Automatic generation of co-working paths for dual-head laser drop feeders and applications

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The cooperative work path automatic generation technology of dual-head laser drop feeder is studied, aiming to improve the efficiency and safety of laser cutting production line. By designing key technologies such as central control system, division of cutting tasks, real-time position feedback, collision detection and avoidance, and coordination of cutting parameters, the cooperative work of two independent laser cutting heads in the same plane is realized. This technology not only optimizes the cutting path, but also ensures the safety and consistency of cutting quality during the cutting process. The experimental results show that the dual-head cooperative work significantly improves the production efficiency and provides a new solution for the application of laser drop feed production line in complex processing fields such as hot stamping.

Keywords: Laser drop; Cooperative work; Safety avoidance; Automatic path generation; Hot stamping.

1. Introduction

Laser drop feed production line is a new type of digital processing equipment, which adopts laser technology to carry out high-precision and high-efficiency cutting and processing of coil materials. Compared with the traditional production line, the laser drop feed production line has the advantages of automation, high precision, multi-function, environmental protection, etc. It is widely used in automotive, sheet metal and other industries. The laser drop-feed production line is mainly composed of uncoiled, leveler, laser cutting system, unloading system, control system and other parts. The core technology of laser drop feed production line covers laser cutting, automation control, conveying and positioning, laser head, control system, software, environmental protection and customization. The continuous development and innovation of these technologies have promoted the wide application of laser drop feed production line in various industries. This research is the use of advanced dual cutting head independent motion system, through the target-oriented path to work together to improve production efficiency, the key technologies in which the research, focusing on collision avoidance methods and joint path optimization methods of research and software development. The project has developed a dual-head, high-efficiency cutting machine for metal sheet widths based on the original belt-supported technology prototype.

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2. Cutting Path Optimization

The laser cutting path optimization problem is an extension of the traditional TSP (Traveling Salesman Problem) and is solved in a similar way to the TSP problem. The material and shape characteristics of laser cutting in the actual production process will affect the selection of laser cutting paths, so when considering the path optimization problem of laser cutting, it is necessary to set some process parameters. Dantzig GB [1] first solved the TSP problem by Linear Programming in 1954, and U. Manber et al [2] developed a method to solve the TSP problem in 1984, which was used to solve the TSP problem. Manber et al [2] discussed the problem of cutting regular or irregular part patterns with a minimum number of perforation points, and V. Cenrny applied the principle of annealing in thermodynamics to the solution of the TSP problem in 1985 [3].

1997 Jordan, J. M [4] developed an optimization algorithm for laser cutting paths at high speeds for solving the TSP problem in CNC machines. cutting path optimization problem in CNC machine tools.2020[5],2022[6], Wang, J. Y. et al. developed the problem of automatic generation of knife path for belt-supported laser cutting machine.

At present, the laser cutting technology at home and abroad has matured, and the research on this key laser cutting path optimization problem has been gradually improved. From the 1950s, when the TSP problem was solved by purely mathematical linear programming method, to nowadays, various intelligent algorithms are used to solve the laser cutting path optimization problem with constraints, and various improved and novel intelligent algorithms, such as simulated annealing algorithm, ant colony algorithm, and genetic algorithm, continue to emerge, which are being tested for their duties in a variety of complex application systems. However, the studies on the laser cutting path optimization problem in the 2D plane are based on the cutting of a single laser head, and there is no discussion on the 2D plane laser cutting with two or even more laser heads.

