# Research on Planning of Multi Vehicle Series Line Based on AGV Adaptive Internal Circulation

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**Abstract.** Different from the traditional linear welding production line, the AGV internal circulation welding production line proposed in this paper mainly drives the AGV fixture and BIW products to realize the process transfer through the AGV in the region. The purpose is to build a welding production line that can accommodate the simultaneous on-line production of four vehicle series and the subsequent integration of N vehicle series, so as to meet the flexible and rapid switching of multiple vehicle series of 60jph. In order to realize the above functions, the fixture three-dimensional warehouse and AGV in the welding production line are introduced for the first time, the switching production of four vehicle series is realized by AGV traction AGV fixture and three-dimensional warehouse inventory fixture switching, and the NC servo system is introduced to realize cross-scale vehicle series positioning, so as to ensure that different vehicle series can realize positioning based on the same ground positioning system.

**Keywords:** AGV internal cycle · flexible production · fast switching · vehicle model delivery

## 1 Introduction

The flexible production of multi-vehicle series has always been the biggest production goal of every automobile enterprise, which can not only solve the problem of newly built workshop, but also produce new models on the basis of the original line body, greatly reducing the production input cost of new models.

This paper proposed a welding production line based on AGV adaptive internal cycle fast switching, and has been put into use in the front engine room wire body of a high-end brand of new energy welding workshop. The main principle is to carry out process transmission through AGV traction AGV fixture, and realize cylinder wireless locking and signal transmission through gas-electric quick-plug equipment. Front engine room parts of different vehicle series are positioned and clamped with different AGV fixtures, and different AGV fixtures can be bound with the same AGV, so that a single AGV


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can pull front engine room parts of different models for process transfer. In order to ensure the quick switching of AGV fixtures, a three-dimensional welding fixture library is added beside the cyclic welding island.

## 2 Theoretical Model of Internal Circulating Wire Body in Flexible Welding

### 2.1 Principle of AGV Inner Cycle Process Transfer

The method of AGV inner cycle realization is mainly through the AGV traction AGV fixture and its body in white products, combined into a process transfer group, in turn stay in different ground positioning mechanism, to complete the current process. In order to meet the current process requirements, the bidirectional idler wheel AGV with lifting function and travel error within ± 3mm is adopted. Fig. 1 shows the theoretical model of ARG1 area in the front engine room. AGV places AGV fixture on the ground positioning mechanism of upper part station, waits for the seven-axis robot to put the product into the AGV fixture and clamp it, then AGV lifts it away from the ground positioning mechanism. Ensure the AGV fixture is locked in the state of no gas and no power. The process transfer group formed by AGV goes to the fixed welding station 1, and places the AGV fixture on the ground positioning mechanism, which is welded by the welding robot. After the welding is completed, it circulates in turn. When the seven-axis lower part robot takes the product away, the AGV returns to the original upper part station and completes an internal cycle. By increasing the number of AGVs to 4 and forming the simultaneous linkage of 4 AGVs, the beat can be controlled within 49 s.

In order to ensure the effective operation of AGVs, AGV charging piles are set in the station. When there are other processes in the AGV station, charging piles are used to charge the AGVs, as shown in Table 1. The number of charging piles required by

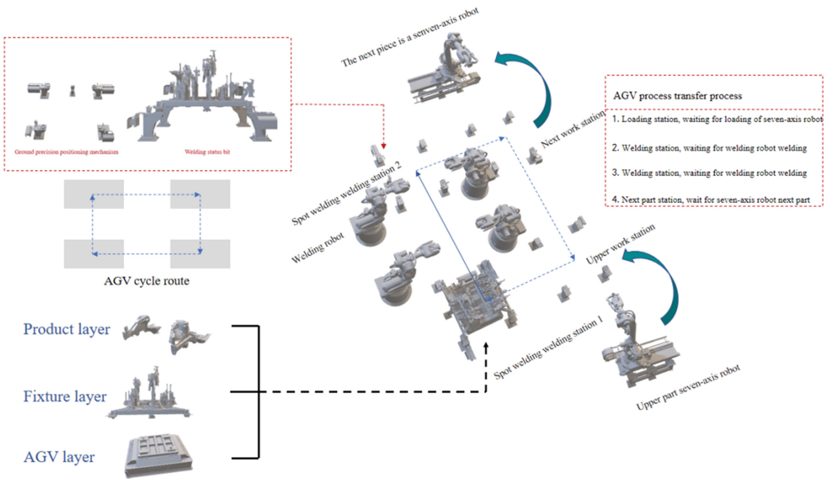


Fig. 1. Theoretical model of process transfer in AGV

**Table 1.** AGV cycle charging pile number calculation table

| Forward engine room path power consumption calculation | | | | | |
|---|---|---|---|---|---|
| Process circuit | Distance travelled (m) | Power consumption/AH | Charging current/A | Charging time (s) | Number of chargers |
| ARG1 | 27.60 | 1.18 | 130.00 | 32.67 | 2 |
| ARG2 | 41.20 | 1.77 | 130.00 | 48.90 | 2 |
| CACHE | 36.50 | 0.69 | 80.00 | 31.02 | 2 |
| ARG3 | 109.10 | 1.67 | 80.00 | 75.32 | 3 |

each safety zone and cache area is calculated by calculating the AGV's driving path, the power required by load lifting and waiting, and reasonably distributed in each safety zone. Ensure that each charge can run the whole cycle, to achieve mass automatic process transfer.

