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Simulation-based rescheduling of the stacker–reclaimer operation

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ABSTRACT

In this paper simulation is applied to reschedule the stacker–reclaimers operation to increase the dry bulk terminal's performance by reducing the waiting time of cargo trains being loaded at the terminal. Stacker–reclaimers perform both the stacking and reclaiming of dry bulk materials. Due to the differences in loads between ships and cargo trains, the time needed for stacking and reclaiming varies considerably per job. The simulation tool developed can be used to support decisions when to interrupt ship servicing in favor of train loading based on the availability of transportation routes and expected disturbances. An experimental study demonstrated that ships and trains have to spend less time in the port when the stockyard lanes are accessible by two stacker–reclaimers due to the higher machines redundancy. Using the stacker–reclaimers rescheduling function the average port time of trains decreased without significantly affecting the port time of ships.

1. Introduction

Dry bulk terminals are essential nodes in the major transportation links for coal and iron ore. These dry bulk materials are used for the worldwide production of electric energy and steel. A dry bulk terminal consists of a quayside where ships are loaded (export terminal) or unloaded (import terminal), a stockyard equipped with machines for the temporary storage of the dry bulk materials and a landside where transport modalities like cargo trains are serviced. Common machines at the stockyard are stacker–reclaimers. These machines combine the two functions of stacking and reclaiming into a single unit. Consequently, one of the two functions can be fulfilled at a time. During stacking, the material is transported through the machine to the end of the machine's boom where the material is discharged and dumped on a pile. During reclaiming, the reclaiming device, which is in most cases a bucket wheel mounted at the end of the machine's boom, digs the material out of the pile. The material is transported in reverse direction through the machine and dumped on a yard conveyor that conveys the material to its new destination.

The terminal operation is complex because both ships and trains have to be served simultaneously and on time to prevent paying demurrage penalties to ship-owners or delivering an unacceptable service to rail operators [1]. Stacker–reclaimers have to handle the incoming as well as the outgoing flow of bulk materials. Consequently, their operation largely determines the terminal's performance. The shiploads and trainloads vary considerably in volume and mass which causes a large variation in operation times. Large bulk ships can contain more than 250,000 t of dry bulk materials but the trainload is significantly smaller. In Western Europe, for example, the trainload is limited with 4000 t while in Australia and South Africa trains loaded with 35,000 t are not exceptional.

Stacker–reclaimers are installed at import terminals as well as export terminals. In this paper the operation at import terminals will be discussed. When during ship unloading a train arrives that requests material that is stored in the reach of an active machine, the train has to wait before being serviced until the stacking operation is finished. The resulting waiting time can lead to an unsatisfactory service to train operators and cargo owners. Rescheduling the stacker–reclaimer's operation by interrupting stacking and handling trains in between is a solution. However, ship unloading cannot be interrupted infinite times because terminal operators have limited time to unload ships.

The paper's objective is to apply simulation for the rescheduling of stacker–reclaimers to decrease the average time that cargo trains have to spend in the port while still guaranteeing the agreed ship port time. This paper is organized as follows. A literature review of stacker–reclaimer scheduling and the related job shop scheduling problem is given in Section 2. In Section 3, the stacker–reclaimers operation is explained and in Section 4, a simulation-based approach for the stacker–reclaimer rescheduling is introduced. An experimental study is included in Section 5 and finally, conclusions are given in Section 6.

