VersaBuilt VBX-160

Machinist Design Manual

VERSABUILT

1 Overview

The VBX is a flexible system for automatically loading parts for processing in a CNC machine. The VBX is designed to be set up and configured by CNC machinists with no special training in robotics or automation. The VBX uses MultiGrip soft jaws to load parts in and out of the CNC machine. Additionally, a simple but powerful VBX Controller is used to configure new parts in the system and allow operators to set up and process parts that have been configured in the system by machinists.

1.1 Machinist Manual Overview

This VersaBuilt VBX-160 Machinist Manual introduces the machinist to the VBX system. This manual includes best practice guidelines that should be considered when designing fixturing for a new part and configuring the part in the VBX Controller. This manual also describes how to configure the VBX Controller for processing.

The VBX series robots use MultiGrip soft jaws to both load parts in and out of the CNC and to hold and machine the part on the vise in the CNC. Using the guidelines in this manual, the machinist will learn to design and create MultiGrip soft jaws that allow the VBX to reliably load and unload parts in and out of the CNC machine. The machinist will also use this manual to learn how to configure the VBX Controller to command the CNC machine to reliably machine each part.

The VBX-160 Operator's Manual is the companion piece to this Machinist's Manual and should be carefully read prior to configuring or operating the VBX-160.

Organization of the manual:

The VersaBuilt VBX-160 Machinist Manual is divided into two distinct parts:

- VBX-160 Machinist Best Practice Guidelines
- VBX-160 Configuration

1.2 Safety

Prior to operating or working in the vicinity of the VBX-160, carefully read and understand the VBX-160 Operator's Manual. Chapter 2 of the operator's manual describes the safety precautions in detail and should be clearly understood and followed by any personnel working in the vicinity of the VBX-160. Additionally, be sure to read the ABB robot safety manuals referenced in chapter 2 of the operator's manual.

The VersaBuilt VBX-160 is intended to be used only by trained personnel in a professional machine shop environment.

Caution: Only authorized and trained personnel should operate this equipment. You must act in accordance with the operator manual, the machinist manual, safety decals and instructions for safe machine operation. Read and understand all referenced safety manuals before operating equipment. Users must use appropriate eye and ear protection while operating the equipment.

2 VBX-160 Machinist Best Practice Guidelines

2.1 MultiGrip Soft Jaws Overview

MultiGrip soft jaws (MGSJ) are the work holding supported by the VBX-160. The robot uses the MGSJ to pick and place parts during processing. MGSJ are machinable and come in two versions, one for outer diameter (OD) clamping and one for inner diameter (ID) clamping.

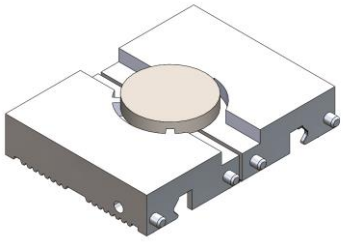
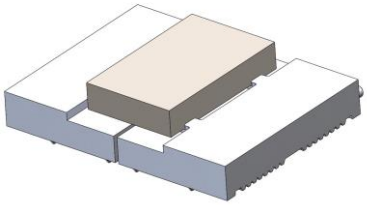
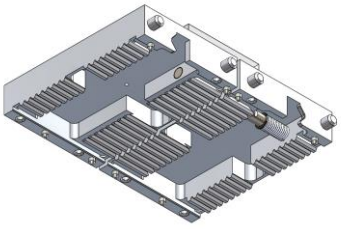
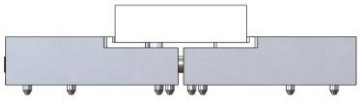
The benefits of using MultiGrip soft jaws include:

- Accommodate almost any part shape and size
- One set of MGSJ can process an entire VBX full of parts
- Capable of processing both sides of a part in one job set up

The following considerations are relevant to choosing MultiGrip soft jaws:

- The parts must lay flat on the shelf both pre and post processing
- MGSJ require careful design consideration to reliably process parts

Figure 2-1: MultiGrip Soft Jaws

Holding Round Part	**Holding Rectangular Part**
	
Interface View	**Side View**
	

2.2 One, Two or Three Op Capabilities

A. One op versus two op parts

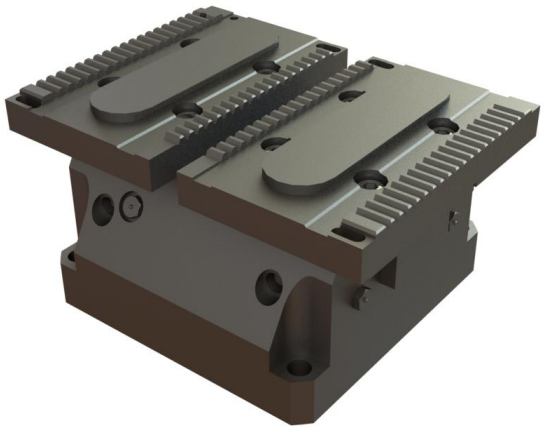
The VBX Series Robot is capable of an Op 1 to Op 2 transfer. If a part requires two operations to complete, allowing the VBX Series Robot to handle both operations as one job will typically result in processing efficiencies. Alternatively, a two op part can be processed as two different single op jobs.

B. Two ops with a single vise

In addition to being capable of an Op 1 to Op 2 transfer using two vises, the VBX Series Robot can execute the transfer using a single vise. The transfer is made on the shelf. Here's how it works:

1. After the robot has placed the Op 1 MGSJ and part on the vise, it picks up the Op 2 MGSJ for the second op
2. The robot will pick up the part after the first op, leaving the Op 1 MGSJ in the vise
3. The Op 2 jaws and part are placed on the top shelf
4. The robot unloads the Op 1 MGSJ and places them on the shelf
5. The robot picks the Op 2 MGSJ with the part and places them in the vise

Figure 2-2: MultiGrip Vise



Important considerations for two Op processing with a single vise:

- The MGSJ and part are clamped until they are put on the shelf
- The part and MGSJ are not clamped while on the shelf
- While on the shelf unclamped, the MGSJ and part must stay in place with gravity
- MGSJ and part design must ensure that the part does not fall out of the MGSJ
- MGSJ and part are re-clamped when the robot picks them off the shelf for second op

C. Probing

A CNC spindle probe measures the location of a part in the CNC as well as the size or shape of a machined feature of the part. Probing verifies the accuracy of both the CNC and the robot processes.

