



Volume 93

2016

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: <https://doi.org/10.20858/sjsutst.2016.93.8>



Journal homepage: <http://sjsutst.polsl.pl>

Article citation information:

Kužma, L., Kužma, D., Miženková, Ž. Helicopter UAV fuselage bulkhead modelling. *Scientific Journal of Silesian University of Technology. Series Transport*. 2016, **93**, 69-78. ISSN: 0209-3324. DOI: <https://doi.org/10.20858/sjsutst.2016.93.8>.

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HELICOPTER UAV FUSELAGE BULKHEAD MODELLING

Summary. This article deals with the design of helicopter UAV airframe components. There is a description of UAV airframe design modelling involving already existing components in three-dimensional (3D) form. The modelling methodology focuses in detail on proposed bulkheads by using “top-down-bottom-up” methodology. In conclusion, there is a brief description of all proposed bulkheads and an outline of possible solutions for how to design airframe stringers.

Keywords: helicopter; modelling; airframe components design

1. INTRODUCTION

The article deals with the description of the design for UAV bulkheads based on helicopters. Due to the large scope of the work performed during the modelling phase, we were forced to limit the description of the design to one of the four bulkheads used to determine the shape of the skin, as well as serve to increase the rigidity of the structure in resisting aerodynamic forces, which are acting on the UAV fuselage during flight. The reason why we have chosen to describe only one structural part is that other bulkheads were designed

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and digitized in a similar manner. For designing, we used the modelling and sheet metal environments of the Siemens PLM software NX 9.0 [3].

2. CREATING A MODEL OF THE EXISTING PARTS

We began the whole process of designing a new UAV design and construction by thoroughly studying the literature of helicopter structures and new trends in the field of UAS systems, and by conducting a dimensional analysis of already existing parts of the research device OKO2. The current real shape of the device can be seen in Figure 1.



Fig. 1. Current shape of UAV OKO2

From the measured dimensions, we created a virtual appearance using the tools in the modelling environment of the two plates, which form the main element supporting the whole structure, tanks and spacing webs, which define the distance between the plates. All the parts we created were saved in a separate *.prt file. After that we linked up all the parts into the “assembly”, where each defined component was positioned relative to other components and gripped by a constraint tool. When using this type of sequence modelling, we are talking about top-down-bottom-up methodology, which means that, at first, we created the individual parts of a structure and then created the whole assembly. The final assembly of the base structure is shown in Figure 2.

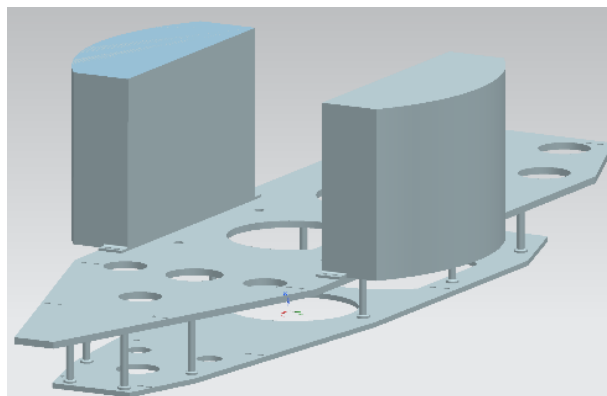


Fig. 2. Basic design of the measured assembly

After completing the previous assembly, we went to the upturned methodology, which is so-called “top-down” stage, where we gradually created more structural parts of the UAV for the assembly. Rather than use reverse engineering, we next created our own new designs for the parts. This method is much more advantageous when creating completely new construction parts without templates. This is because all parts of the assembly are always visible and can be seen in real time, such that we can review whether the units are compatible with each other in size and design. Both methodologies are explained in the general procedures chart shown in Figure 3 [1][2].

