FORI AUTOMATION

Module Assembly & Alignment Systems

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GLOBAL HEADQUARTERS

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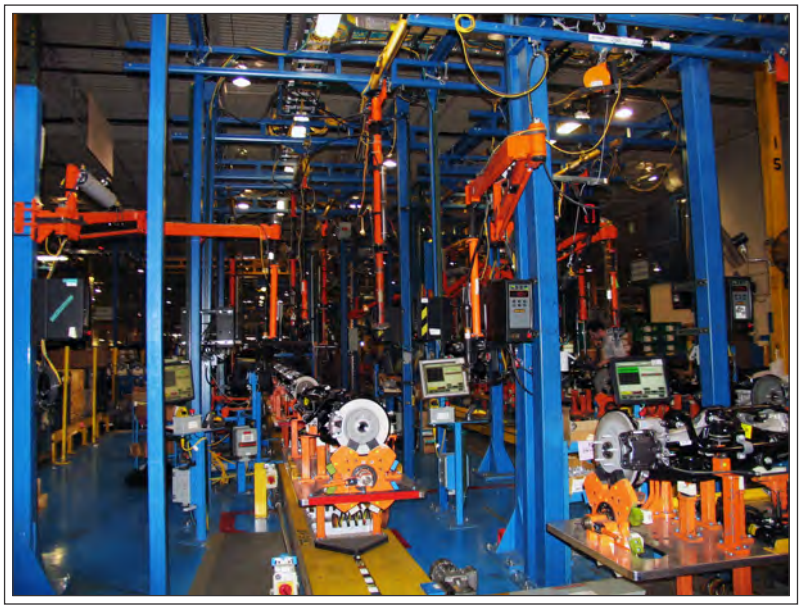
Corner Module Assembly

Fori offers a wide range of Brake and Rotor assembly systems. Different levels of automation are available, including: manual, semi-auto and fully automatic. Multiple assembly test stations are also available. Test stations include: Lateral run-out, Brake drag, Wheel speed sensor Continuity & Pole Pitch test, leak test.

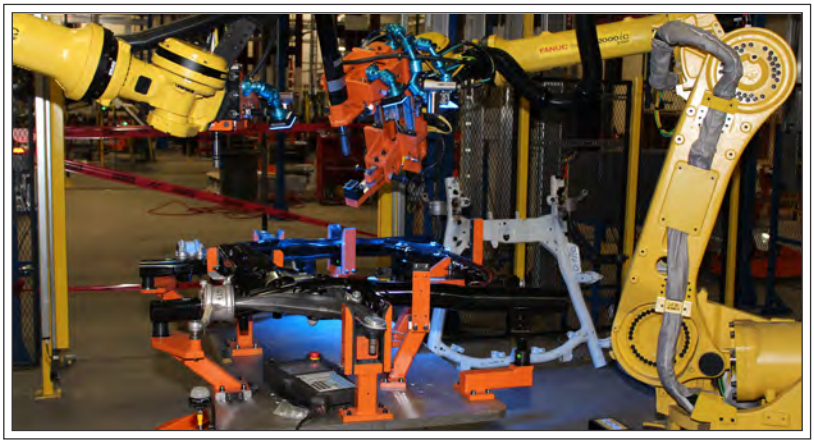
Additional systems include caliper poka yoke stations and brake pad presence. Mixed model production lines available with specialized interchangeable tooling and automation.

- Manual, semi-auto or automatic fastening
- Fori twin strand conveyor
- Fori Rail Guided Carts or Automated Guided Carts
- Custom Presses available & can be integrated into the conveyor system
- Assembly fixtures are designed for ease of assembly & Poka Yoke
- Ergonomic fastening utilizing lift assists
- Complete system is flexible to volume adjustments

Front & Rear Suspension Module Assembly



Complete Turnkey Systems - from conception to design to production ready – Fori Develops the Process, Engineers the Equipment & Installs the system for Production.



- Assembly fixtures are designed for ease of assembly & Poka Yoke
- Ergonomic fastening utilizing lift assists
- Complete system is flexible to volume fluctuations
- Manual, semi-auto or automatic fastening
- Part transfer by Fori twin strand conveyor or Rail Guided Carts

Fori's suspension assembly systems are designed to accommodate varying levels of automation and volume. Assembly fixtures are designed for ease of assembly and poka-yoke.

The module assembly systems can contain any or all of the following: manual, semi-auto or fully automatic assembly. Within the levels of automation is the availability of robotic auto-torque stations versus the manual process. There are also varying levels of material transfer for work in process and line side delivery.

Fori will customize the assembly system around the expected performance and throughput of the end user.

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Automotive Assembly Systems

Automated Assembly & Alignment for Rear Suspension Modules

Fori Module Alignment cells that adjust toe, camber and caster simultaneously, while ensuring the balanced marker for the drivetrain for 4WD models is properly positioned for ease of vehicle assembly at the OEM.

The required changes for a 2016 model year were accompanied by many challenges.

- JPH increase.
- Minimal downtime to add equipment.
- Product complexity.
- Change of model geometry.
- Rework of three current production alignment machines.

Fori was able to provide a solution that added two additional alignment cells each with a re-sequencing stand & integrated robot.

In order to keep of the flexibility of maintaining these machines, maintaining sequence of the modules being built and quality, additional logic and hardware had to be developed.

