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Jamological approach to steel production and logistics

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Abstract: We applied Jamological approach to steel plate production process. Jamology is the method to treats the actual complex flow problem with macroscopic view, which key tool is on ASEP model and the fundamental diagram. For abstraction of the actual plant, we applied ABC categorizing to the practical data according to the bottle neck process. Moreover, we analyzed the reason of make span variation and derived the optimal sequencing pattern by using pair gap list. We indicated effectiveness of the proposed algorithm based on a transition matrix for practical data and derived the corresponding fundamental diagram which is much different from the traffic flow case.

Keywords: Jamology, fundamental diagram, steel production process, pair gap, transition matrix

1. INTRODUCTION

Jamology is a new region of science which scope of analysis is all kind of flow and congestion in the world, and originally comes from the analysis of nonequilibrium dynamic system. ASEP model (Asymmetric Simple Exclusion Process) and the fundamental diagram is the key tool for analyzing the dynamic system (Fig.1). Since the first analytical solution of ASEP was derived (Derrida, 1993, Schuts 1993, Schadschneider 1993), ASEP model has contributed to detailed analysis of a driven diffusive system, vehicle traffic models and ants trail traffic model. These results have been summarized elsewhere (Evans 2005).

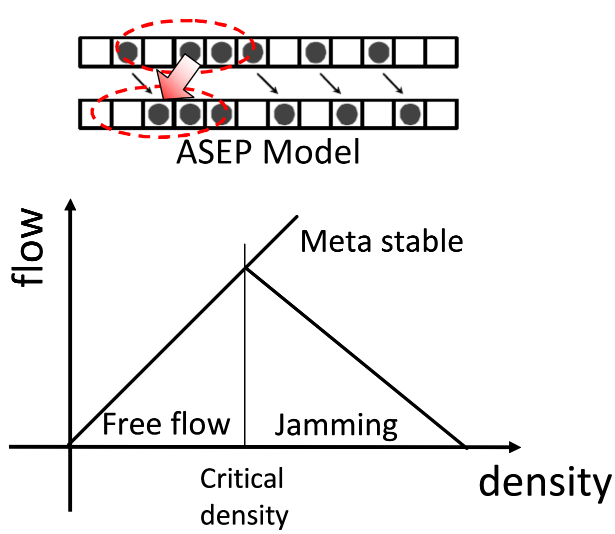

Fig.1 ASEP model and fundamental diagram

Practical examples of Jamology are traffic flow, pedestrian flow, money, molecular motor, etc(Chowdhury 2003, Nishinari 2004, Nishinari, 2009, Schadschneider 2010). Fundamental diagram, which is also the key tool of Jamology, represents a flow in vertical axis with the corresponding density in horizontal axis, and visualizes several phases of the flow dynamics as shown in Fig.1. When density is relatively low, the system stays in the free flow phase where the flow increases linearly without having congestion. As the density is becoming higher and surpass the critical density, the system transits into the jamming phase where the flow linearly decreases to zero. In the traffic flow case, meta stable phase is observed at the moment of jam starting.

The fundamental diagram is very informative. Once you obtained the diagram for a dynamic system, you can always observe the state of the system and control its density to maximize the flow.

Sequencing or scheduling problems, which exist everywhere in the world and also in steel manufacturing processes, are quite important for effective production and have been well analyzed since 1950's. After the theory of computational complexity have established in 1970's(Cook, 1971), these combinatorial problems are categorized in NP-hard problem. the strict optimal solution is derived with a simple rule only in a few case. For example, Johnson rule (Johnson,1954) provides the optimal solution only for 2-machine flow-shop problem with make span minimization.

Several approaches have been developed for NP-hard problem. Branch and bound method for Mixed Integer Linear Problem(MILP, Gomory, 1958) theoretically provides the

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strictly optimal solution if it can take an infinite time. Genetic algorithm(GA, Goldberg, 1989) is utilizing evolutionary mechanism of life. Tabu-search(TS, Glover, 1989) and Simulated annealing(SA Kirkpatrick, 1983) has developed for the effective search. Particle swarm optimization(PSO, Kennedy, 2004) is an analogy of communication among a group of insects in searching of food. GA, TS, SA, PSO are called meta-heuristics, which derives semi-optimal solution in a practical calculation time, and very applicable to the NP-hard problem like scheduling or sequencing problem.

There are lots of reports describing those optimization method applied to sequencing problem in steel making process, which is also categorized as flow shop scheduling problem. Branch and bound method for MILP(Sun(b),2010), Lagrange relaxation method with the surrogate sub-gradient algorithm(Sun(a),2010), and constraint programming approach (Li,2015) are successfully applied to the actual problem. Hybrid algorithm is also proposed, which is based on a combination of ant colony optimization (ACO) and non-linear optimization methods(Atighehchian,2009). PSO method with cooperative strategy(Gao,2007) is suggested to solve the steel making continuous casting problem.

