Rapid Manufacturing with FDM in Jig and Fixture Construction

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This report is from the Department of Jig and Fixture Construction that has used an FDM 3000 for years.

Daily projects comprise, among other things, designing and manufacturing production tools and testing devices, as well as supporting initial production runs and special resources.

Typical areas of application for the FDM prototypes are package space tests, function tests, display models, and cubing models in the area of vehicle development and production.

Beyond these areas of application, BMW uses the FDM process for the direct production of components for manufacturing and testing. The following have become important reasons for the use of FDM testing and production tools:

- Ergonomic improvements
- Production of complex and organic component shapes
- Material properties comparable to PA 6
- Reduced detail costs
- Reduced warehousing
- Reduced production expenditures

In certain areas, the FDM process can therefore be regarded as an alternative to the conventional metal-cutting manufacturing methods, like milling, turning, boring etc. As examples, two of the reasons mentioned will be explained in greater detail.

Ergonomic Improvements

FDM production tools lend themselves particularly well to hand-operated devices. It is important, for instance, that a device is easy to handle and comfortable to grasp for the user. This is particularly important when the device is frequently used, as is the case for the assembly-line production of vehicles. For example, the geometry of the grip influences the ergonomics of a device.

Figure 4: Four devices for attaching the model badge at the rear of the vehicle

BMW Regensburg
Employees, approx. 10,000
Production: approx. 965 vehicles daily
Models: 1 and 3 Series sedan, coupe, wagon, convertible, M3, und All Wheel Drive variants

Four devices for attaching the model badge at the rear of the vehicle are represented in figure 1. For the three FDM devices, the grip could be designed as required; for the aluminum device, two standard grips were used, which limits the designer's creative latitude.

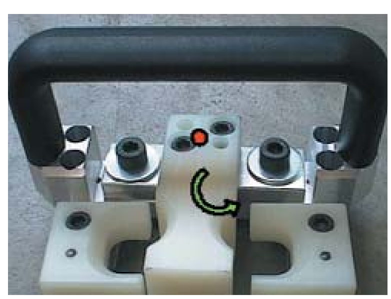
The weight of a device is an ergonomic criterion as well. Devices that are carried and operated by people may not exceed a weight of 5 kg (11 lbs.). Previously, this was achieved by using low-density materials, such as aluminum or polyamide. An additional weight reduction, however, can be obtained through the use of ABS plastics and the FDM process. The density differences of ABS and polyamide do not appear to be great, but the difference in weight of the finished device becomes noticeable if the ABS material is applied inside the component in the form of a grid. This way the weight can be reduced substantially. The tradeoff of this grid structure in the device is its reduced stability and toughness. This disadvantage is partially offset, however, since many devices only use aluminum and polyamide for reasons of weight. Their superior material properties, such as tensile strength and hardness, are often unnecessary for the function in question.

If the ABS plastic in the FDM system is applied as a three-dimensional grid, a weight reduction of up to 72% can be achieved compared to the solid ABS material. A difference of 800 to 1300 g in this example may appear small, but if this additional difference must be manipulated over 100 times during a shift, this undoubtedly has an effect on the user's physical condition. In addition, a hand-held device must be well-balanced in order to keep work fatigue to a minimum. A striker gauge for positioning and assembling strikers on the driver and front-seat passenger sides of the E46 Coupe/Convertible is shown in the illustration at right (figure 3).

The use of aluminum and polyamide results in an unfavorable position of the center of gravity (red dot). This causes the striker to turn slightly to the right when it is picked up by hand. The device must be aligned again and again through the opposite arm joint movement. This could be prevented by repositioning the grip toward the center of gravity. This, however, is not possible since the electric screwdriver must have access to the mounting screws of the striker.

Using a basic FDM body and grip with grid construction could be the solution. Additionally, the grip would have to be in the shape of an arc whose two ends reach the recesses for the electric screwdriver. This would result in a balanced device and, therefore, more ergonomic handling.

Figure 2: Position of Center of Gravity of the Striker Gauge



Firgure 3: Center of Gravity Rotational Direction During Use

Production of Complex and Organic Component Shapes

The production of organic forms is no problem anymore, due to the layered structure of the FDM parts. The term "organic" is taken from nature and stands for round, soft forms that follow no strict geometrical rules. Past constructions are characterized by the use of basic geometric bodies. Organic bodies can take on arbitrary forms, which leads to a new manner of construction. The geometry of the device can be adapted to the load (see human skeleton). This can be achieved through the variation of the wall thickness and diameter. As with cast parts, ribs can also be used for reinforcement.

Figure 4 shows the prototype of a device for mounting a support for attaching bumpers. The device was manufactured from aluminum, polyamide, and FDM parts using a mixed-component method of construction. The tubes contain wire ropes that extend and retract magnets via a lever. The production of the tubes does not represent a problem for the FDM system, due to the manufacturing process. The tubes were attached to a rib to stabilize the magnets.

Figure 4: Complex and Organic Shape of a Production Tool

The layered FDM manufacturing process is therefore well suited for the production of complex bodies that, using conventional metal-cutting processes, would be very difficult, intricate, and costly to produce.

Use of FDM Production Tools for Vehicle Assembly

In order to find out to what extent future assembly fixtures can be manufactured using the FDM construction method, existing devices that previously were produced using conventional machining of plastics and metals, were considered.

The following four **main criteria** were used for pre-selection:

- Working temperature
- Contact with chemicals
- Manufacturing precision
- Approximate stress

These criteria are all met in the area of vehicle assembly, since here the devices by and large do not come in contact with chemicals or high temperatures (> 95°C). The manufacturing precision (±0.1 mm) of the selected devices can also be achieved with the FDM system.