Modules are picked on a first come, first serve basis. After alignment, the robot places the completed module in its sequence stand. From there another robot on a track extending parallel to the conveyor line will pick and place the module to the pallet it was picked from.

The two additional alignment cells were integrated during the 4th quarter of 2015. One alignment cell was reworked to accommodate 2016 changes during the 4th quarter of 2015 while the remaining were reworked 1st quarter of 2016.

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Automotive Assembly Systems

Automated Assembly & Alignment for Suspension Modules

Fori's custom End of Line System consisted of a main build line, two Module Alignment machines and a final assembly build line.

A unique characteristic of the system was the robotic loading of the modules to the aligner. The loading sequence occurred from the front side of the alignment cells & robotically unloaded back into sequence on a secondary assembly loop. A controls mezzanine above the aligners was built to keep foot print to a minimum due to customer constraints.

Modules are picked from their respective Rail Guided Cart (RGC) and placed into either alignment cell.

As the module completes its alignment the equipment tooling retracts and the module is removed by the unload robot whom places it back onto an RGC cart on a secondary loop. The module then moves into its next station and continues through the assembly process.

The average time to align versus the time taken for the cart to enter is directly correlated so that there is always an alignment cell available. Meaning less wait time and a better overall throughput.

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Automotive Assembly Systems

Automated Assembly & Alignment for Suspension Modules

Module Alignment requires the ability to transmit & review data for thousands of vehicles in order to document the quality of the vehicle produced.

In this case, alignment data and how each module being aligned correlates to the target values and other modules was the focus. In order to accomplish this task Fori Automation controls engineers implemented a logic pattern software common to most OEMs as diamond pattern plots.

The program runs an automatic process that will find the high spot & low spot of the toe cam bolt profile locating it at its high and low spot and rotating the camber cam bolt 360° to produce a diamond study graph.

The results of the study are plotted, so that they can be compared to detect difference in the modules being tested. The results in this case are an X - Y graph file showing capability of the part.

The average time to align versus the time the cart enters and is picked is directly correlated so that there is always an alignment cell available, meaning less wait time and a better overall throughput.

The Diamond Plot software was integrated into all of the end users module alignment systems, totaling eight aligners, five front & three rear.

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Automotive Assembly Systems

Automated Assembly & Alignment for Front Suspension Modules

Fori recently supplied a drive through Automated Dynamic Alignment cell that adjusts Camber & Toe. This unique module aligner handles two vehicle models that have unique geometry.

The summary of the challenges included:

- Packaging of additional tooling
- Limited modules for tryout

Providing customized equipment such as this starts with a concept design phase. Fori engineering was requested to complete an engineering study to determine if the existing model could be aligned in the same aligner as the two new models. Once feasibility was determined, the Fori engineering team completed the design, process & simulation for the two new models with unique geometry.

A challenging portion to any project is the ability to debug & tryout the process. This project had limited time of debug.

The key to success was analyzing every failure mode with precision in order to correct & provide results that would normally require more debug time.

Modules are aligned as a module enters the station. The aligner knows which model based on a broadcast from the OEM, as well as position sensors placed in the machine, automatically initiating the correct tooling combinations.

The Fori aligner was outfitted with unique per the vehicle frame locator clamps toe & camber adjust then secure tooling.

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Automotive Assembly Systems

Rail Guided Cart Assembly System for Rear Suspension Modules

Fori supplied an assembly line that consisted of a main build line, two module alignment machines and a final assembly build line. The main & final build line utilized Fori's flex rail system for build on cart transportation.

Utilizing a flex rail system and RGCs provides the upmost flexibility for customers who need to be able to accommodate change easily. The ability to be flexible in the automotive world means less downtime, cost & reduced infrastructure during installation. Whether it be adding a station or a product impact change.

The level of flexibility offered by an RGC system is now becoming the norm in majority of our Automotive Assembly Systems. The RGC system provided to the customer can easily be modified, whether it be adding a station or accommodating a product change.

Overhead support for tooling in most cases were simple jib booms or inverted L posts that bolted to the floor to promote flexibility of the system. In one instance where sequence and repeatability were extremely important for final torqueing camber links to the cradle & knuckle, a robot was integrated to ensure repeatability.

FORI CHINA
Beijing, China

Automotive Assembly Systems

Rear Module Assembly Line

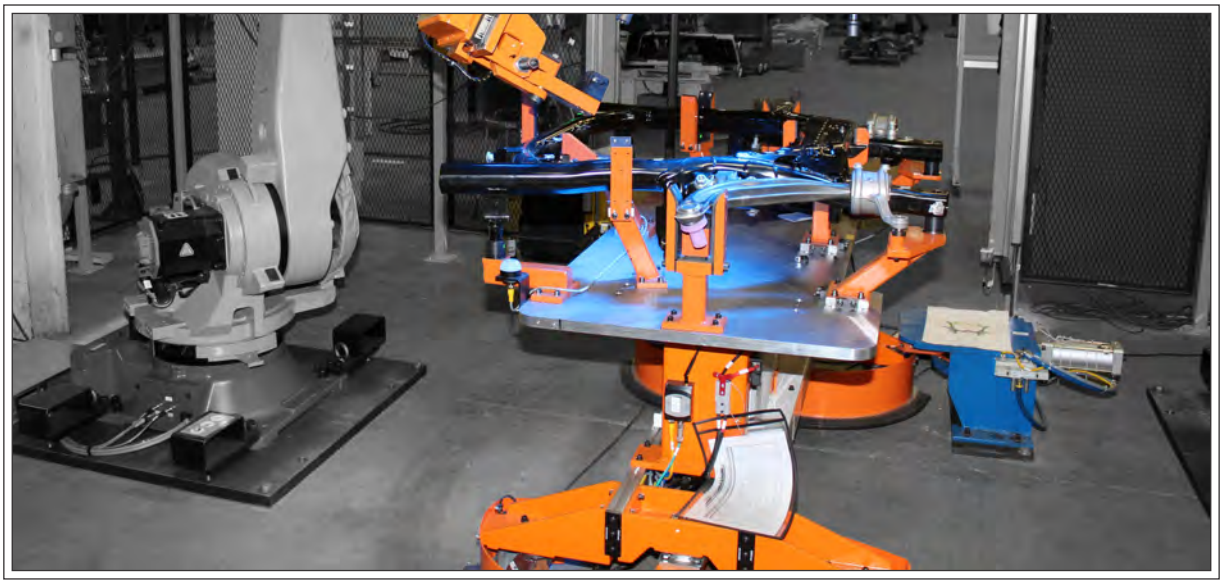
Fori China recently designed, built and integrated an assembly line which included China's first wheel aligner.