However, searching algorithm in the scheduling system often becomes a black box and is unfamiliar to human operators and has less robustness, which easily lead the scheduling system becoming obsolete. For this reason, a simple algorithm, which is similar to Johnson rule, is expected for the sequencing problem.

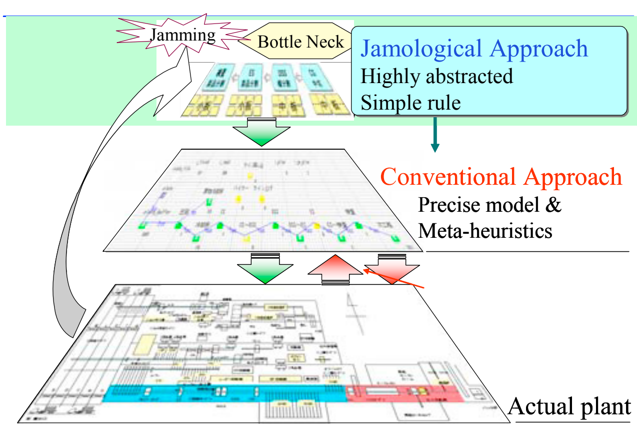

Fig.2 Sharing line in plate production process

Fig.2 indicates the relationship of the actual plant, the conventional approach such as meta-heuristics and Jamological approach. The conventional approach normally constructs a virtual factory, which is numerical model or dynamic simulation model with the precise operating parameter and searches the optimal solution with a high speed computer.

On the other hand, Jamological approach uses more abstracted and simplified model and aims to extract a simple rule, which is easily introduced in the actual operation. Jamology is the method to treats the actual complex problem with a macroscopic view, while conventional optimizing methods are relatively microscopic.

In this report, we apply Jamological approach to steel plate production process, which is 4-machine flow-shop problem. Firstly, we simplify the problem by using ABC categorizing according to the processing time at the bottle neck process. Secondly, we analyze the mechanism of how make span is determined by introducing pair gap concept. Thirdly, we show a fundamental rule of efficient production sequence by using transition matrix and pair-gap table. Finally, we derive the corresponding fundamental diagram.

2. ANALYSIS OF PRODUCTION LINE

2.1 *Model of steel plate production process*

Steel plate production process discussing here is shown in Fig.3. The rolling mill provides thick plate which size varies from 2.0 meter to 4.0 meter in width and from 10 meter to 15 meter in length, its rolling pitch is approximately 3 min/piece. After rolled by rolling mill, a big-size plate is gradually cut off and resized into production size plates while passing through three shearing line called "Crop Shear ", Double Side Shear ", "End Shear", respectively. The crop shear trims the edge away from the big-size plate and cut off into the mid-size plate. The double side shear cut on the horizontal line of the mid-size plate. The product size plate is obtained after the end shear. After a surface inspection

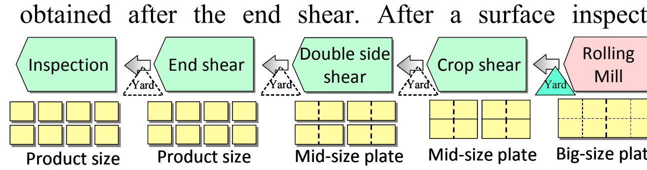

Fig.3 Sharing line in plate production process

process, the plates become the final products. The number of products in the big-size plate varies 1 to 15 in actual, and clearly causes the difference of processing time in each sharing process. The process model discussing here is 4 sequential process including crop shear (CS), double side shear (DSS), end shear (ES), inspection (Ins.) without any buffering space between any consecutive 2 processes.

2.2 *ABC categorizing and optimal sequence of small lot size*

In this section, we apply ABC categorizing to obtain an abstracted model of plate production process explained in the previous section.

To simplify the model and its data is very important step of Jamological analysis. Firstly, we divide the practical

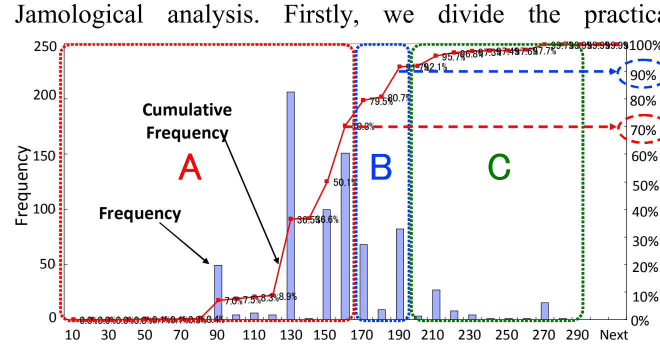

Fig.4 ABC categorizing of the products