Development and Application Analysis of AGVs in Modern Logistics

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Abstract
As the development of automatics, intelligent factory, production and logistics will become the mainly future development modes. Recently, intelligent automatic is changing the patterns of original manufacturing enterprise as well as logistics plants. The trditional logistics enterprises are also facing with the intelligent upgrading and reforming. As one of intelligent automatic equipment, AGV systems are used more and more in industrial plants. This paper is intended to provide a view of AGV based logistics system. Furthermore, it analyzes the AGV application modes in modern logistics area, and proposes the discussion of problems. This paper provides reference for future research and practice.

Key words: AGVs, intelligent automatic, logistics, industrial application

1. INTRODUCTION
As the rapid development of automatics and communication technology, the manual equipment is being replaced by automatic equipment day by day. The intelligent automatic has changed the original industrial pattern, as well as changed the intralogistics. The AGV (Automated Guided Vehicle) is an automated guided cart that follows a guided path. It is one of the intelligent automatic equipment in these days. About 20% of the time is utilized for actual processing on product manufacturing or storing. However, about 80% of the time is used to move the material from one place to another or waiting for processing. So, the logistics automation aimed at to realize the material flow automatically by using facilities. The material moving includes horizontal movement, vertical movement or their combined motion.

Nowadays, the mainstream logistics automatic facilities are also AS/RS and multi-shuttle systems. AGV realizes the horizontal movement of materials automatically in manufacturing systems and other material handling systems. Furthermore, AGV system has several advantages over other logistics equipment. It is more flexible, modular and intelligent. Because of its flexibility, it also uses less field area with low time and cost for initial installation. With logistics standing point, it can be used in any scenario which has material flows exists. The system has already developed into a tested means for organizing the modern intralogistics.

AGV is a driverless vehicle that used to transport unit or larger loads from one place to another in factory floor or warehouse. According to the definition of American Council of Logistics Management-AGV is a self-guided vehicle which equipped with magnetic or optical guided sensor and could follow with the prescribed path as well as achieve turning and parking functions. Furthermore, it has equipped with programming device, security protection and goods transfer. The enterprises always install several vehicles into original system or new plant for multiple vehicles can play tremendous role in whole system. There is a central controller is used to regulate the traffics and task dispatching. Each vehicle can receive the messages coming from central controller computer and obey the fleet management regulations. Otherwise, each vehicle also has enough independent control ability. These functions owe to its vehicle-mounted controller. The controller finishes receiving vehicle sensors perception messages from outside and doing corresponding decision and then sending command to the force-driven mechanism. So, the control pattern is three stage control mode. AGV is a battery-powered vehicle with lithium battery always. It has a power management module to do the energy detection and low-electric warning. The vehicle-mounted controller can also support the cart to charge itself when condition is needed.

In a word, AGV is an intelligent automatic device which gathered sound, light, electricity, magnetism technologies and so on. In the future, the AGV will equip with more autonomous logical judgment ability and decision making. However, the success of a system depends on many factors. Not only the vehicle’s stability, but also the successful installation, sequence management, the environment, flow path design, fleet size and the throughput of system. So, before adopting AGV into system, the decision makers need do some work to ensure the normal running. There are all indispensable works include the reliability analysis, the central rules and reliable security dealing regulations. The more complicated the system is, the higher reliability required for the designer. Therefore, many cases running today are all using the simple AGV, which is the vehicle with only goods loading-unloading, parking and self-protection these basic functions. And the designers always use the fixed guidance technology, such as magnetic guidance or optical guidance.

Although the automotive industry was initially the leader in adopting AGV, now almost all industries have come to use AGVS to optimize their material flows. The application of AGV system mainly contains tobacco industry, electric field and e-commerce industry. AGV has been regarded as one of the intelligent transportation system in industrial plants. The paper is organized as follows. The history of AGV and the review methodology
are discussed in next section. The application modes in logistics will be mainly discussed in third section. The final section gives discussion and conclusion.

2. REVIEW ON DESIGN AND METHODOLOGY OF AGV

Since AGV began around 60 years ago, the design and methodology of AGV keep studying in theoretical and practical work. Here provides a review on the history and methodology of AGV.

