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Designing and verifying a disassembly line approach to cope with the upsurge of end-of-life vehicles in China

Chunliang Zhang, Ming Chen *

School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

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ABSTRACT

An upsurge of end-of-life vehicles (ELVs) is emerging in China, which means a potential monumental environmental crisis. The approach of disassembly line is expected to be an effective solution to such increasing volumes. Due to the complexity of vehicle product and uncertainties of disassembly processes, a complete set of disassembly line system should be taken into detailed consideration. We have designed and constructed a novel disassembly line using a flexible transition technique with the objective of complete disassembly. Prior to productivity testing, comparative Arena-based simulations on four scenarios have been performed and finally a best scenario is selected. The results show that the guarantee of cycle time is the key to meet the productivity target of 30,000 vehicles for one year. To achieve it, some constructive measures such as forcible entry tools are given.

1. Introduction

Disassembly line has become a particular focus of researchers' attention on end-of-life (EOL) products because of its higher productivity levels and reduced labor cost (Gungor, 1999). However, the disassembly of returned products is involved in a high degree of uncertainties the structure, quality, reliability and the condition and it cannot be just considered as the reverse process of assembly operations (Kalayci and Gupta, 2013). In contrast to mature assembly line techniques, the disassembly line is still being explored.

The rapid development of Chinese automotive industry is characterized by its vehicle production and sales in the forefront of the world. Its downside is the upsurge of end-of-life vehicles (ELVs) in China. According to incomplete statistics, both of the Chinese car production and sales in 2016 are 28 million vehicles, up 14% from 2015 (China Association of Automobile Manufacturers, 2017). Estimates show that the ELV volume could up to 10 million by 2017 (Zhang and Chen, 2017). Such huge scrapped volume is unique for all the world. Directive ELV 2000/53/EC has regulated that ELVs must be recovered (Alwaeli, 2016). Hence, the pressure from the sheer ELV volume has been increasing an urgency to solving the productivity problem of Chinese ELV industry.

The current popular ELV disassembly system mainly adopts manual operation and intensive labor, which is not appropriate to the present ELV upsurge situation in China. Considering the tremendous success of assembly line in the manufacturing industry, a disassembly production line for scrapped vehicles may be the only effective approach to deal with the increasing productivity, without precedent and this moment also provides a major developing opportunity for disassembly line techniques.

Reasonable resource (i.e. personnel, machinery, equipment) configuration is the core of the design of a disassembly line (Drira et al., 2007), which can have a potentially significant impact on cost efficiency and productivity. In addition to the specialization of operators, Capraz et al. (2017) emphasized the effect of transition type on the production line performance. The layout of scrapped vehicle disassembly line is generally characterized based on the shape and the number of disassembly sub-line and its workstation numbers along with the transition type between sub-lines (Hesselbach and Westernhagen, 1999). This has the benefit of flexibly allowing for some operations for humans and others for automated machines so long as a reasonable cycle time is met. However, vehicles are one sort of the most complex consumer products with tens of thousands of parts as well as pollutants and hazard substances (Chen, 2005). Although disassembly lines have been pictured to be the most effective method for recovering used products (Filip, 2011; Huang et al., 2000), some special considerations must be given ELVs, such as the treatment of pollutants and hazard substances, the disassembly of parts and components that lies in various direction as well as uncertain factors (Gungor and Grupta, 1999) and the line balancing problem (Gungor et al., 2001).

* Corresponding author.
E-mail address: mingchen@sjtu.edu.cn (M. Chen).

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Based on the above deliberation, we have constructed a physical ELV disassembly line with an "L" shape fit for standardized plants. In some sense, this construction is ahead of time because current amounts of end-of-life vehicles collected by individual dismantling company are un-sufficient for the normal operating of the disassembly production line, but the trend is obvious with the support of Chinese governmental policy. So massive market funds are streaming into the industry for market opportunities, which is the major reason why the disassembly line was developed and constructed. From a research perspective, physical experiments on this line, so far, cannot yet be performed for the lack of enough volumes of end-of-life passenger cars with same brand. In this case, we try to analyze and optimize the production processes and productivity of the line be means of the software 'Arena' in view of its successful application in disassembly field (Pisuchpen, 2012). It should be pointed out that there lie other solutions for disassembly line balancing problems (Kizilkaya and Gupta, 2005).

The rest of the paper is organized as follows: In Section 2, the recovery flow process of end-of-life vehicles and some concerns for an ELV disassembly line are presented. The detailed constructed disassembly production line is described in Section 3. Section 4 develops a system model of the disassembly line and simulates it using Arena. Simulation results and discussions are provided in Section 5. Finally, some conclusions are given in Section 6.

