DEFORM™ Application #123

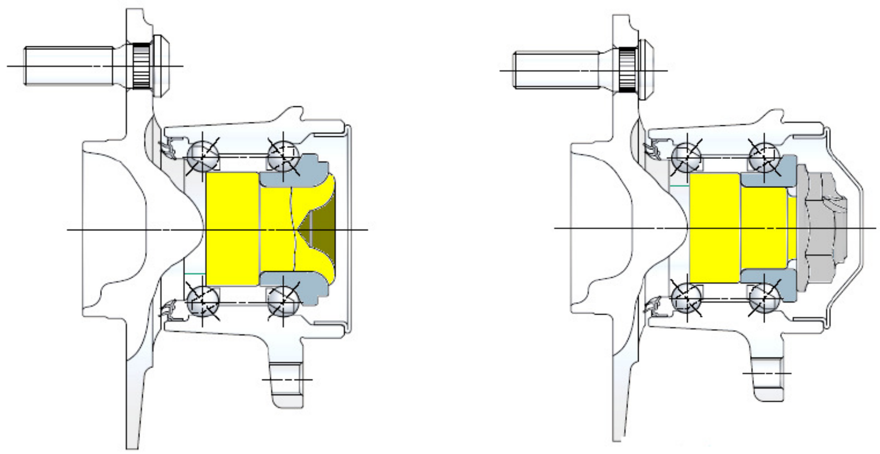
Orbital Forming Assembly

Background:

Automotive front wheel bearings have traditionally been assembled on the car by tightening a nut with a torque wrench, to ensure an optimal restraining force. A cotter pin is then placed through the nut to prevent it from loosening. Recently, bearing assemblies have been manufactured by orbital forming. The resulting process has reduced the weight, cost, part count and risk of improper assembly. Illustrations comparing the orbital forming and nut clamping assemblies are shown on the right. The orbital forming process (left) does not require a nut to restrain the bearing race.

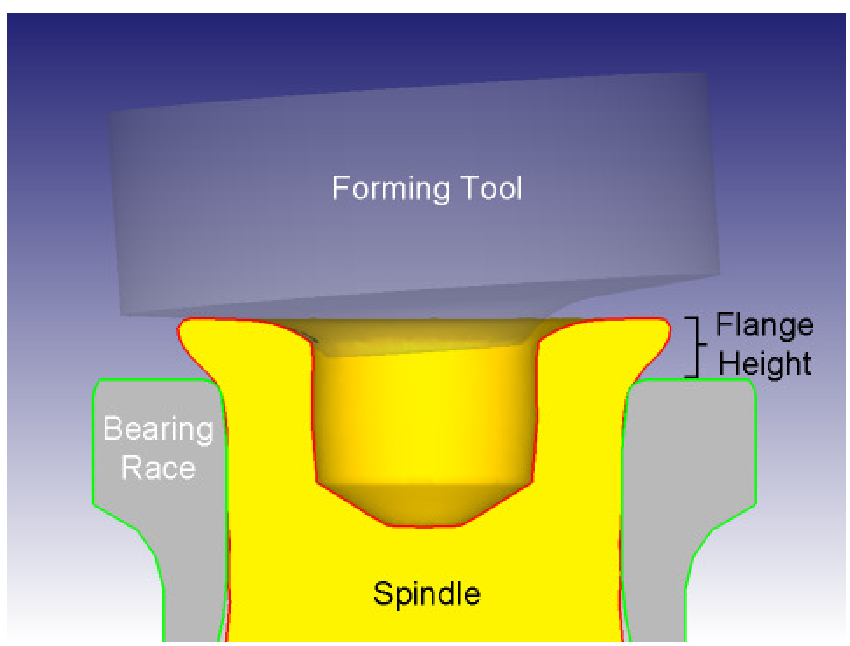
Process:

Orbital forming is a metal forming technique where the workpiece is incrementally formed by a rotating tool. The forming tool is tilted at an angle, rotated around the vertical axis and translated in the axial direction. The tool progressively forms the workpiece with a small contact area. In this case, orbital forming is used as a joining process to form a flange on the end of the spindle as a retainer for the bearing race. Orbital forming offers the advantage of smaller contact area between the punch and workpiece. This decreases the forming load and lowers the risk for buckling and fracture.



