

CP468036

Fusion 360 Freeform Modeling: Tips and Tricks

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Learning Objectives

- Learn how to model 3D objects with scan data.
- Learn how to model with Fusion 360 Freeform.
- Learn how to model with basic 3ds Max.
- Learn tips and tricks for converting meshes to solids

Description

In this class, the speaker will share the Fusion 360 free-form modeling tips and tricks that were used to model the Ironman Suit and the Ironman Armor: Mark XLIV—HulkBuster. The process of making these suits was presented at Autodesk University 2017 and 2018. These two models were also posted on the Fusion 360 Gallery:

<https://gallery.autodesk.com/projects/110798/ironman-suit>

<https://gallery.autodesk.com/projects/120141/iron-man-armor-mark-xliv---hulkbuster>

Speaker(s)

Hung Nguyen has 28+ years of experience in Autodesk Products. He has a strong background in Architectural and Manufacturing fields. He is a BIM & Manufacturing Technical Consultant. Hung also has extensive experience in a diverse range of CAD-related software such as: Revit, Inventor, Fusion 360, Alias, and Simulation to name a few. He has presented multiple times at Revit Technology Conference (RTC), Canadian Festival of Architecture, CanBIM, and Autodesk University from 2013 to 2016.

Lina El-Khoury is the Design Applications Manager at James K.M. Cheng Architects in Vancouver BC. With over 25 years of experience in Architecture, Building Systems, Interior Architecture and Building Manufacturing, she now specializes in BIM technologies. She has been the National BIM Lead for GEVINAR (WSP) and worked at Perkins + Will locally and firm wide – always raising the bar for better BIM collaboration, deliverables and efficiency. Equipped with CAD knowledge and BIM expertise in multidisciplinary platforms, combined with 10 years of Building Manufacturing experience, Lina has trained and coached many teams in multiple design and subcontracting AEC firms. Her passion, dedication, contributions to the BIM development and implementation have been very valuable and appreciated by many firms in which she worked.

Introduction

The world is rapidly changing. Industries are converging, and they're innovating increasingly faster. The entire manufacturing environment is in the midst of a dramatic transition and the costume-product-design sector is no different. Advance materials and Industrial-Grade Additive Manufacturing have made their way into hobbyist and professional's designs and costume-making.

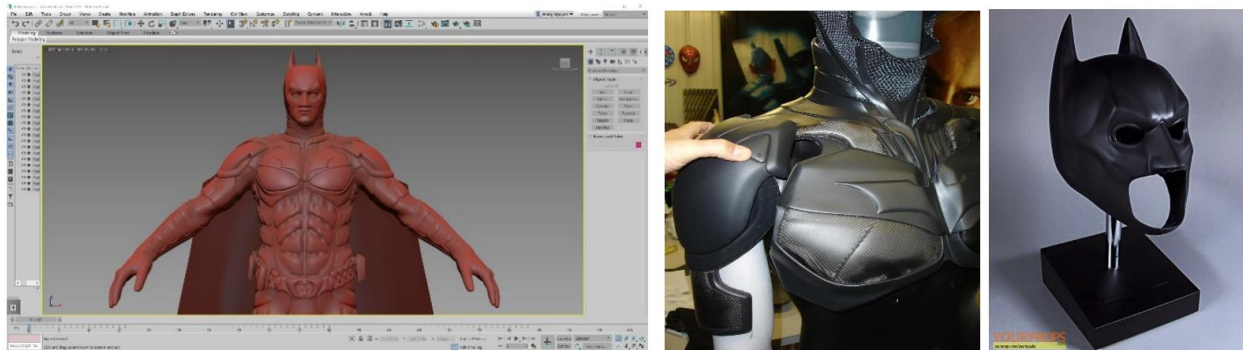


FIGURE 1: HOBBYIST AROUND THE WORLD ARE SERIOUSLY MAKING COSPLAY COSTUMES ([source](#))

As these trends grow rapidly as never before, the use of innovative software such as Fusion 360 to move quickly between different design ideas becomes imperative. These trends drive the achievable digital workflow for doing textile-based product design. Digital designing is faster since:

- Digital models are adaptable.
- Models are linked to pattern creation which saves time and increases accuracy.

Fusion 360 and its plugin is **superior** for the tasks.

The Inspirations

Meeting the Dutch based Hi-Tech Fashion Designer and Innovator **Anouk Wipprecht** at Autodesk Research Pier 9 in San Francisco, CA was a fascinating encounter. I never thought that I could use Autodesk products for fashion design or costume making. I learned that Anouk "is working in the emerging field of "FashionTech"; a rare combination of fashion design combined with engineering, science and interaction/user experience design. Producing an impressive body of tech-enhanced designs bringing together fashion and technology in an unusual way: she creates technological couture; with systems around the body that tend towards artificial intelligence; projected as 'host' systems on the human body, her designs move, breath, and react to the environment around them" (source). Her designs of dresses including a Spider, cocktail, heartbeat, smoke, and electric dress made my head spin, and inspired me to think of Fusion 360 in a different way.



FIGURE 2: *HEARTBEAT DRESS, SMOKE DRESS AND ELECTRIC DRESS DESIGNED BY ANOUK WIPPRECHT*

Ironman & Hulk buster Suit with Fusion 360

The goals of these projects are:

- Uncover the all-in-one environment of Fusion 360
- Create something that can be flattened for cutting
- Create something that is fun and can be worn at Comic-Con International - San Diego

With research and learning from past AU, and after several design sessions we converged on the following process workflow:

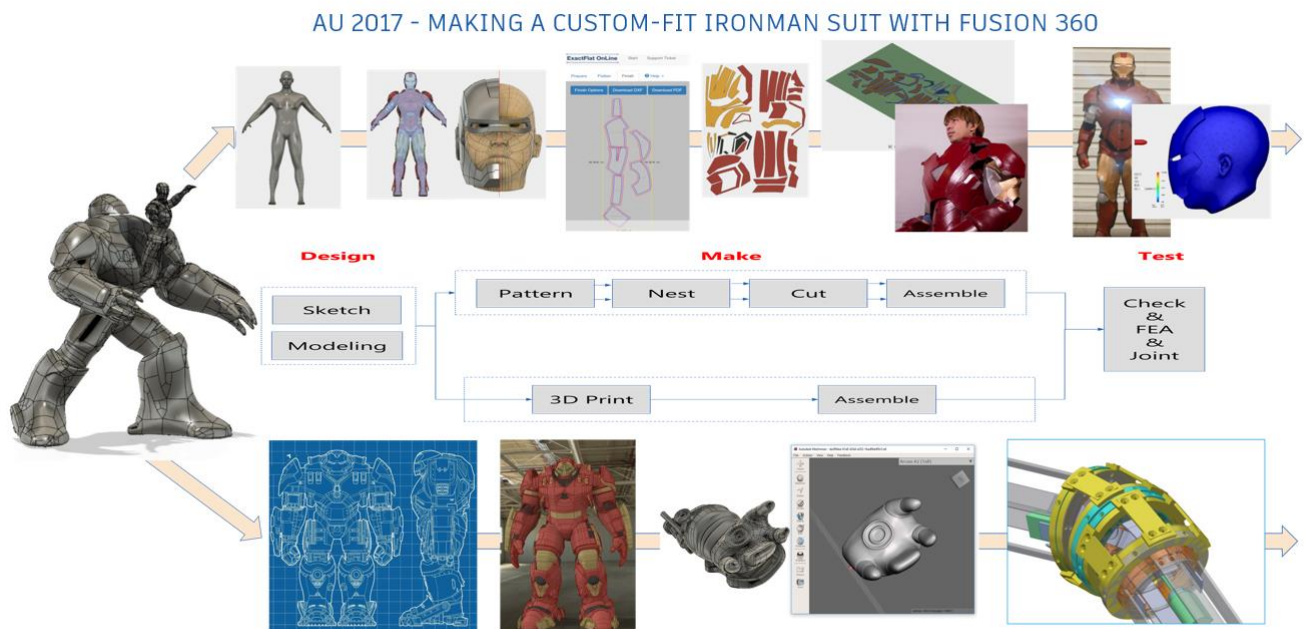


FIGURE 3: *PRODUCT-DESIGN PROCESS OF IRONMAN SUIT AND HULKBUSER*

The Mannequin

A mannequin is an often-articulated doll used by artists, tailors, dressmakers.