Fori China recently installed a Rear Module assembly line complete with a mezzanine storage system which feeds pallets to and from the main marriage line.

The assembly system consists of the following:

- Fori twin strand palletized over/under conveyor system for rear suspension assembly – (23) stations
- 26 Rear suspension assembly pallets
- Fori twin strand palletized "flow through" conveyor system to deliver the assembled rear suspension into and out of the Fori rear module aligners.
- Integrated lift and locate tooling to accurately present the suspension to the aligner.
- Fori twin strand palletized conveyor system to deliver the aligned suspension to the overhead storage line and chassis marriage system
- Four elevator / lowerators with a 4 M lift stroke to transport the pallets between the floor and mezzanine level

Rail Guided Carts (RGCs) with 1,500 lbs. / 680 kg. Capacity

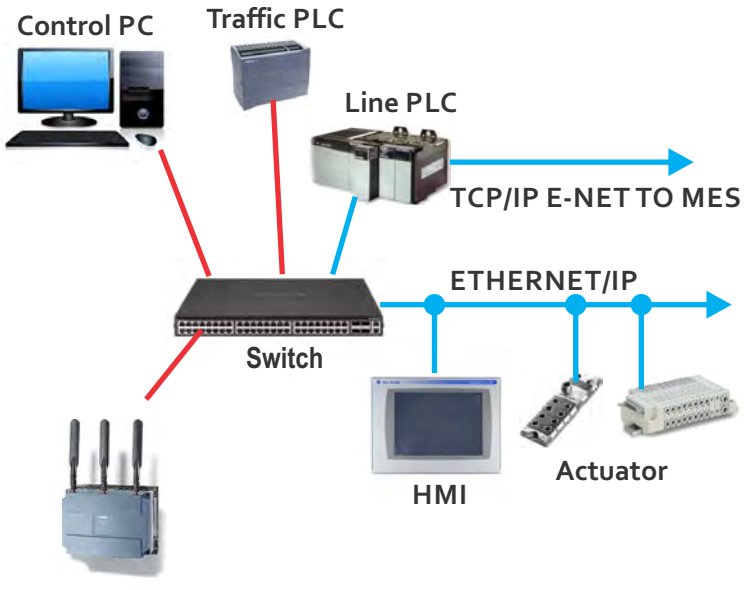


Utilization of a Fori Flex Rail system and RGCs provides increased flexibility for customers who need to be able to accommodate change quickly. The ability to be flexible in the automotive world means less downtime, cost & reduced infrastructure during installation.

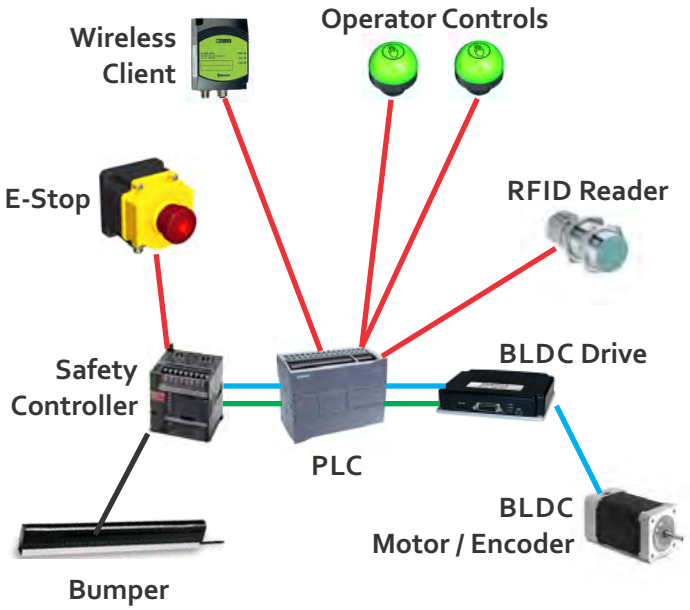
The level of flexibility provided by the Flex Rail and RGC is now becoming the norm in majority of Fori Automotive Assembly Systems. The RGC system can easily be modified, whether it be adding a station or accommodating a product change.