### 2.2 Flexible Production and Fast Switching Methods

The main purpose based on the AGV inner loop is to realize the coupling of the same AGV with the corresponding AGV fixture and the car system. At the same time, a four-layer fixture three-dimensional library is set up beside the inner circulation area of AGV, which is used to store the corresponding AGV fixtures of four kinds of vehicle series. In the process of vehicle model switching, the AGV fixture on the AGV is sent to the entrance of the stereoscopic fixture library through the cargo fork of the stereoscopic fixture library, and then lifted to the corresponding number of layers of the vehicle series for storage. When the AGV runs to the lower part station, place the AGV fixture ready for switching on the AGV at the outlet of the stereo library. Through this process, the purpose of fast and flexible switching can be achieved.

### 2.3 Dynamic Equation and Solution

The new AGV inner cycle production line proposed in this paper is mainly suitable for the production requirements of 60JPH. While the 85% actuation rate is satisfied, the theoretical beat of 60JPH is 51s after simple calculation. The production beat calculation formula of welding workshop is:

$$T_s = \max[F(\omega, \xi_m, \xi_p)] \tag{1}$$

where $T_s$ is the production beat of the welding workshop, $\omega$ is the transmission beat parameter of the in-line logistics, $\xi_m$ is the transmission beat parameter of the in-line mechanized platform, and $\xi_p$ is the production beat parameter of the in-line. Therefore, the production beat of welding workshop is the maximum value of the three parameters in the calculation function of $F(x)$ beat. The calculation method of $F(x)$ is as follows:

$$F(x) = \max[a_i \psi(r_i)^T],\ a_i = \begin{pmatrix} a_\omega \\ a_{\mathrm{m}} \\ a_{\mathrm{p}} \end{pmatrix},\ \psi(r_i) = \begin{pmatrix} \psi(r_\omega) \\ \psi(r_{\mathrm{m}}) \\ \psi(r_{\mathrm{p}}) \end{pmatrix} \tag{2}$$

where, $a_i$ is the operation rate matrix of external logistics, mechanized platform and line production, and $\psi(r_i)^T$ is the transpose matrix of the theoretical production beat function of external logistics, mechanized platform and line production.

And the way we compute $\psi(r_i)^T$ is:

$$\psi(r_i) = \max[b_i G(s_i)^T], b_i = \begin{pmatrix} b_1 \\ b_2 \\ \cdots \\ b_i \end{pmatrix}, G(s_i) = \begin{pmatrix} G(s_1) \\ G(s_2) \\ \cdots \\ G(s_i) \end{pmatrix} \quad (3)$$

In the formula, $b_i$ is the branch beat coefficient matrix, which is due to the existence of double logistics transportation or double beat production technology in the external logistics or line body. $G(s_i)^T$ is the beat transpose matrix of each line body.

The formula for calculating the production beat of each production line is:

$$G(s) = \sum_{i=1}^{k} s_k + e_k H_k \quad (4)$$

where, $s_k$ is the time required by each process at the current station, $e_k$ is the feedback time of taking the current process signal, and $H_k$ is the feedback time coefficient. The difference of $H_k$ coefficient is due to the different response time corresponding to the safety signal, driving signal and detection signal. $k$ is the number of processes at the current station.

The above calculation method summarizes the beat parameters of each process, but for the inner cycle AGV welding line body can still be carefully divided. The running beat of the AGV is:

$$t_a = \frac{s - 2s_0}{v_{\max}} + t_0 \;..v_{\max} = \int_0^{t_0} (bt^2 + ct)dt \;..s_0 = \int_0^{t_0} v_{\max} dt \quad (5)$$

where $t_a$ is the total running time, $s_0$ is the running displacement when acceleration is 0, and $v_{\max}$ is the maximum acceleration. Therefore, according to the acceleration constitutive equation provided by the AGV manufacturer, the travel time of any length AGV can be calculated.

Based on the above calculation formula, the production beat of welding workshop can be obtained. Therefore, in the planning process, the theoretical production beat of welding workshop can be obtained by using TECNOMATIX software for simulation analysis of each station.