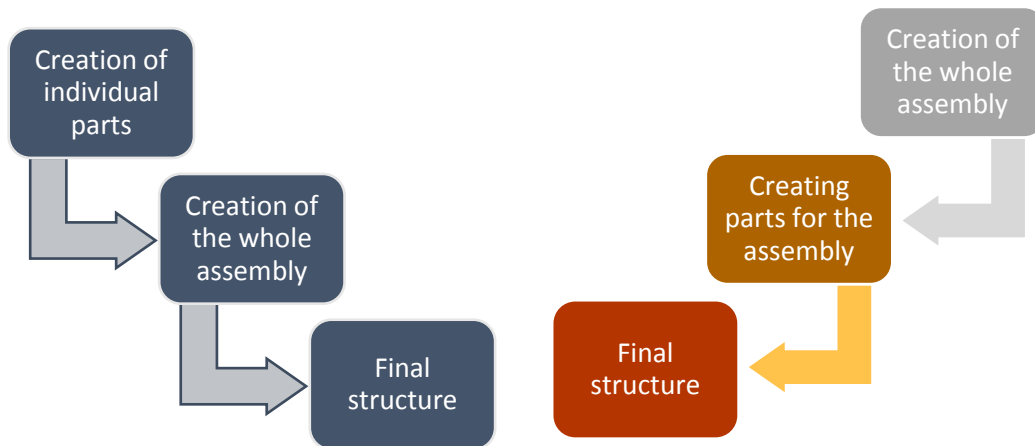


Fig. 3. General creation methodologies of structural units

3. CREATING OF BULKHEAD

As mentioned above, the purpose of the proposed construction of bulkheads in UAVs is to determine and maintain the shape of the fuselage structure. The detailed description of the one bulkhead is sufficiently applicable to the creation of the other three, because they are structurally similar. The creation of the final dam was divided into two phases. Initially, we created a solid body, whose outer edge reference line we received and used as the local circumference of the fuselage, as well as in the creation of fuselage skin. We conducted after the completion of creating the skin in the second creation phase of the final bulkhead. The reason for making a division to create two phases was the need to make the rim face compatible with the bulkhead-shaped skin, so that all sides lay flat on their covers to enable the bulkhead to link to the skin. This type of reverse modelling was initially done using the metal sheet environments in the Shape Studio, after which we created solid bodies from the sheet surfaces [2].

4. CREATING A SOLID BODY FOR THE BULKHEAD WITHOUT ADAPTING THE RIM

In the first step of creating a bulkhead, we added a new part to the assembly using “Add → Create New” in the assembly environment. Adding a new part required a definition of the plane in which the new part was to be located after its creation. We added a new plane

using the Datum Plane tool, then determined its distance from the reference plane by choosing the “At Distance” drop-down dialogue box in the Datum Plane.

In the Extrude tool dialogue box, we defined the plane on which we created the first shape of a bulkhead. We created this plane before we clicked on the Extrude tool in the same manner as when establishing the plane in the assembly environment. After defining the plane, the program automatically transferred us to the two-dimensional Sketch modelling environment. In this environment, we set up a perimeter and an internal shape of the bulkhead profile. The exact shape of the proposed bulkhead is shown in Figure 4

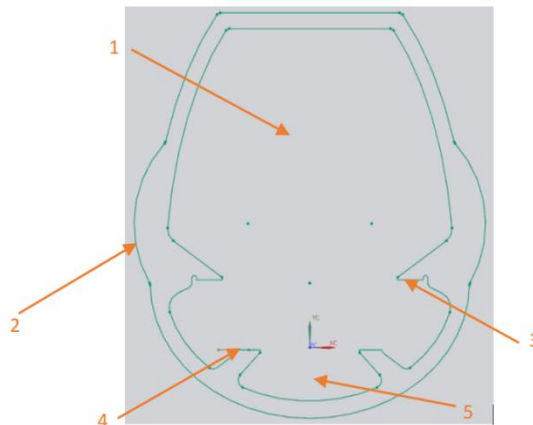


Fig. 4. Contours of the bulkhead's final shape

Parts of the rib profile and their meanings:

1. The upper internal space - The largest open space is used for locating the engine, main UAV systems and supporting systems. This can be found near to the second and third bulkheads. The size is diminished around the first and fourth bulkheads.
2. Tank extension and air intake - To achieve the smallest possible size and weight of the UAV, the frame was designed with the smallest possible width. In order to include fuel tanks, an extension had to be created in the centre of the side wall since our UAV power unit is an internal combustion engine. It was necessary to ensure an adequate airflow supply for its operation and cooling. The figure shows the shape of the extension designed to fulfil this function. The extension is used for the second and third bulkheads. The second bulkhead in the area of extension also includes a hole for decongestion and air supply.
3. Attachment to the top plate of the main frame - This attachment is the main bearing element of the bulkhead and the skin; therefore, it has a wider shape.
4. Attachment to the bottom plate of the main frame - This attachment prevents the bulkhead twisting and bending, thereby maintaining the shape of a frame.
5. Lower interior space - This space is used to accommodate the attachment of the landing gear, transmissions and optional additional equipment of the UAV (infrared camera, scanner etc.). This space is much smaller than the upper internal space.

After completing the required drawing shapes, we completed the creation of the layout using the Finish Sketch command. The software automatically redirected us to the modelling environment, with the Extrude dialogue box remaining opened. In this dialogue box, we set the required pull-out parameters to make the 3D element.

From the solid body created in the previous step, we created the shell using the Shell tool. We defined the wall thickness to be 1 mm. By simply clicking the tool icon, the software automatically requested us to clarify the surfaces, which had evolved into a recess of the shell.

The Shell tool did not remove the inner rim of the bulkhead, which was helpful because of the need to create a small bent section along the inner edge. Such upturned edges are used to increase the bulkhead rigidity in the transverse direction. We also wanted to keep the bulkhead tabs attached to the lower and upper plates. We used Extrude to reduce the height of the inner rim in order to reduce the weight. In the Sketch environment, we drew a profile using Extrude in order to remove excess surfaces from the rim. Our suggested new profile had to be larger than the inner rim, but at the same time smaller than the outside one.

We confirmed the use of the Extrude tool by clicking “OK” and continued modelling. Another action involved “rounding off” the outer edges of the bulkhead. For this purpose, the Edge Blend tool was used. By clicking on this tool, we opened up a dialogue box, which requested us to mark the edges that we had planned to round off. We rounded off all the outer edges of the bulkhead profile with a radius of 2 mm.

5. CREATION OF THE FINAL BULKHEAD BODY WITH A TIGHT-FITTING RIM TO THE SKIN

This part of the bulkhead modifications came after creating a skin, which is the subject of the work reported in another article. In this case, we could create a projection of the skin shape within the desired distance of the future bulkhead rim. The spacing was determined according to the created plane at a distance of 15 mm.

The projection of profile curves of the skin was conducted using the Intersection Curve tool during work on the skin. This was subsequently projected on the work component of bulkhead. Being able to see the projection of the skin curves and interact with it in another component of the bulkhead is an advantage of the top-down modelling methodology. To create projections of these curves, we first created a new working plane using the Datum Plane tool at a distance 17 mm from the plane, which determined the rear wall of the bulkhead in the previous procedure. The difference of 2 mm was established by using the far side of the radius, related to the formation of the skin. On this plane, we created a separate Sketch environment, using the Project Curve tool to project the shape curves created by the skin. These projection curves can be seen in Figure 5, as highlighted by the red line.

The second curve needed to create the surface of the bulkhead was created, namely, the curve forming the vertex of the angle between the rim and the back surface of the bulkhead. We first set up a working plane at a distance of 2 mm from the initial plane of the bulkhead part. The reason for the difference of 2 mm is the same as for the first curve. Sliding the edge of the bulkhead by 2 mm achieves the difference between the radius of the bulkhead and the skin.

