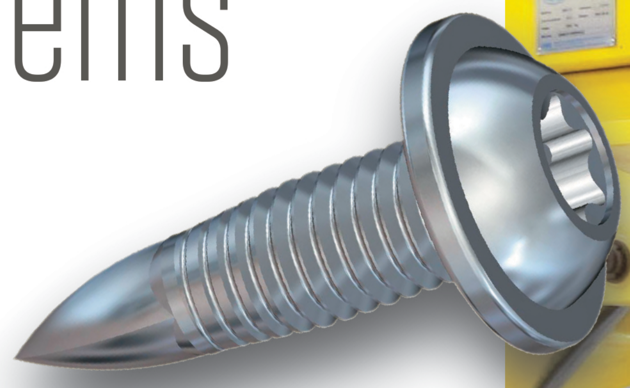
Assembly Systems Features for Lightweighting



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Alternative materials can't be joined through conventional methods. New approaches are needed.

INTRODUCTION

To reduce vehicle weight, designers are using thinner layers and alternative materials, including aluminum, high-strength steels and composites. While offering lightweighting advantages, thin materials reduce thread engagement and weaken fastened joints. In fact, composite materials including carbon fiber reinforced plastics may spall and delaminate.

These materials cannot be joined with conventional spot welding. The joint may include heterogeneous layers that prevent complete welding. In addition, manufacturers don't want more steps to join different materials, a practice that would be required using conventional fastener assembly methods, such as pre-drilling, back-up nuts or inserts.

The ideal assembly solution for divergent, lightweight materials should include:

- Low cost
- High speed
- High strength
- Single-sided installation
- Repairability

The fastener installation equipment should have:

- Flexibility so it is capable of installing the full range of flow type screws for future requirements
- The ability to adapt to various joint conditions (material thickness, joint flexing) by sensing the point of penetration
- Head-first feeding
- Inline stroke with drive
- An automatic adjustment of drive cycle.
- An automatic adjustment of drive cycle when tolerances of product or fastener occur
- Minimal parameterization
- Ability to choose hose or magazine feeding

There are challenging issues with lightweighting fastener assembly. Here are some of them.

TRADITION IS NOT THE ANSWER

In the past, car bodies were mostly steel on steel and welded. Welding robots were used in most frame assemblies. A welded frame gives impact protection and was a relatively cost-effective assembly solution.

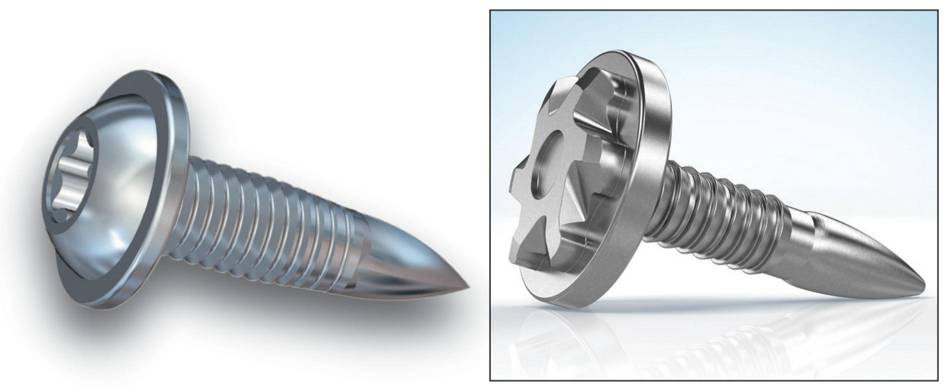


FIGURE [1] / Examples of flow-type fasteners

> Today's most common light-weighting fastener assembly uses flow-type fasteners.

