

# Chapter 16

## Machine Retrofitting for Tissue Paper Industry—INTERFOLDER Case



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**Abstract** This paper is a presentation of applied design knowledge as well as practical experience in mechanical engineering and industrial automation in order to retrofit machines. The main goal is to offer affordable solution for automated log transfer and at the same time extend the life of those tissue paper converting machines that are already in operation. We exhibit practically tested solutions for a module for sheet counting and log separation that can be mounted onto existing semi-automated machine. The digital prototype e.g. CAD model is generated for a preliminary module design. Rapid prototyping is used to refine delicate geometry of moving segment before tangible manufacturing. By machine retrofitting we attain a fully automated production that consequently increased efficiency of the line by elimination of the log manual transfer operation. Also, data collection from built-in sensors and analysis provide optimization of the overall equipment effectiveness. Additionally, retrofitting includes repairs, replacements and adjustments of electrical and pneumatic systems, implementation of software for controlling that adapts machine for conformity marking and for regulations.

**Keywords** Retrofitting · Fully automated · Modular design

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## 16.1 Introduction

Producers and consumers of tissue papers are turning to interfolded wipes, as an economically and environmentally friendly alternative, resulting in savings in transport and storage space and 40% lower consumption according to [1]. They are additionally supported by more demanding hygiene standards, especially recent after COVID-19. Such interfolded wipes are produced on INTERFOLDER machines. Currently, the wipes transfer from INTERFOLDER machine to the automatic packaging machine which requires increased workers for transferring wipes by hand, according to [2]. The producers in tissue paper converting industry are under pressure to optimize production, to reduce costs and to introduce automation technologies. At the same time, the benefits from I4.0 are encouraging enough to provoke the next stage of tissue paper industry [3].

If the current machines are still operational or purchasing of the new machines is costly, the retrofitting offers acceptable solutions. Retrofitting increases machine functionality and reliability, as well as enabling older machines to be compatible with new technologies [4]. Traditional retrofitting is prerequisites for upgrading machines suitable for smart retrofitting, which is discussed in [5]. Industry 4.0 requires smart retrofitting for taking full advantage of it. Although practitioners deal with retrofitting long before this topic gains attention in research domain, the retrofitting process still suffers variation in the implementation in different industries [6], which makes the identification of common points in retrofitting difficult. Useful generalization will provide the platform presented in [6] that assists in the process identification of requirements for retrofitting and implementation technologies for integration with Industry 4.0 and the methodology presented in [7] that provides efficient way to retrofit by deriving new functions and features based on data analysis results.

The developed technical solution for retrofitting refers to the field of mechanical engineering of special purpose machines for the production of interfolded. Given the current presence of semi-automatic INTERFOLDERS in plants around the world and the lack of interest of manufacturers of original machines for their full automation, there was a need to retrofit them. Retrofitting was realized by introducing an automatic transfer of a log with a given number of wipes. It is a prerequisite for further automatic transport by conveyor to the packing and sawing section. The construction, manufacturing, assembly and verification of modules for automatic counting and separation of logs of self-folding wipes were realized through the cooperation of the company ENERTEH, the Consulting Agency 25. MAJ and the Department of Production Engineering, Faculty of Mechanical Engineering in Belgrade.

## 16.2 Problem Interpretation

There are several manufacturers of Interfolder machines on the market, such as: PERINI Italy, PCMC Italy, DCM France, Dechang Yu China, BaoSuo China,

HINNLI Taiwan, [8–13] and others. Interfolders, which process raw material from two roll widths up to 1500 mm, requires the constant presence of an operator who manually transfers a log of wipes up to 1500 mm wide to the conveyor for further processing (log sawing, packaging). This manual work is a bottleneck in the production process and an obstacle to automating transport.