RGC Control Configuration

Main Control Enclosure



Cart Enclosure



RGCs Specifications

- RGC top speed 2 ft. / 0.6 meters/second*
- Carrying Load: Load up to 2,000 lbs. / 908 kg.
- Encoder positioning feedback +/- 5mm linear.
- Position accuracy: +/- 1mm
- Waypoint Control: RFID Reader
- Power supply: (2) Sealed lead acid gel batteries.
- Wireless WLAN: IEEE 802.11a/b/g.
- Safety Bumpers
  Integral station buttons on cart
  - (2) Cycle complete
  - (1) E-Stop
- PLC Controlled configuration
- Open controls architecture using standard components
- Track Switches
- Cart Positioners - Verify exact cart positioning

* Speeds greater than 1ft / 0.3m per second may require the addition of a safety scanner

ADAPTABLE

The RGC cart can accommodate almost any configuration and type of tooling tray, within its weight limitations.

Cart Features

- 360º Assembly access
- Simple path configurability / modifications
- Inside & outside line access
- Modular assembly line configuration
- Quick setup times
- RGC Length can be modified to fit the application
- On Board expandable I/O Poka Yoke accommodation
- Low maintenance costs
- Efficient maintainability
- Almost unlimited tooling tray configurations
- Flexible line configuration
- Simple quick process change menu drive PLC configuration thru single line traffic controller

Power / Energy Options

Fori offers a variety of different power options depending on the RGC configuration and required throughput. A power source is generally selected once the process has been determined and a few factors are known such as: number of shifts/moves, current throughput, environmental conditions, available charge versus run time and required system voltage.

Power Options

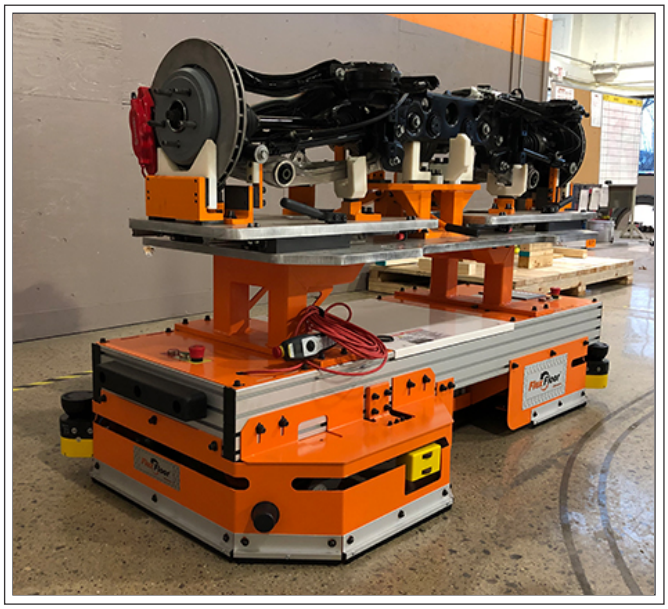
Lead Acid AGM Battery, Lead Acid TPPL Battery, Lithium Ion Battery, Inductive Power: IPT and Opportunity Charging Stations

Fori Flex Floor - Automated Guided Cart (AGC)

Fori has recently designed and built the Fori Flex Floor, which is an upgrade to the standard Rail Guided Cart (RGC) solution that is utilized within module assembly systems. The Flex Floor is an Automated Guided Cart (AGC) upgrade to the RGC.

The Flex Floor removes the guide rail from the process, instead the Flex Floor utilizes a magnetic sensor and magnetic tape for guidance from station to station. The Flex Floor further increases layout and process flexibility. RGCs can be upgraded with a simple retrofit that removes the single drive and replaces it with a full drive and steer system.

The Flex Floor is another robust, material handling and conveyance solution in the Fori portfolio.



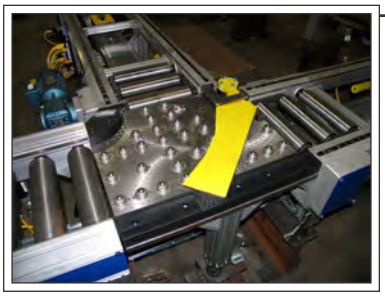
Conveyors

Fori Automation will design and manufacture the conveyor system including all material handling (overhead rail and lift assists), material transfer (conveyors, RGCs or AGCs), tooling (pallets, fixtures and presses), data collection (error proofing), line side presentation of material, controls, quality control (vision) and process the assembly line.

Fori will process the line, focusing on the efficiency rates, tooling, capacity, cycle time and throughput.

- Any length
- No Crossover Conveyors required for turns
- Minimized amount of motors
- Pallet lift and locate
- Minimal lubrication
- Built in cable tray
- Conveyor lane diverter
- Cushioned stops with anti-backup devices
- Conveyor hinge out section
- Elevators & lowerators

Conveyor Features

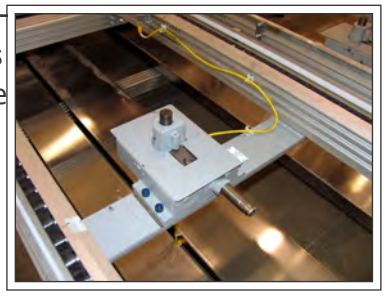


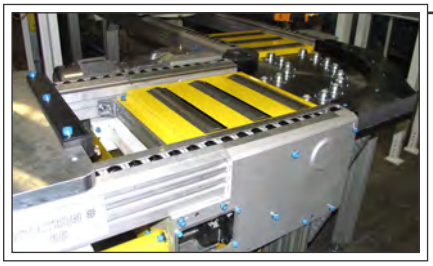
Diverter

The diverters allow the conveyor to utilize less floor space and streamline the process

Pallet Stop

The Fori pallet stop incorporates an adjustable buffer to allow the pallet to be stopped without jarring the pallet as well as an anti-backup feature that ensure the product only travels in one direction.