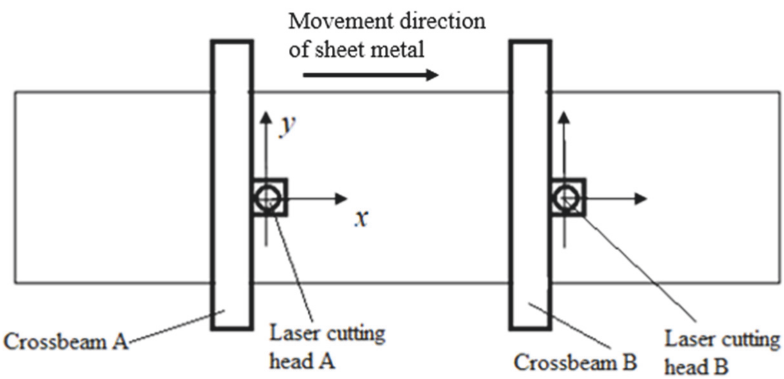

Fig. 1 Motion system with two independent laser cutting heads

3. Independent dual laser head motion system

3.1. *Co-operation of independent systems for dual head motion and their realization*

When two independent laser cutting heads have independent motion control systems and are required to work in the same plane for collaborative cutting, this can be achieved in the following specific ways:

(1) System Architecture Design a central control system that is responsible for coordinating the work of the two independent laser cutting heads. This system can be a computer or PLC (Programmable Logic Controller) whose function is to monitor and manage the cutting process.

(2) Cutting task division Subdivide the cutting task into multiple parts. For example, for a complex workpiece, cutting head A is responsible for cutting the upper part of the workpiece, while cutting head B is responsible for the lower part. The algorithm ensures that the working areas of the two cutting heads do not overlap to avoid mutual interference (see Figure 2).

(3) Real-time position feedback Each cutting head is equipped with a position sensor that provides real-time feedback of its position to the central control system. Based on the feedback, the control system adjusts the motion of the two cutting heads to ensure that they cut in the same plane and follow a predetermined trajectory.

(4) Collision detection and avoidance A collision detection algorithm is implemented to monitor the distance between the two cutting heads in real time. If a potential collision is detected, the control system will immediately adjust the path of one of the cutting heads or pause the cutting to ensure safe operation.

(5) Coordination of Cutting Parameters Coordinate the power and speed settings of the two laser cutting heads according to the material type and thickness to ensure consistent cutting quality. During the cutting process, the cutting quality is monitored in real time and the cutting parameters are fine-tuned as needed.

3.2. *Example of dual cutting heads working together*

Assuming that a large circular workpiece is to be cut, see Figure 2, head A starts cutting from the top half of the workpiece (red trajectory), while head B starts from the bottom half (blue trajectory). During the cutting process, the two cutting heads move along their respective trajectories at the same speed, and the central control system monitors the cutting progress in real time to ensure that they are accurately aligned when they cut to the center of the workpiece. In this way, the two independent laser cutting heads can effectively work together in the same plane to achieve an efficient cutting process.

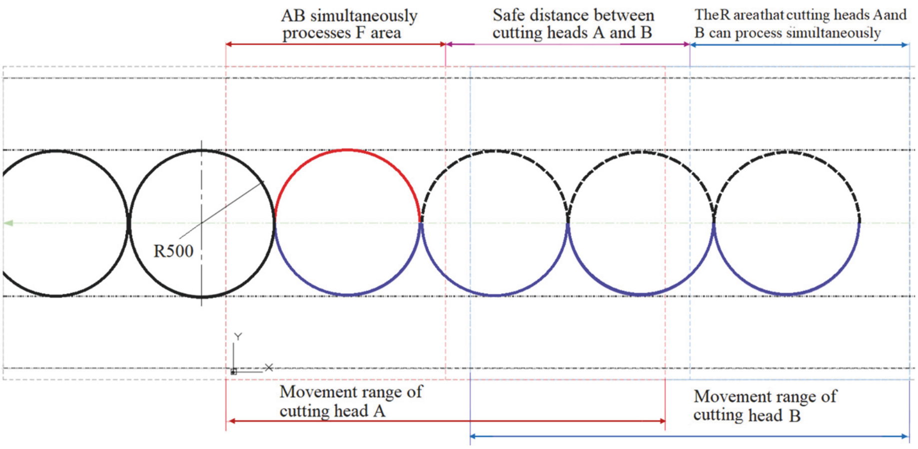

Fig. 2 Schematic diagram of double-head synergistic cutting

3.3. *Principle of avoidance for double-headed planar motion*

In a dual-head cutting system, the planar motion of the dual heads needs to follow certain avoidance principles to ensure that cutting head A and cutting head B do not collide or cross during the motion. The following is the definition and mathematical expression of the avoidance principle for the planar motion of the dual heads.

