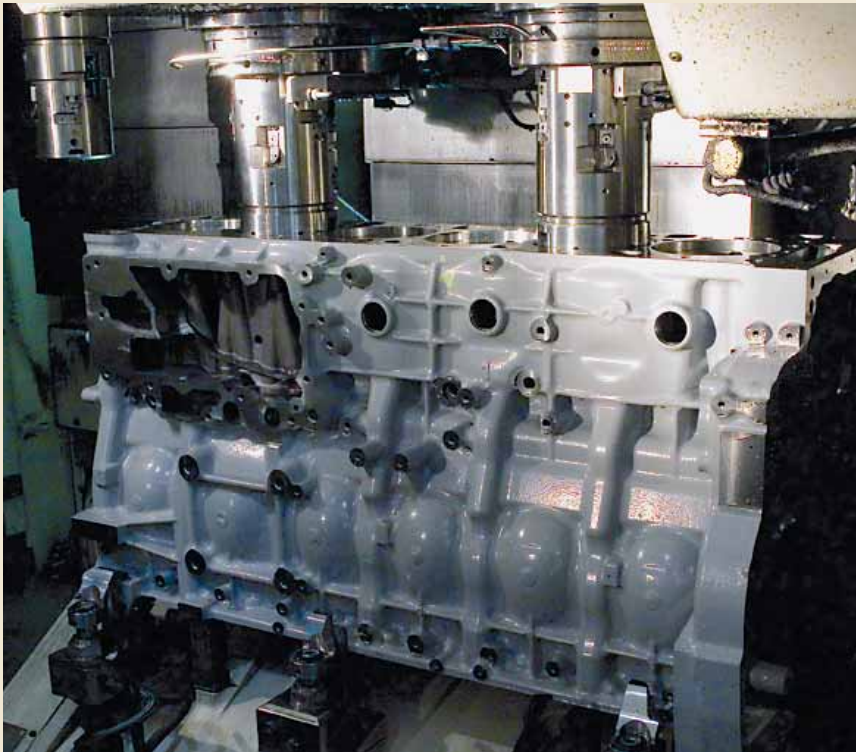


Diesel Engine Line Goes Flexible



Hybrid machining system can produce batch size of one

Jim Lorincz
Senior Editor

The flexible manufacturing system is capable of cylinder boring and all other machining processes for three different-size engine blocks, which are designed with common locating and clamping points.

After more than five years, and after parent company Daimler AG spent \$1.5 billion to develop a new heavy-duty engine platform, Detroit Diesel Corp. (Redford, MI) has introduced the DD15 diesel engine to US trucking fleets. The six-cylinder, 14.8-L DD15 engine features technology which optimizes fuel efficiency and produces greater output power, while reducing harmful emissions.

The DD15 is the first of three models in the new global family of engines with blocks that are designed to be machined interchangeably on a flexible machining line without changeover. "This concept of a heavy-duty engine platform for truck diesel engines is similar to common platforms that are used by automobile manufacturers. One basic engine can be manufactured anywhere in the world, with brand-specific applications for different countries and different markets," explains

Joerg Sieverding, director of manufacturing engineering, Detroit Diesel.

To achieve the results it wanted, Daimler developed a global production concept in partnership with its suppliers. “Contracts were awarded based on best technical concept and Total Cost of Ownership (TCO) considerations. TCO included not only the usual cost items such as capital, spare parts, utilities, and labor, but also long-term costs including servicing and maintenance,” Sieverding explains.

At the same time, several production locations were prepared in Europe, and production modules for the block, liners, and connecting rods—as well as for assembly and test—were installed at Detroit Diesel. Liners, connecting rods, and bearing caps are currently produced at Detroit Diesel, with a line for cylinder heads and bearing caps coming in the near future.

Engine blocks for the DD15 are being machined on a turnkey engine-block manufacturing system supplied by Heller Machine Tools (Troy, MI). The three-phase manufacturing system is a fully automated, gantry-loaded hybrid system in which 1200 lb (544-kg) special-grade, cast-iron blocks are machined ready for assembly in ten machining operations.



One side of the flexible engine-block machining line at Detroit Diesel that features Heller MCH-400 HMCs as the primary machining centers and gantry load/unload.

A combination of heavy-duty MCH-400D HMCs, a CNC head-changing machining center, and Heller’s Flexible System Transferlines (FSTs) make up the hybrid system, which is capable of machining three different size engine blocks. Common locating and clamping points on the blocks for the 11, 13, and 15-L engines allow any of the blocks to go through the system in the same fixture, making a lot size of one possible. The DD15 engine is the first to be manufactured on the line; the DD13 will follow later.