We created another Sketch environment pertaining to a new plane. In this environment, we used the Show tool to observe a solid body of the bulkhead created by the previous procedure. According to the edge of this body, we created a projection of the corner curves' shape. The top side of the curve was removed from the distribution curves due to the need for at least two parts. This step was essential for the creation of the surface of the bulkhead rim. Without this split, the program was unable to assign directions and the beginning of the surface creation by the curves.

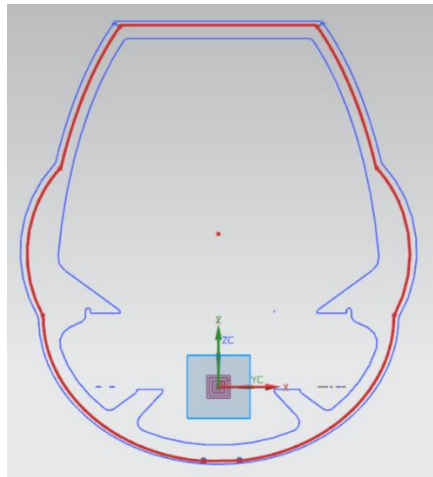


Fig. 5. Projected curves' intersection of the skin and the Datum Plane

We have made progress towards the creation of interconnection lines between the front and rear rim lines of the bulkhead. These connections are required for creating sheet metal where these lines define the start and end sections, which need to be created. These interconnection lines were created using the Line tool without the Sketch environment. During the creation of interconnection lines, we captured the start and end points of the segment directly in relation to the front and back rim lines. These connections had to be defined by clicking “Point” in the dialogue box of the Line tool. By doing so, we were able to open a new window, in which we were able to choose the end point in a list of attachment options. This meant that we created the start/end point at the very end of the curve, which was located where we wanted to catch the generated line. Thus, we created a line on both sides. If the line had not exactly fit the curve, it would have been impossible to create a surface using the interconnection line segments.

The last part was created in the same way the second part of the back rim line by joining the rim and backs. This curve was created in the same way as in the first part, using the Quick Trim difference usage tool in a new Sketch environment and deleting all lines except the top one (see the inset in Fig. 6).



Fig. 6. Creation of the top curve

After this step, we were able to continue creating new sheet metal to cover the bulkhead. For this purpose, we used the tools in the sheet metal environment. The first was the Bounded Plane tool, which fills the space between two predefined curves. We chose it because of the formation of the dorsal surface of the new bulkhead. First, we marked the outer curve. The program automatically filled the entire interior space. Then it was necessary to select the second inner curve, which was created on the surface cut out of the desired shape.

In the next step, we created the rim surface using the Through Curve Mesh tool. After clicking on the tool, a dialogue box automatically opened with instructions for using this tool. As first, we marked the primary curve in the Primary Curves input field. At least two curves had to be present. We distinguished every mark of the curves out of the plane by clicking “Add New Set”. After determining the primary curves, we continued marking the cross curves, which were bound together at the beginning and during the end surface’s creation. These curves had to be marked in the Cross Curves input field in a similar way as in the previous case. We had to separate the individual curves by clicking “Add New Set”. The sheet metal surface was automatically created after marking the order of the second (final) curve. We created the second part of the bulkhead edge using the same procedure. The usage of the Through Curve Mesh tool is shown in Figure 7.