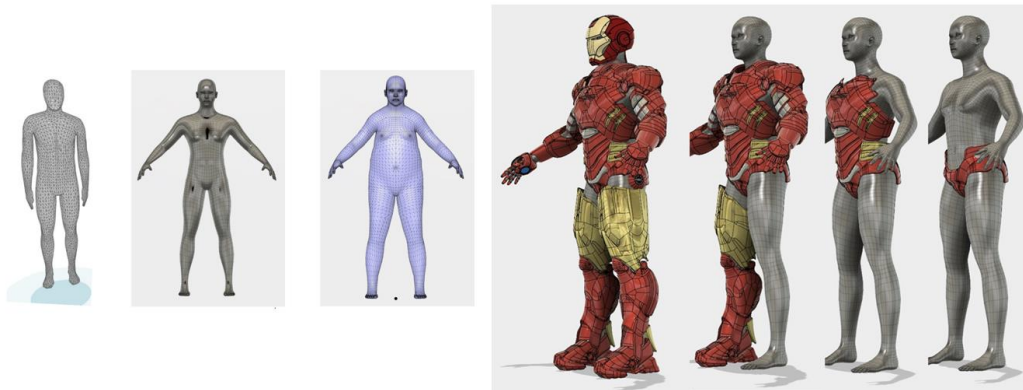


FIGURE 4: THE MANNEQUIN USED TO MODEL IRONMAN SUITE

There are many different ways to create a mannequin to be used as the foundation of our digital design:

The 1st one from the left came from 3D scanner. Scans are very useful for digital design since it produces point cloud that can be meshed using on-line meshing service from Recap Pro and Recap Photo.

The 2nd method is to use software. A mannequin can be easily produced by using a software called MakeHuman 1.1.0. MakeHuman is a free and open source software for creating realistic 3d humans for:

- Illustrations
- Animations
- Games
- Zbrush/Mudbox sculpting

Tip: Modelling Mannequin from 3D Scan Data

Nowadays, 3D scanner apps are getting better and better. They've become not only easier to use but also better in quality and reliability. With a simple to use mobile phone application, the world is ready to be digitized. Whether focusing on the details of a small object or capturing an entire environment. In this example, I used a mobile 3D Scanner App called **Trnio**.

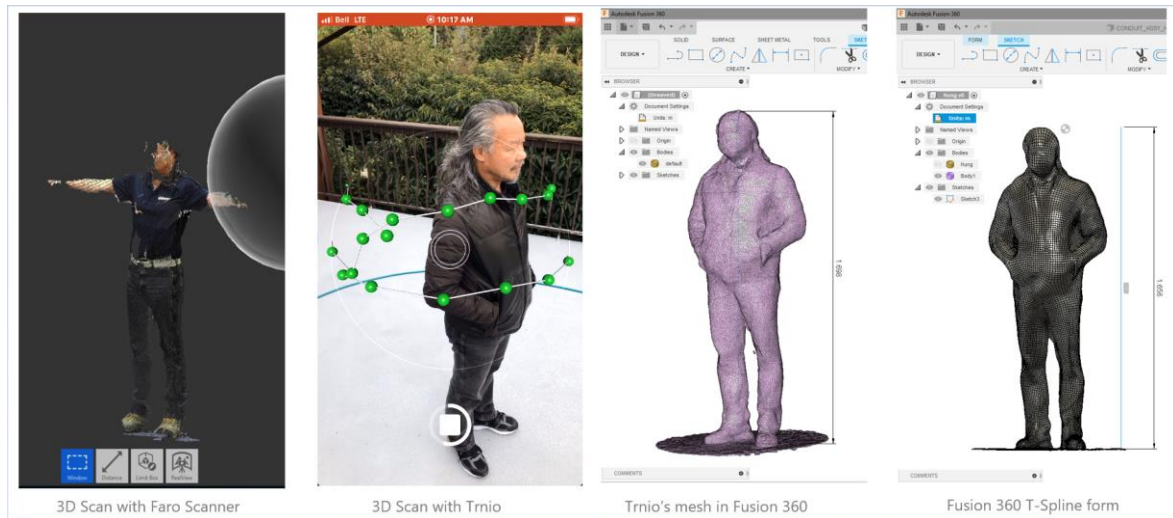


FIGURE 5: 3D SCANNER APP– TRNIO WAS USED TO SCAN AND CONVERT HUMAN BODY TO SOLID

Reverse Engineering Service at SolidCAD

The step of turning a mesh to solid is very tricky. At SolidCAD, we provide reverse engineering service to our clients. Reverse engineering is a difficult and time-consuming process. There is no magic button for converting a 3D scan data into a usable CAD file automatically. But there is a standardized workflow that makes reverse engineering possible. Here are some samples of my works at SolidCAD where I converted scans to solid sheet metal parts for heavy mining trucks that have broken parts.

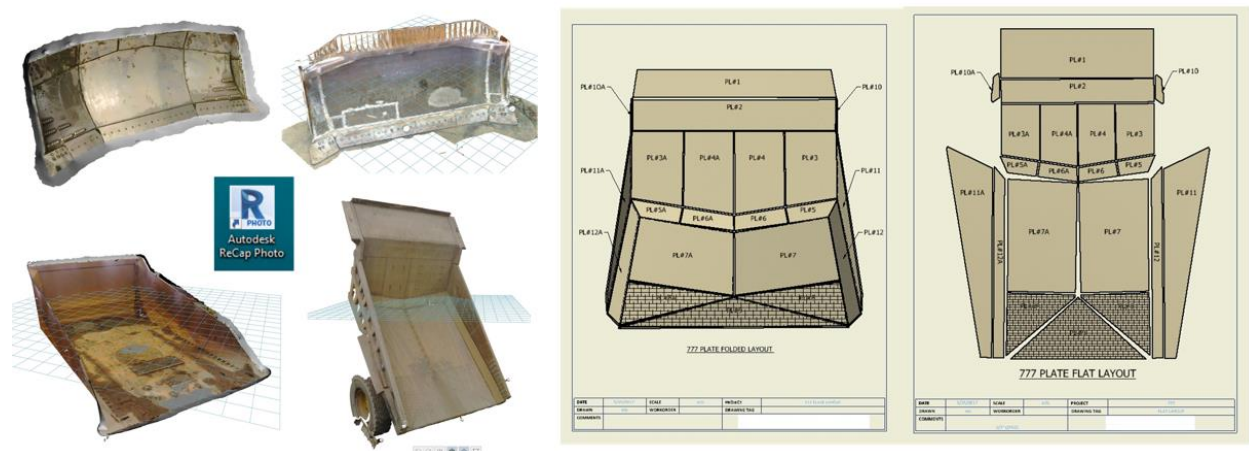


FIGURE 6: REVERSE ENGINEERING FROM SCANS TO SOLID SHEET METAL PARTS FOR HEAVY MINING TRUCKS

Trick: Model 3D Human Model with MakeHuman

MakeHuman is an open source (AGPL3) tool designed to simplify the creation of virtual humans using a Graphical User Interface, also commonly referred to as a GUI. This is a specialized branch of the more general subject of 3D modelling.