With the need to reduce CO_2 emissions and make vehicles more fuel efficient, the use of lightweight materials instead of conventional steel for chassis and bodies has dramatically increased. Vehicle manufacturers are exploring alternatives and have found that other materials can be used, as well. While keeping an eye on safety, reliability, repair and/or replacement requirements, and considering recycling and reuse applications, a complete rethinking of chassis assembly was necessary. Today's most common lightweighting fastener assembly uses flow-drill fasteners that belong to the flow type family. These include flow drill, flow point, flow push or flow form fasteners.

Manufacturers are supplying flow type fasteners engineered for various material requirements, including CFRP (carbon fiber reinforced plastic) in some instances. Fasteners of the flow family call for an assembly system that takes into account the importance of creating a solid joint while protecting the fastener itself, its properties and the heavy-duty sequence required from the fastener.

[1] **Heating the joint area through friction**—The flow type fasteners use precisely engineered tip geometry, material and coatings that withstand the high loads and speeds required to heat the joint layers without melting the fastener tip. Precise control of the speed and feed in this step optimizes the cycle time while protecting the fastener.

[2] **Penetrating**—As heating softens the layers, the fastener tip displaces the substrate and pierces the layers. During this transition step, the fastener feed forces decline. Early models of flow fastening systems used a pneumatic cylinder with a closed servo-controlled valve. The response time from the pneumatic system was too slow for an automatic switchover to the next step. For these pneumatic feed systems to anticipate the switchover point, the geometry of the joint had to be programmed into the recipes. Variations in layer thicknesses required changes to the parameters. With the dual servo system (for rotation and feed), the system can recognize penetration and adapt to variations in layer thickness and material properties. This adaptive processing simplifies the setup and assures high-quality joints with varying conditions. See Figure 3.

[3] **Funnel Forming**—During funnel forming, the process is adjusted so that the material can cool, stretch the funnel without cracking or splitting the edges, and synchronize the speed and feed to prepare for the thread-forming step.

[4] **Thread Forming**—The fasteners have been engineered to form high-quality threads in the cooling layers. The newest screwdriving systems incorporate dual servos for rotary and feed. This means there will be no extraneous loads during threading synchronization. Synchronized speed and feed are used in machine tools for thread forming and tapping applications to ensure thread quality. High-quality threads safeguard the maximum joint integrity.

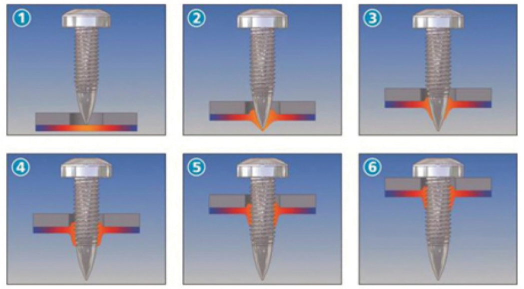
[5] **Screwdriving**—The fastening system drives the fastener at high speed while monitoring torque and screw depth so that switchover comes at the optimum point in the final step.

[6] **Final Tightening**—The fastener is turned to the specified torque. The final height of the fastener and the achieved torque are monitored for a quality joint.

The entire screwdriving process is usually finished in less than two seconds.

FIGURE [2] / Flow fastening sequential process

Each cycle considers the following steps:
- Step 1: Heating up
- Step 2: Penetrating
- Step 3: Funnel forming
- Step 4: Thread forming
- Step 5: Screwdriving
- Step 6: Tightening



In between step 1 and step 6 the parameters such as force and speed change several times. One cycle takes about 2 seconds, depending on the materials and the stack-up.

