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Incorporating fuzzy approaches for production planning in complex industrial environments: the roll shop case

B. Adenso-Díaz[a,*], Ignacio González[b], Javier Tuya[a]

[a] Industrial Engineering School-University of Oviedo, Campus de Viesques, E-33204-Gijón, Spain
[b] Accenture Consulting-Madrid, Spain

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Abstract

Operation of complex shops needs specific, sophisticated procedures in order to guarantee competitive plant performance. In this paper we present a hierarchy of models for roll shop departments in the steel industry, focusing on the calculation of the priority of the rolls to produce. A fuzzy-based model was developed and implemented in a real environment, allowing the simulation of expert behaviour, considering the characteristics of an environment with imprecise information. A description of the model and implementation experiences in a real shop are reported.

Keywords: Fuzzy systems; Production planning; AI application tools; Roll shops

1. Introduction

Mature industrial sectors in Europe, such as iron and steel, have suffered important changes in recent years in order to be able to competitively remain in the market. Some of the most relevant challenges are to restructure and expand markets (Berry, 2001), increase flexibility using new processes (Ritt, 2000), and the minimising of inventories (Ninneman, 1997).

After a critical shrinkage of the human factor in the 1980s, companies in the iron and steel sector have begun to invest heavily in R&D, in a search for continuous improvement of their methods and processes, adapting their logistic and productive systems to the latest requirements. Thus, new challenges in the iron and steel industry impose new challenges to production planning and scheduling techniques.

A case where the complexity of the different models needed for managing an industrial environment can be seen is the Roll Shop Department. Rolling mills and roll shop departments are very closely related, as the quality of the final product depends to a great degree on the quality of the rolls. Moreover, continuous steel production depends on the availability of rolls. About 70 percent of the roll changes are due to roll marks and 30 percent are due to order changes (Greissel, 1999). In order to decrease the cost of inventory assets, it is mandatory to have a policy to keep inventories low, while having enough rolls to be able to respond to production changes and to extend the life of the rolls (Ray et al., 2000).

In this paper we present a sequential procedure that identifies six hierarchical models to manage the activities of the Roll Shop Department, developed and implemented in a Spanish steel company. These models, which cover all the managerial aspects of the shop operation, are (Fig. 1):

- *Priority model*: The output is a value that indicates the processing priority of the next type of roll to process in the shop.
- *Scheduling model*: The output is the route that each roll currently being processed must follow through the roll shop to optimize its productive capacity. This is the second level of the priority model, complementing it with more detail.
- *Maintenance model*: This indicates when each machine or other components of the installations must

*Corresponding author. Tel.: +34-985-182-118; fax: 34-985-182-150.
E-mail address: adenso@etsiig.uniovi.es (B. Adenso-Díaz).

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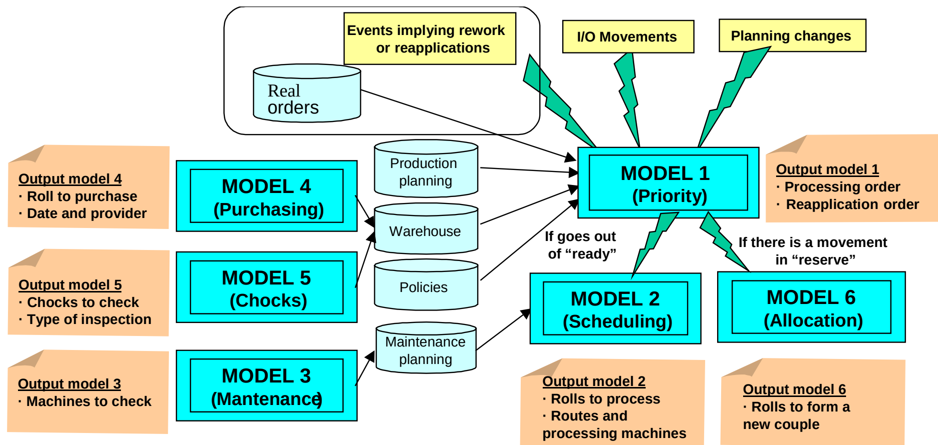

Fig. 1. General scheme of system models.

be checked. This, in conjunction with the two previous models, constitutes the whole roll shop management model, incorporating the perturbations to the system associated with predictive maintenance.

- *Purchasing model*: This determines the right moment to place roll orders and decides the best provider of new rolls in each case. The target is not only to get the lowest cost but also to take into account the purchasing policy criteria of the company. It must be borne in mind that rolls lead-time is normally around 6 months, and may occasionally be longer than a year. The purchasing schedule must be made for the next four years and revised periodically so as to check the deviations between actual and predicted consumption.
- *Chocks management model*: Taking into account the availability and the necessities of chocks, this model determines the plan to check these. The objective function is to minimize the time between inspections for every chock, considering the existence of two different major inspections: visual (routine) and complete (needed just sometimes).
- *Roll allocation model*: Two rolls form a couple to work, and this couple must stay together until one of them suffers an important incident or both lose their working coat. If one of them suffers a critical incident, the model tries to allocate the most suitable one among those available to form the couple.

Each of these models needs different techniques to achieve the sought-after solution. Of all of these, the priority model is the central one in the management system, as can be appreciated in Fig. 1. It is this model that the present paper shall focus on. The model is activated by events implying reworks and reapplications, movements of rolls in or out of the roll shop, and each time that there is a change of roll shop or mill planning. With respect to the rest of the models, it will need information from the purchasing and chocks models, and its output activates the allocation and scheduling models.

2. The production process in the roll shop

Although the approach we are presenting was implemented in a specific plant, most of these types of shops are very similar. Roll shops are usually divided into two main areas: installations for cold and hot rolling mills, in our case giving service (providing rolls) to 10 mills. Different types of rolls are needed in the stands of the different mills. One of the first steps in the development of a model like this one is the definition of the concept of unit to manage, i.e. the final type of roll that must be prepared for use in the mills. We call it "*aca-tipo*" (abbreviated Spanish for "finished type"), which includes three characteristics: the destination mill for the roll, the stand of the mill where the roll will be allocated and the final product that will be processed in the mill using this type of roll. Obviously, every *aca-tipo* has different characteristics (different dimensions or requires particular processes). Usually, there are around 150 defined *aca-tipos*, but this number may change depending on the productive moment and the company's client portfolio. All the decisions to take are related to this concept.

Rolls have a cyclical life through the shop (Fig. 2): two new rolls form a couple, and are subject to different processes to obtain an *aca-tipo*. Once the couple is ready, it is stocked in the "ready area". When the *aca-tipo* is going to be used in a stand, some of these couples are sent to a place close to the stand, where they are stocked until needed for rolling. After a number of laminated tons, the rolls present certain defects caused by their use, so they must be replaced. The replaced rolls return to the roll shop and the cycle closes. This cycle is repeated until the rolls lose their working coat. At that