MakeHuman provides Macro that quickly size human model based on gender, age, muscle, weight, ethnic background etc. Models from MakeHuman can be exported out as Wavefront obj format. The Wavefront obj can be inserted into Fusion 360 and ready to be converted into T-Spline and Patches.

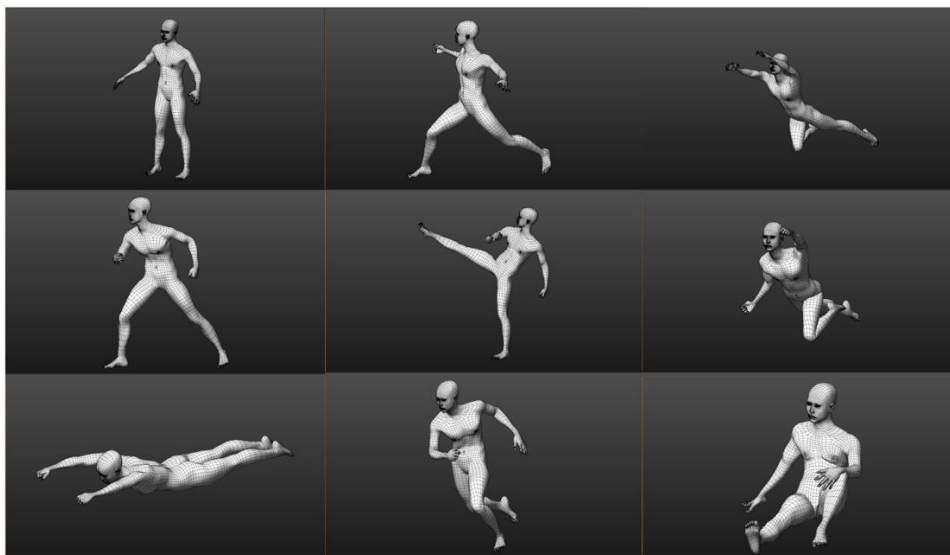


FIGURE 7: MAKEHUMAN PRODUCES MULTIPLE POSITION WHERE THE SUPERHERO CAN RUN, KICK, FLY OR PUNCH

Trick: Model Human Model & Convert to Fusion 360

MakeHuman can be exported out as Wavefront obj format. The Wavefront obj can be inserted into Fusion 360 and ready to be converted into T-Spline, Patches and Solids.

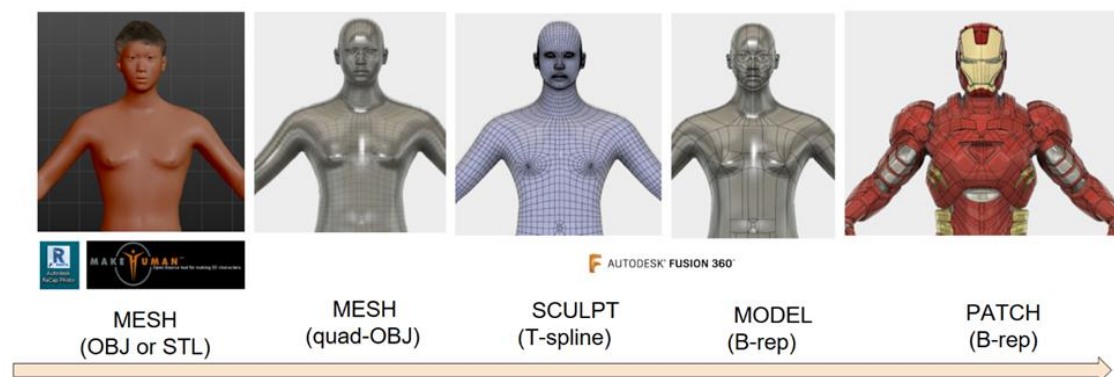


FIGURE 8: FROM MESH TO PATCH TO SOLID CONVERSION BETWEEN MAKEHUMAN AND FUSION 360

Trick: Sculpt design Textile with Fusion 360 & MakeHuman

In the Video, I took a model from MakeHuman, turned it into T-Spline and unwelded a few edges to make the T shirt and pants in which later on I can use ExactFlat to flat them out for pattern making.

With Inventor 2020 and up, you can also flatten out any surface now. To make the shirt, you can remove that portion and use fill hole or bridging to make it look like a Tshirt. You can also split the T-Spline to front and back assuming that the Tshirt will be made with a seam.

After T-spline form turn into surface, you can further cut arm hole and make sleeve using a simple spline sketch. The beauty of this technique is you can adjust the arm hole or the sleeve by moving the vertexes of the sketch. By modifying the vertex of the spline, the surfaces are updating along.

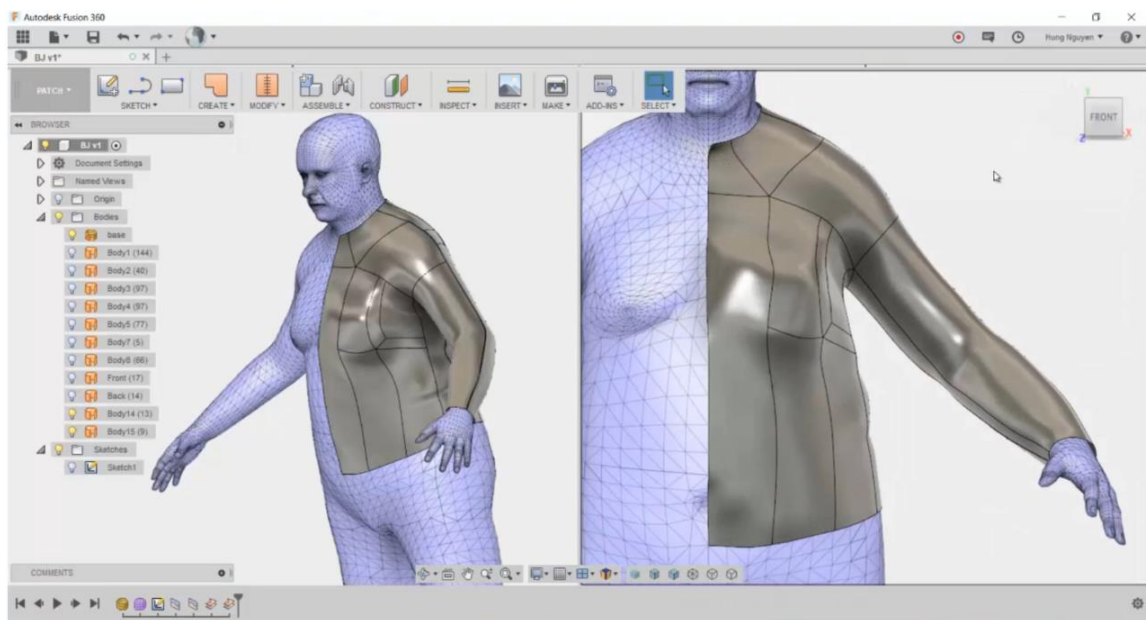


FIGURE 9: SCULPT DESIGN TEXTILE WITH FUSION 360 & MAKEHUMAN

Sculpting With Fusion 360

With the Sculpt environment, Fusion 360 gives you the ability to explore any number of conceptual and aesthetic designs right alongside any mechanical workflows:

- Use primitive shapes to start with predefined closed- or open-profile shapes depending on your design requirements
- Apply symmetry to create uniform features as you sculpt primitives into organic shapes
- Add faces and edges to manage the level of detail you apply as you edit and refine shapes.