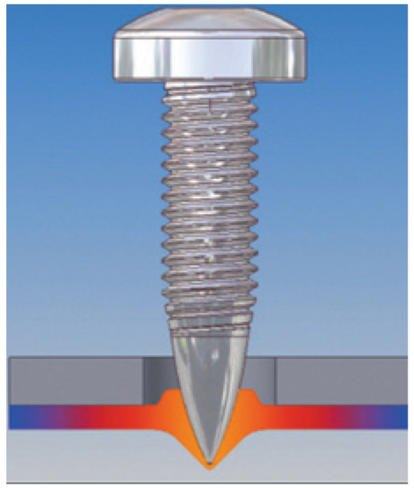


FIGURE [3] / Screw heating material

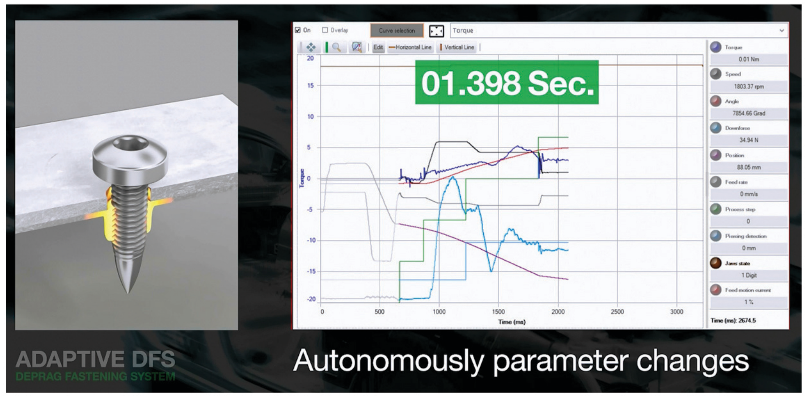


FIGURE [4] / Drive cycle timing flow-drill screw

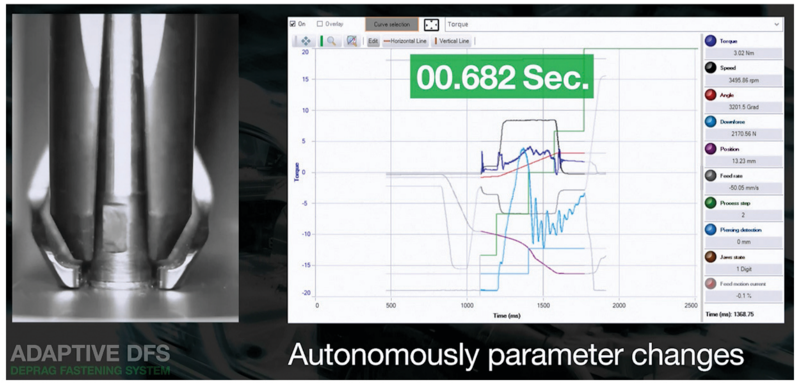


FIGURE [5] / Drive cycle timing flow-push screw

WHY CONVENTIONAL ASSEMBLY SOLUTIONS FALL SHORT

Resistance spot welding requires layers to be substantially similar and are traditionally limited to steels. Spot weld-

FIGURE [6] / Flexible robot mount – rear or side (shown)

ing also requires access to both sides of a joint. Flow type fasteners join dissimilar material layers, such as aluminum and steel, and CFRP and aluminum, as well as materials that are not suitable for resistance spot welding. Flow type fastening is completed with access to only one side of the structure.

Adhesives effectively join lightweight materials. Typically, adhesives require extended clamp times so that they may set. Flow type fasteners are frequently used to stabilize adhesive-joined assemblies while the adhesive is curing.

Remember, typical screw joints require material thickness of several threads or back-up nuts to achieve full joint strength. Flow fasteners overcome these limitations by forming a funnel before threading to maximize screw engagement.

Rivets require holes be drilled through the layer stack before the rivets are inserted. Flow type fasteners eliminate or reduce predrilling and aligning drilled holes.

There is a danger that if the screwdriver speed and/or pressure is reduced too early, the funnel is not fully formed and the heightened drilling torque could destroy the screw or component. Any delay in the transition might damage the newly formed threads, compromising the joint altogether.