Drive through Corners

The drive through corner eliminates corner lift and transfers which historically are the largest source of downtime. The drive through corner system ensures the pallet orientation stays the same throughout the process.

Lift & Rotate

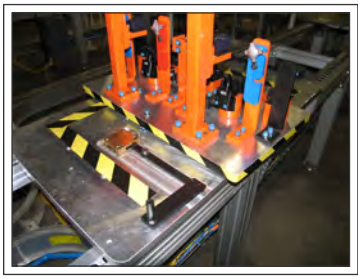
The Fori lift and rotate station allows the operator to assemble the opposite side of the pallet. The pallet is lifted, rotated 180º and lowered back onto the conveyor.

Hinge Out

Powered hinge out sections provide the operators access to the center of the conveyor system.

Elevator / Lowerators

The over / under conveyor layout allows for multiple pallets to be utilized while taking up less floor space. The empty pallets return to the elevator which lifts it into position to begin the assembly sequence. Once complete a lowerator lowers the empty pallet and it travels on the bottom return conveyor back to the elevator.



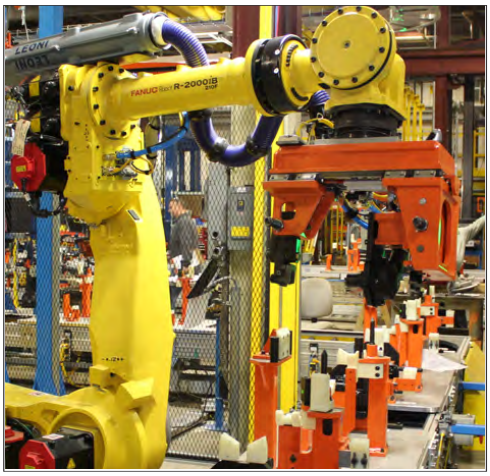
Pallet Switch

Pallet switch allows the pallet to be manually rotated and locked in numerous positions for part access. The release handle moves the lock pin which allows the pallet to turn on the bearing.

Lift & Fasten

The friction roller conveyor uses a scissor lift to elevate the pallet and part to a fastening station. When the fastening is complete the pallet and part lowers back onto the conveyor.

Lift Assists / Torque Tooling

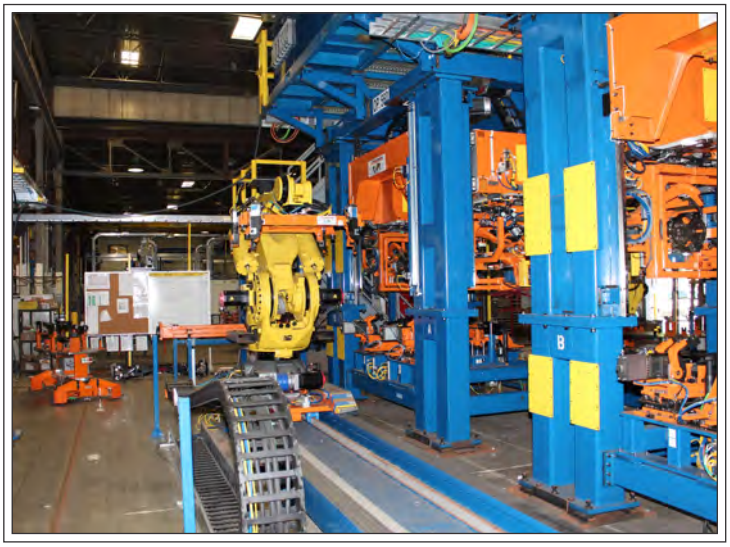


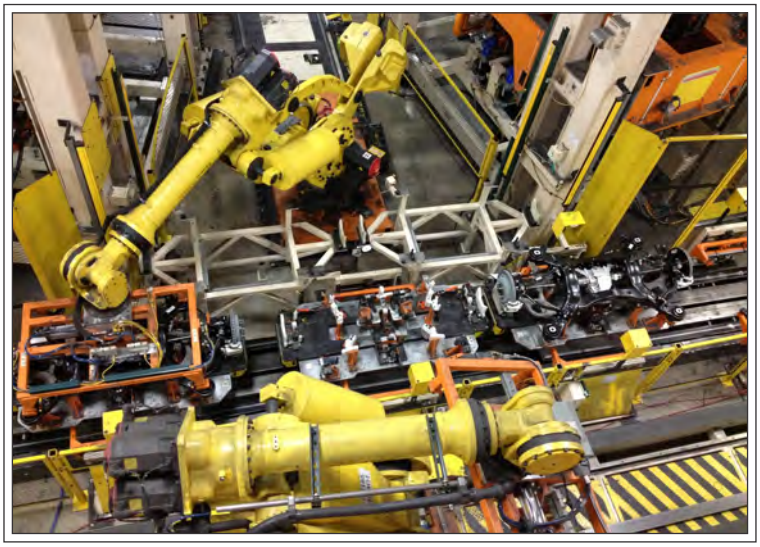
Robotic / Auto Torque

- Many styles of torque tube designs are available to suit customer torque requirements with manual, semi-auto or automatic tooling.
- Wide array of Torque reaction devices for special operations.
- Robot / Auto Torque stations offer a compelling pay-back opportunity over semi-auto stations.