Define the positions of cutting head A and cutting head B as $P_A=[x_A,y_A]$ and $P_B=[x_B,y_B]$, respectively, then the planar motion of the double cutting head can be expressed as follows.

$$P_A(t+1)=P_A(t)+V_A * \Delta t_A \quad (1)$$

$$P_B(t+1)=P_B(t)+V_B * \Delta t_B \quad (2)$$

Among them, V_A and V_B are the speeds of cutting head A and cutting head B respectively, and Δt_A and Δt_B are the time steps. When the trajectories of cutting head A and cutting head B are close to each other and may collide, the speed and direction should be adjusted according to the principle of avoidance, so that the two can avoid crossing or collision, that is.

$$V'_A = f(V_A,V_B) \quad (3)$$

$$V'_B = g(V_A,V_B) \quad (4)$$

Among them, f and g are the avoidance functions, which are used to calculate the whole speed V'A and V'B according to the current speed and position information, in order to achieve the avoidance maneuver.

4. Double-head cutting and dropping production line

A plan view of a wide-format double-head laser cutting line is shown in Figure 3. This cutting machine adopts a belt to support the metal plate belt, and the support belt forms a subsequent optical slit under the cutting head, and the air and dust in the optical slit are discharged, so the surface of the punched parts is free of scratches and dust; the optical slit follows the movement of the cutting head, and there is always no obstacle under the cutting head except for the material to be cut, so there is no formation of cutting slag, and it can ensure the reliable cutting as shown in Fig.2. shown in Fig. 2. The machine is belt-supported, which reduces the friction damage to the cut sheet caused by the commonly used toothed nail plate support sheet, and can therefore be used for dropping steel or aluminium sheet material for body cladding parts. The belt drive and the cutting knife path gap are realized by a specially designed drive mechanism as detailed in [6].

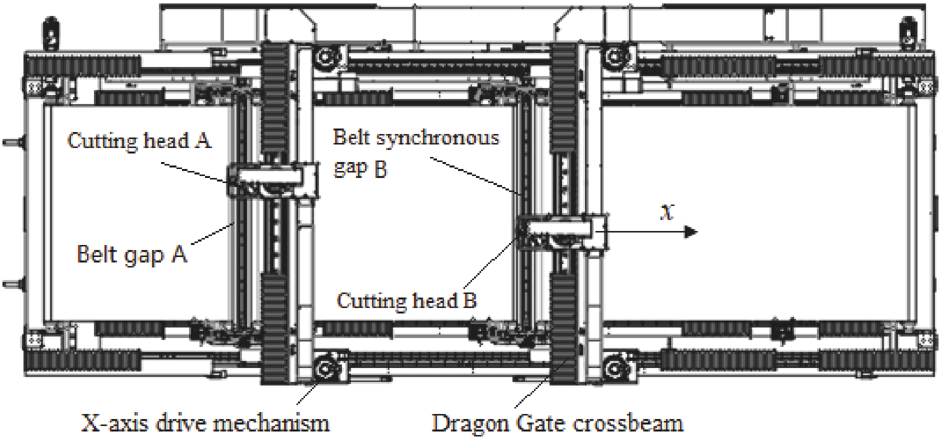

Fig. 3 Belt-supported double-head laser cutting machine (partial structure of the production line)

The line has been used for the precise dropout of aluminium alloy plates for engine covers, with high stability of the cutting trajectory and the safety of the double-heads working in tandem. Particularly for large laser welded plates, the clever design of the special belt seam reduces, or even completely eliminates, the contamination of the cut edge of the completed plate by cutting spatter, which can directly affect the quality of the subsequent laser welding. As an example, in the case of a weld plate dropout for the door ring of a certain car model (see Fig. 4(a)), the use of a wide plate width (1850 mm to 2000 mm) allows for the publication of the layout and optimization of the cutting paths, which improves the utilization of the material and reduces the overall cost of the welded plate hot stamping part, see Fig. 4(b).