The quality of the assembly stems from the shape of the formed spindle flange. A large flange diameter will provide more contact area between the bearing race and spindle. This allows for a higher restraining force with a lower induced stress on the bearing race. Inward material flow will reduce the contact area and is undesirable. The flange geometry should sufficiently restrain the bearing race when the desired flange height is reached.

Once the flange geometry has been determined, the process variables can be optimized. The major process variables include tool geometry, tool angle, lubrication and axial feed rate. The axial feed rate has proven to be the most important variable when optimizing this process. The feed rate changes the tool contact area with the spindle and affects forming load and material flow. In production, the feed rate starts fast to minimize process time. During the process, the feed rate decelerates, to minimize forming load and springback.



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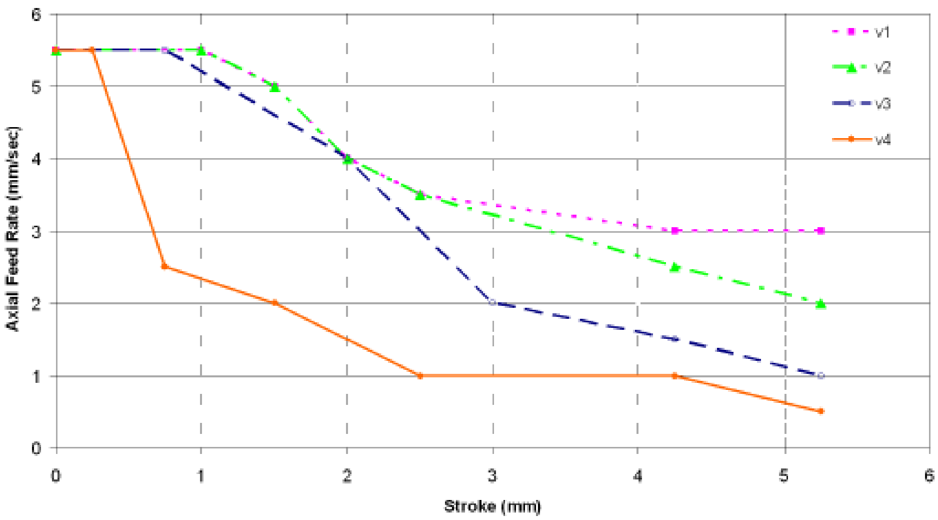
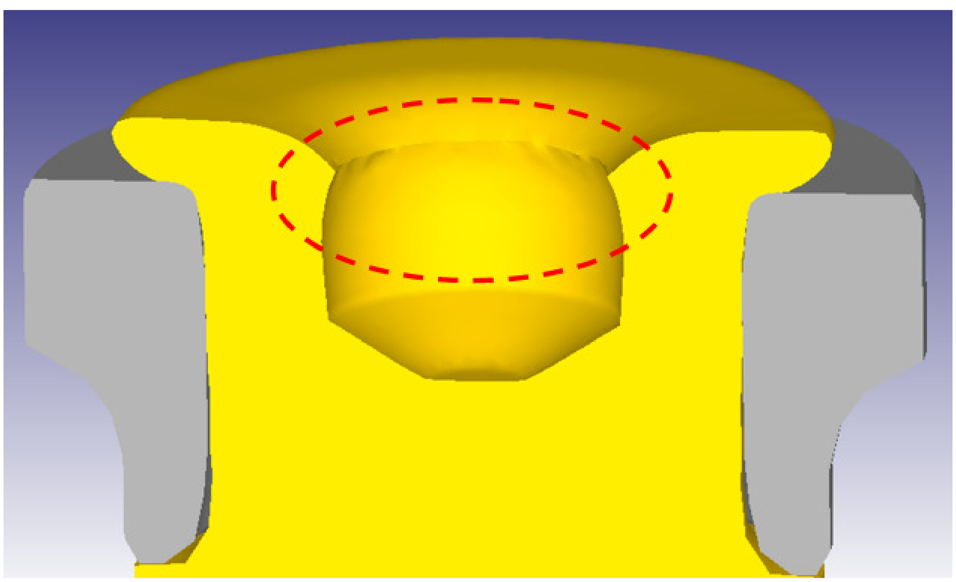
Analysis:

DEFORM-3D was used to simulate the material flow during an orbital forming assembly process of a bearing race and spindle. The purpose of this work was to determine an optimal axial feed rate profile. The orbital tool was tilted at 4 degrees, rotated at 500 RPM and translated until the flange height was reduced to 3.1 mm. Four axial feed rate profiles were simulated, and are plotted below as a function of forming tool stroke.





