Automatic-Controlled Intelligent Production Line for Shoe Soles

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Abstract: In order to protect the health of workers from the damage caused by their contact with toxic chemicals such as xylene and acetone during manual production of shoe soles, this thesis presents the realization of automatic and intelligent processes of production of shoe soles, such as automatic glue spraying, automatic hot printing, automatic film pressing, and automatic abrasive spraying, with the application of technologies, such as visual positioning, automatic spraying, automatic drying, automatic printing and automatic cleaning, and the intelligent production procedures, such as automatic glue spraying, automatic hot printing, automatic film pressing, and automatic abrasive spraying. The processes of the presented production line include automatic glue spraying, automatic hot printing, automatic film pressing, automatic shoe sole cleaning and automatic wear-resistant spraying. This thesis is conducive to the establishment of a typical model of intelligent production for the industry of shoe soles.

1 INTRODUCTION

With the development of modern manufacturing technology and the improvement of people's quality of life, the markets for clothing and footwear accessories are growing constantly with an continuously increasing market demand for the output of related industries. As the basic component of footwear that is essential to people’s shoe-wearing and travelling experience, shoe soles also witness a growing demand in the market. As the cost of personnel and factory land continues to increase, shoe processing factories are experiencing fierce competition. It is therefore imperative for these factories to find a method of shoe sole production with higher efficiency and lower cost. (Chen, 2022; Luo, 2022; Fülöp Melinda Timea, 2022; He, 2022; Stockinger Christopher, 2021; Tian, 2020) The prevailing processing technologies of shoe sole production can be generally categorized into two qualitative methods: direct injection molding and reprocessing after molding. Direct injection molding relies on special formulas of agents with wear-resistant, anti-skid, and other properties, by mixing these additives into the injection molding materials of a shoe sole, so that the injected shoe sole directly becomes wear-resistant, anti-skid, portable and comfortable. (Eversheim, 1982; H. Sasaoka, 1987; Layek, 1988; Ferrarini, 1997; G.W Zhang, 2002; Hidehiko, 2007; Gheorghe, 2014; Yin, 2013) On the one hand, this method has the advantages of convenient processing and low equipment cost, but the high cost of special additives and the method’s application limited to the upper and lower sides of shoe soles make the material cost of shoe soles still remain high. (Peter, 2013; Morosan, 2013; Fatih Mehmet Özel, 2013; H N Nagendra, 2019) In addition, the appearance of shoe soles needs to be molded at one time, so if a special appearance is required, the wear-resistant and anti-skid effects of its printing will be reduced. On the other hand, shoe soles can be molded by hot melt materials, or processed by leather and other materials before surface treatment such as spraying and printing, which can maximize material cost savings. (Indri Marina, 2019; Pierluigi Petrali, 2018; Alexandru Nitu, 2018; Chen, 2018) However, the existing sole processing procedures are cumbersome and require a

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large amount of manpower in production for division of labor and cooperation, so that the cost of labor and equipment for the processing of shoe soles remains high with unstable review efficiency, and unified efficiencies between each post. In particular, the production of leather soles needs to go through the processes of glue spraying, printing, film pressing, cleaning, and wear-resistant spraying, so even though the manufactured products of leather soles can meet the needs of the appearance, wear resistance, skid resistance, etc., the expensive production equipment and labor force the processing cost of the soles high.

2 INTELLIGENT PRODUCTION LINE

In the process of feeding, the formed materials are “fed to” (fixed on) the station of the conveyor machine. Then, in the process of handling, the materials on each station are processed through the procedures as follows: one or any combination of glue spraying, printing, film pressing and abrasive spraying. Afterwards, during the process of blanking, the processed materials are taken from the station and sent to the finished product area. The invention of this production line is the integration of the processing technologies of glue spraying, printing, film pressing and wear-resistant spraying, so that the molded sole (upper) can be processed at one time, and the stability of processing efficiency and precision through the production process is improved. By using assembly lines and multi-axis mechanical arms to connect the production processes in series, the production efficiency, processing accuracy, and labor cost savings of shoe sole manufacturing can all be improved. (Fig. 1)

Figure 1: Application of an automatic processing method for shoe sole production and the adopted equipment

2.1 Artificial Shoemaking

With the continues development of technology, Intelligent technology persistent to impact traditional manufacturing. As a traditional industry, the footwear industry requires a large amount of labor and the production technology is relatively backward, and the level of automation is low. (Fig. 2)

2.2 Technical Proposal

The production process of shoe making mainly comprises the processing of soles, shoes, uppers, insoles and other parts. In this case, an automatic processing method for sole processing is introduced and the automatic processing of formed soles is realized. The production process consists of a series of consistent steps: automatic glue spraying, automatic printing, automatic film pressing, automatic cleaning, and automatic abrasive spraying. (Fig. 3) The production frequency is set to ≤ 16s/pair (or 2475 pairs/day, 11 hours per day). See Table 1 for robot selection.

Figure 2: Manual operation with health hazard risk

Table 1: Robot selection.

