ROTARY CUT OFF KNIFE
THE MECHATRONIC SOLUTION
For the Corrugated Paper Board Production Line

With the term “mechatronics” we refer to the combination of mechanical engineering, electronic engineering, computer science and automatic control with the purpose of evolving machine manufacturing into the next generation. The rapid growth of electronics has led to the re-designing of traditional mechanical elements. Arrays of gears and mechanical cams, are replaced with “virtual” elements materialized as software in suitable controllers and servomotors drives. New possibilities appear in maintenance, flexibility, extendibility, easy reconfiguration, after sales support, but also possibilities of networking and interconnection with the factory automation. A typical mechatronic configuration is constituted mainly by controllers, drives and servomotors but also various other elements are essential for the concretization of the particular automation task e.g. I/O components, encoders, sensors etc. The heart of the system is the controller. Modern controllers are powerful systems that incorporate different operations in a single unit.

Raycon Systems and Machines ltd, in collaboration with Siemens SA, introduced a rotary cutoff for the corrugated paperboard production line based on the mechatronic philosophy. A schematic illustration of such a machine is shown in Figure 1. The rotary knife motion trajectory calculation is a non-trivial task since several position/speed restrictions must be met:

- At the cutting point the rotating blade should have a linear velocity equal to that of the moving carton board (synchronization phase).
- The time it takes for the blade to complete a full rotation must equal the time it takes for the board to traverse the desired cutting length. Thus the rotation time of the blade depends on both the paper speed and the desired cutting length.
- To minimize vibration and ensure minimal mechanical stress, the motion profile of the blade, should be as smooth as possible without violating the previous constraints.
In the past, this functionality was achieved solely by mechanical elements, where a change in cutting length translated into a change of the transmission ratio, through mechanical adjustment of pulley belts. Although this was prone to low precision, wear, instability, and the whole system was of increased complexity and high maintenance need, it was the only option for high-speed rotary cutoff knives in the corrugated paperboard industry for more than 50 years. A reason for this is that, despite its drawbacks, the mechanical cutoff, if high quality constructional standards were met and proper maintenance followed, was able to achieve a good cutting accuracy of (0.5cm). Possible improvements therefore were justified only in the need of higher accuracies, less than (0.5mm). As this need emerged and the trend in the field of electronics and control was reducing the cost of high-speed controllers, affordable servomotors and programming applications to drive them with electronic cams, began to appear. Mainly due to the initial high cost of servomotors, attempts by using DC motors, also appeared at this point but introduced great complexity with an impact on reliability, support and performance of the final system.

The current state of the art, in the corrugated paperboard industry, is using servomotors driven by high-speed controllers with customized software to achieve cutting accuracies less than 0.2mm. Usually, the companies that manufacture production machinery develop "close" software that drives the servo rotary cutoff knives. The solution presented here, for the rotary cutoff knife, extends the current state of the art, mainly because it introduces the concept of "open" mechatronic technology in place of "custom" software that usually exists today in these applications. The presented herein rotary cutoff is a product of Raycon Systems and Machines ltd. The mechanical part is based on the design and construction of A. Raftopoulos ABEE. The engineering approach gives emphasis on simplicity and durability; the main drive is conducted with a pulley and timing belt. This ensures accurate transmission, vibration reduction, low mechanical stress, and the possibility of reconfiguration for various specifications. The motion control part of the rotary knife is an implementation of Siemens mechatronic technology.
The automation is realized by means of a Simotion D controller that is used for calculating the desired trajectory. The restrictions in position and velocity (synchronization with the paper at the cutting position and rotation time according to the cutting length and paper speed), dictate a specific cam motion profile, which must be recalculated continuously, in real time, so that the restrictions are met, even after dynamic changes in cutting length and/or paper speed. For this reason, the position of the knife is resampled every 125 millionths of a second and the cam profile is recalculated by polynomial interpolation of fifth order (quintic). The motion control signals are transmitted to a Sinamics S120 servo rotation regulator, the logic of which is incorporated in the Simotion controller, driving a 1FT7 synchronous servomotor. The actual set points for position/speed are provided by an external measuring encoder. The system is operated through a Simatic touch panel connected via profibus network. Due to the inertia of the rotating load, the motor operates as generator, during braking. The returned energy can be consumed either in braking resistance, or returned in the supply network by means of a suitable Sinamics S120 module. In the later case, a significant reduction in energy consumption is achieved.

The rotary knife solution presented herein evolves the current state of the art, mainly due to the mechatronic design, in contrast to the logic of "custom" software. Mechatronic design, in this case, means that all the above theoretical algorithms, preconditions for the proper functioning of the cutoff knife, are implemented with existing building elements that have been developed, optimized and brought to an “embedded” form for general use. The reported solution therefore, is not "custom" software, but instead is an “open” implementation of the mechatronics library design infrastructure available by SIEMENS. This paradigm has important implications, both for the end-user-purchaser of the machine, but also for the cost-effectiveness of the manufacturer. Firstly, avoiding “custom” software solutions contributes to the autonomy of the equipment. With respect to after sales, this is a critical issue for the end-user. At the same time, this autonomy adds value to the rotary knife as a product. This is an issue very important for the manufacturer, as it involves SIEMENS in the after sales global support network with worldwide capabilities. The robust repetitive cutting accuracy, the capability for mark cutting and the “on the fly” change of cutting length, are the features that differentiate this solution from similar "custom"
solutions. These were integrated at relatively low cost because RAYCON succeeded in utilizing the existing modular mechatronic infrastructure of SIEMENS rather than developing "closed" software from scratch. As a result, even more innovative features were incorporated, like micro adjustment in the cutting profile for cardboards of variable thickness. All these advantages, in combination with the ease of maintenance, reliability, scalability and the possibility of incorporating a web-in production line automation (totally integrated automation) not only position this rotary cutoff, at the top of the global state of the art in corrugated industry, but also make it a first-choice product, capable of competing at an international level.

“RAYCON S&M cooperates with SIEMENS to introduce a novel open business practice, where the industry specific and electronic systems integration expertise of RAYCON S&M is combined with the mechatronic expertise of SIEMENS. In comparison to other approaches, where the electronics are realized by closed software developed in-house by non experts, the advantages are apparent in technological superiority, autonomy, after sales support in a global scale and advance of the state of the art. This result can only be achieved by interweaving different expertise in an open, customer oriented paradigm”.

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