Sculpting in Fusion 360 is a shaping technique for: Carve, Sculpture, Cast, Form, Shape, Fashion design, or dressing your dog with Halloween costume...

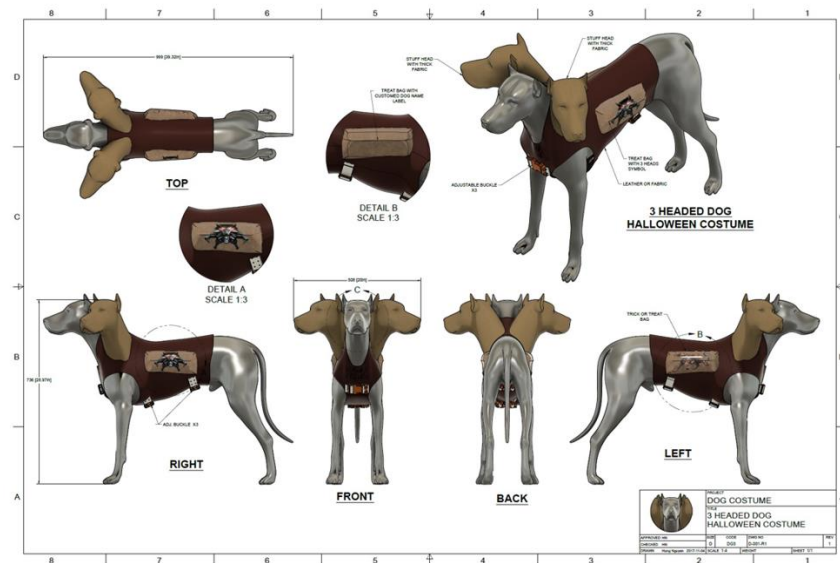


FIGURE 10: HALLOWEEN COSTUME FOR DOG WITH FUSION 360

Fusion 360 Freeform Techniques

There are two separate modeling strategies:

- EDGE MODELING: Extruding Edges
- BOX MODELING: Extruding Faces.

Both strategies produces the same result at the end and depends on Users skill.

- Edge modeling is easy, but time consuming.
- Box modeling is more difficult but less time.

In Edge modeling, you start with a simple plane then add edges or faces, to form the model. In Box modeling, you start with a primitive geometry such as box, sphere, or cylinder. Then move adject edges or faces, to form the model.

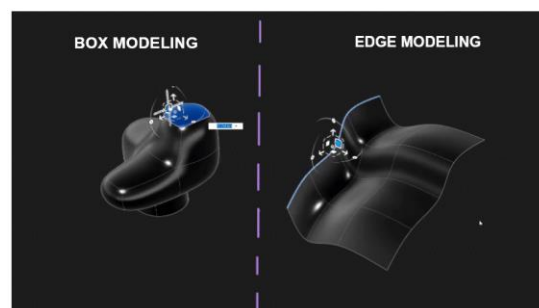


FIGURE 11: SOURCE: TOPOLOGY WITH T-SPLINES IN FUSION 360 – YOUTUBE BY NAME NOTIMPORTANT

Method 1: Edge Modeling

1. Background images are very helpful. Try to use at least 2 images: front and side. It would be better if you also have a top view image.
2. Learn some fusion shortcut – there are many Fusion shortcut image which you can download.
3. Use Multiple views for modeling with image background. 2 views, side by side, often help shaping models.
4. I love the “S” key where you can search and add your favorite command to your shortcut.
5. Holding down the “Alt” key while moving, rotating or scaling will add extra edges to the model.
6. When adding new edges, Fusion, by default, will add uncreased faces to the model. By holding down Alt + Ctrl, you can force Fusion to add creased Faces.
7. To select a ring of faces, select a face then hold down the Shift key and Double Click a next face.
8. Alt+1, 2 or 3 will display form in different mode.
9. Finally, learn to identify between components and bodies if you want to turn a multi bodies part to an assembly.

Setting Up Background Images– Edge Modeling

Here is a example of how to setup background image for the ironman helmet.

I separated the head of the mannequin for modelling the helmet that I will use for a FEA simulation of a bullet shot from a gun to the ironman mask. I also used the head as a reference for sizing my 2 background images.

Using Insert image, I insert the front picture of the mask. After positioning it, I use edit canvas to scale the image to the size of my son’s face.

Repeat the step for the side view. Draw a reference line to edit the side canvas to the same size as the front. I will then move the side to align with the front image using the center of the ear patch as a reference position.

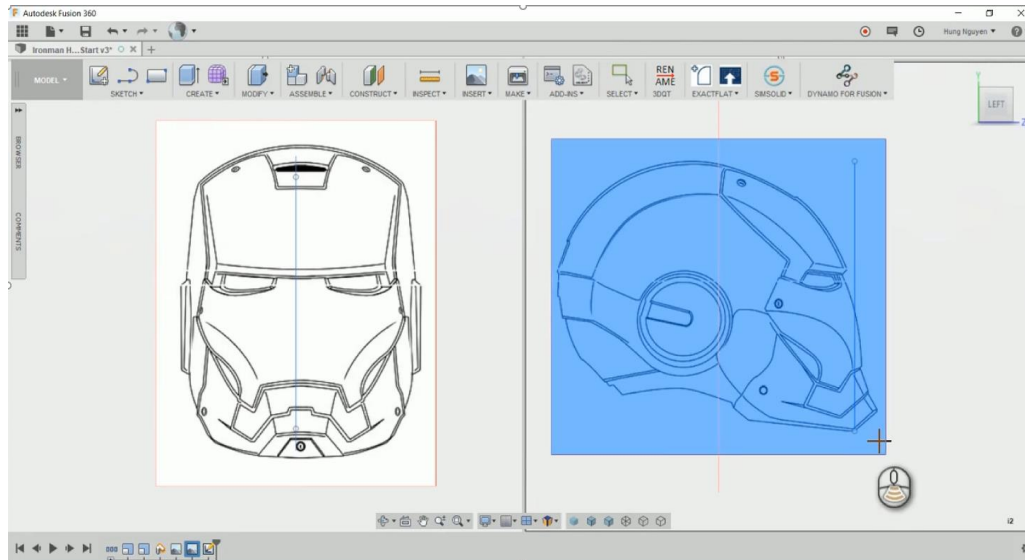


FIGURE 12: SETTING UP BACKGROUND IMAGES

Sculpt Ironman using T-Spline – Edge Modeling

After setting up background images and using the head as a reference object, you can start edge modeling. These are steps that were used in the demo video:

1. Bringing down the opacity of the images, will help you to see the see your model better. In this example, I bring the opacity of both images down to about 25%.
2. On the front view, you can create a simple plane under create form using 2 points rectangular and position the rectangular about the middle and on top of the jaw.
3. Make the rectangular plane without any edges. You can add more edges later.
4. On the side view, move the plane to the right where the start of the reference line of the jaw.
5. Use edit form, you can rearrange the corners and edges of the plane to match the 2 views.
6. Select the top edge and hold down the ALT key to add 4 more faces to the plane.
7. On the side view, rearrange all the vertexes on the right of the plane to the curvature on the side image.
8. You can use Alt+1 to display the model as box mode for the easy of arranging the edges.