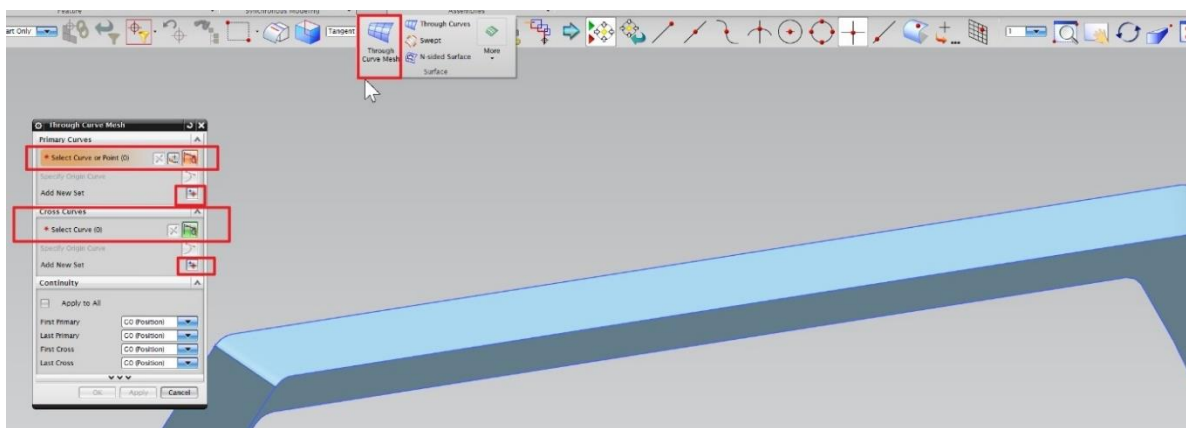


Fig. 7. Creating the bulkhead rim

After creating the surface, it was necessary to define the thickness of the sheet metal to forge it into a solid body. The easiest method of creating a solid body from sheet metal was to use the Thicken tool. This tool can create the desired thickness of the body by a simple click. As first, we created a solid body from the surface of the bulkhead’s back part, where we defined a thickness of 3 mm, followed by the surface of the bulkhead rim, where we defined a thickness of 1 mm. A thickness of 3 mm in the case of the back part is justified by the need to create an end radius on the edges due to the increased rigidity of the structure.

The intersection of two materials in the connecting part between the rim and the back was solved using the Chamfer tool. This tool allows chamfering bodies around the desired curve.

After the edges were finalized, they were ready to be knitted together into one solid body. We continued with this operation using the Unite tool. We clicked successively on other body parts, which were automatically merged.

By merging other body parts, we continued with the creation of soft edges around the body of the bulkhead. The Edge Blending tool was used to create the radius, which involved a similar process as that in the first phase of the bulkhead creation. We also created a bended edge at the free end of the bulkhead’s back using the Shell tool. To remove the top edge of the back, we had to turn off the display by right-clicking on the rim and selecting “Hide” in the shortcut menu. Then we removed the desired edge by simply clicking on the Shell tool. After this operation, we observed the rim by clicking on the Show tool and choosing the desired rim.

The next task was to create the turning points of the flanges for mounting the bulkhead to the base plate of the assembly. We created the turning points by drawing the desired profile in a Sketch environment of the Extrude tool. Then we defined the setup in the Extrude dialogue box in order to subtract the solid body. We expanded our subtraction as shown in Figure 8 and accepted the changes by clicking “OK”.

Mounting flanges were created using the Extrude tool, with which we defined the sketch plane. As a reference, we selected the surface on the mounting flanges.

By clicking on the surface, we were automatically redirected to the Sketch environment. There, we simply projected rectangular shapes of future mounting flanges using the Project Curve tool. Then we returned to the 3D environment, in which we defined the distance from the flange (see Fig. 9).