Result:

As expected, the slower feed rate profiles produced a smaller deformation contact area and therefore required a lower load from the forming tool. The profiles with the lowest feed rates (v4 and v3), developed inward material flow at the end of the stroke (illustrated by the dashed red oval in the cross-section image below). Inward material flow reduced the strength of the assembly and was considered a defect.

Simulation has shown that the orbital forming assembly process can benefit from a decreased feed per revolution. Decreased forming contact area requires a smaller forming load and press size. The flange provides a greater restraining force because the springback is reduced when the forming tool is removed. However, if the feed rate becomes too low, inward material flow can occur which is undesirable. In this case, the v2 feed profile will be used because it provides the lowest feed rate at the end of the stroke without producing a defect.

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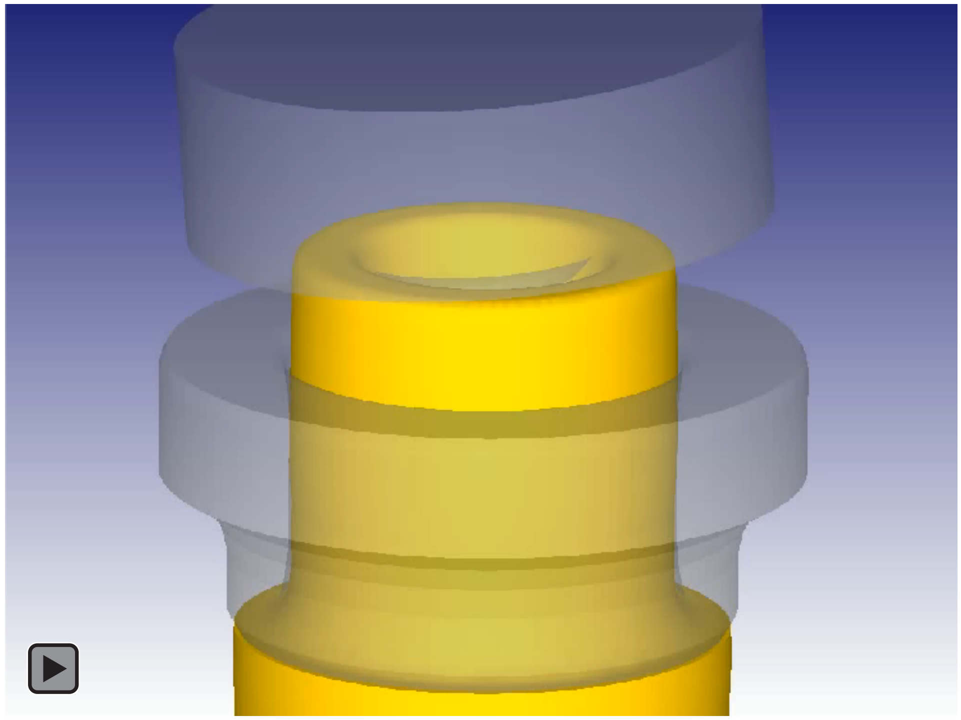
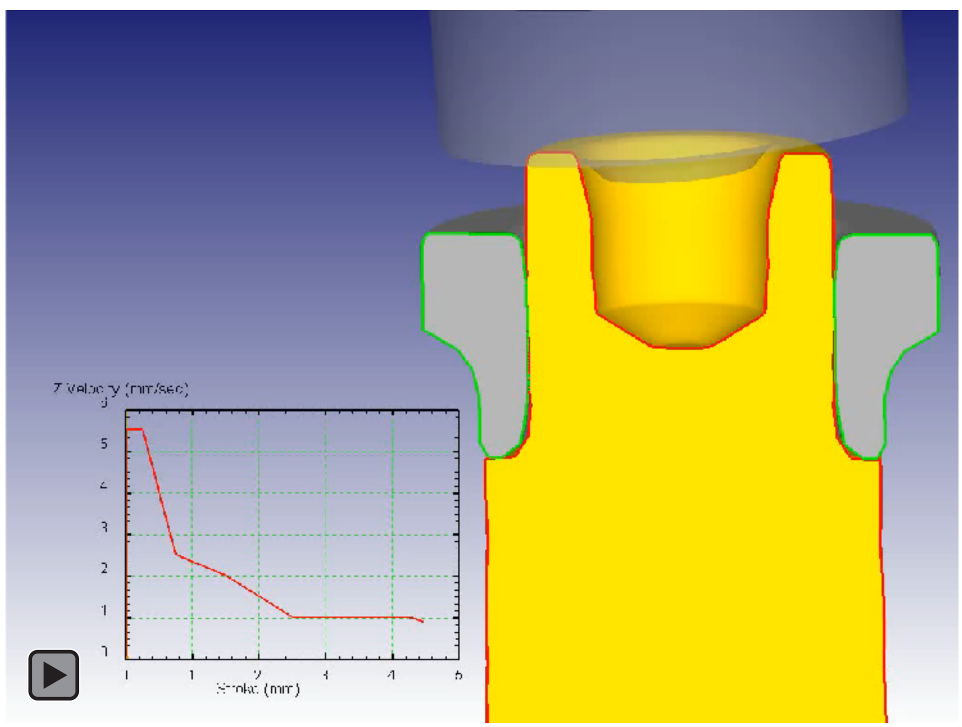


