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RECONSTRUCTION OF SIMPLE PARTS USING FDM TECHNOLOGY

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Abstract: This article shows the experiences of component reconstruction supported by FDM 3D printing through a few examples. It presents the profile copying technique that can be used as an alternative to traditional measuring methods and 3D scanners for relatively complicated parts.

Keywords: *FDM printing, machine element reconstruction, copying geometry*

1. INTRODUCTION

The reconstruction of machine components is one of the most elementary engineering tasks. Because of this, already at the BSc mechanical engineer students in all universities meet with this challenge during their studies.
The essence of this elementary creative activity is to determine the original geometry of a touchable, but in most cases unusable (worn, broken) part. An important task of the process is the preparation of a technical drawing of the selected part containing the dimension, tolerance and material information required for remanufacturing if production documentation is not available.

2. THE AIM OF THE RECONSTRUCTION

2.1. Unavailable parts for replacement

The reconstruction of machine components may be necessary in several cases. Sometimes the productive machine is simply so old that product support or the purchase of spare parts is not available. However, by replacing a single failed or worn part, the lifetime of this expensive equipment can be significantly extended.

2.2. Reducing lost time

Another frequently occurring problem is that the part that we need to be replaced can be available, but the delivery takes much longer than we can afford by taking the machine out of production. A solution may be to temporarily use a machine component with a shorter service life –or even a narrower functionality–, but which can be quickly accessed by means of component reconstruction.

2.3. Economical repairing

A similar situation is when an original part can only be purchased at such a high cost that it is not economical to pay for continued operate of the equipment. In this case the machine part can be replaced by an element, produced by a proper rapid prototyping technology (RPT), that is perfectly suitable in long term.

3. Traditional practice

For each of the cases listed in paragraph 2, it is essential to define the precise geometry required for assembly and operation. (Bihari & Szente, 2011) Engineer students in the practical courses of the Machine Elements I. subject at the University of Miskolc usually have to perform the documentation process of the reconstruction of axle, disc, gear and simple cast parts. This work, which may seem to be difficult at first sight as a second-year student, gives them practice in the use of conventional measuring tools (vernier calliper, micrometres, radius templates, thread combs, etc.) and the application of their knowledge of engineering drawing.

4. Use of new techniques

4.1. Stand-alone modelling equipment

In addition to traditional measurement methods, it is also possible to define the geometry of the component using advanced equipment. In the past, engineers used a profile projection device to determine 2D projections, which is now an important segment of the history of technology (Figure 1.a). But nowadays 3D coordinate measuring machines or even contact or non-contact optical surface digitizing devices are also common solutions. (Sarka & Tóbis, 2017) (Figure 1.b)

a) b)

Figure 1. *a) Past: CarlZeiss Projector 320*
b) Present: Roland LPX-1200 laser scanner

4.2. An alternative method

These modern geometry digitisation techniques also have limits and, in most cases, require specific training for operators. In such cases, the use of old methods supported by modern technologies is a good alternative solution.

Taking a digital photo with the right resolution and orientation is very similar to the ‘old age’ profile projector principle, but the image is processed by a computer. In all cases, it is essential that the photograph (or microscope image) of the part to be reconstructed has an accurate millimetre (or micrometre) scale on the picture, which can be used as a reference for processing. (Figure 2)

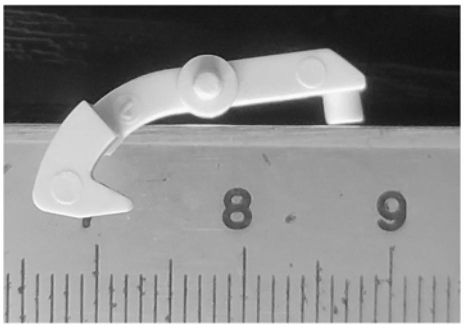


Figure 2. *Mechanical timer clock switch arm with millimetre scale*

5. Workflow

5.1. Preparation and photography

If not all the dimensions of the part are defined or a complex CAD model is not obtained by scanning, the final geometry can be determined by reconstructing the edges and proportions shown in the projection photograph of the part. This can be aided by colouring the edges before photographing, for example with graphite powder for light parts or chalk powder for dark machine parts. After photography, it is possible to further highlight the edges using image manipulation programs (e.g., GIMP, PhotoShop).

5.2. Processing in CAD

The prepared and cropped photo can be set up as a background image in a suitable CAD software (e.g., Solid Edge, Creo, etc.) as a desktop in the editor. Of course, the size of the part is not yet defined, so it is a good idea to crop the photo to fill the drawing area of the CAD program as much as possible.

The next step is to redraw the bounding curves of the visible projection as accurately as possible. At this point, the dimensions are still flexible and only the shape of the sketch is drawn. In this step, information from the operation of the part and from the measurement of surfaces that can be specified with conventional tools is used. So, for example, if we know that there is a rounding, we do not approximate it with a perpendicular spline, but with a normal circular arc. In the same way, straight lines, parallels, and perpendiculars, known angles or even the coaxiality are available from our knowledge of the features of the part through our engineering experience. It is useful to indicate the known dimensions on the sketch, but not yet as a construction definition, but as a flexible guide that can be freely varied during the subsequent steps of the design.

5.3. Scaling

After the 2D shape sketch is complete, the key step follows it in the process, which is the scaling. Every CAD program has a tool that can zoom in and zoom out on the selected drawing elements while maintaining their fixed relationship to each other.

