental impact is not part of this paper.