Another potential problem comes when feeding the fastener. Generally, a screw is fed through a feed hose with the tip first and head last. Since the tip of these flow fasteners are needed to drill into material, damage by tooling or premature touching of the part is possible. The perfect solution would be a feeding system that has the head fed first and then the screw is flipped at the last possible moment to be tip first. This type of feeding can be done at the same time while the previous fastener is assembled, so that there is no time delay or longer drive cycle.

Keeping in mind that materials and fasteners change often, conventional assembly systems must be modified from the ground up. That is expensive and time consuming. A much better solution would be an assembly system that easily and flexibly adjusts to handle a different fastener, different parameters, different materials.

The systems needed for flow-fastener assemblies are primarily used on robots. These robots have a payload limit, and a heavy assembly system requires a robot with a high-duty payload.

Earlier generations of assembly system required lots of operator involvement, such as parameter input, parameter change, adjustments to cylinders, air, etc. If an intuitive assembly system is used where the adjustment is done automatically, less time is spent on babysitting the robot or the screwdriving system.

WHAT ARE IDEAL ASSEMBLY SOLUTION FEATURES?

The best assembly system is one where the communication of a twin closed loop system automatically identifies layer penetration—independent from material and screw tolerances. Such a control continuously evaluates the relevant actual values and automatically adjusts the process variables, such as contact pressure, feed distance and speed to the predetermined set points. The process will then be constantly optimized. Ideal process parameters are reliably put into action during each individual screwdriving cycle. Costly and time-consuming parameter adjustments and joint-analysis processes are reduced to a minimum or totally eliminated.

A continuous feedback from the control module provides an automatic, accurate recognition of the penetration point, and real-time autonomous parameter alterations are made by both the screwdriving and feed-stoke system. An ideal and automatic adjustment of the processing parameters would assure that the connecting parts and fasteners are exposed to the least possible stress. While all of these features are important, they should never increase the cycle time and always adhere to the condition limits of the material, like speed and torque.

A separate electronic regulation of stroke and screwdrive can offer wide-ranging parameter-setting possibilities, such as flexibility in processing different materials or material combinations and substantially reducing joint pre-analysis and parameter setting.

Flow type fasteners eliminate or reduce the need for predrilling or alignment of drilled holes.

FIGURE [7] / Flow cycle parameter list

Programm	
0. General	
1. Downholder force	300
1. Pre Positioning	
1. Feed motion	
1. Downforce upper limit	500
2. Feed rate	125
3. Switchover offset pre positioning	0.50
2.Screwdriver	
3. General	
1. Supervision time	2000
2. Detection	
1. Feed motion	
1. Downforce upper limit	500
2. Feed rate	10
3. Recess depth	75
2. Screwdriver	
1. Torque upper limit	2.00
2. Speed right	700
3. Speed left	700
4. Angle right	45
5. Angle left	45
3. General	
1. Supervision time	2000
3. Piercing	
1. Feed motion	
1. Downforce upper limit	2500
2. Feed rate	10
3. Start downforce	500
4. Threshold downforce	50
5. Switchover offset pierce detection	0.00
2. Screwdriver	
1. Torque upper limit	10.00
2. Speed	1800
3. General	
1. Supervision time	2000
4. Thread forming	
1. Feed motion	
1. Downforce upper limit	500
3. Switchover offset seating point	0.20
2. Screwdriver	
1. Torque upper limit	10.00
2. Speed	1800
3. General	
1. Supervision time	2000
5. Final thightening	
1. Feed motion	
1. Downforce upper limit	2000
3. Depth lower limit	-1.00
4. Depth upper limit	1.00
2. Screwdriver	
1. Shut-off torque	9.00
10. Torque hold time	0
2. Torque lower limit	8.00
3. Torque	10.00
4. Speed	750
6. Angle supervision	False
7. Threshold torque	0.00
8. Angle lower limit	0
9. Angle upper limit	0
3. General	
1. Supervision time	2000