Since a known size is entered as an informative dimension, it can be divided by the real equivalent of the original part measurement to determine the exact ratio of magnification or reduction. Then it can be used to scale the part to obtain the scale projection. From this sketch, we can use a protrusion or revolved protrusion tool to create a 3D body model, on which we can make further refinements based on our previous measurements.

5.4. Modification, redesign

After getting the original part geometry, it is possible to improve the part before production. Either by carrying out tests with FEM or simply by considering expected loads, failure that has occurred or the space available for the part in the machine, we can usually reinforce the critical cross-sections –mostly through the addition of material to the set.

6. 3D PRINTING

After conversion to a file format managed by the 3D printer (e.g., STL), the CAD model is ready to print. In the present case, FDM printing –using a thermoplastic polymer substrate fed as filament– is considered as one of the most common rapid prototyping processes.

6.1. Building structure and fibre orientation

More research has shown that the orientation of the component structure, in other words the plane in which the printing layers are parallel to each other, has a relevant influence on the mechanical properties of the finished product. (Konya & Ficzere) (Albert & Takács, 2023) It is easy to see that, in a technology where layer separation is an existing problem, the directions of load that result in their mechanical separation should be avoided.

Similar to this, fibre orientation and the rate of internal filling are parameters that need to be chosen consciously. For example, results from a series of measurements carried out at John von Neumann University GAMF Department of Materials Technology show that in all cases measured, a 45° fibre orientation resulted in specimens with higher impact-bending strength, higher tensile strength, and higher elongation at break. (Ádám & Polgár, 2019)

6.2. Material selection

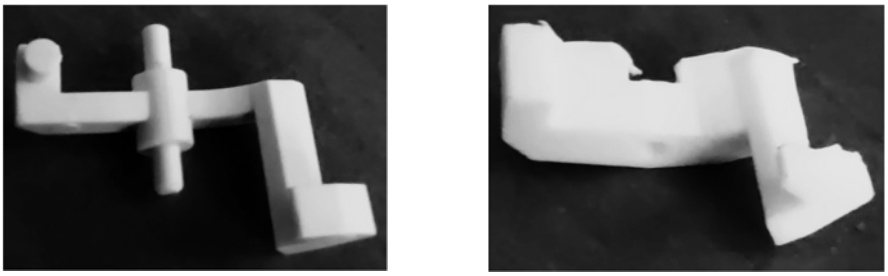
The choice of FDM printing material is also a crucial consideration when aiming for a product with a relatively long lifetime. The most commonly used materials are ABS, ASA and PLA (Marada & Bihari, 2022) and their doped versions. Among these, PLA known for its easy (lower temperature) printability, is perhaps the most popular. Of course, its heat resistance is correspondingly lower than usual, limited

to max.60°C. Care should be taken when printing finished products that may be exposed to higher temperatures at the point of installation or during operation.
A solution can be found in CPLA (crystallised PLA), a material designed for products with higher heat requirements. Products printed from CPLA have a heat resistance up to 80°C. (Qingdao Knowledge Industry & Trading Corporation, 2022)
If you are expecting higher stress, TPLA (tough PLA) with increased mechanical performance is a good choice. The name TPLA refers to PLA doped with talc, where talc is a natural mineral that helps PLA to form a harder material. Thus, while maintaining the lightweight printing authority, you can get increased impact resistance, but only at the lower heat resistance typical of PLA. (MakerBot Industries, 2023)

7. PRACTICAL EXAMPLES

7.1. Switch arm

The first example shows the reconstruction of a component that cannot be purchased, because the structure containing this component is also not a particularly expensive product, so spare parts are not provided. However, after the cause of the failure had been identified, the reconstruction of this low-material-demand switcher arm was a natural step (also due to the availability of 3D printing).



a) b)

Figure 3. *a) original part b) redesigned switch arm*

As shown in Figure 3, the original geometry of this rocker arm has undergone several modifications. The broken small cross section of the arm has been given maximum thickness considering the available space. A further modification was the replacement of the crankshaft, injection moulded from the same material as the original part, with a hole of the same diameter, into which a steel rod was later inserted, thus increasing the lifetime of the component (Figure 4).

It is obvious, but important to note in the case of a printed spare part, that it is advisable to print in the laid down position, taking into account the expected loads. Experience has shown that a part produced in this way has been working continuously and correctly for a year after installation.

Figure 4. *3D printed switch arm being installed*

7.2. Cooling fan

In this example, a higher thermal load is applied to this machine component. The interesting aspect of the problem is that a special shaft-hub connection had to be reconstructed. The compressor fan shown in Figure 5 is a component that fits on the eccentric shaft end of a crank mechanism.

Figure 5. *3D printed fan in motion*

In order to ensure a shock-free operation, it was important to determine the most precise hole position as possible. The stiffening ribs of the hub have been slightly modified to allow the impellers to be held in place by a larger support. As a result, the product has operated without problems for many years with intermittent use.

7.3. RC car part

The last example is an often-breakable plastic part. This is a sleeve bearing, closed at one end, which is a radio remote control model car component that holds the front swing fork axle in place without play. Due to the variability of the chassis geometry, its design is not symmetrical (Figure 5.a). Experience shows that it has a long life in normal operation, but it works as a breaking element in a crash and in this way it protects more expensive components from damage.

a) b)

Figure 6. *a) CAD model of the shaft positioning sleeve*
b) Spare parts printed in multiple copies

8. SUMMARY

Experience has shown that 3D printing based on FDM technology has become suitable for the reconstruction of real and working parts. With the right choice of layers, printing directions and other parameters, long-life and properly functioning replacement parts can be produced.

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