Based on these points, the technical designer can specify the choice of the manufacturing method even before the creation of the CAD model. If one of the four criteria is not met, the device or its components are not directly suitable for the FDM process and must be manufactured using other manufacturing methods or a combination thereof. The technical designer for the production tools is thus able to make a pre-selection based on little information about the operating conditions and in a short time.

Conclusion

Rapid prototyping has become a standard concept in product development. Therefore the FDM process has also become an important component in vehicle development and production in the Regensburg plant of BMW AG. Beyond the mere construction of prototypes, an attempt is made to extend the application of the FDM process to other areas.

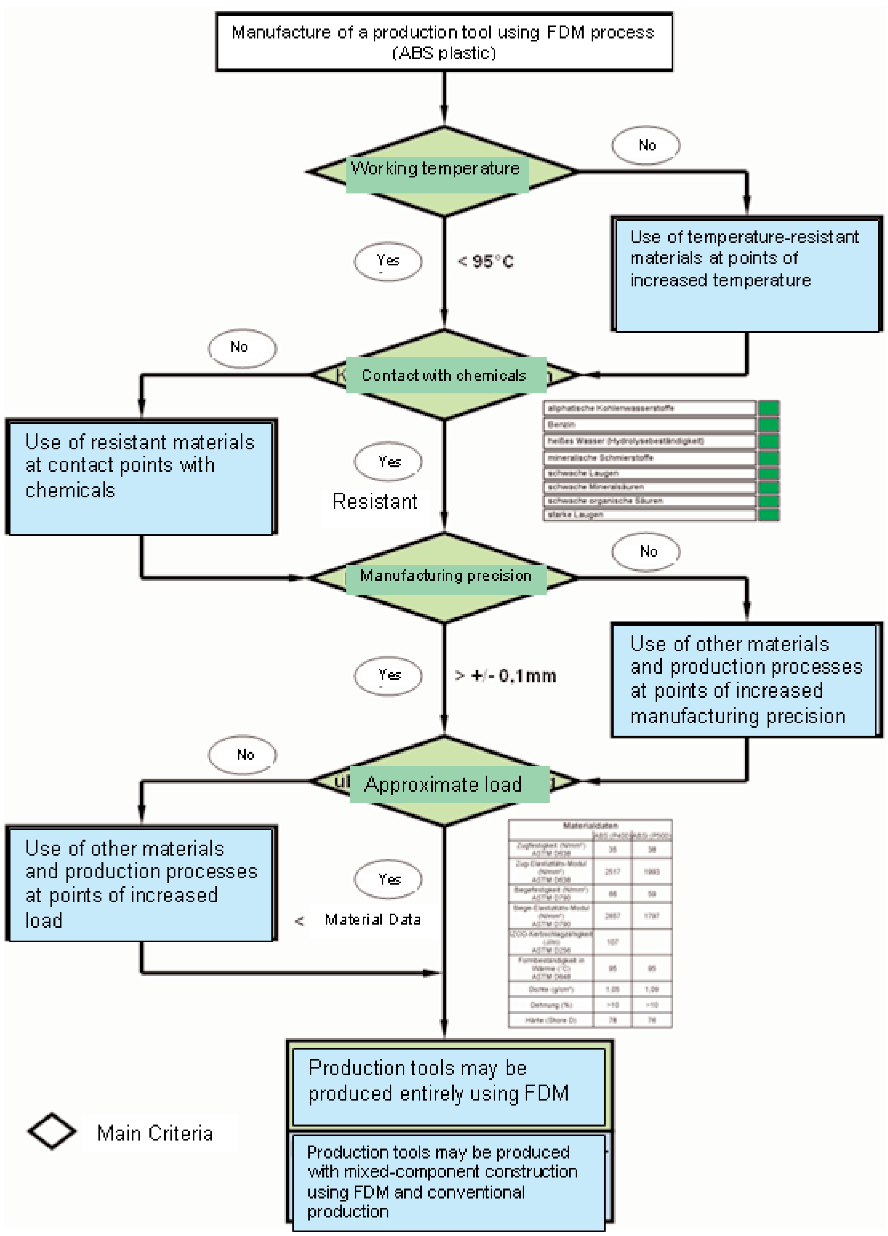
The manufacture of production tools and their components has evolved as an additional application of the process. This, however, is only possible within the framework of the material properties of the ABS plastic. The application as a production process for devices is therefore still limited to smaller hand devices for vehicle assembly.

In general, the production costs for FDM parts are at present still above those of conventionally manufactured components. On the one hand, this is due to the comparatively higher material costs for the ABS plastic and, on the other hand, is a consequence of longer machine times. Nevertheless, the machine times and the quantity of the material used could be reduced by construction processes custom-tailored to the FDM process. This means that the wall thickness and layer structure must be adapted according to the load and point of load incidence. In the future, the costs will continue to decrease since the machine times will be significantly reduced with the installation of new systems. Systems of the TClass Series can also process new plastics, such as PC, which has twice the stability and resistance of ABS, or the new blend of PC and ABS.

As a result, it may be said that the FDM process makes sense particularly for devices with complex geometries (free-form surfaces, undercutting, etc.) and for low-load devices (limited to the ABS material data).

Due to the progress in machines and materials, FDM prototypes and components can be used in more and more areas of application. The useful area of FDM parts may be extended beyond vehicle assembly to bodyshell construction and paint jobs. As initially mentioned, no enterprise can afford today to do without rapid prototyping for product development. In addition, it takes on increasing importance as an alternative manufacturing method for components in small numbers.

Selection Flow Diagram



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