While probing is not required, it is highly recommended. Probing can be the key to successful processing of almost any VBX tended parts. Probing is useful to both the CNC process and the robot process.

Although probing incurs a penalty to the part processing time, often the penalty is justified because parts are produced within tolerance, minimizing scrap.To minimize the penalty to part processing times, reduce probing to once every 5 or 10 parts. Doing so leaves the process vulnerable to intermittent variations while still detecting and adjusting for ongoing process variations.

Typically, probing identifies problems in a new process. As the process problems are resolved and confidence in the process increases, it may be possible to eliminate probing altogether as long as the process is strictly controlled.

Probing Applications and Benefits

CNC process:

- Verify that dimensions and tolerances are being held
  - Measuring part features allows the probe to verify the CNC process is cutting the part as expected
- Adjust for tool wear
  - Using the probe to offset tool wear allows the machine to hold very high tolerances without operator intervention
- Identify tool breakage

Robot process:

- Verify process has loaded a part into the vise
  - Measuring certain features after an op-to-op handoff allows the probe to verify that a part is in its expected position
- Verify part is centered and parallel to the expected datum
  - Using a pre op to cut reference features, the probe can validate the part remains flat and centered after a first to second op handoff
- Probing can be used to find and set a part's datum after load when the part shape and the MGSJs do not adequately set the datum

Probing for verification of part placement

- Fixture offset locations can be updated
- It is recommended to store and reset the location at the beginning of each load to avoid drift
- probe "Fails" are almost always due to chips between the part and the MGSJ or between the MGSJ and the MultiGrip intermediate MGSJ
- An adequate wash program should eliminate these types of probe fails
- Probe "Fails" are handled by the VBX controller by unloading, washing, and reloading the operation a number of times that is defined by the user
- If the probe failures continue on a specific part, the system will put that part away and continue onto the next part

Note: Routine calibration of the spindle probe is recommended. Consider using a table mounted ring gage for calibration.

Advanced capabilities:

- Built in support for advanced spindle probing
- Easy to use spindle probing library verifies that the VBX-160 part load is on center and parallel
- automatic part wash and load retry if part is not loaded on center
- CNC to VBX-160 communication protocol allows mid operation change in vise pressure

D. Using a Pre Op to Verify Op1 to Op2 Positioning

When processing multiple operations with the VBX, there is a possibility that a chip could lodge between the part and the MGSJs or between the MGSJs and the vise. Probing a part after loading the part into the Op2 MGSJs verifies that the part is properly loaded and minimizes scrap.

Probing the part after loading into the Op2 jaws can verify that the part is in the MGSJs parallel and that it is properly located in X and Y. If the raw material prior to processing is not within the final part's parallelism, square or roundness tolerance, then to verify the Op2 load, features need to be cut in a pre op. This ensures that the part is parallel and properly located in X and Y after the first op.

For example, consider a round part that has a parallelism and concentricity tolerance of 0.005". If the raw material has a roundness tolerance of 0.01" and is saw cut with a parallelism tolerance of 0.03", a pre op can be used to verify the OP1 to OP2 transfer.

- **To verify parallelism:** A flat surface is cut into the raw material
- **To verify that the part is centered:** Cut either a bore or an X and Y reference into the excess material area of what will become the second op

Note:
Ideally, the features cut in the pre op are used to rigidly secure the part in the first op. Cutting a dovetail feature in the pre op is ideal.

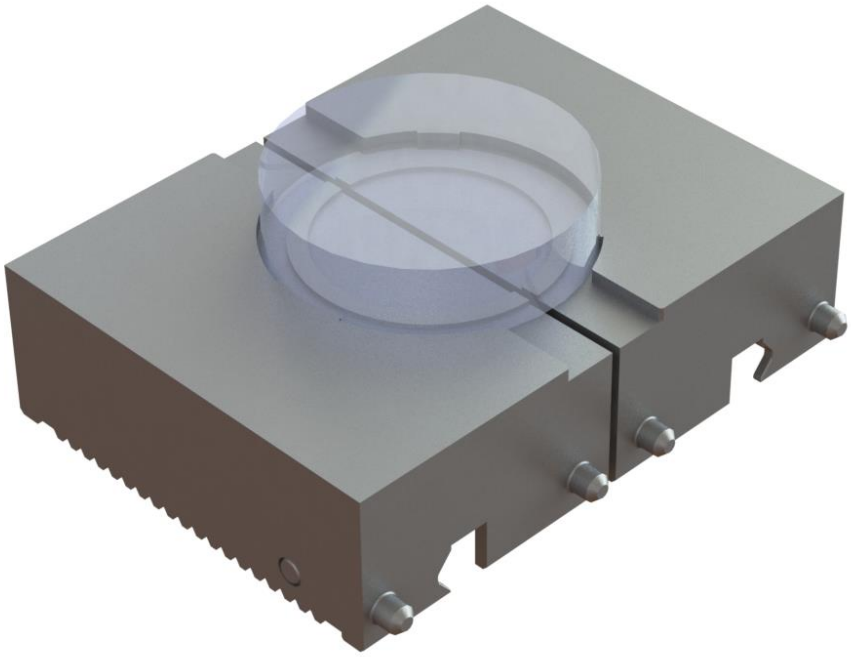
2.3 MultiGrip Soft Jaw Fixturing Considerations

MultiGrip soft jaw fixturing involves cutting a pocket to fit the part that will be picked and placed. There are many factors to consider prior to fixturing a MGSJ. The size and weight of the part both before and after processing are important considerations, but there are several others that influence the performance of your machined MGSJ.

MultiGrip soft jaw fixturing considerations include:

- Shelf constraints
- Shelf pick point template options
- Parts that overhang the shelf
- Shelf part locator options
- Part shape
- Part weight and size
- Part material
- Locating surfaces

Figure 2-3: MGSJ with Pocket for Round Part



A. Shelf constraints
The MultiGrip soft jaws must clear the part when the robot is picking or placing parts on the shelf.