2.1 The history of AGV

The history of AGV began at 1953 in America, when the first AGV was installed as a tractor-trailer. After the Second World War, the production industry was resurgent and the economy was booming all over the world. The rapid development of sensory and microelectronics technology paved the way for AGV. After that, the European market developed rapidly in AGV study and manufacturing and keeps taking the leading position in the world today. China starts relatively late in the study of AGV until 1976, when the first AGV was designed.

The design and application of AGV can’t do without the development of industrial technology. A chart will be used to reveal the history and break point of AGV below.

![Figure 1. The history of AGV in Western and China](image)

As is shown in the picture, the development of AGV can be divided 4 eras. The above curve represents the development history of Western and the below one means the history of Chinese AGV’s development.

1) The 1st era: Start and idea realization.

It’s mainly happened in Europe and America. Because of the limitation of automatics technology, the design of AGV in this stage developed slowly. The main step was the idea realization. There were rarely industrial application cases during this period.

2) The 2nd era: Computer and microelectronics support.

As the simple on-board computer invention and daily mature microelectronics technologies, AGV developed very quickly and began the usage in industrial plants, especially in the automotive industry.

3) The 3rd era: Proven technology for application.

During this period, the technological standards had been set and the new applications were established. The devices have electronic guidance and contact-free sensors. They are controlled by a standard PC.

4) The 4th era: Challeging.

More and more AGV manufacturing enterprises appears in market including from Asia. The application market will be expanded and the design of AGV will highly promote.

2.2 Design and methodology of AGV

As is known to all, there are much more difference between theoretical and practical area. This experience is also verified in the design and methodology of AGV. The practical area tries to make more flexible and reliable vehicle to integrate original material handling system. Their point is to reduce the cost and take more benefits to company. The complex logical schedule only brings high cost and risk. Differently, theoretical area wants to design more advanced and strong vehicle to verify the newest technology.

Through searching and reading the available research journals online, the main study today focus on 3 problems. The below content will give a comprehensive introduction.

1) The AGV hardware design.

AGV is an intelligent automatic device which gathered sound, light, electricity, magnetism technologies. If regard the design except the central controller as the hardware, the hardware design includes the mechanism design, the guidance controlling, the security protection, the power design. There are many articles on this aspect, especially in China. Almost 170 dissertations on hardware design from 2000. The design of hardware
will improved along with the development of automatics. It will found more and more new technologies used in AGV design.

2) Flow path optimization.

Before adopting AGV into system, the flow path design plays an important role in practical usage. This is the essential factor that will influence the efficiency of whole system. Gaskins and Tanchoco (1987) made the first model for the AGV path design problem. Except it, the vehicle blocking and traffic congestion problems also keep hot from 90s. The objective of this aspect is to reduce the travelling distance. In practice, many companies choose the fixed flow path design to ensure the flexibility of AGV system. Although this is not the optimized method, the fixed circle avoids risks of traffic jams and blocking.

3) The resource allocation and throughout estimation.

This is suppose AGV can do tasks as the designing and it’s important to company that supposes to import it into plants. This problem contains serval sub-problems to solve. Such as the fleet size of vehicle, the throughout estimation, the configuration of charging station, the unit load size, the quantity of guidance tape. It’s rarely study on this aspect now.

3. APPLICATION ANALYSIS OF AGVS IN LOGISTICS

Because of the flexibility and intelligence, more and more industrial plants adopt AGV into initial system, container terminals, distribution centers, manufacturing and assembly plants, storage and warehouse. The main reason of using AGV into system is to integrate the material handling flow and increase the material flow rate. In the final analysis, it is the logistics integration. From the function of material flow point of view, the application scenes can be divided into 4 kinds, production intralogistics, supply logistics, warehouse intralogistics and e-commerce intralogistics. The follow content will analyze these applications one by one.

3.1 production intralogistics

The manufacturing enterprise can’t do without the successful management of production logistics from raw material to final product. According to the production processing, the raw material flow through appointed working stations until become the final product and out of the production line.