The orbital forming tool requires several revolutions
to form the desired flange height.



The process using the V4 axial feed rate is shown above.
The axial feed rate decreases as a function of the stroke.
Near the end of the stroke the axial feed rate becomes so low
that inward material flow is observed.

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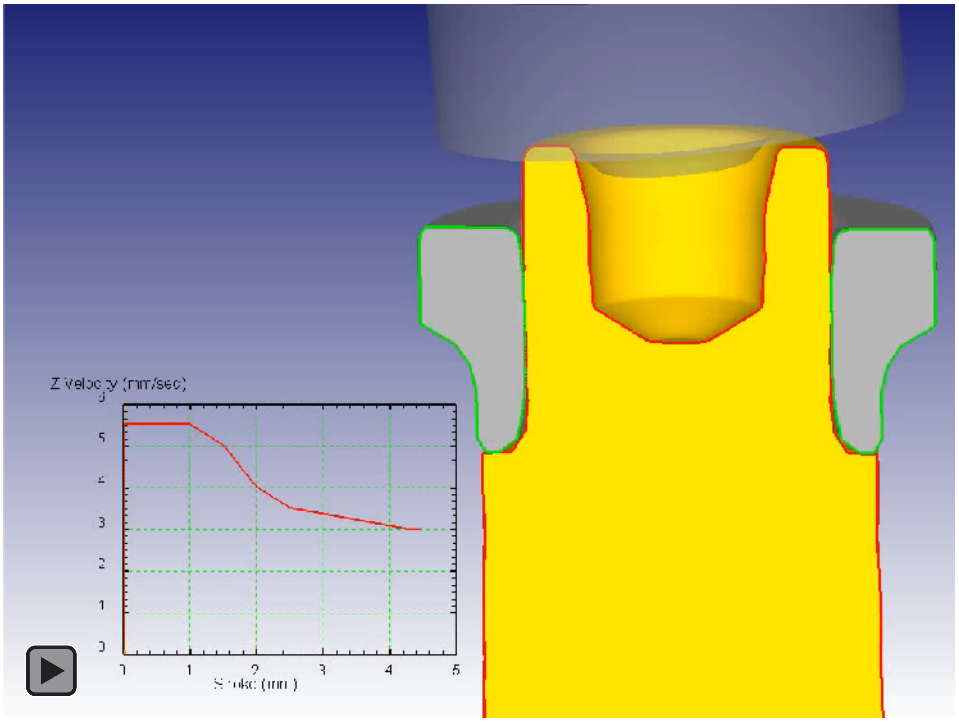
Adobe® Reader® X required to play animations



The V1 axial feed rate also decreases as the flange is formed.
In this case the axial feed rate remains high enough to maintain
outward flow of material throughout the process.

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