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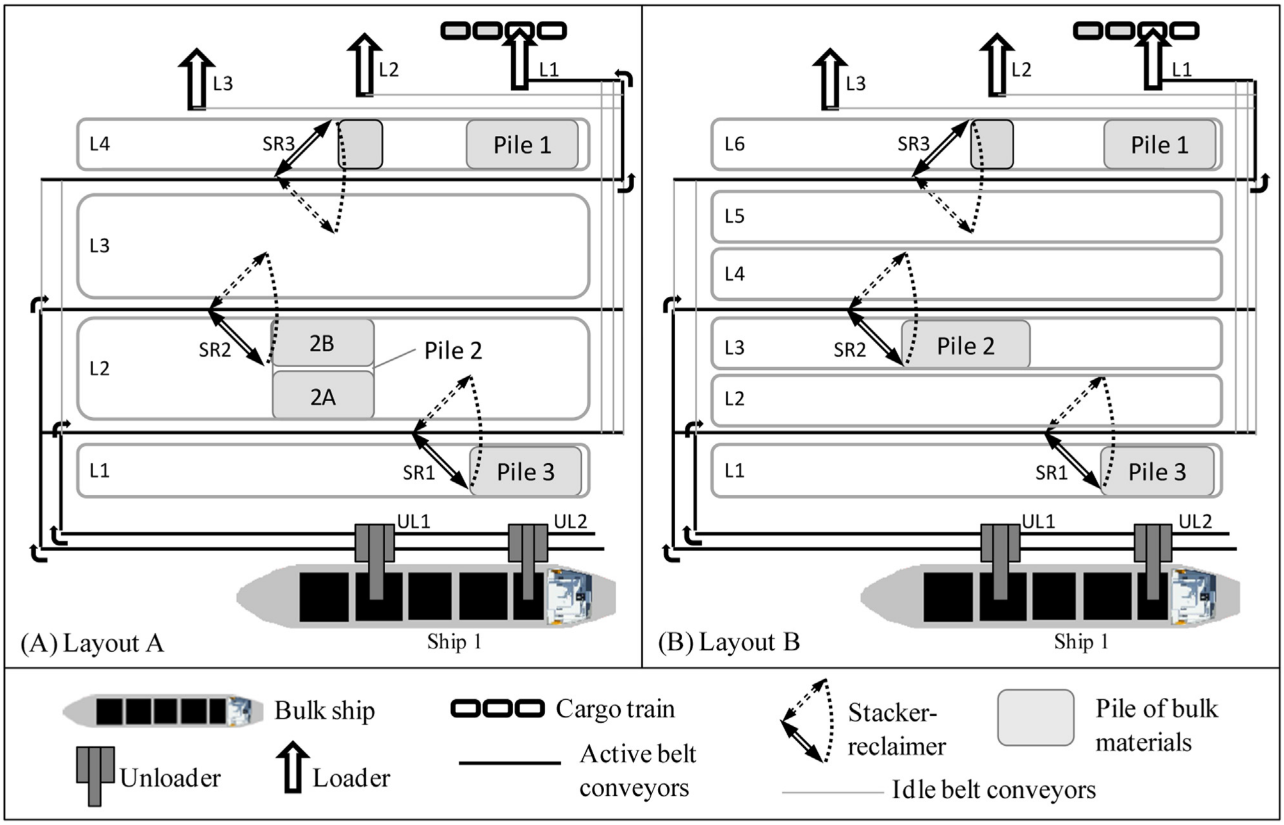

Fig. 1. Schematic representations of a dry bulk terminal with stockyard lanes (L1–L6), three stacker–reclaimers (SR1–SR3), two ship unloaders (UL1–UL2) and three railcar loaders (L1–L3).

2. Literature review

During the scheduling of the operation at dry bulk terminals many decisions must be made. For example, where to berth the arriving ships, which quay crane must be assigned, where to store the material, which transportation route must be selected and which stacker–reclaimer must be used. Many researchers studied the terminal's seaside operation; see for an extensive literature review [2]. A limited number of papers discussed the allocation of bulk materials at stockyards [3–9] and only two papers were found addressing the route scheduling problem [10,11].

The stacker–reclaimer scheduling problem was discussed by Hu and Yao [12]. The authors formulated the scheduling problem as a mixed integer programming model with the objective of minimizing the makespan (which is the total time between the start of the first operation and the end of the last operation) for a given set of handling operations. The approach developed was based on genetic algorithms using two types of chromosome representations. In the greedy assignment procedure, operations were assigned to machines based on their availability, minimized completion time and minimized setup times. Computational experiments were performed for a specific case for a planning horizon of 8 h. Hu and Yao assumed that the processing time per operation varies between the 60 and 150 min and that a stacker–reclaimer completes the operation without any interruption or shift.

The stacker–reclaimer scheduling problem has similarities with the job shop scheduling problem. A stacking or reclaiming operation can then be defined as a job. Some authors extend the standard job shop scheduling problem by taken the machine breakdowns and the arriving of new priority jobs into account [13,14]. However, the assumption that a machine cannot be interrupted until the operation of the job is finished, prohibits the use of the job shop scheduling problem for the rescheduling problem of stacker–reclaimers.

3. Stacker–reclaimers operation

This section provides details about the stacker–reclaimers operation. Fig. 1 shows two typical stockyard layouts for import terminals where only the active belt conveyors are shown. In layout A (Fig. 1A) the stockyard contains four lanes. Both outer lanes (L1 and L4) are accessible by one stacker–reclaimer while the middle lanes (L2 and L3) can be reached by two stacker–reclaimers. In layout B (Fig. 1B) each stacker–reclaimer has exclusively access to two lanes. Usually, at import terminals the *identity preserved* storage policy is applied to assign piles to storage locations [6]. Piles are stored individually to prevent mixing and for realizing tracking and tracing of dry bulk materials. Consequently, a specific grade of material is then stored at one specific storage location and must be reclaimed by the correct stacker–reclaimer when requested to be loaded in rail cars.

Fig. 1A and B shows an arbitrary situation where stacker–reclaimer SR3 reclaims material to be loaded in a cargo train by loader L1. At the same time, two ship unloaders (UL1 and UL2) unload a bulk ship (ship 1). Two transportation routes, formed by multiple belt conveyors in series, are used to transport the unloaded materials to the stacker–reclaimers SR1 and SR2. These machines stack the material into piles. Usually, there is limited storage area available for large piles. That's why large shiploads (e.g., more than 100 kilotons [kt]) are split into multiple piles [15]. In Fig. 1, the load of ship 1 is divided across piles 1, 2 and 3. Fig. 1A shows that pile 2 is formed out of pile 2A and pile 2B and both stacker–reclaimers SR1 and SR2 are needed to create pile 2.