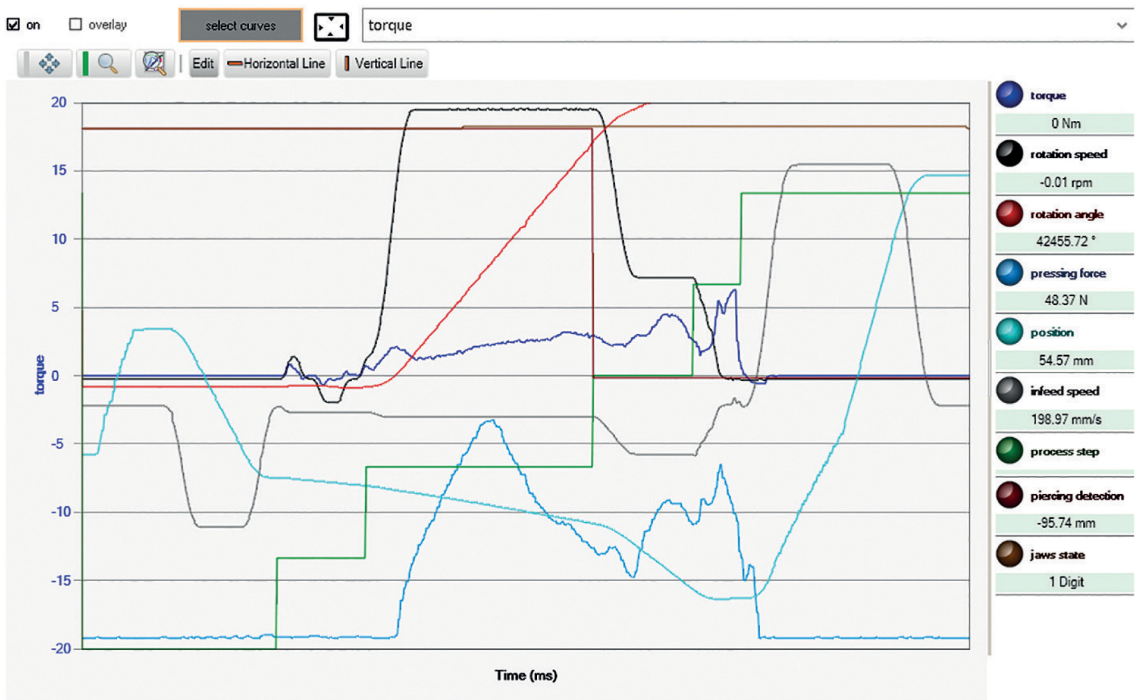


FIGURE [8] / Graphic display of drive cycle

Through a controlled-positioning technology, it should be possible to assure that desired parameters are matching the process values at each step of the cycle. For example, a defined positioning force, already covered transition distance or pre-determined angle values need to be available to process future materials or new fasteners.

It is also recommended that a precise joining be maintained to conform with the screws' thread pitch if the material or fastener does not allow any axial load. Such additional processing data would increase the consistency of the screwdriving documentation. A central lead-in of the contact pressure of up to 3500N to the fastener axis would prevent transverse load. Naturally, such an assembly system needs to be optimized for the shortest cycle times. Also, it is recommended pre-feeding the next fastener to some sort of distribution hub while the system is processing a current fastener.

To eliminate any damage to the fastener itself, a head-first feeding principle should be implemented. This type of head-first feeding feature would definitely protect the screw's tip and also its threads. Taking into consideration the need to have short feeding times, a screw preload function (buffer) would optimize the cycle time. To minimize tangling the robot dressing or damage to any of the cables or hoses on the feeder, there is now an "on-board magazine station" available. A predetermined number of screws is automatically fed into a magazine. The robot unloads an empty magazine on a fastener refill station and picks up a full magazine. This completely eliminates feed hoses.

An important feature is an ergonomic, intuitively serviceable operator interface (HMI). Such an HMI should include extensive functions, such as program selections system settings, assembly results, service recommendations, exterior links with access to all operating booklets, catalogs, additional features, and also maintenance instructions and scheduling.