- Custom lift assists are available to accommodate specific product variations.
- Heavy duty lift assists are also available to accommodate increased weights and provide additional rigidity.

7th Axis Robots





The Fori 7th Axis robot uses a linear belt that eliminates backlash. The systems is capable of 5,500 lbs. / 2,500 kg. at 6.5 ft. / 2 m per second. The robot loads and unloads modules from the aligners.

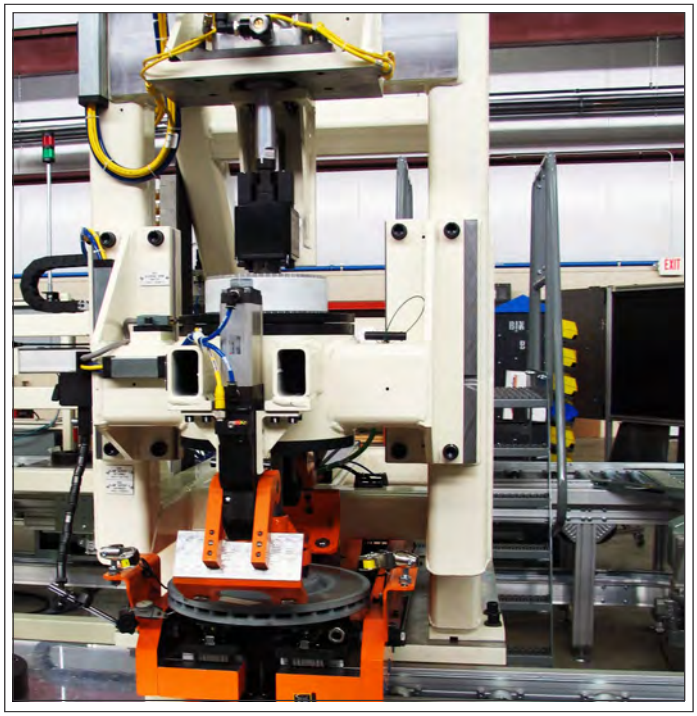
Module Assembly WIP

Fori creates special material handling equipment to present parts to the line to aid in the assembly process. This is completed to handle space issues as well as throughput issues.

Many line side material delivery options:

- Line side flow racking
- Line side rack handling systems (lift & tilt, lift & rotate etc.)
- Special means racking for:
  - Line side part staging
  - Gravity and power conveyance for sequencing and buffering parts

Lateral Run-Out Stations



Single or dual automatic rotor TIR (total indicated run-out) test cells available. Incline or free standing are available to fit various needs. These machines are servo controlled and utilize high resolution linear probes with force apply for the most demanding requirements. The run-out machines will validate and report quantitative data.

Press Systems

Hub Press

Knuckle Press

F-20kN

- Stroke: 120mm
- Speed: 0-57 mm / sec
- Linear Accuracy: +/- .03 mm
- Force Repeatability: +/- .12% of Load
- Maximum Load Capacity: 25 kN
- Measuring Range: 0-20 kN

F-50kN

- Stroke: 300mm
- Speed: 0-100 mm / sec
- Linear Accuracy: +/- .03 mm
- Force Repeatability: +/- .10% of Load
- Maximum Load Capacity: 62.5 kN
- Measuring Range: 0-50 kN

F-100kN

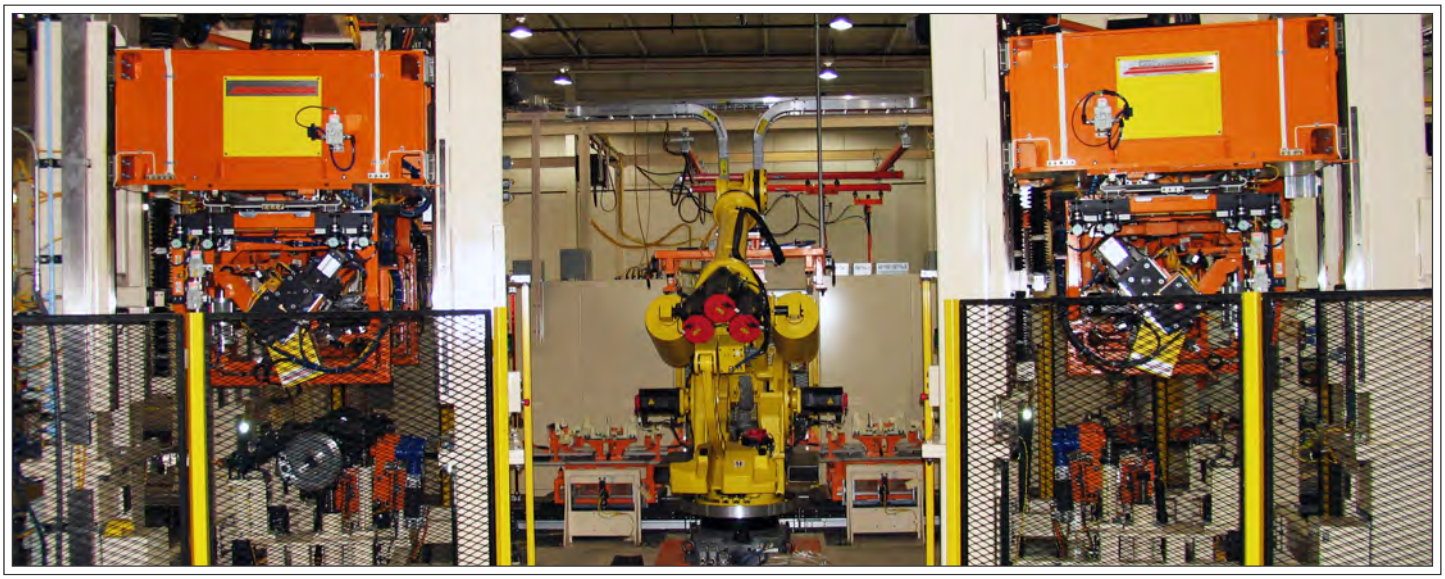
- Stroke: 300mm
- Speed: 0-100 mm / sec
- Linear Accuracy: +/- .03 mm
- Force Repeatability: +/- .10% of Load
- Maximum Load Capacity: 125 kN
- Measuring Range: 0-100 kN