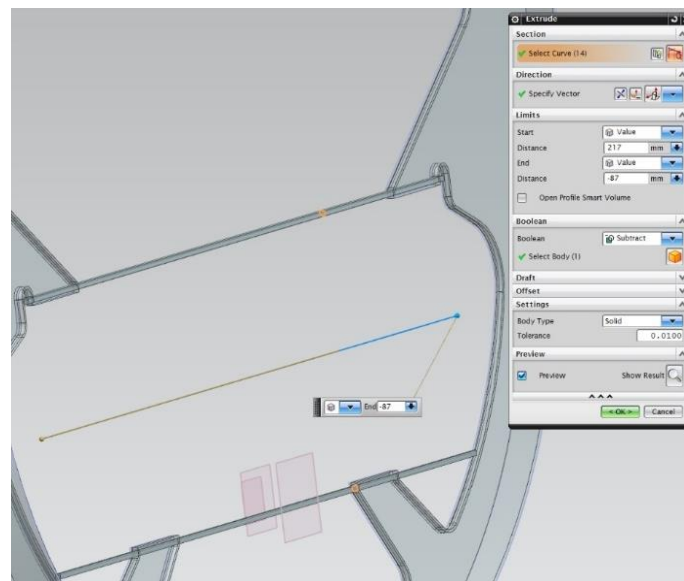


Fig. 8. Creating the turning points of the mounting flanges

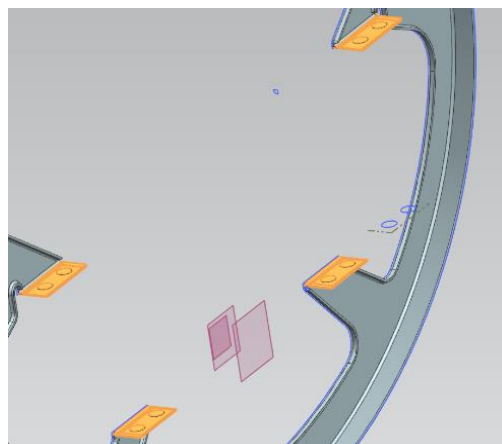


Fig. 9. Creating the mounting flanges and holes

In Figure 9, it is also possible to see the outlines of the holes for attaching the bulkhead to the base plate. These holes were created using the Extrude tool with a similar procedure to that for the mounting flanges. The only difference was in removing the volume option in the Extrude tool settings. Before cutting holes, we used the Unite tool to connect the newly created bodies of the flange to another body.

6. CONCLUSION

The final version of the bulkhead spacing in the UAV structure is shown in Figure 10. Bulkhead numbering starts with number 1, located on the left side of the image, with numbers 2, 3 and 4 towards the right.

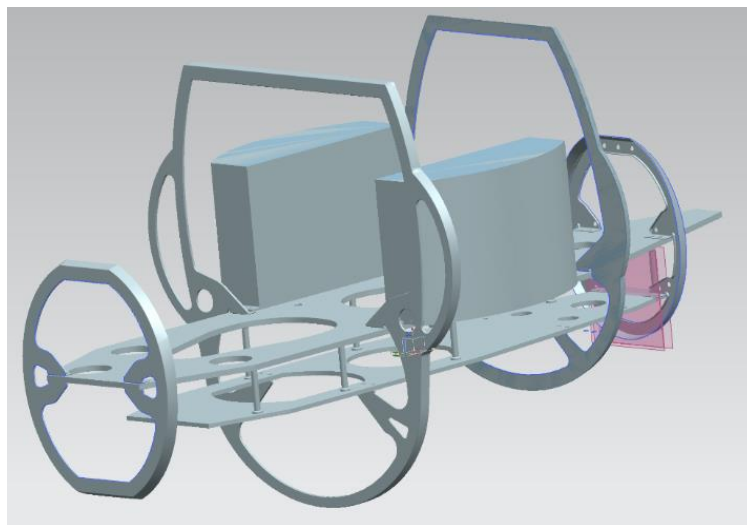


Fig. 10. Final model of the UAV structure

Bulkhead 1 is attached to the base plate designed to form the nose cone of the model with the possibility of sensor or camera positioning. Bulkheads 2 and 3 are structurally the most complex, with their shape designed according to the needs of the UAV airframe systems' location. The tail section and transmission of the UAV should be attached to bulkhead 4, which is the most rigid compared with the others in terms of effectively transferring loads from the tail section to the frame. The system of stringers will be the subject of further research. It is assumed that two stringers along the fuselage will be located on top of the airframe and one will be located on the bottom.

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Received 09.10.2016; accepted in revised form 25.10.2016



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