Shelf constraint considerations:

- The vertical distance between the shelves limits part height.
- The maximum height of the part and the MultiGrip soft jaws, measuring from the bottom of the MultiGrip soft jaws to the top of the part, is 5”
- MultiGrip soft jaws must either clear the part entirely in Z

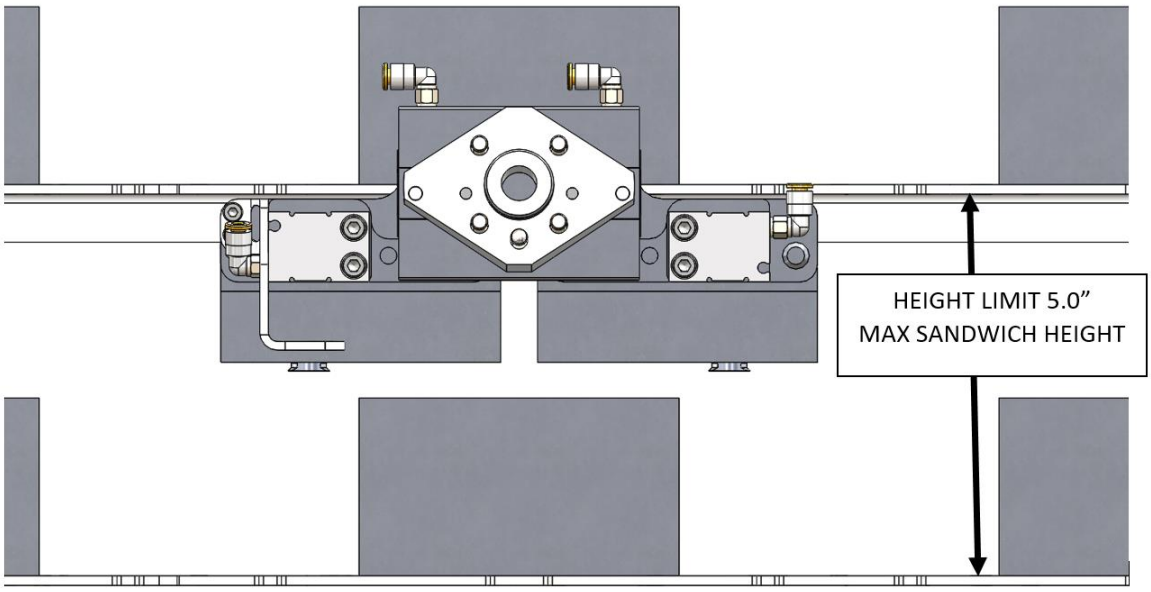
or

- jaw pocket, (OD clamping), or boss, (ID clamping), must clear the part in X as the robot approaches the shelf for pick or place.

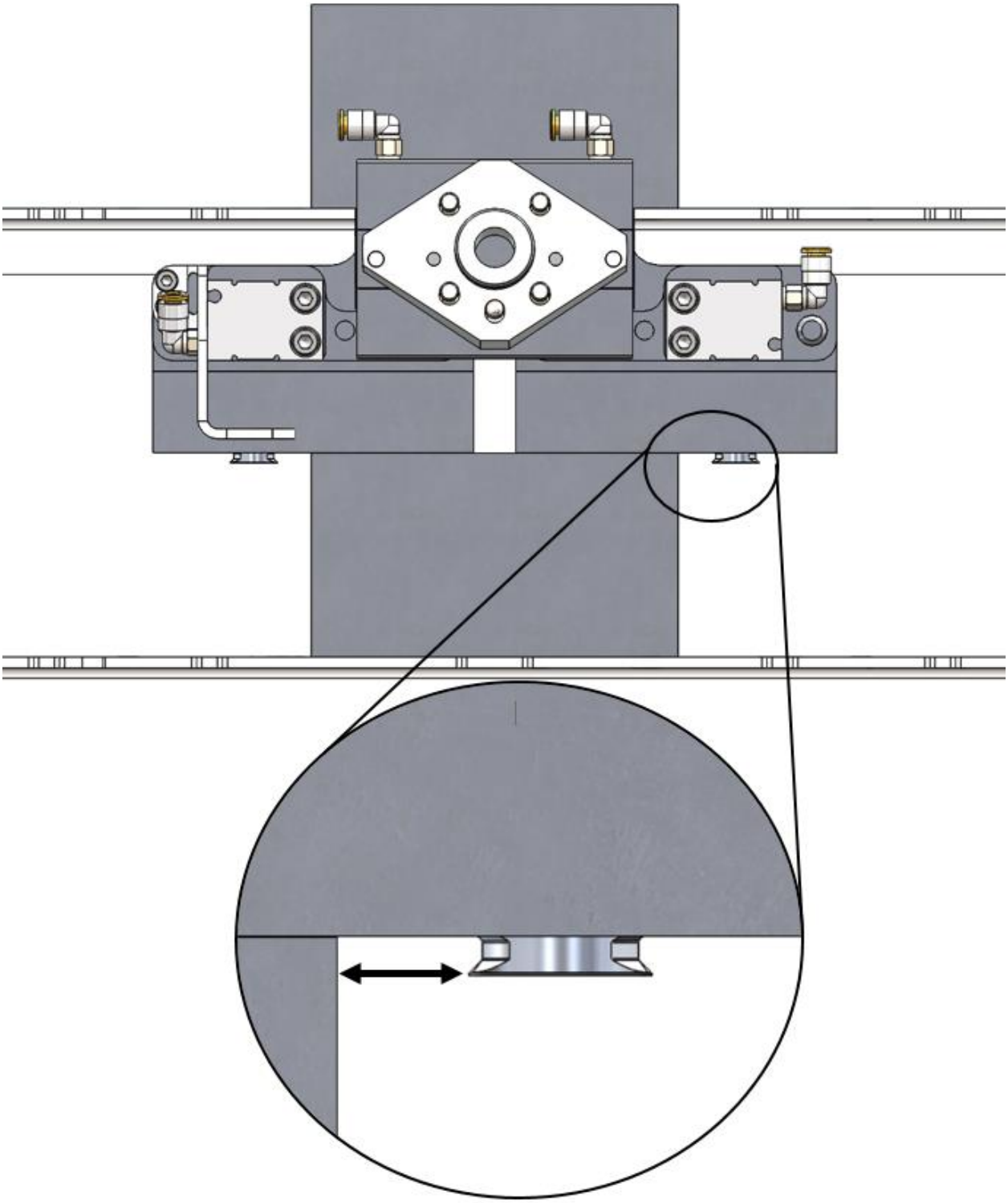
Note: In a two op job using a pre op, (3 operations), the first operation jaw never picks or places a part on the shelf. MultiGrip soft jaws that do not pick or place the part on the shelves can be taller, with a 3” max from the bottom of the MultiGrip soft jaw to the top of the MultiGrip soft jaw, not including a part.