Choosing a manufacturing system for the engine-block engine line involved early collaboration with Heller, the turnkey supplier. “We actually conducted a simultaneous engineering process with Heller, and evaluated budgetary proposals and concepts for a system with all transfer machines to one with all machining centers and several steps in between,” explains David Mitchell, manufacturing engineering manager. “We identified five options along the flexibility path. The consensus choice was a hybrid system in which the bulk of the work is done by machining centers. Critical finishing operations, such as line boring of crank bores and cylinder bores, are done in special machines, but still with lot size of one part,” says Mitchell.

“The consensus choice was a hybrid system in which the bulk of the work is done by machining centers.”

“The Heller concept of a flexible, hybrid machining system which allows machining centers to be added as volume grows was appealing to us. The hybrid system allows us to manage our capital investment, launch at lower volumes, and use the system’s flexibility to increase capacity as needed,” Mitchell explains. Launched with Phase I and some 25 machining centers, the hybrid line is being expanded in Phase II with the addition of 16 Heller MCH-400D HMCs to double capacity, still with the ability to change the mix of engine production. A Phase III was planned from the very start of the project to minimize the upset to the system by adding machining centers to get incremental production capacity.

“The front of the line is composed of machining centers fed by gantries, and even the special machines are gantry-fed,” says Mitchell. “There are some advantages with gantries throughout because you don’t have idle stations between working stations and gages. As a result there’s less work in process, with automatic feedback from an in-process automatic gage right back to the metalcutting station,” Mitchell says.

Gantry load/unload also provides flexibility for the FST special machines “One of our transfer machines loads and unloads from the same end of the machine for optimum use of the working plant layout. That’s very difficult to do with a lift-and-carry transfer bar, but very easy for the overhead gantry,” says Mitchell.

The Heller MCH-400D HMC is the primary machine in the hybrid manufacturing system. It’s designed for direct loading of large prismatic parts, weighing up to

4000 kg. The DD15 cast iron engine block weighs 1200 lb (544 kg), well within the system's capability. The MCH-400D's working volume of 1400×1000×1250 mm can handle workpieces 66" (1676-mm) in diam and 57" (1448-mm) long. The MCH-400D features a rigid one-piece cast-iron bed and thermosymmetrically constructed gantry column. Acceleration of 4.0 m/sec² and rapid traverse of 40 m/min provide fast, accurate positioning.

"Each HMC is fully enclosed, as are the stations on the transfer machines."

In the Detroit Diesel's first operation, the system's 400D HMC center mills the crankshaft half-round and rough face mills the front and rear face, pan face, and bearing cap face, and also drills transport holes.

Next, the Heller HCS 450 D head-change machine utilizes a milling head with a gang-mill arbor to mill the engine bulkhead. In the same section of the system, an FST next face-mills the rear side of the blocks 'ears'. The critical operation at this point utilizes an angular-head face mill.

"One advantage of the Heller solution is the use of a head-changing machine in the process for one of the critical operations, rough-milling the build heads," says Mitchell. "It allows us to do a tool change while the machine continues to run, allowing greater uptime. Other builders proposed a special machine which would have to stop during tool change."

The next six sequences of operations are performed on HMCs, direct-loaded and unloaded automatically by Liebherr gantry loaders. To meet tolerances and part feature specifications, Heller chose to present the large prismatic parts to the machining centers in line for series processing.

A technical advantage to the Heller proposal, which competing vendors did not include, says Mitchell, is related to the rough cylinder-boring process. "Heller offered a version of a standard machining center that has a U-axis tool-actuation device that comes through the spindle, which allows us to do an undercut in the water jacket."

In the next operation, also performed on an MCH-400D, holes are drilled and tapped on the head and pan face, and the pan and bearing-cap mounting faces are finish-milled. The subsequent operation includes gun-drilling the oil-gallery holes and finish-milling side bosses.

Next, oil holes are gundrilled and pan-face holes are drilled, tapped, and counterbored. In Op 70, the left and right sides of the blocks are drilled, reamed, and tapped. In the final in-line section of the system, the front and rear

face holes are drilled, tapped, and reamed, and a ball mill on an angular head completes a chamfering operation.