Coil Over Shock Press

- RH/LH/Mixed model capable coil over shock (COS) machines available with common or independent bases.
- Auto spring compress rams, servo ball-screw spring compress systems.
- Center single automatic guide pin units - providing programmable tuning, certified fixture, quick interchange RH & LH tooling.
- Automatic torque top nut, pneumatic powered vertical slide system
- Spring location detection switch
- COS fixtures are designed for ease of assembly & utilize checks to protect proper part loading by mechanical and electrical means.
- Handles Range of Springs Lengths and Shapes
- Can be Stand Alone or Conveyor Mounted

Module Alignment

- Front & rear suspension module alignment
- Dynamic measuring under load. System rotates wheel measuring run-out while exercising the suspension under full vehicle spring load.
- Designed for flexible part loading (conveyor, robotic or manual lift assist)
- Capable of running any suspension module with large travel & jounce load
- Standardized structural design
- Modular design will accommodate all suspension types
- System is built to allow new product with tooling change, upper and lower tooling only change.

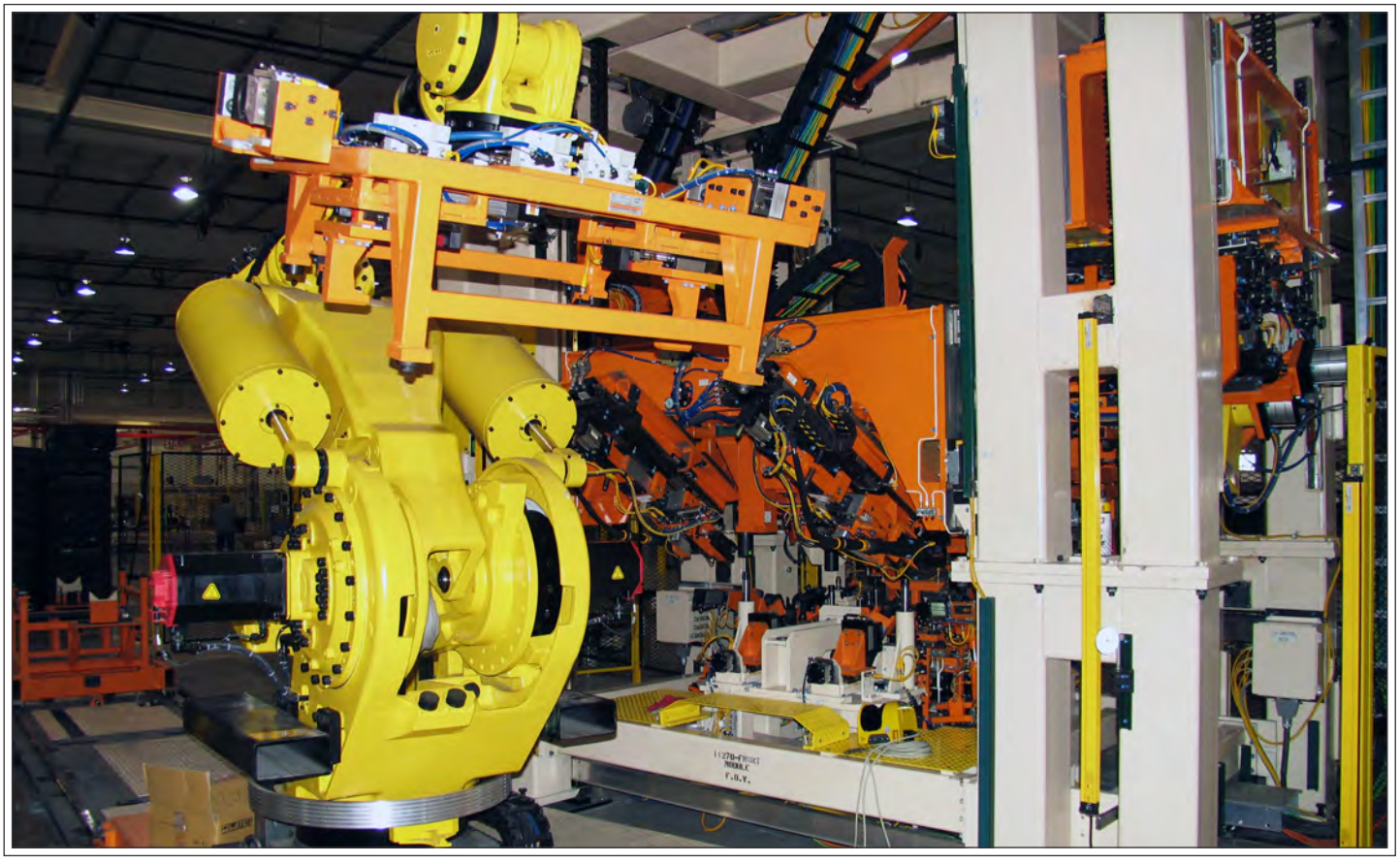


In a typical sequence the module is loaded into the machine and lowered onto the fixture. The main center slide lowers down to within 10 mm above the body mount bushings. Locking cylinders in the lower fixture raise the module up until the body mount bushings contact the upper locators. The alignment heads locate and secure the wheel corners and move them up to vehicle curb / height. Locking cylinders in the strut / spring locator advance and position the strut / spring in the proper position.