The answer to the increased market demands and the reduction of unit product costs is the automation of the transfer of a log of interfolded wipes from the machine to the conveyor. The only offered construction solution for new INTERFOLDER type machines with a working width of 1500 mm counts the sheets just below the machine heads, lowers the stack and removes it to the side, perpendicular to the direction of the paper, through the side opening. Such machines are from the manufacturers Ocean Taiwan [14] and OMET Italy [15]. The described solution is not applicable to already existing semi-automatic machines for constructive reasons, primarily due to the lack of a side opening in the supporting structure of the machine. Currently for the improvement of the existing semi-automatic machines of the INTERFOLDER type for roll widths up to 1500 mm, there is no adequate engineering solution on offer. Therefore, we offer retrofit solution that is modular for automatic counting and separation of packages of inter-folded wipes, which provides automation of production lines by introducing automatic transfer of logs with a given number of wipes, as a precondition for further automatic transport by conveyor to the packing and cutting section.

### 16.3 INTERFOLDER Machine Retrofitting

The offers of INTERFOLDER machines indicate similar construction solutions, which include the following working sections of the machine:

- Unwinders,
- Lamination sections or joining two layers of paper over the entire surface by using glue,
- Embossing sections, i.e. edge joining layers of paper,
- Paper ironing sections or calendars,
- Towing rollers,
- Wrapping section,
- Automatic towel cutting and stacking heads, and
- Longitudinal paper cutting sections.

The tissue paper unwinds with pneumatic paper roll loading system, by use of pneumatic control for driving paper roll unwinding, and passes through vacuum based folding heads to the automatic counting and transfer system. Folding heads are coupled by gears powered by one AC motor equipped with independent frequency inverter control. Vacuum based folding heads consist of vacuum blade roller with three movable bottom blades with holes to hold the paper firmly while cutting.

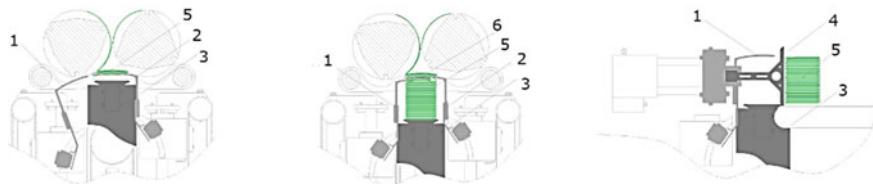
Therefore the each sheet is same size and good cutting. Anti-paper twist device prevents a big scrap of paper to go into the folding system, and protect the blades.

Vacuum based folding heads form a log of wipes by coupling two sheets of paper that come from the parent rolls. Each folding head has three spiral cross-cutting blades and three stator blades placed on the perimeter of the head in alternating order. This enables alternating cut of each sheet of paper and fold of other sheet at the same time. It is the point where sheets of paper become inter-folded. Sensor is reading the number of turns/revolutions of the folding heads enabling the successive countdown of wipes with permanent lowering of the log.

Pulling belts and pushers ensure infallible transport of logs towards infeed conveyor of the wrapping unit. After wrapping, logs are transported into the log saw and output table. Sensors check the paper break, wrap up or jams on the machine, stopping it automatically when paper is broken. Emergency stop buttons are installed on each part of the machine.

At the end of the converting process, a continuous series of folded wipes up to 1500 mm wide was obtained, which slides through the slope straight and accumulates on the table. To achieve it, we produced a module that through complete automation provides a reduction in production costs, because the presence of a man who manually moves logs is unnecessary. This allows easy handling and automatic transport of the wipe stack to the packing and cutting sections. Automation is the necessary basis for the introduction of Industry 4.0 by setting up a sensor that provides the necessary data on the number of folded wipes. To achieve this retro-fitted machine performs three main functions schematically presented Fig. 16.1:

- forming a set of wipes just below the heads for cutting and stacking using front and rear claw (Fig. 16.1-left),
- successive countdown of wipes with permanent lowering of the log standing at bench and separation from following log using claws (Fig. 16.1-middle), and
- tracing the log in a shorter of paper movement through the machine using pusher (Fig. 16.1-right).