1) The production intralogistics application scenario description.

AGV can be used in this material flow integration. The follow chart shows this application scenario.

![Figure 2. Production intralogistics application scenario](image)

2) The operations of AGV in production intralogistics.

In this scene, AGV can finish 3 kinds of operation.

a) Material handling processing: The handling operation of raw material, semi-finished product and final product and manufacturing tools worked in production line.

b) Assembly platform: AGV can be used as the assembly platform directly, which induces the cross loading and unloading processing.

c) Out of line: The final product will move out from production line and AGV can transport the product to the appointed storage zone.

3) The characteristics of production intralogistics application.

a) simple: The task always simple and single, so the vehicle needn’t so many functions and the working environment is always fixed.
b) Limited by production steps: In this application environment, the key function is to produce goods under the customer requirements. The work of AGV system is to match up the production processing. So, the efficiency is limited by the production steps.

c) Loading mechanism module complex: It is difficult to standardize the loading mechanism for there are a lot of material types in whole line.

d) Wire guidance pattern: The guidance pattern should stable and try to reduce the influence of working stations. So the wired guidance technology is better than without wire. Such as the magnetic tape guidance.

There are a lot of this application cases in the world, especially the automotive industry which almost all automotive companies are using AGV system to integrate the production material flow. The AGV material handling system makes the FMS more flexible and efficient. The manufacturing enterprises can choose this handling system into the original system according to their production steps. And it’s already mature of this type vehicle and application analysis.

3.2 supply logistics

B. It’s different from the manufacturing enterprise that the material flow is complex and huge. There are some companies has simple material flow and only from the supplier to customer. This scenario always happens in some service companies.

1) The supply logistics application scenario description.

This application scene also can use AGV system to integrate the intralogistics. The application can be described as follows.

2) The operations of AGV in supply logistics.

In this system, the customer can be real human or the virtual requirement point. Here AGV can be used in the follow operations.

a) Supply products in cycle: The vehicle keeps running in the service zone and holding the products the customers may be need. The customers take down things themselves.

b) Waiting for called: AGV waits in the appointed zone and transports goods to customer who calls.

c) Transport the customer to service window: Vehicle can transport the customer from inbound to the specialized service window and also can take them back.

3) The characteristics of supply logistics application.

a) High requirement of human-computer interaction: If the customer is real human, the level of human-computer interaction design will very high and always be found in service area, such as the restaurant.

b) Limited by service processing: It’s also difficult to standardize the vehicle for the complex service processing. The company needs to ask the producer to design uniquely.

c) Throughout depends on the demand frequency: The demand frequency always keeps changing. So the AGV system’s throughout can’t calculate exactly for this limitation.

There are many cases for this application scenario, such as the restaurant, hospital, parking lot. Especially in the real service area, the AGV used should be the robot and this is also the popular topics in research. Also in the simple service situation, the vehicle can really improve the supply flow.
3.3 warehouse intralogistics

Warehouse and distribution centers (DCs) play more and more important role in modern society. For each warehousing company, the most fundamental idea is of the management of two resources: space and time. Although the automatic intensive storage and retrieval systems, such as AS/RS, allows enterprise realize automation, the general single deep racks, gravity racks and drive-in racks are still widely used in warehouse.

1) The warehouse logistics application scenario description.

One of the mainly operations in warehouse is the inbound and outbound of goods. AGV can achieve the traveling automatically. This application situation can be described in follow chart

![Figure 4. warehouse intralogistics application scenario](image)

2) The operations of AGV in warehouse intralogistics.

In this system, the main operations are inbound and outbound of goods. Here AGV can be used in the follow operations.

a) Transport the unit load from AS/RS: The vehicle can transport the unit load from AS/RS’s conveyors and finish the operation automatically.

b) Multiple floor racks load: AGV can unload and load goods from multiple floor single deep racks. This operation needs precise location technology for each storage space.

c) Floor and station storage load: The floor storage and the other station storage modes can also be transported by vehicles, such as traying station in chart above.