## 3 Central Control System and Vehicle Transmission Scheme

### 3.1 Flexible Production and Fast Switching Methods

In the welding workshop, vehicle type information transmission is mainly divided into the following four levels. As can be seen from Fig. 2, the central control system, as the bridge between Enterprise Resource Planning (ERP) and PLC of each line, can

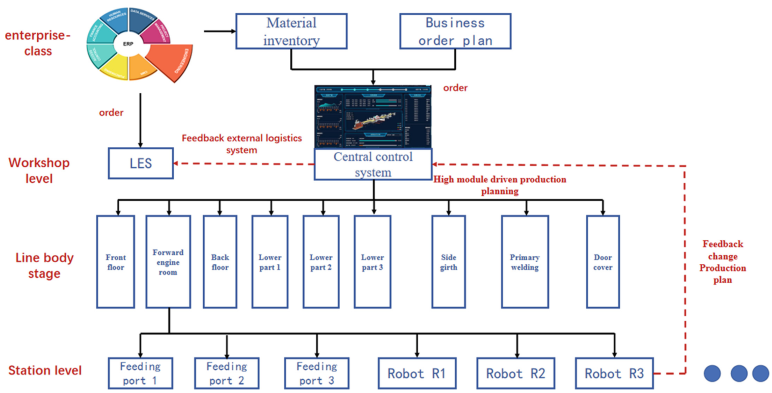


**Fig. 2.** Welding shop control flow chart

reasonably optimize the operation and production scheduling. The central control system needs to send the production plan of different wire bodies to the PLC control system of different wire bodies, and the PLC will send the production plan of the wire bodies to each material port display screen and the key station in the wire body respectively.

# 4 Simulation Analysis and Field Verification

## 4.1 Simulation Research Based on TECNOMATIX

In this paper, PD (PROCESS DESIGN) and PS (PROCESS SIMULATION) software in Siemens TECNOMATIX are used to simulate and analyze the cyclic welding island in AGV. PD is used to build the 3D digital model basis of the front engine room wire body, and solder joints of the front engine room are imported into the welding feature database, and all solder joints are associated with the digital model of the body. The welding spot was projected by PS, the welding mechanism and AGV operating parameters were defined, and the AGV operating path and robot welding action path were created. Match RCS configuration file, simulate each process running time. Finally, the SOP linkage of each safe area can obtain the theoretical beat data of all stations in the front engine room line.

## 4.2 Verification of Actual Process and Beat on Site

After the on-site installation was completed, two tests were conducted on the actual production beat of vehicle A, as shown in Fig. 3. In the simulation verification process, the three safety zones in the front engine room could all meet the requirements of the production beat, while in the first debugging process, most stations interacting with AGV exceeded the beat. Therefore, in the subsequent optimization process, the robot running track is optimized, anti-collision guide rail is added to the AGV running track, and PLC releases signals in advance. Finally, ensure that every station in the front engine room area is within the beat range.

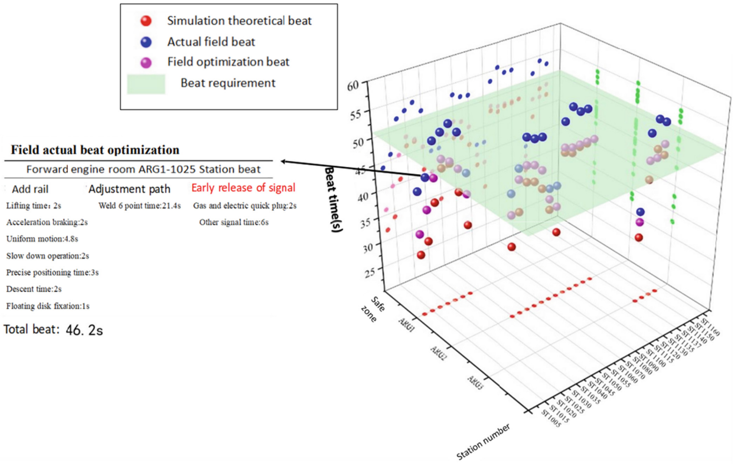


**Fig. 3.** Simulate beat and optimize beat scatter diagram

## 5 Conclusion

The proposal of fast switching wire bodies based on AGV adaptive internal cycle not only breaks the technological monopoly of foreign wire bodies, but also provides a new platform for Chinese proprietary technology, realizing fast and flexible switching of 4 + N kinds of vehicle systems for the first time. 4 Chinese vehicle systems are produced online at the same time, and N kinds of vehicle systems are integrated into later fast and flexible. The switching time is fully included in the beat while meeting the 60JPH production beat requirements.

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Research and development of emergency evacuation and rescue simulation system for new energy power plant.

Number: 21ZGM38.

## References

1. Ning Yu, Han Yingchun,Li Yue.Advanced Planning of BIW Welding based on Digital Factory [J].Automobile Technology,2010(05):58–61.
2. NING Y, HAN Y C, LI Y. Advanced Planning of BIW Welding based on Digital Factory[J]. Automobile Technology, 2010(05):58-61.

3. Teng Jidong, Piao Yongcan,Huang Dawei,Xie Kuiying,Su Biao.Research on stamping workshop digital simulation platform based on plant simulation[J].Manufacturing Automation, 2021,43(02):92–97.
4. HU L L, SHI Y.Reaearch on Flexibly Universal NC Unit of Automotive BIW Welding Jig. Machine Tool & Hydraulics,2017,45(20):68–69.
5. Sun Xuan and Wang Zhi-yong and Ma Zhe-dong. Research on wireless communication technology based on automatic logistics system of welder[J]. ITM Web of Conferences, 2018, 17