Figure 2-4: Shelf Constraints

Clearing Part in Z



Clearing Part in X



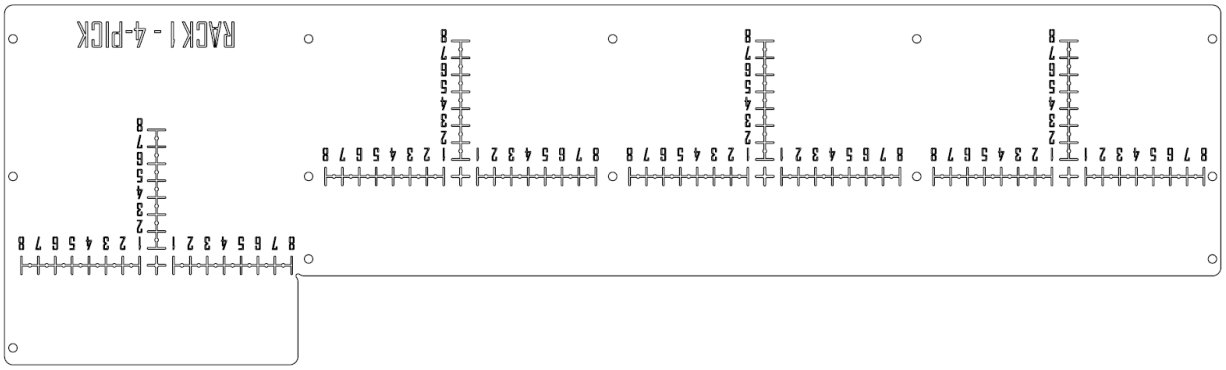
B. Shelf pick point templates

A Template is used to set up the number and location of the points that the robot will pick parts from and place parts to. Each of the VBX-160 shelves that is designated for parts can be individually configured for pick point templates.

Template considerations

- A higher number of pick points reduces the allowable dimensions of the part
- Pick point templates for 3, 4, 5, 6, and 8 picks per shelf use a common Y pick offset and allow for parts up to 8” deep
- Pick point templates for 18 picks per shelf use a staggered Y pick offset
- When shelf densities are greater than 4 picks, the VBXC allocates an empty slot between jobs as a precaution to avoid a MGSJ collision

Figure 2-5: Template Showing 4 Picks



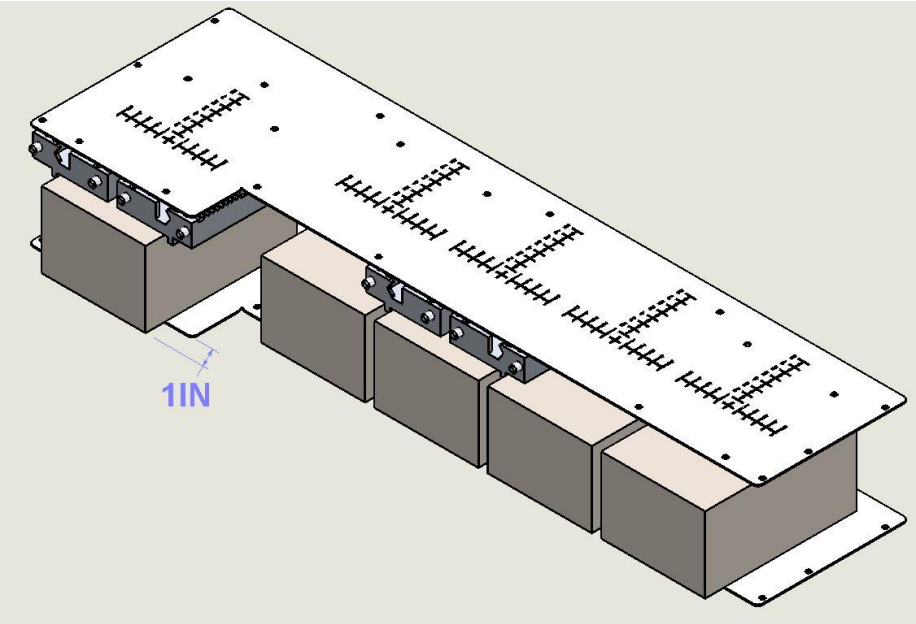
C. Overhanging parts

Parts that overhang the shelf towards the robot are allowable, but they can interfere with part placement and picking. It is important to carefully plan for the processing of overhanging parts. That maximum allowable overhang is 1”.

Overhanging parts considerations

- When the robot moves into a shelf to pick or place a part, the robot gripper could come into contact with a part that is overhanging on the shelf above the location of the part being picked
- The robot may push the overhanging part toward the back of the shelf, moving it out of its correct shelf position
- The VBXC uses designations in the part configuration to identify if a part overhangs or needs high entry (tall part)
- The VBXC will not allocate a tall part to a slot that is below an overhanging part
- Keep this in mind when planning multiple jobs

Figure 2-7: Overhanging Parts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D. Shelf part locators

Shelf Part Locators are custom aluminum sheets with holes cut out to locate parts. They are designed for quick and easy part location by the operator. The part locator is held in place with nylon ribbed rivets that are pushed through holes in the shelf. The rivets are pushed up from below the holes .