The programs need unlimited assembly sequences parameterization, fastener setup, fastener selection and their specifications, as well as material input in regard to type, thickness, penetration strength and resistance.

Obviously, being able to archive the assembly results is of utmost importance, and there should be unlimited data storage with access to all assemblies ever undertaken by a particular system.

Looking for a reliable result-and-data management system should not be limited to just the screwdriving results. Rather, there should be a graph that provides trend analysis. It should also cover the set parameter and results for each parameter setting.

A good feature would be flexibility to create your own data screen. Not every assembly has to have all results displayed. Some may just show the most important graphs. Such a flexibility in regard to data screen display would simplify recognizing the main results, and keep misunderstanding or reading errors to a minimum.

The functions include individual testing of all function modules, be that the controls, screwdrivers, feeders, etc. All these function modules need individual checking for accurate performance. The complete system status, as well as all inputs and outputs, has to be verified by a service function.

The individual system setting will include user administration, where operators can sign in and set their preferences. It requires a setup for use on a global scale. That means multiple languages on the menu, and not just English and German. It's imperative that a global system include at least 10 of the world's most common languages.

Extensive integrated diagnostics form the basis for preventive maintenance and maximum uptime of the machine. Some maintenance features should include the wear and tear of the most common parts or feed hose.

NOTES

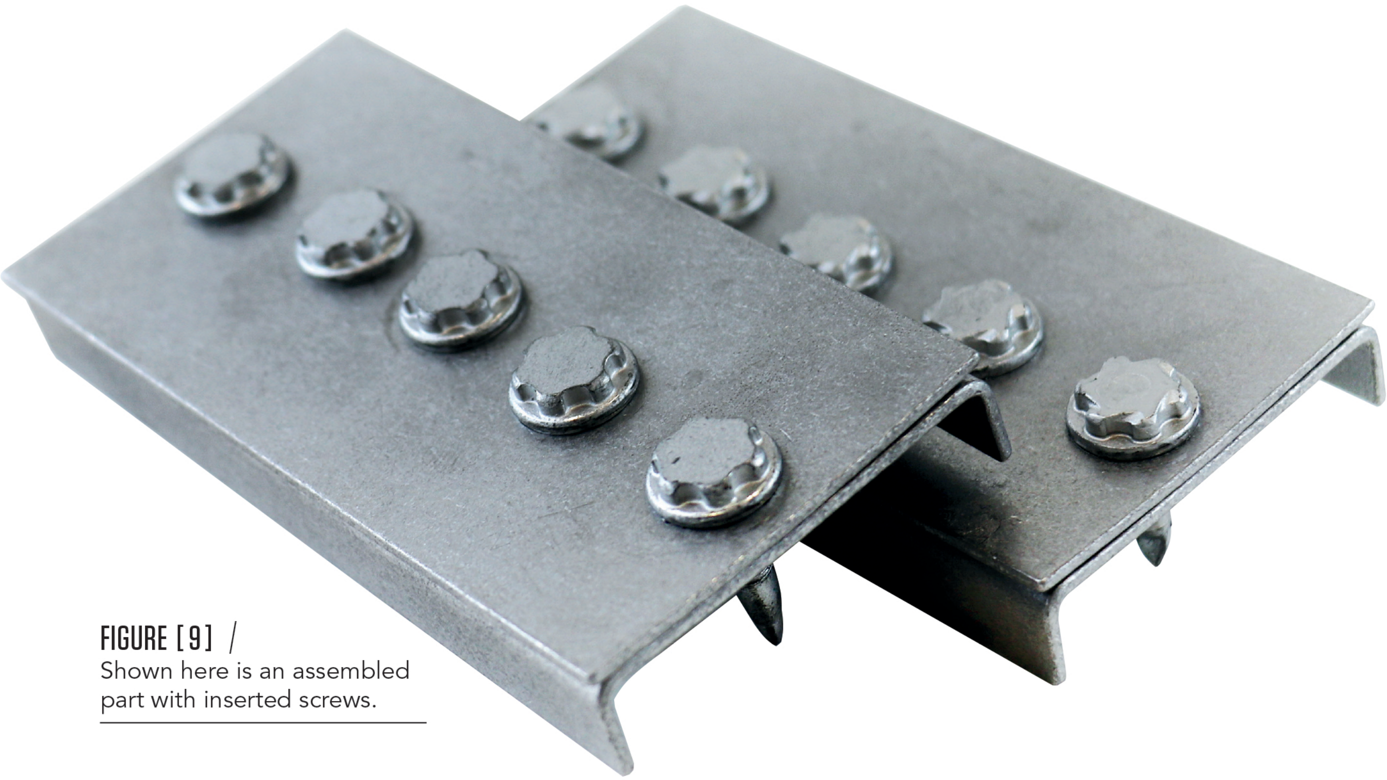


FIGURE [9] / Shown here is an assembled part with inserted screws.

Another would recommend periodic cleaning of tooling, such as jaws, and parts that are in contact with the fastener. More intensive maintenance schedules, including timing-belt wear and parts replacement, should be included in a functional maintenance diagnostic as well.

The ideal system makes a detailed recording of all processing parameters and screwdriving results. A complete process documentation and process analysis is required. Due to the regulated electric drive of the stroke, any screw position has to be accurately accessed. In applications where the fastener is assembled underfloor (inverted), the fastener must be rigidly held by the socket.

Speaking of the socket, it is very important that the thrust is applied to the center of the assembly axis. That is achieved by having the drive in line with the press force. Such an alignment creates the direct transfer of the thrust into the assembly axis and eliminates lateral forces on the guide mechanism. In turn, such a feature reduces the weight of the assembly cell and limits extensive wear and tear of all parts having direct impact on the stroke.