9. The plane is covering the image, you can turn the transparency of the model to about 30% in order to see the reference line work on the image.
10. Continue arranging the vertices on the right side of the plane to match the image.
11. On the side view, Repeat the steps for all the vertices on the left side of the plane and try to arrange them roughly parallel to the right. After that, you can add an extra face to the plane using insert edge.
12. Rearrange the new edges to roughly about the lower level of the eye.
13. Hold down Alt key + move to add 5 more faces to the front, and switch to the side view, you can rearrange all the new edges to the side image.
14. Between the 2 views, you can use the middle as a reference guide to move the edges and vertices to roughly parallel to each other. You can also move the vertices around the eye on both views.
15. On the front view, window select the 5 new edges and quickly add 5 new faces by moving and hold down the Alt key.
16. Rearrange the vertices on both view to cover half of the mask front part.
17. To weld the vertices, select a vertex and use weld vertices to merge them.
18. Keep using this technique to add edges, and use your common sense to rearrange them to cover the face mask. Take your time to match the vertices to the boundary of face mask.
19. When you done, hit finish form you will have a nicely curve patch.
20. You can always edit the form using edit form to add a mirror duplicate to the T-spline body. But, before doing so, make sure you use flatten and flatten all the right vertices to the original plan to align them accurately.
21. Use the Flatten tool from Modify, select all of the vertices on the right side of the mask, and choose the vertical original plane to align them accurately on the plane.
22. Add a mirror duplicate to the T-spline body using mirror duplicate Symmetry.
23. Hit Alt+3 to turn the model to smooth mode.

A few instructional demo videos have been posted on Fusion 360 Gallery. You can download them here:

<https://gallery.autodesk.com/projects/110798/ironman-suit?searched=>

Method 2: Box Modeling

Here are common tools and tips for Box Modeling technique:

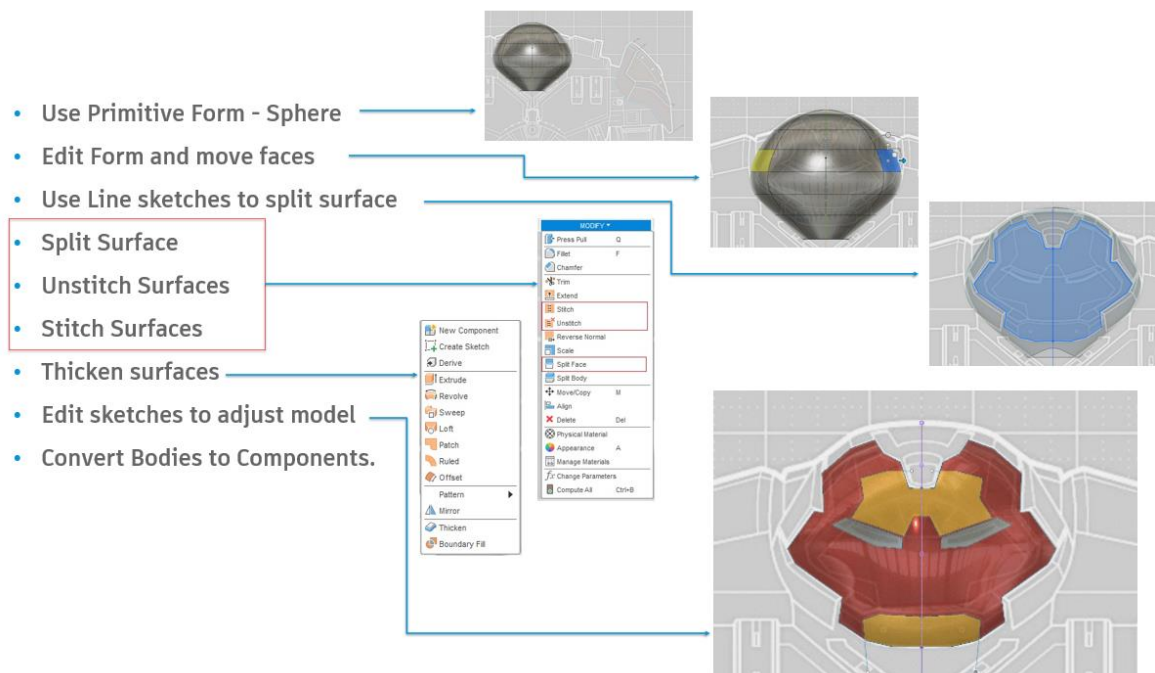


FIGURE 13: COMMON TOOLS AND TIPS FOR BOX MODELING TECHNIQUE

Sculpt HulkBuster using T-Spline – Box Modeling

From the presentation video, Box modeling technique was used to sculpt the hulkbuster mask. These are the steps which I used:

1. With my screen already is split in 2 views, I opened one of the files on my fusion 360 project called Hulk modelling demo.
2. The file already had 2 canvas inserted and scaled to the real size of the Hulkbuster.
3. Notice that, I also had some sketches already drawn on the XY plane.
4. After turning off the sketches, I'm ready to jump into the T-Spline environment to create a form.
5. I chose a primitive sphere to sculpt out the mask of the model.

6. On the right view, roughly about the middle of the hulk, I created a sphere and size it approximately to cover the hulk head.
7. I rotated the sphere to point up on the right view and moved it to the left of the sketch on the image.
8. I added symmetry tool to the sphere on the right view so that when I modify the geometry, my model will automatically mirror to the other side.
9. On the right view, I moved some vertices to slowly shape the sphere to the reference sketch on the image background.
10. Similarly I switched to the front view and continued to modify the faces, edges and vertices to match the canvas.
11. When I had a reasonable shape, I finished the form and had a closed surface shape like a pumpkin which is ready for Halloween carving.
12. Turning off the canvas and turning on “sketch 11” which will be used to carve out the 1st part of the hulk buster mask, I’m ready to split the pumpkin.
13. To do that, I used surfacing command to extrude the sketches into extruding surfaces.
14. I then used split face to split the pumpkin into a stitched surface.
15. Turned off the extruding surfaces, now you can see I have 2 regions shown on the pumpkin. To separate them, all you need is unstitched the pumpkin. Unstitched surface can be found under modify.
16. Turned the canvas back on; as you see, the front face of the hulkbuster was very closed to the reference images.
17. To continue, I divided the face into the jaw, forehead and cut out the eyes. I repeated those previous operation to separate the hulk buster face.
18. To create a body, which I’ll convert to components later, I used Thicken tool to turn the surfaces into solid bodies.
19. To modify the solid bodies, I turned on the selection filter to only use sketches curve and sketches points which will make it easy to select and move the points on the sketches.
20. As you see, I refined the model by adjusting the points and watch the solid bodies updated.
21. After adjusting the model, different material can be applied to the bodies.