Shelf part locator benefits:	**Shelf part locator design considerations:**
● Properly locates the part for accurate picking ● Easily placed on and removed from the shelf. ● Makes placing material quick and easy ● Increases speed of part placement for larger production runs ● Best choice for parts that are difficult to locate with just a shelf template	● Center of the locator opening should match the center point of the part pick point ● Part pick point driven by the selected shelf template and any locating features of the jaws ● Locator opening should not over or under constrain part

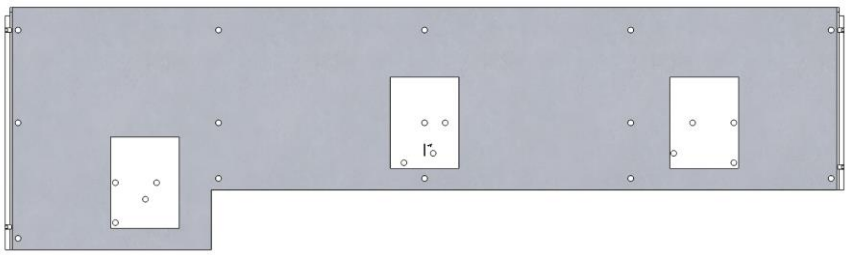
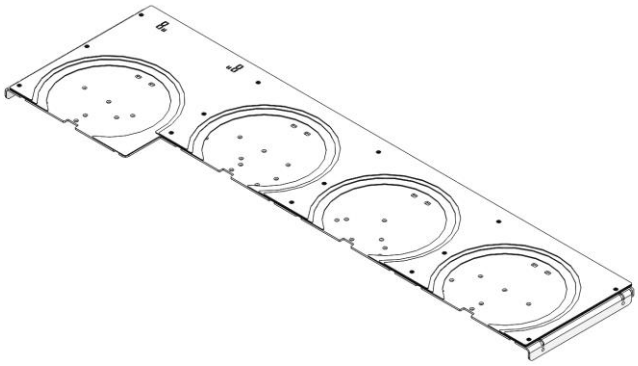


Figure 2-8: Part Locators



E. Part shape

Part shape must be carefully considered when fixturing the MultiGrip soft jaws. Part shape affects the ability of the robot to accurately pick and place the parts during processing.

General part shape considerations:

- Before pickup, the part must lay flat on the shelf
- After processing, the part must lay reasonably flat on the shelf and must not tip over onto adjoining parts

For pick point templates with greater than 4 picks per shelf, MGSJ may need a relief cut to clear adjoining parts

Part shape and first to second op robot transfers:

- Second op MGSJ is used by the robot to pick the part out of the first op MGSJ
- In best case, the part shape after the first op has features to locate the part in X and Y and also about Z (clocking)

If not:

- The CNC may need to move the part against a datum
- For example, if the first op leaves only a large rectangular feature for the second op MGSJ to engage
- First operations that leave only a round feature for the second op MGSJ will not “clock” the part

A probe may be needed to determine rotation about Z or a feature may be needed to assist in clocking

F. Part weight and size

General considerations:

- Maximum part width is 11”
- Maximum part depth is 8”
- Maximum height of part and MGSJ is 5”. (Typically, MGSJ use at least 3/4” of available height.)
- Maximum weight of the part and MGSJ combined is 15 lbs.

Note: Up to a 1” part overhang in front of MGSJ and a 2” part overhang in back of MGSJ is allowable.

Standard VBX-160 MGSJ are 8” wide and 6” deep at nominal clamp. Part size and weight are bound by the following MGSJ specifications:

- **OD MGSJ**
  - 0.125” gap at nominal clamp
  - Open 0.390” greater than nominal clamp
- **ID MGSJ**
  - 0.390” gap at nominal clamp
  - Close 0.390” less than nominal clamp.
  - When a part is clamped in the MGSJ, the MGSJ must be in a position that is +/- 0.060” of nominal clamp

Figure 2-11: Part Width and Depth Maximums

Shelf Capacity	Full Load Capacity	Max Part Width	Max Part Depth
2	40	11.75”	8”
4	52	8.5”	8”
5	66	5.5”	8”
6	78	4”	8”
8	108	2.5”	8”
18	240	2”	2”

Heavy parts

The robot gripper is limited by its gripping force to pick heavier parts. Gripping parts that are over 5 lbs in weight requires additional considerations to keep the part from slipping out of the MGSJ during the pick. These considerations include the following:

- Swivel jaws give best gripping force
- 3 points of contact with standard jaws
- Deep pockets/bosses
- Mitee-Bite VersaGrips - bite into material
- Dovetail feature in the MGSJ
- Features to “catch” part in Z during pick

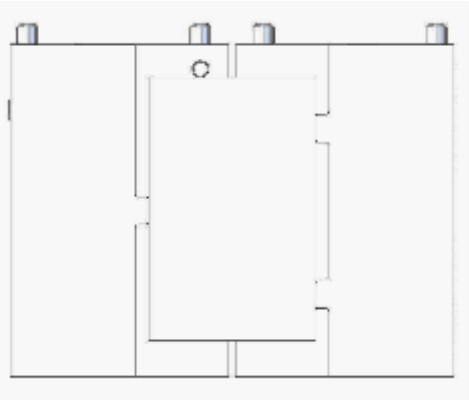
The heavy part considerations apply differently in each op. The following best practices apply to each op:

- **Shelf pick:** Mitee-Bite VersaGrips on raw material
- **Second op:** Deep Grip, feature in jaw to catch an edge on the side of the part
- **Op transfer:** choose side with most material removal to lower weight for second op pick