2. The recovery flow process of end-of-life vehicles and some concerns

Fig. 1 shows a flow chart representing the treatment process of a scrapped vehicle at its end of life. Whichever recovery you suit, it always is beneficial sorting by structure or material. To meet the demand of similar structure for the disassembly line (Tuncel et al., 2012), ELVs are sorted before or after their pre-treatments and if the volumes are not enough, they must be stored. Instead of partial disassembly approach for selective disassembly, a disassembly line pursues as many parts or sub-assemblies as possible and most researchers have focused it on complete disassembly for maximizing the profit target (Ren et al., 2017). For such many parts of ELVs, it is impossible to design an enough long disassembly line to get them and it is more recommended that the line emphasizes sub-assemblies and necessary parts or components and a special area be formulated for fine disassembly for sub-assemblies.

It should be noted that hazardous substance stream is not showed in Fig. 1. because they are also one sort of stocks that can be recycled after dismantled. In detail, the battery and air bags will be dismantled in register for scrapping phase; refrigerants, various waste oils and fluids in pre- treatment phase, and the rest in individual dismantling workstation. After the fine disassembly of the disassembly line, the only hulk will be fed into shredders. Therefore, automobile shredder residues (ASR) would be negligible owing to the feeds' single component.

Due to the complexity of vehicle products and the difficulty in dealing with the NP complete problem caused by the balancing of the ELV disassembly line (McGovern and Gupta, 2007), one ELV disassembly line aiming at a high productivity becomes difficult in dynamically adjusting the process by market demands of some components or sub-assemblies. Therefore, the process of a disassembly production line should be relatively fixed for some time, which can contribute to higher workers' skill levels and amounts of reused or remanufactured components as well as the purity of recycled materials.

To understand the disassembly line in a systematic manner, it is necessary to highlight the difference between a disassembly line and an assembly line as well as some uncertainties as follows:

- An assembly line is to converge to a complete and functional product form part to whole based on many divergent parts or components, while an opposite process from whole to part takes place for a disassembly line (Gungor, 1999; Kizilkaya and Gupta, 2004).
- To ensure the functionality of final assembled products, some tests must be performed before or during the assembly process, or even a final test after all the assemblies may be conducted (Puthumanappilly, 2015). On the contrary, for a disassembly process, no tests will be performed and the amounts and quality of disassembled components are uncertain (Tian et al., 2017). At the same time, a disassembly process may result in the damage of the structure or functionality of disassembled products.
- There is an obvious target that emphasizes a batch production with same structure and composition for an assembly production line (Lei et al., 2014), but objects for a disassembly production line are difficulted to be sort by batch in view of different service lives and different disassembly subjects. For this reason, it is necessary to sort and storage vehicles for providing the disassembly line some similar used products in terms of structure and composition.
- The production plan of an assembly production line is relatively fixed, but the end-of-life vehicles that can be collected may be uncertain considering various factors such as the service life and the policy influence (Wang and Chen, 2013).
- The station time of common assembly lines can seem constant (Sotskov et al., 2006), but that of a disassembly line may vary from disassembled vehicles' type, condition, deforming, corrosion, upgrading and downgrading.

Based on the above consciousness, we have constructed and built our ELV disassembly described in the next section under the following assumptions:

- The disassembly line is confined to the treatment of end-of-life vehicles with same brand and similar structure.

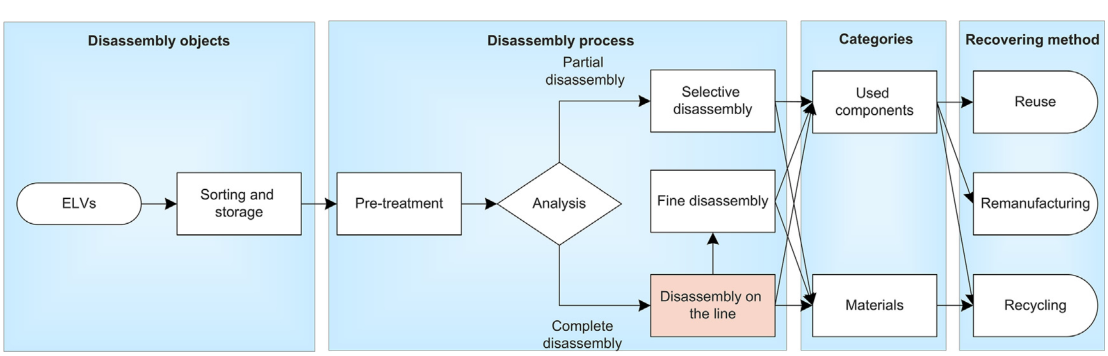

Fig. 1. The flow chart of ELV treatments.

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