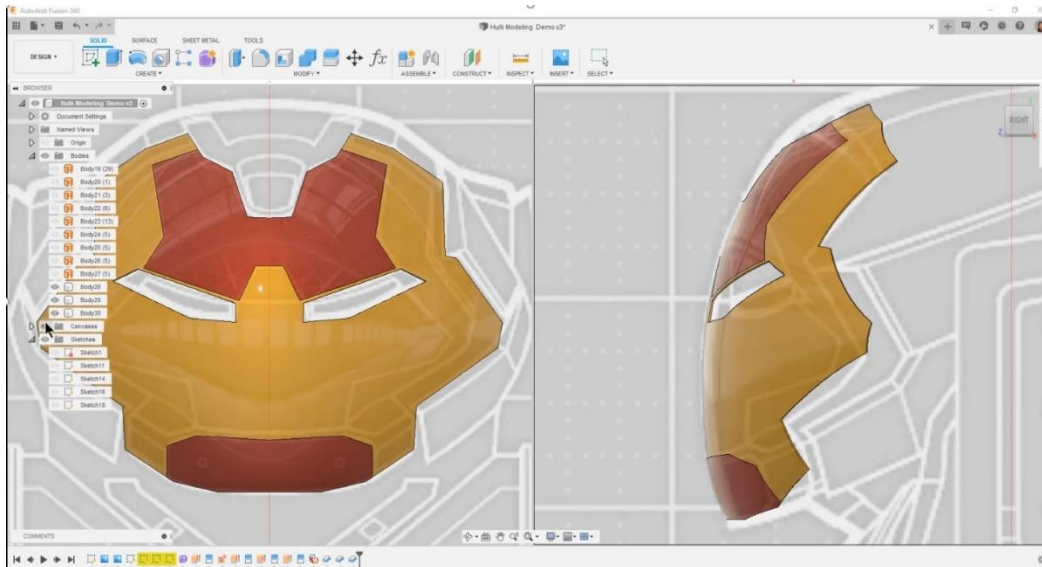


FIGURE 14: SCULPT HULKBUSTER USING T-SPLINE – BOX MODELING

Model with Fusion 360 Freeform Tips

Here are common tools and tips for Fusion 360 Freeform:

ESSENTIAL TOOLS

Edit Form

Selection Options

Selection Filters

COMPLEX TOOLS

Symmetry

Pull / Match Tool

Insert Edge

UTILITY TOOLS

Display Mode

Repair Body

Convert

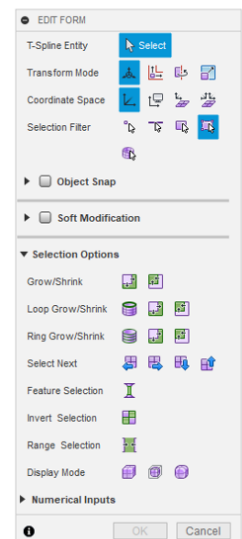
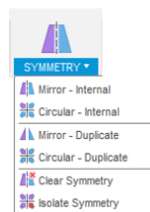


FIGURE 15: FUSION 360 FREEFORM TIPS

Model with 3DS MAX Poly modeling

Polygonal modeling (polygonal modeling or poly modeling) is the most popular and universal method of constructing objects in the 3Ds Max program. Poly modeling is a low-level 3D modeling and is based on the direct manipulation of the vertices, edges, and faces (polygons) of objects, which allows full control over the process of creating a model.

The essence of this method is to create models using as few polygons as possible: surfaces defined by several points. Any vertices can be moved in any direction, even if this creates incredible intersecting surfaces. Usually, there is no reference to real units of measure – the vertex, edge or the whole polygon are just dragged, at once to some distance, focusing only on intuition and appearance.

- You are modeling a purely artistic thing, not for mass production and you do not need the exact dimensions.
- You do not make a model for production in principle: for games, animation or rendering a picture
- You need a high-quality artistic study of the model.

Tip: Model with 3DS MAX Poly modeling

Using 3DS Max you can create models in the mesh and poly formats. When editing, you should always use the poly format. Mesh models offer more room for error when editing. They also come with fewer settings, which means you have less flexibility when working on the model. Don't fret if you have started work on a model in mesh mode. You can always convert it to a poly model to gain access to more editing settings and reduce the amount of issues you run into. Just use the "Turn to Poly" option in the "Modifiers Menu".

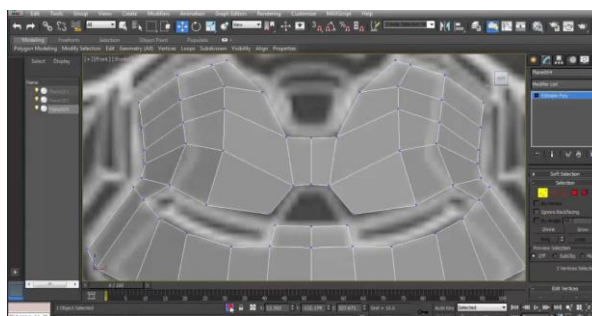


FIGURE 16: MODEL WITH 3DS MAX POLY MODELING

Converting Meshes to SolidsTips

Any 3DS Max model can be inserted and converted to T-Spline model; however, the mesh has to be:

1. Editable Poly
2. Editable Poly with "Quadrify All"

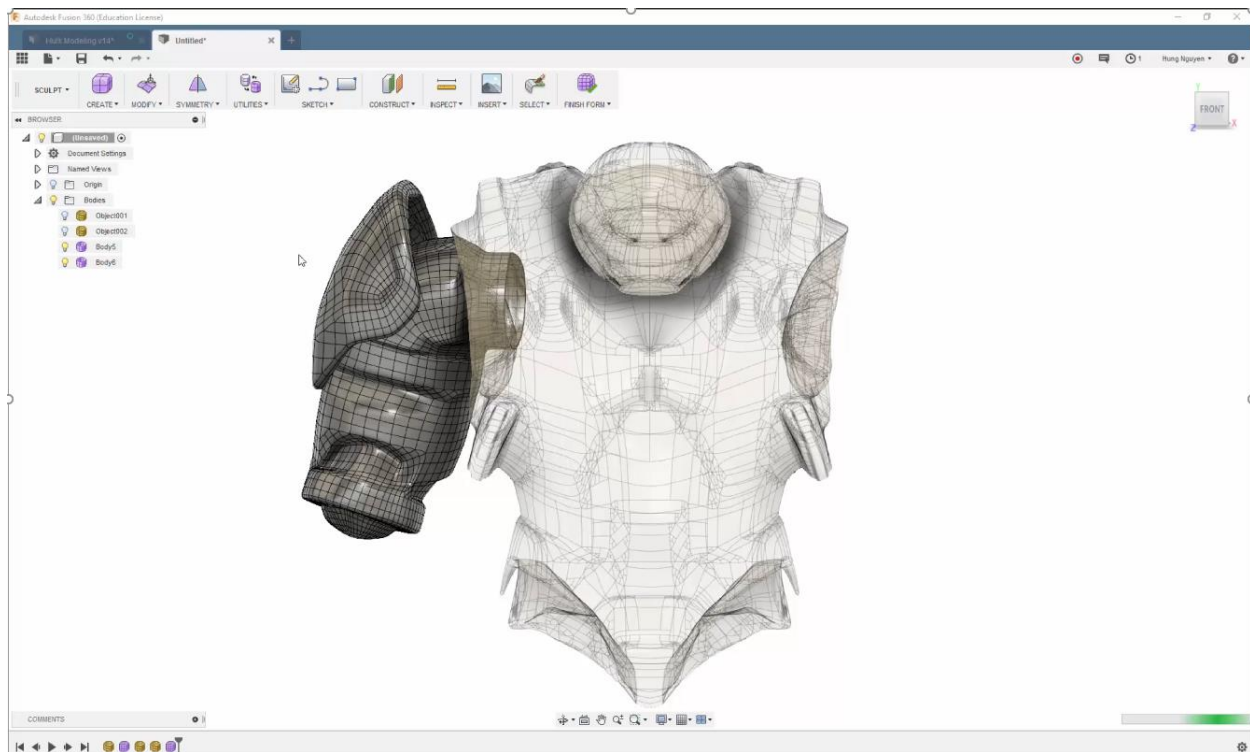


FIGURE 17: CONVERTING MESHES TO SOLIDS

Tip: Converting Meshes to Surfaces

Existing triangulated mesh need to be converted to Editable Poly before inserting into Fusion 360. The steps include:

1. Import triangulated mesh into 3DS Max
2. Apply Subdivide (WSM) with "Display Subdivision" turn OFF
3. Use "Collapse To" to Collapse mesh
4. Turn Collapse mesh to Poly mesh
5. Apply "Quadrify All".

Another way to convert triangulated mesh to Quadrify mesh is using Autodesk Recap Photo. With Recap Photo, triangulated mesh can be exported to Fusion 360 – OBJ(Quads).

Tip: Model with 3DS MAX - MAXScript

Particle Flow is a versatile, powerful particle system for 3ds Max. It employs an event-driven model, using a special dialog called Particle View. In Particle View, you combine individual operators that describe particle properties such as shape, speed, direction, and rotation over a period of time into groups called events. Each operator provides a set of parameters, many of which you can animate to change particle behavior during the event. As the event transpires,

Particle Flow continually evaluates each operator in the list and updates the particle system accordingly.

Particle Flow provides several tools for determining where in the system particles currently reside, including the ability to change particle color and shape on an event-by-event basis. You can also easily enable and disable actions and events and determine the number of particles in each event. To speed up checking particle activity at different times during the animation, you can cache particle motion in memory. Using these tools, plus the ability to create custom actions with scripting, you can create particle systems of a level of sophistication previously unachievable.

Tip: Create Metallic Strip Animal Sculptures With Fusion 360

3DS MAX MAXSCRIPT

- Script all aspects of 3ds Max use, such as modeling, animation, materials, rendering, and so on.



Sung Hoon Kang's Metallic Strip Animal Sculptures Radiate the Energetic Flow of Wind:
<https://mymodernmet.com/kang-sung-hoon-sculptures/>

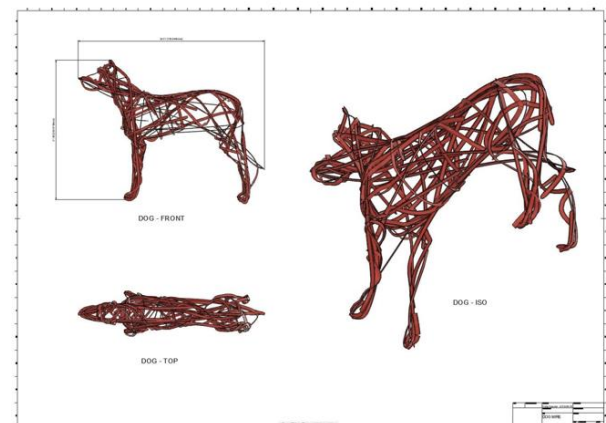
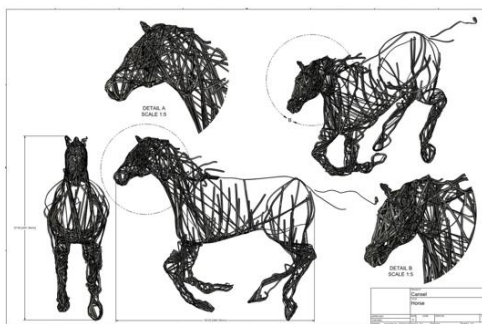


FIGURE 18: CREATE METALLIC STRIP ANIMAL SCULPTURES WITH FUSION 360

To create a Particle Flow, you need to place a PF Source and assign the PF source to an object. I used a dog model as an example to illustrate the use of PF source in this GIF image.

Step 1 – Saving Particle Flow trails and Export them to AutoCAD

You can make Particle Flow to generate animated Splines and save Particle trails. The animated Splines can be exported to AutoCAD format to be used for creating structural model or Poly mesh that will be turned into solids using Fusion 360.

Step 2 – Creating Metallic strips from exported AutoCAD file

The AutoCAD file can now be imported back into 3DS MAX. You can turn all the splines into Polymesh by simply turn on the 'Enable in Viewport' under Rendering option. In my example, I chose "Rectangular" option with Length =15mm and Width = 3mm

At this stage, the model may require some modification for different strip thickness or clean up according to the artist's design. Whenever you are ready, you can then export the entire MAX model out as a OBJ format to bring into Fusion 360 for fabrication.

All Splines with rendering thickness property can now exported to OBJ format for Fusion 360 to convert to solids.

Step 3 – Creating Metallic strips and complete the model in Fusion

This step is very simple. There are various Insert commands you can use to insert other file formats. These options insert data into a current Fusion 360 design rather than opening the existing Mesh (STL or OBJ format), SVG, or DXF file. Refer to the following links for more information about inserting meshes, DXF, and SVG files into Fusion 360 designs: [How to insert a mesh body into Fusion 360](#).

The next step is converting a mesh body to a b-rep or t-spline body in Fusion 360, the current limit for number of mesh elements is roughly 10,000. Meshes with greater than 10,000 elements will cause the performance of Fusion 360 to suffer and Fusion 360 may not be able to convert them to solid bodies.

Ironman & HulkBuster on Fusion 360 Gallery

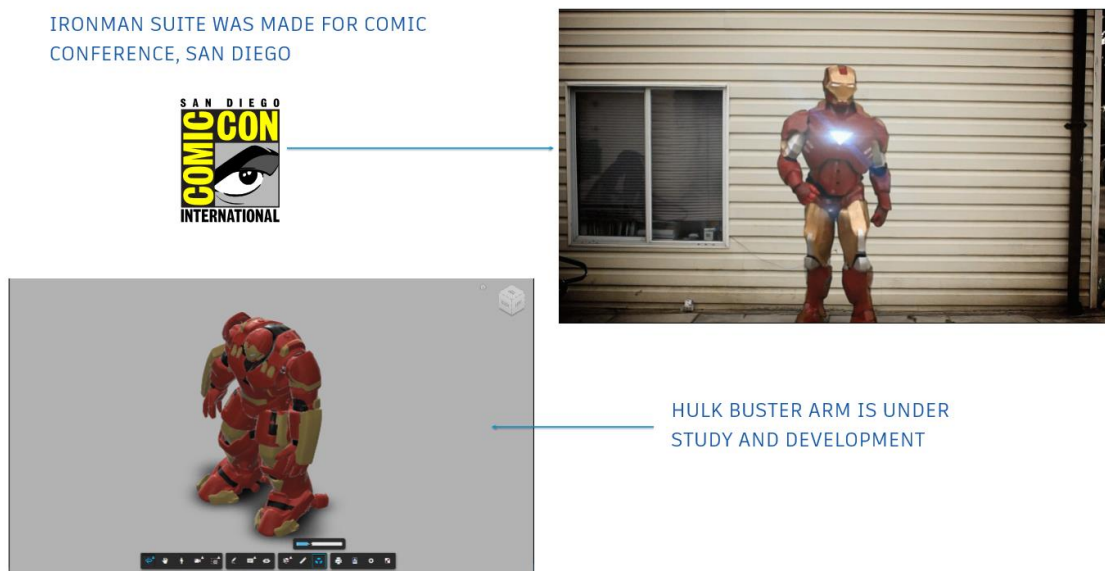


FIGURE 19: IRONMAN & HULKBUSTER ON FUSION 360 GALLERY

Tip: The Best of Fusion 360

Do not stop at modelling ...Simulate and make it. Remember that Fusion 360 is an environment for design, test and fabricate in a single tool. You can use Fusion 360 to collaborate with Anyone, Anywhere.