**Fig. 16.1** Schematic presentation of forming a log of wipes just below the heads for cutting and stacking (left), successive countdown of wipes with permanent lowering of the log (middle) and removal of the log through the machine to the conveyor (right); Legend: 1—front claw, 2—rear claw, 3—bench, 4—pusher, 5—current log, 6—next log

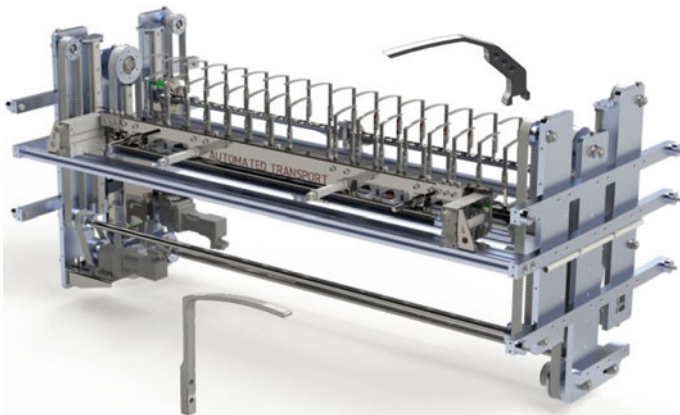
### 16.3.1 Modular Design and Retrofitting

The last two working sections from the original machine form the base of the machine and they are retained, but the section for longitudinal paper cutting and the table for lowering the inter-folded wipes have been removed. The design solution presented here is **parametrically designed** in SolidWorks (see Fig. 16.2) and the **principle of modularity** is applied primarily for the upcoming rapid reactions to market demand, i.e. efficient and effective implementation of this module for retrofit semi-automatic machines from other manufacturers with different working widths. In this way, it is achieved that the design process does not go back to the beginning, but only to certain final stages that are automated with the application of contemporary CAD software.

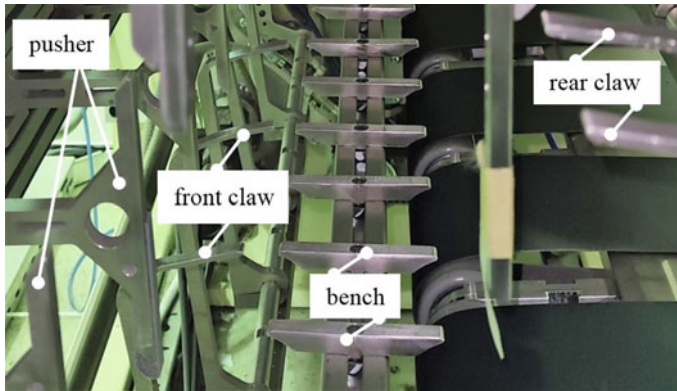
The CAD model of the module is a digital prototype, which enabled the verification of the adequacy of overall dimensions, fitting into the existing structure and assembly with the rest of the structure with physical limitations arising from the folding heads, under which it is installed. Special attention during the design was required by the front and rear claws due to the complex movement of the claw tips (see Fig. 16.1).

On the existing construction of the semi-automatic machine type INTERFOLDER manufactured by Dechang Yu China, new working sections have been designed, manufactured and installed. The main parts of working sections are the front claw, the rear claw and the bench. Front and rear claw are engaged in automating separation of logs while the log permanently takes down standing at the bench. Physical representations of them are given in Fig. 16.3.

Process of automatic counting and separation of a set of self-folding wipes is consist of following functions:



**Fig. 16.2** CAD model of module for automatic counting and separation of a log of inter-folded wipes with two versions of claw tips



**Fig. 16.3** Physical representation of the module for automatic counting and separation of a set of self-folding wipes

- Automatic counting of inter-folded wipes using mounted sensor which collects data directly from machine useful for enhancing productivity,
- Formation of wipe logs using the front claw, back claw and bench (see Fig. 16.1-left),
- Logs lowering on the bench (see Fig. 16.1-middle), and
- Log transferring onto the conveyor using the pusher (see Fig. 16.1-right).