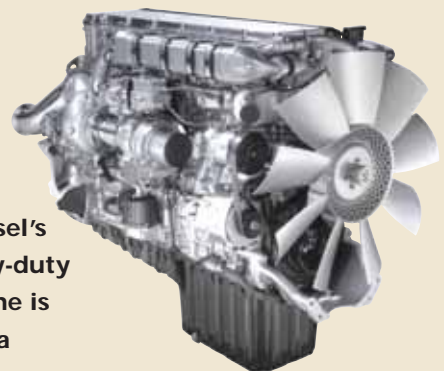
The remaining operations are completed on Heller Flexible System Transferlines. The main goal of selecting the FST concept is to provide the ability to achieve high productivity along with high flexibility. The FST utilizes flexible, configurable machine units mounted on a standard base. The interfaces to the units are standardized, and allow parts-related units like tool heads and clamping fixtures to be used throughout.

Benefits of the FST concept include cost advantages with initial investment and rebuilds, short lead times, reduced space requirements, and high system availability.

The Diesel Engine of the Future, Today

Reception of the DD15 by Detroit Diesel's customers has been positive because of its performance as an EPA '07-compliant engine and the fact that it is ready for EPA 2010 without having to add complex, new fuel systems.

The DD15 is a totally new design, from the block up. Its fuel efficiency and power result from use of proven turbo compounding technology. It works by converting heated waste exhaust to run a turbine that produces power that is fed straight into the drivetrain. Recycling the waste exhaust adds 50 hp (37 kW) without using any extra fuel and can increase fuel mileage up to 5% at road loads. Other features include:



Detroit Diesel's DD15 heavy-duty diesel engine is the first in a family of three.

- Multi-injection event capability of the ACRS systems enables combustion rate shaping for a quieter, vibration-free ride.
- Jacobs-designed engine brake that is integrated into the DD15 gives three levels of engine braking depending on the grade: bunny, steep, and uh-oh!
- Electronics system is Detroit Diesel's familiar DDEC VI.

FSTs can be reconfigured once a program has been completed, and fall well within Detroit Diesel's Total Cost of Ownership requirement. TCO takes into account not only initial capital investment costs, but also repair and maintenance cost over the lifetime of the equipment. Reduced downtime and meantime between failure and repair are key TCO factors.



Trunnion workholding presents different faces of the engine block to the MCH-400D HMCs for machining.

In Op 120, the next to the last series of operations, FSTs are used to generate the thrust-bearing face, employing a line boring bar to finish the crank bore and to gage the crank-bore diameter. The next FST finish-mills the front face. The loader transports the blocks to the next operation, where they undergo finish counterbore, ream, and flange-end gaging, all performed on a MCH 400 D HMC.

During the final series of operations, an FST is used to finish cylinder bores, gage the bores, face-mill the rear side of the 'ears' and, finally, generate a waterway groove. After that, the heavy blocks are ready for engine assembly.

"There is a big difference between our traditional transfer lines and the Heller system here, not only in flexibility but also in plant environment," says Sieverding. "The assembly area is near the line to optimize material flow. The machining centers are basically enclosed. It was important for us to have minimal contamination in the area, because engine assembly is located next to the Heller system. We would never have done this before, and we thought about it carefully, but in the end we decided the machines are well-enclosed. It works," Sieverding explains.

"What's critical is the dry floor guarding. Each HMC is fully enclosed, as are the stations on the transfer machines. Centrifugal pumps on each machine pick up coolant and chips and pump them back to the central coolant system. There are no in-floor flumes to generate mist, and each wet operation is connected to a mist-collection device."


It will pay benefits long-term to have the machining and assembly in one area. Mitchell explains: "It took a good deal of planning and thought to locate all events to save time in process. Also, as the layout is today, from one location you see block offload and block load. They are only 150" [46-m] apart, so assembly guys know if there are blocks in process. Gage stations are easy to see, and we tried to organize nearly all the human work along one side of the system and minimize the number of times a fork truck has to come into the system area."

Early input with the Daimler product development team led to some important answers to significant production questions for the new model engines: What is being produced? What are the volumes and for how long? How much will the product design change? "We had to plan to have the flexibility to produce engines that had different bore centers, and to adapt to any product changes in the future. And of course our production volumes are different from those of a typical car engine line. They machine as many engine blocks in an hour as we do in a shift," says Mitchell.

"We worked very hard from the start to design the engine for manufacturability."

"We worked very hard from the start to design the engine for manufacturability," observes Mitchell. "Our initial objective was to develop a system that would allow small batch production, but once we saw what the Heller hybrid manufacturing system was capable of, we realized that with a little ingenuity we could adapt the special machine FSTs to lot-size-of-one production with only a little fine tuning.

"The result is a system that minimizes inventory of finished product and eliminates the time lost in changeovers," he concludes. ■



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