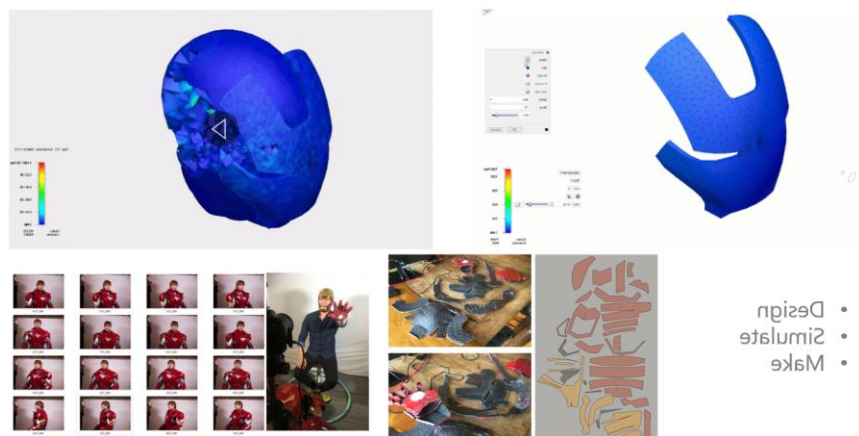


FIGURE 20: THE BEST OF FUSION 360

The Ironman suit was fabricated using Fusion 360 CAM and the material study was done with Fusion 360 FEA.

To study the material for making a real life Ironman suit, we turned to Fusion 360 for its amazing FEA Analysis. Our purpose is to find out if the Ironman suit can remain undamaged under an impact force such as a bullet. We setup several Event Simulation studies for the front of Ironman mask.

The following analysis results show accurately how the mask's material can react against strong impact force:

Case Study #1

Ironman mask is made with Titanium – High strength alloy
Bullet is made with Lead and fired at speed of 450m/s

Case Study #2

Ironman mask is made with Copper
Bullet is made with Titanium – High strength alloy and fired at speed of 450m/s

Fusion 360 proves to be the best software for digital prototyping and testing.

Tip: Fusion 360 + 3DS Max – Best of Both World

Do not stop at modelling...Make them Move & Dance.



- Fusion 360 Animate Joints
- Character Rigging in 3ds Max

FIGURE 21: FUSION 360 + 3DS MAX – BEST OF BOTH WORLD

Prototype of HulkBuster Arm - Under Development

Prototype of Hulkbuster arm is under development using patented “Rotatable Envelope Modules”. REM was invented by Adam Bakir and co founder Najib Jomha with the assistance of designer Earl Gifford. The company is focused on the development of this articulated joint mechanism that can be used for robotic wrist arm assemblies along with other industrial specific applications.

The REM stable conduit is entirely novel in mechanical engineering. No other joint provides a stable conduit that is, wherever one has seen cables hanging out side a point of mechanical movement, in flimsy protective housings, gives proof to the historic need, to solve this long-standing forced workaround.

Industrially, having no cables hanging, ready to be tangled, is faster safety inspections, increased safety and decreased down-time.

REM superior accuracy comes from the drive point being at maximum radius; This significantly lowers the cost of motors and electronics.

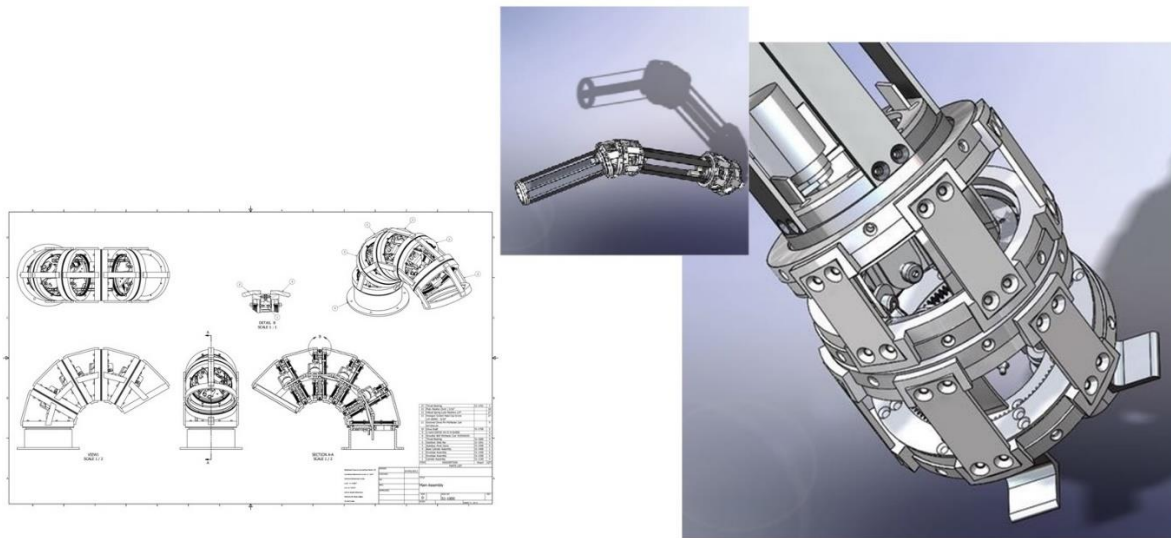


Figure 22: Prototype of HulkBuster Arm - Under Development

The images and sketches are based on the working prototype, expanding the design to six REMs and an effector/gripper.

There are 5 simple wedge shaped REMS (2x30 shoulder, 1x30 & 2x15 elbow); while the forearm section may look elongated and distorted, the forearm is the sixth module.

With the motors removed, one can insert their arm into the system turn on position sensors and electronic recording; take some actions, then stop recording; remove one's arm and install all motor assemblies in a short time.

Conclusion

In our workflow of design and making a Ironman Suit and HulkBuster, we were able to explore the power of Fusion 360 Free form Modelling. We explored a digital designing methodology for improving designer productivity through designing digitally which spanned through multiple apps. This class shows how the comic Ironman suit and HulkBuster can be made by combining Fusion 360's direct and sculpting tools, or converting 3DS Max model.

A Thank You Note

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- The Autodesk Fusion 360 developing teams
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- Bill Dieter – President Terrazign and Michael Aubry – Technology Evangelist Autodesk for your fantastic AU 2016 class titled “Integration of Textiles in Fusion 360”
- MakeHuman for developing & freely sharing the knowledge, the code, the algorithms and the technology with the World.
- Topology With T-Splines In Fusion 360 - YouTube by name not important
- Adam Bakir, Najib Jomha and Earl Gifford for the development of this articulated joint mechanism.

You truly inspired us for putting this session together.