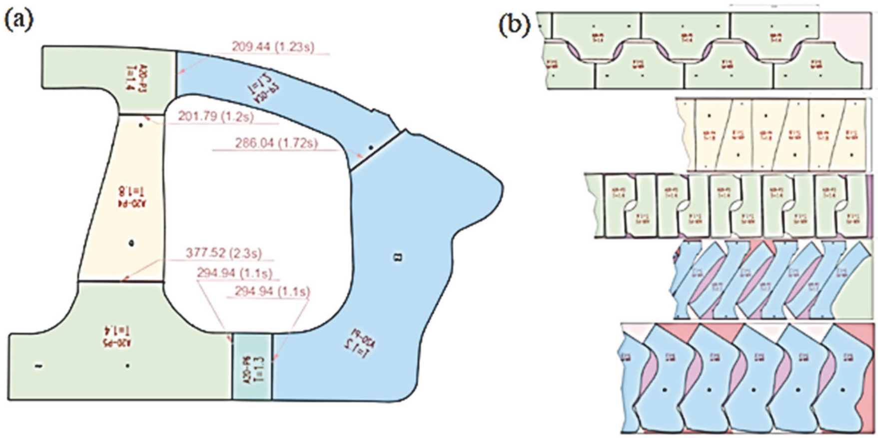

Fig. 4. (a) Spliced weld plate for the body door ring; (b) Optimized sheet for nesting dropouts.

5. Conclusion

This paper proposes the automatic path generation technology for the cooperative work of double-head laser cutting machine, which successfully solves the collision avoidance and path optimization problems faced by two independent laser cutting heads when they work together in the same plane. Through the design of the central control system and the application of optimization algorithms, it realizes the reasonable division of cutting tasks and the automatic generation of cutting paths, which effectively improves the cutting efficiency and safety. Experiments and practical applications show that the technology not only reduces the downtime and material waste in the cutting process, but also ensures the stability and consistency of cutting quality. In addition, the technology has good scalability and adaptability, and can be applied to cutting workpieces of different shapes and sizes, which provides strong support for the wide application of laser drop production lines in complex processing fields such as hot stamping. In the future, we will further optimize the algorithm and control system to enhance the intelligence level of the double-head laser drop feeder and promote the further development of laser cutting technology.

References

1. Dantzig GB. Solution of a Large-Scale Traveling Salesman Problem. Operation Research, 1954, (2).
2. Manber U, Israni S. Pierce point minimization and optimal torch path determination in flame cutting. Journal of Manufacturing Systems, 1984, 3(1):81-89.
3. V. Cenrny. Thermo dynamical Approach to the Traveling Salesman Problem: An Efficient Simulation Algorithm. Journal of Optimization Theory and Applications,1985, 45(1): 41-51.
4. Jordan, J. M., & Bradbury, J. L. (1997). NC tool path optimization technology for high-speed machining. Modern Machine Shop, 70(4), 185.

5. J. Y. Wang, P. Zhang, Y. P. Yang, J. W. Xie. The Principle and Control Method of Belt Support Industrial Laser Cutting Machine. Proceedings of the 6th International Conference on Advanced High Strength Steel and Press Hardening (ICHSU 2022), Atlantis Press:421-426.https://doi.org/10.2991/978-94-6463-114-2_56
6. J. Y. Wang，J. H. Zhong，G. C. Wang and L. Wang. Automatic Generation of Laser Blanking Toolpath for Multiple Cutting Heads on One Beam. Proceedings of the 6th International Conference on Advanced High Strength Steel and Press Hardening (ICHSU2020)，Inno Science Press，ISBN 978-981-5038-19-4, P.460~469.