Camber or toe tooling advance and engage the bolts while the alignment heads begin jouncing. The measuring heads can move a total of 250 mm to simulate vehicle jounce. When jouncing is complete the measuring heads rotate the corners and measure toe, camber and run out. The camber and toe tooling then automatically adjusts the module to within specification. The measuring heads and torque tools then release and return to their home positions.

Module Alignment

- 60-80 second cycle time / vertical module cycle time & jounce
- Jounce load: 2,000 lbs. / 910 kg. or actual spring force at jounce
- Programmable servo driven jounce travel & jounce speed - 1 ft. per second / 225mm per second
- Main servo driven center slide maximum travel : 47 in / 1194 mm for part load & unload access
- Main center slide maximum travel: 47 in / 1194 mm
- Measuring head servo drive slide maximum travel: 41 in / 1041 mm
- Standardized structural design
- Machine height is adjustable by adding columns, which allows a conveyor to pass through.
- System can be loaded by robot, floor level conveyor or table top conveyor in all four (4) directions.
- Mixed model production is possible with these machines for significant capital savings.



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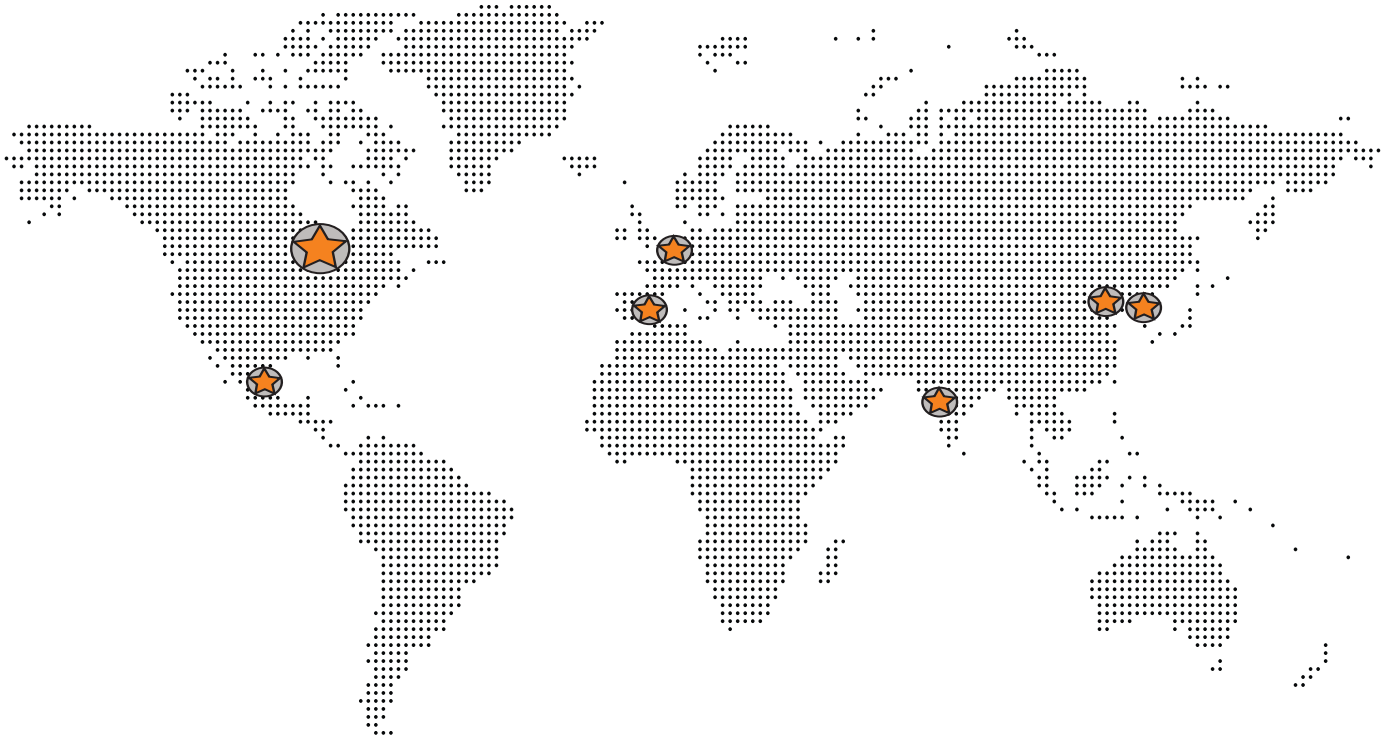

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