Using 3-Points of Contact to Pick Parts Using Standard MGSJ

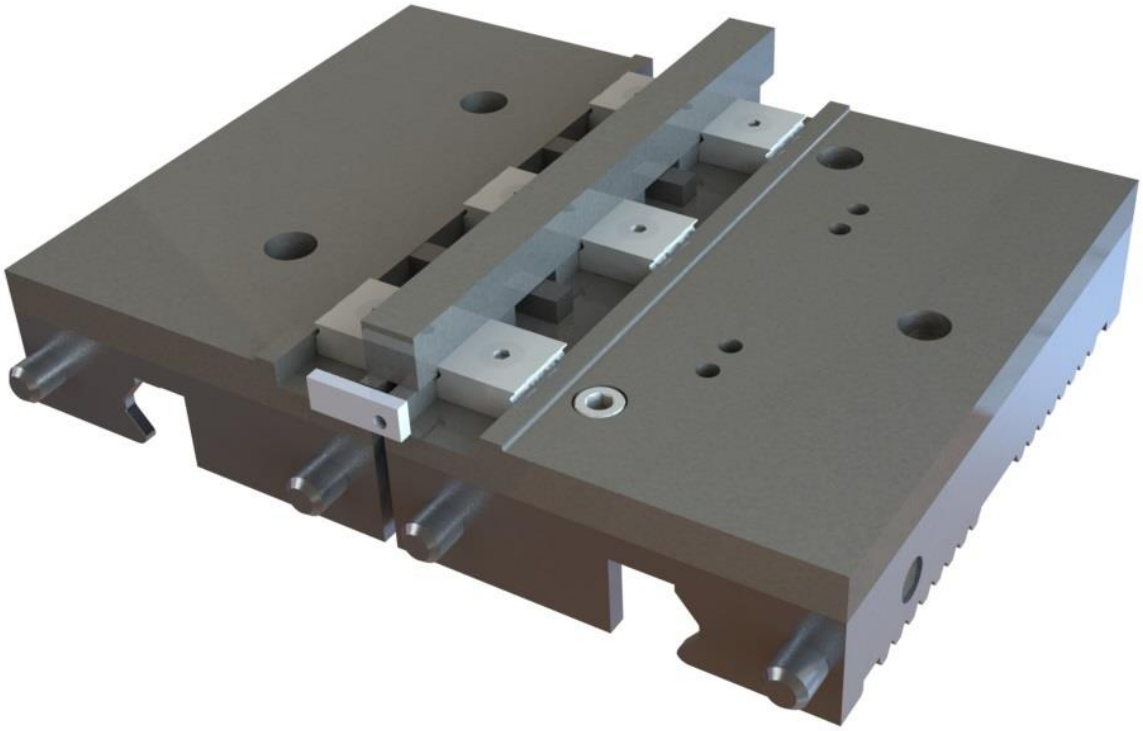
MGSJ deflect slightly when the robot grips a part. Using 3 points of contact allows the robot gripper to secure the part during a pick.

Figure 2-12: Three points of Contact on Part



Using Standard MGSJ

Figure 2-13: Soft Jaws with VersaGrip or TalonGrip

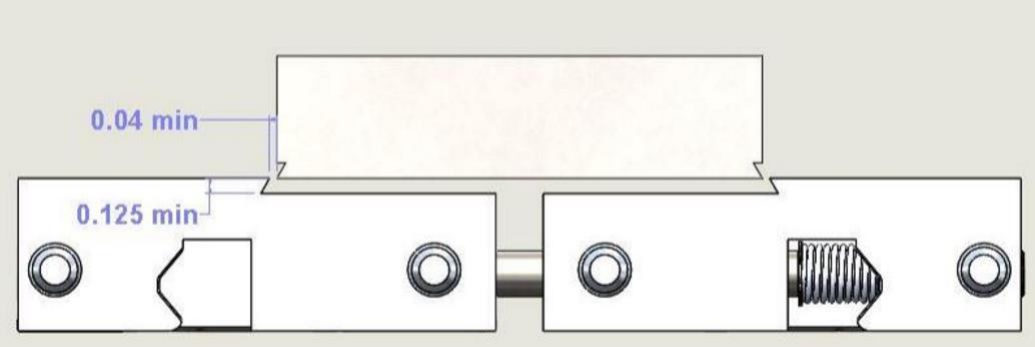


Dovetail Fixturing

A dovetail fixture allows the MGSJ to easily pick heavy parts without slip. It also provides a secure grip for aggressive machining. The dovetail is typically cut in pre op. Dovetail considerations include:

- Appropriate for ID or OD clamping
- A diamond shape increases rigidity in X and Y
- Opportunity to share first op MGSJ among multiple parts by using same dovetail feature across multiple parts
- About 0.390” of clearance for entering dovetail for ID or OD clamping
- Dovetail overhang must be less
- Recommend a minimum of 0.040” of side clearance for entry and a minimum of 0.125” of dovetail engagement

Figure 2-14: Cross Section of Dovetail Fixture Grabbing a Part (Showing dovetail overhang clearance)



G. MultiGrip Swivel Jaws

MultiGrip Swivel Jaws have several advantages over standard MultiGrip jaws. Swivel jaws incorporate a fixed jaw and a jaw that is able to swivel about the Z axis slightly. When the robot's gripper grabs a part, the underlying MGSJs deflect slightly due to the leverage of the relatively long MGSJs. By allowing one jaw to swivel slightly, the jaws will conform slightly, allowing the swivel jaws to remain parallel to one another and to grip the part evenly.

- Swivel jaw top plates can easily be replaced or interchanged for different parts at a much lower cost than a complete set of jaws
- Swivel jaw top plates are also available in heat treatable steel for increased jaw life especially when clamping harder materials
- The primary disadvantage of swivel jaws is their increased height

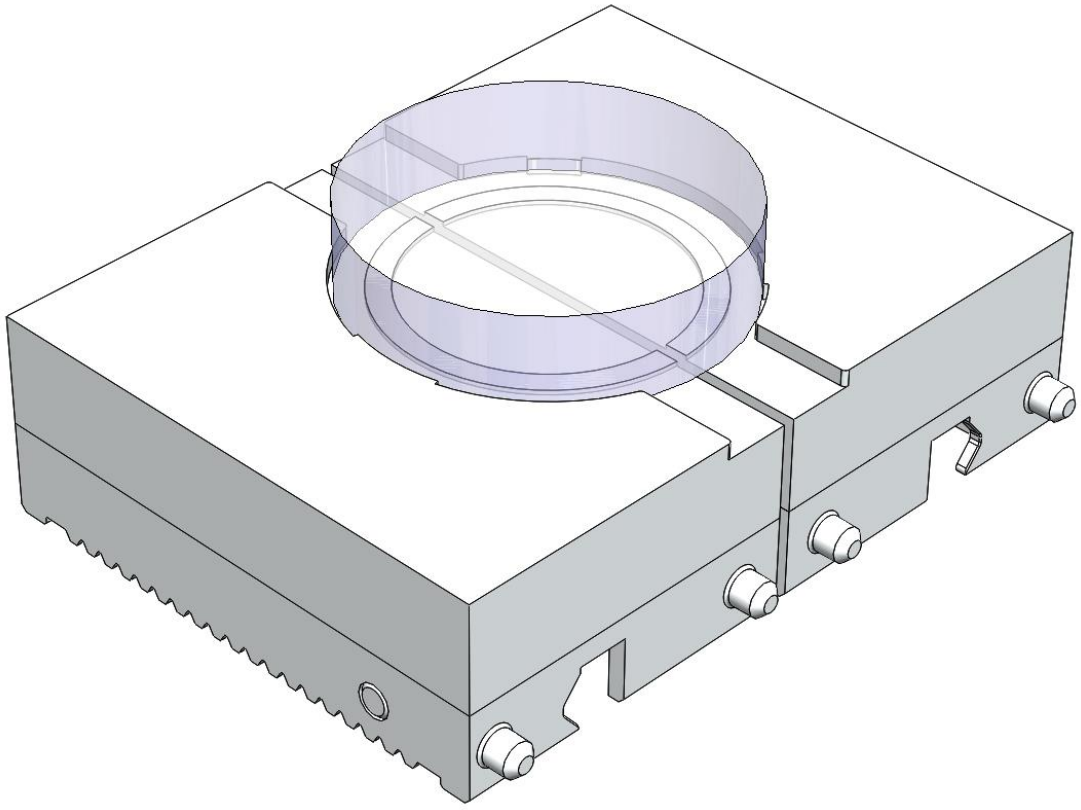
Figure 2-15: MultiGrip Swivel Jaw with Top Plate