In order to comply with the strict requirements of the CE mark, the improvement of the machine included the replacement of certain machine parts, pneumatic and electrical components. Checking the functioning of the module required the new program implementation for managing the complete production line, which along with INTERFOLDER contains a conveyor, a machine for log packing in foil and a log saw for cutting packages. The functionality of the module for automated transfer is tested in real industrial conditions of tissue paper converting in the company ENERTEH. Afterword, the retrofitted fully automated INTERFOLDER machine which is given in Fig. 16.4-left is considered as technological ready. Evidence of this statement can be seen in the video at the link given in [16]. Figure 16.4-right shows the moment of folding the wipe captured from the video.

### 16.3.2 Retrofitting and I4.0

When a machine is retrofitted a connected sensor is installed on an old machine. It is an incremental optical encoder BAUMER with 128 pulses and two phases, which converts the rotational movement of the working roller into an electrical signal which represents the feedback for the control system. As the working roller prepares the wipe sheets for V stacking, the exact position of the individual sheet is known at any time via the encoder, on the basis of which information on the number of sheets is



**Fig. 16.4** Upgraded machine INTERFOLDER 1500, left: front view from where the paper enters, right: section for folding and folding wipes

obtained, but also the right moment when the front and rear claws should entry, in order to achieve proper separation of the two logs (see Fig. 16.1-middle).

Three sheets of two rolls of paper are cut through each of the two coupled work rollers, which have paper cutting knives on them. In this way, during one turn, a total of six sheets are formed, mutually inter-folded in a V within the log. The incremental encoder allows the movement to be divided into 512 segments during this rotation, which has been empirically proven to be quite sufficient for precisely determining the moment of claw entry. That moment depends on the speed of stacking, because the speed of rotation of the rollers changes, and the time required for the claws to come out of the extended position is constant. Specifically in this case, it depends on the speed of the rotating pneumatic cylinder and the working air pressure. Based on that, the speeds and moments of claw entry, which correspond to the counted number of wipes, were empirically determined. It is software-regulated that this happens in the first free moment after the last sheet has been selected.

The encoder whose pulses enable the counting of slips is the basis for the production process monitoring and the entire production line, with the possibility of making decisions based on data collected directly from the machine. Data on the number of folded wipes and the number of records collected during the hour, shift, day or year with their digital processing in the manner of Industry 4.0 are necessary for optimizing **OEE** (Overall Equipment Effectiveness) and provide insight into the condition of the machine without interrupting its operation. This enables preventive maintenance and appropriate reaction to the occurrence of irregular conditions.

The team responsible for retrofitting process was able to improve productivity (12 logs per minute, number of sheets per logs 50–200), efficiency and working speed up to 170 m/min, increase the life span of the machine and reduce maintenance costs. The performance of a retrofitted automatic machine of the INTERFOLDER type is given in [17].

## 16.4 Conclusion

Most production equipment is designed to last for decades. Although the appearance of advanced technologies cannot be ignored during that exploitation period, the procurement of completely new and modern equipment cannot always be realized. One of the possibilities to simultaneously realize the benefit that comes from the introduction of advanced technologies, while maintaining the existing equipment is the retrofit of old machines. This implies the replacement of existing and the addition of the necessary more advanced components, primarily sensors, with designed changes to individual sections of the machine to support the introduction of advanced technologies. The upgrade of the semi-automatic machine of the INTERFOLDER type enabled complete automation of the production line in the ENERTEH plant, which fulfilled the necessary precondition for improving productivity, safety at work and the final quality of the product. Retrofit paper processing lines can become more than a series of insulated machines between which paper is transferred. The developed technical solution refers to the field of industrial machine retrofitting. This is an example of the necessary design changes for the technological improvement of wipes INTERFOLDER machines with working space up to 1500 mm.

The physically representation of the module for automated transfer are tested in real industrial conditions of tissue paper converting in the company ENERTEH, assessment by **rate TR9** of the highest level of technological readiness. Retrofitting of the special purpose machines can be easily commercialized via fitting the module for automated transfer into semi-automatic machines, which are installed in plants around the world.

**Acknowledgements** The results presented here are the result of a survey supported by the RS MPTR under Contract 451-03-9/2021-14/200105.

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