Robot performance parameters	
Performance Parameter	Specifications
Payload	7kg
Scope of work	918mm
Number of control axes	6
Repetitive positioning accuracy	±0.02mm
Degree of protection (wrist)	IP54
Body weight	51KG

2.3 Automatic Processing Equipment

The automatic processing equipment consists of the following components: The feeding component is used to fix the formed materials on the station of the conveyor machine; The conveying component is used to convey the materials to each station; The processing components include one or any combination of the glue spraying module, the printing module, the film pressing module and the abrasive spraying module; The glue spraying module is used to locate materials via mechanical vision, grab them from the work station via the first six-axis spraying robot, spray glue on them, and dry the materials in the first dryer; The printing module is used to grab materials and place them on the printing machine mold via a four-axis robot, conduct air bag extrusion printing on materials in the printing machine, and dry the materials in the second dryer; The film pressing module is used to put materials into the film pressing machine via a four-axis robot for film pressing; The wear-resistant spraying module is used to press and fix the materials on multiple stations via a multi-station compactor, wipe clean their bottoms via a bottom wiping robot, spray wear-resistant agents on them via the second six-axis spraying robot, and dry them in the third dryer; The blanking component is used to remove the finished materials from the station and send them to the finished product area. (Fig. 4)

Figure 3: Automatic unmanned machine operation

Figure 4: Automatic glue spraying, automatic hot printing, automatic film pressing, automatic sole cleaning and automatic wear-resistant spraying for the processing of shoe soles.

3 AUTOMATIC CONTROL

Feeding: place the formed materials on the station of the conveyor machine and fix them on the station. Handling: the materials at each station connected by the conveyor machine are processed through procedures including one or any combination of glue spraying, printing, film pressing and abrasive spraying. Glue spraying: locate the material through mechanical vision, grab the materials from the work station through the first six-axis spraying robot, spray glue on them, and make them dry in the first dryer. Printing: the materials are grabbed by a four-axis robot and placed on the printing machine mold, before they are pressed and printed in the printing machine, and dried in the second dryer. Film pressing: the materials are put into the film pressing machine through a four-axis robot for film pressing. Wear-resistant spraying: press and fix the materials on multiple stations through a multi-station compactor, wipe clean their bottoms using a bottom wiping robot, spray wear-resistant agents on them through the second six-axis spraying robot, and dry them in a third dryer. Blanking: the finished materials are taken from the station and sent to the finished product area. Preferably, the conveyor machine is one or any combination of a conveyor belt, a transport robot and a multi-axis mechanical arm. Preferably, the following processing procedures of alignment are included: alignment, identifying and positioning the materials through mechanical vision, and adjusting the position of the station according to the positioning of the materials to align the materials with the processing coordinates. Preferably, the three steps of alignment are set after feeding, glue spraying and printing, respectively. Preferably, the following processing procedures of cleaning are included: cleaning, cleaning the materials after film pressing using a cleaning machine, and drying the materials in the fourth dryer. Preferably, the glue spraying quality inspection, printing quality inspection, and film pressing quality inspection are implemented to detect the quality of the processing of glue spraying, printing, and film pressing, respectively, through mechanical vision, and remove the defective materials from the production equipment after corresponding procedures. Preferably, each station is provided with a unique identifier that will be read before and after each processing step, while the corresponding processing steps are executed according to the unique identifier, so as to record the production information of the materials on the station. Preferably, the processing procedures are optimized through the digital twin optimization system: The digital twin optimization system includes a physical space subsystem, a digital twin model, a virtual space subsystem and an optimization model; The physical space subsystem is used to acquire the assembly working conditions of the material processing equipment and the production working conditions of the material processing equipment through signal acquisition; The digital twin model is used to collect data according to the signals of the material processing equipment provided by the physical space subsystem, and obtain the twin data of the equipment body, the assembly processes, the production processes and the performance of the material processing equipment according to the collected signals; The virtual space subsystem is used to examine 3D physical models, simulate virtual intelligent assembly scenarios, as well as virtual intelligent production scenarios according to the information from the digital twin model; The optimization model is used to iteratively optimize the twin data of the equipment ontology, the assembly processes, the production processes and the performance according to the simulation results of the virtual space subsystem through deep learning algorithms, and output the optimized results. (Fig. 5)

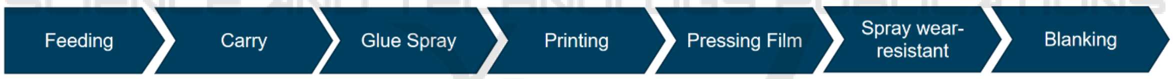

Figure 5. Processing Procedures

4 CONCLUSION

In this case, the processing technologies of glue spraying, printing, film pressing and wear-resistant spraying are integrated into the the automatic production process, so that the molded soles (uppers) can be processed at one time with stabilized processing efficiency and precision. By using assembly lines and multi-axis mechanical arms to connect the production processes in series, the production efficiency and processing accuracy of shoe sole manufacturing can be effectively improved, and the labor cost can be reduced. Through the combination of digital twin technology, 3D model simulation, the Internet of Things, virtualization and digital technology, various attributes of sole production equipment are mapped into virtual space to form digital images, so as to help production personnel redesign and optimize the equipment assembly and the parameters of shoe sole production line, thereby improving the production efficiency, utilization of production equipment, and labor cost savings for shoe sole manufacturing.

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