3) The characteristics of warehouse intralogistics application.

a) Almost fork-lift refitted vehicle: Because the goods always storage in pallets, the AGV can be refitted by fork-lift. This way, the vehicle has more flexibility to load goods from different places.

b) Without wire guidance pattern: There are many storage spaces in the warehouse companies always. So it’s difficult to do by using wire guidance. Here the laser guided technology can achieve the requirement perfectly.

c) Limited by WMS: The AGV system should obey the WMS management and receive the tasks from WMS, so it’s limited by the level of warehouse management.

There are many cases for this application scenario, such as the electric warehouse, tobacco distribution. It always integrated into the AS/RS. Although there are more and more AGV manufactures can design the laser AGV, but most of running cases in China are using the vehicle coming from Europe.

3.4 e-commerce intralogistics

Shopping online is affecting more and more people’s life all over the world. People choose the product online and finish the payment also. After that, the e-commerce companies receive the orders and try to find the product ordered from enormous goods in warehouse. After package operation, the express company will deliver the pack to customer. From the whole process, there are two logistics steps in this procedure. One is the external logistics which controlled by the express company and the other is intralogistics that decided the efficiency of each order. Actually, the bottle neck of e-commerce logistics is the picking process. In this operation, the picker always spends 50% time in all in travelling.

1) The e-commerce intralogistics application scenario description.

As the handling vehicle, AGV can do much more in e-commerce intralogistics to improve the material flow efficiency. The follow chart gives a view of one of its application scenario.
Figure 5. E-commerce intralogistics application scenario

The application scene is coming from the Amazon’s kiva system which is popular these years. It has similar fulfillment system running in China now. This mode realizes the goods transport from storage to picker automatically which makes the picker needn’t travel.

2) The operations of AGV in e-commerce intralogistics.

It’s one of goods-to-piker picking mode above. Except this application mode, there are other operations that can be done by AGV in e-commerce intralogistics.

a) Goods to picker: it’s the operation introduced above.

b) Travelling through each zone and combing items for each order: AGV can travel through each zone by carrying the orders. And each zone has one or more pickers to extract items from racks and puts into vehicle. This is a method that combined with zone picking.

c) Gathering the items picked by staff: AGV also can be used to gather the items that already picked by staff and transport to the sorting and packaging line.

3) The characteristics of e-commerce intralogistics application.

a) Difficult to manage: The fleet size will be huge in this application and it needs high level central controller, which makes the system become very difficult to manage. The main factors for central controller are sequences dispatching, vehicle scheduling online and path layout design.

b) Small, fast and flexible : The vehicle should be fast for the huge orders, flexible and small for the space utilization.

c) Limited by order profile: The order profile will influence the throughput of AGV handling system. The profile includes the order size, items distribution and order frequency.

The e-commerce intralogistics is much more complex than others because this industry has high demand frequency, short order for each and items huge. The difficulty isn’t vehicle design, but the central management. This keeps open to research and practice.

4. DISCUSSION AND CONCLUSION

This paper gives a comprehensive view on development and application of AGV system. And it focuses on the different application in industrial plants based on logistics analysis.

From the content of paper, the flexibility and intelligence of AGV system contribute to integrate the material flow inside company and improve the enterprise to achieve automation and information. Therefore, it plays a role to improve the core competitiveness constantly. However, only the specific industries, such as the automotive plants, are utilizing AGV material handling system in large scale. There is a huge open market space in other industry that is waiting for being expand. In order to open the bigger space, many problems have to been settled.

Before the enterprises adopt AGV into initial system, it is essential to analyze the characteristics of intralogistics to find the suitable vehicle to use. Firstly, the designer can stand in the view of logistics to analyze the material flow inside and find the key flow path and factors which can be replaced by AGV handling system; secondly, to estimate which mode of the intralogistics is, and select the suitable vehicle on the basis of intralogistics mode.

It will induce the benefits of material handling system if selects the vehicle blindly. Therefore, a reliable estimation method will become more and more essential to decision makers. The researches not only need to study the strong and intelligent AGV, but also to develop the reliable estimation system to support the practical
area to expand the application of AGV system. This is a comprehensive problem that needs much more further research.

REFERENCES