H. Locating surfaces

Locating surfaces are the surfaces of the MultiGrip soft jaws that contact the part. These surfaces typically contact the sides and the bottom of the part. Locating surfaces are necessary to properly locate and secure the part in the MGSJ. Consider the following when determining locating surface area:

Too little surface area could result in:	**Too much surface area could result in:**
● Part or MGSJ deforming from vise clamping or machining pressure ● Part may not be adequately located	● Increased chance of a chip interfering with part location; especially Op2 MGSJs ● Part might stick in the MGSJ during op transfer or placement on the shelf as a result of the surface tension of the cutting fluid between the part and MGSJ

The following image shows a MutliGrip swivel jaw for a round part with 3 points of contact in X and ring to support the part in Z.



2.4 Machining MultiGrip Soft Jaws

MultiGrip soft jaws are machined in the CNC using the MultiGrip vise to hold the MultiGrip jaws.

MGSJ machining considerations:

- MultiGrip jaws should be machined in the vise they will be processing parts in:
    - Accuracy of the part location is greatly reduced if the MultiGrip jaws are machined on one vise and then used in another vise
    - For first op parts on raw material, accuracy of the part location is not typically important and in most cases first op jaws do not need to be used solely on the vise they were cut on
- Before machining MGSJ for the first time, clamp and unclamp the MGSJ at full vise pressure on the spacer or the boring ring at least 3 times to break in the MGSJ so that they will repeat better
- Machine the MGSJ at the maximum intended clamping pressure for the part
- OD MGSJ need to be clamped with 0.125” nominal spacer
- ID MGSJ need to be clamped with MultiGrip ID Boring Ring leaving a 0.390” nominal clamping distance between the MGSJ halves

2.5 CNC Vise Control Library

A G-code library routine is used to control the MultiGrip vise. The G-code library programs are provided by VersaBuilt and loaded into the CNC machine interfaced to the VBX Controller (VBXC). The G-code library allows the CNC to control the MultiGrip vise and is useful for the following:

- Using a CNC program to settle a part in the MultiGrip vise
- Setting a part's Y datum in the vise
- Changing the clamping pressure of the vise during an operation

Usage:

G685 P82002 Vvv Ccc Sss
vv = vise number (1, 2 or 3)
cc = vise command
cc = 0 set vise to float - no clamping pressure other than friction on part
cc = 1 open vise
cc = 2 close vise
cc = 3 set vise pressure
ss = vise pressure (0 to 130 psi)

2.6 Part Settling and Locating Tool

The part settling and locating tool is an option available from VersaBuilt. This option can be installed in a CNC tool holder and controlled with a CNC program. The part settling and locating tool is multi-purpose and is used for:

- **Part settling** - compliant material and flat bottom allow the CNC to apply pressure to locate a part in Z in the MGSJ
- **Setting a part's datum in Y** - for rectangular parts, square side allows CNC to push a part to or against a datum
- **Through coolant wash** - hole through center of tool can be used with through spindle coolant to wash chips off of the part and MGSJ

A. Settling a part in the vise

After a part is loaded in the vise, the part may not be laying flat in the MultiGrip jaws. There are two methods to correct this and settle the part in the MGSJ:

Gravity settling: This is an option in the part's operation configuration. Gravity settling simply opens and closes the vise, relying on gravity to settle the part. This option does not work well for parts that are light.

CNC settling: This option is performed in gcode with the Versabuilt vise control library. (program 82002). The general algorithm is:

1. Load the vise
2. Load the part settling tool
3. Position part settling tool over the part
4. Push down on the part so that compliant material is compressed
5. Open the vise
6. Dwell
7. Close the vise
8. Move the tool away from the part

B. Setting the part datum in the vise

Rectangular parts with straight sides typically require that the part datum be set in the vise. The part vise control library and part settling tool can be used to set the part's datum in the Y axis. The general algorithm is:

1. Load the part in the vise offset away from the needed datum
2. Load the part settling tool
3. Position the part settling tool behind the part
4. Open or float the vise
5. Move the table in Y so that the part is located to the proper datum by the part settling tool
6. Close the vise
7. Move the tool away from the part

2.7 Wash Program

A wash program is used to clean the part, the vise and the MGSJ. The wash program prevents chips from the machining process from interfering with the robot loading process. The wash program is defined in the system configuration and is designed to be customized by the end user to match the environment in the CNC machine. If a part has unique washing requirements, those washing requirements should be added to the end of the CNC part program. The wash program is used:

- At job start to wash the vise and MultiGrip Vise intermediate jaws
- After each op to wash the part and the MGSJ
- In single vise systems, after the part is unloaded to wash intermediate MGSJ
- In dual vise systems, the wash program should wash both the loaded vise and unloaded vise

The wash program is ***CRITICAL*** to the success of the VBX-160 processing. Chips from the CNC cutting process getting between the part and the MultiGrip jaws or the MultiGrip jaws and the MutliGrip Vise intermediate jaws can and will affect the tolerance of the parts. The best wash programs are developed over time by closely observing and monitoring the robot loading process.