A modular construction with some sort of quick-change adaptation would make the assembly system especially maintenance friendly. An option is equipping such a system with a quick tool changer. Components that continuously come in touch with the product and are exposed to higher contamination or wear could then be exchanged by pressing a button, without any tools or special knowledge.

Flexibility is extremely important when selecting an assembly system. One consideration is having a robot mounting either on the rear of the assembly cell or assembly cell on the side.

Automatic recognition of the material's point of penetration needs to be independent from tolerances in the fasteners and products. The process parameters will automatically adjust, resulting in an optimized process.

> Components could be exchanged by pressing a button, without any tools or special knowledge.

Such a process can only be achieved using a closed-loop and adaptive assembly unit that combines EC-Servo screwdriving with EC-Servo stroke technology.

The constant data reported by the control modules enables the precise and automatic recognition of all relevant penetration points. Time-critical and essential parameter changes are autonomously performed by the fastening system. The system ensures the ideal processing parameter, independently from the tolerances of the product or fastener. It significantly reduces the effort of preliminary analysis and parameterization.

Costly and extensive repairs caused by inaccurately formed holes, jammed screws or ruined threads are kept to a minimum or completely avoided.

The best possible processing parameter that has been automatically adapted to suit any situation guarantees that the parts to be connected (fastener and product) are subjected to the least amount of stress. The captured processing data increases process documentation. Separate electronic controls for the servo screwdriver and the servo stroke technology, in combination with the extensive parameterization possibilities, provide the highest flexibility during the processing of different materials. Implementing special tightening sequences for new fasteners and materials is possible. Especially for the assembly of future materials such as carbon-fiber and CFRP, the controlled feed stroke creates exact positioning, and trigger points are clearly defined.

ABOUT THE AUTHOR

Lori Logan has been with DEPRAG, Inc. for nearly 34 years. She is responsible for marketing and sales of DEPRAG products throughout North America.

Cecil Morgan is an applications engineer with DEPRAG, Inc. responsible for project management, including systems, tools and assembly machines.

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