2.8 Vise Program

A. Load position program

Each vise has a default program that positions the CNC table to the robot vise load location.
In some instances it may be desirable to position the table offset from the robot vise load location.
For example, after the first op, the feature to be gripped in the second op is off-center from second op MGSJ gripping feature. The VBXC part configuration allows for an alternative table position program.

- Load Position Program is defined in CNC
- Load Position Program ID is entered in Vise Configuration
- Elect to use the program when configuring an applicable part
- Load Position Program is called instead of the default table position program to position the table to the appropriate offset
- Robot will always pick on the center of the vise calibration point

2.9 Calculating Heights

Calculating heights is an important step in the configuration process. The VBXC needs to know the height of both the part and the MultiGrip soft jaws for picking and placing the part. The height is calculated from the bottom of the MultiGrip soft jaw to the top of the part.

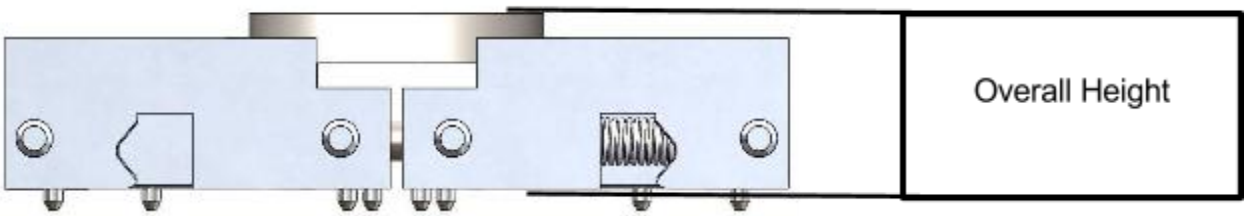
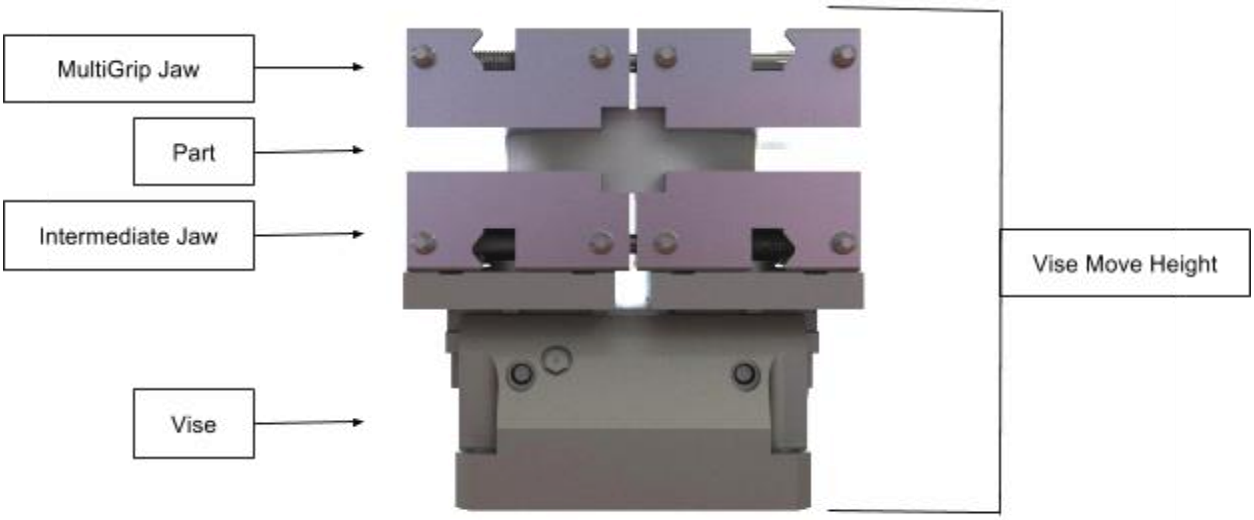


Figure 2-17: MGSJ and Part Showing Dimension of Overall Height

The VBXC recognizes three types of heights:

1. **Shelf pick height -** height when picking the part from the shelf for processing
2. **Vise move height** - height when picking the part from one op to another
    a. measured as the complete stack from bottom of jaws in vise to bottom of jaws that are picking the part
3. **Shelf place height** - height when placing the part back onto the shelf

Figure 2-18: Vise Move Height



Shelf pick height considerations:

- Consider raw material height variations
- Set shelf pick height to max height - if nominal height is 3.0” and material is +/- 0.030” in height, set height to 3.030”
- Op-to-op picks should be very near net calculated heights but in practice, leaving 0.010” of extra height helps ensure smooth operation
- Normal shelf approach height is 3.5”, tall approach is 5”
- Shelf 2 in both racks is limited to a 3.5” approach height
- A little extra height allows the part to drop - an extra 0.30” is typically sufficient

Important: The robot will try to go to the height that is configured in the VBX controller. The robot can exert a lot of force getting there. If the robot can’t get where it wants to go, it will generate a motion supervision error and the system will enter recovery mode. If the robot enters recovery mode, review the recovery instructions in the Operator’s User Manual.

2.10 Verifying A New Part

Verifying a new part confirms that the process is all working together correctly to process the parts accurately. Verifying a new part involves:

- Verifying the CNC process
- Verifying the robot process

A. Verifying the CNC process:	**B. Verifying the robot process:**
● Verify that the fixturing for each operation works as expected for the machining process ● If you are probing part features, verify that the probing routine works as expected ● After verification is complete, edit each op program in the CNC to change the M30 to an M99; this allows the VBX controller to continuously process parts in production	● Create a new part configuration with all of the appropriate configuration information by going into the jobs screen and entering a new job for the part, quantity of 1 ● Load the MGSJ and the raw material onto the shelf as prompted ● Click Cycle Start to begin the robot process **Note:** Using a video camera is helpful when diagnosing robot problems. Consider the following: ● Most problems occur when the robot is picking or placing a part ● Slow motion video is especially helpful ● Any video must be made with all safety provisions of both the robot and the CNC in place