REFERENCE DOCUMENT: Help Topics for CADS V3.0

1. Target Users for CADS Tool

2. Main Menu with Inputs and Outputs

3. Data Structure, Processes and Properties Definitions

1. Target Users for CADS Tool:

Casting Alloy Data Search (CADS [R]) software is intended to be used as a search tool by OEM design engineers and foundry engineers, who are in the process of designing and developing new products and components, re-designing from existing non-metal cast products, and/or converting from other manufacturing processes for value engineering, and/or are looking for down selecting a suitable metal casting alloy, meeting the desired performance with respect to the it's mechanical strength, fatigue, impact and flexural strength properties at room and elevated temperatures, including design allowables. The output from CADS can be exported digitally for structural analysis using FEA and casting process simulation. The tool offers three search options to users:

I. **Select Alloy from Grade List:** This is designed for engineers just looking for engineering data of an alloy grade with pedigree information. This is generic drill down search for various alloy groups containing the list of currently available grades in each. Various alloy grades in each generic alloy groups such as ferrous and non-ferrous and sub-groups, for example, in case of ferrous iron, various grades, are listed. The initial and detail casting alloy search data with pedigree information such as chemical composition, designations, physical and mechanical properties can be printed, or saved into CSV file formats.

II. **Strength Property Search:** This second option is for design engineers looking for suitable cast alloy (ferrous or non-ferrous) based on their minimum strength properties requirements, namely, ultimate tensile strength, yield strength and elongation (ductility). They can pick the desired minimum with the help of sliders for either ultimate strength and/or yield strength and/or elongation and CADS will list all the cast alloys that exceed the values picked with the sliders.

III. **Global Alloy Search:** This first option is for engineers knowing the generic alloy grade name; but looking for the availability of the same alloy grade in various processes and/or section thickness and then finding the suitable grade and process that meets their requirements.

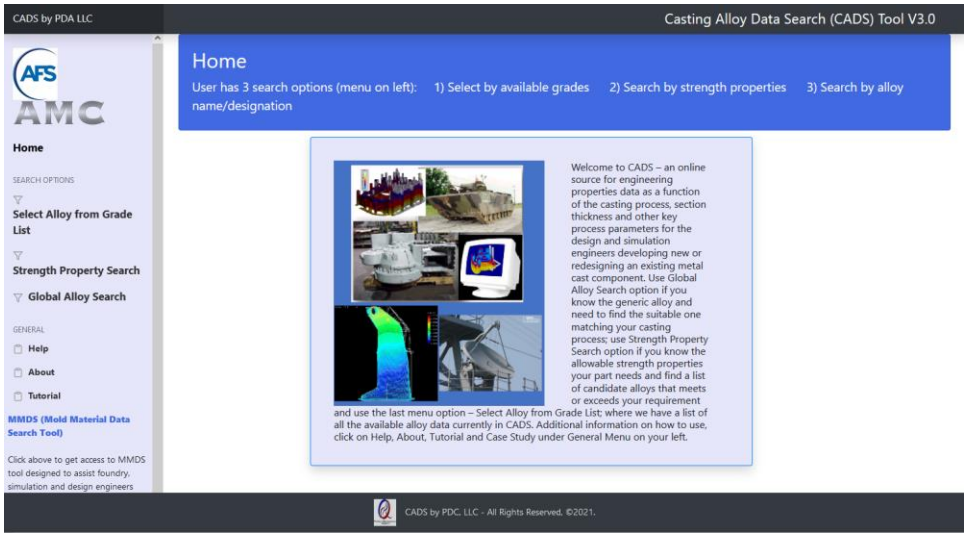


Figure 1: Home Page with Main Menu Options

2. Main Menu with Inputs and Outputs:

The three search options are on the left of the screen. By clicking on home button during the search, brings the user back to the main menu as shown in Figure 1 above.

On the left, under General, there are following useful links:

i. **Help** – Links to this document.
ii. **About** – Offers disclaimers about the software tool.
iii. **Tutorial** – with examples on various search options available within CADS Tool.

Also, on left, by clicking on MMDS – Mold Material Data Search tool, another window will open.

The default unit system for CADS is in ksi, lbs, F and inch.

User can click on any one of the three options.

1. **Select Alloy from Grade List**: In this search option, after clicking on **Select Alloy from Grade List** on left, CADS will list all the currently available grades in various alloy types – Iron Alloy, Aluminum Alloys, Magnesium Alloys, Steel Alloys, Copper Alloys and Other Alloys consisting of Zinc alloys, Lead Alloys and Super Alloys. Figure 2 shows current list of the alloys in the database. User can use the slider under each category and scroll down and pick the alloy grade of interest. All the available data per various processes, molding methods and section thickness will be listed below, for example, by clicking on 356 under Aluminum Alloys, list of available data sets are listed in the search result as shown in Figure 3. User can print the results by clicking on **Print Results** button.

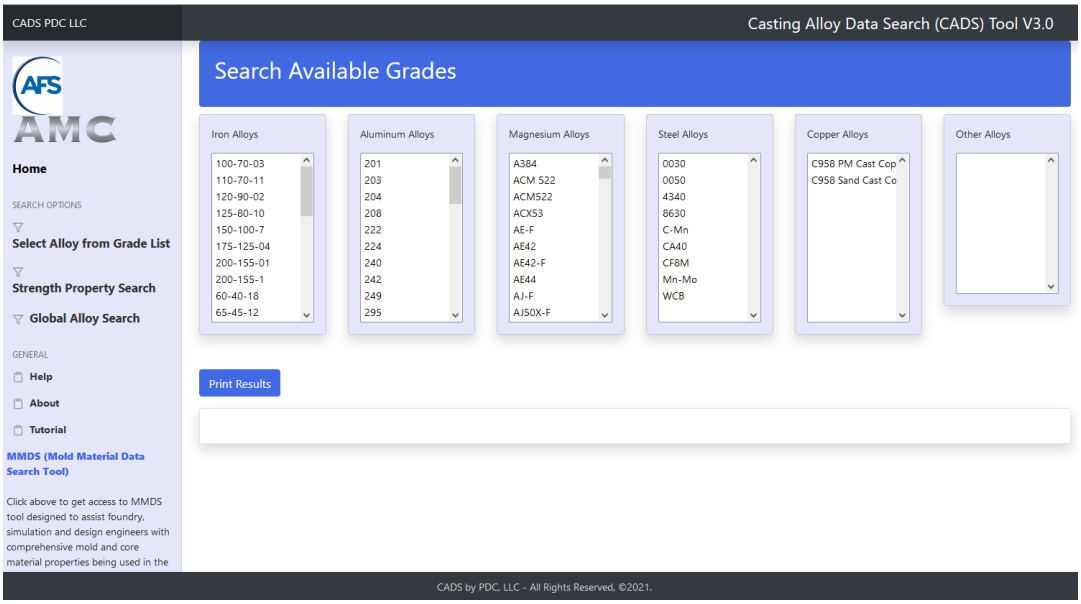


Figure 2: Select Alloy from Available Grades List Output

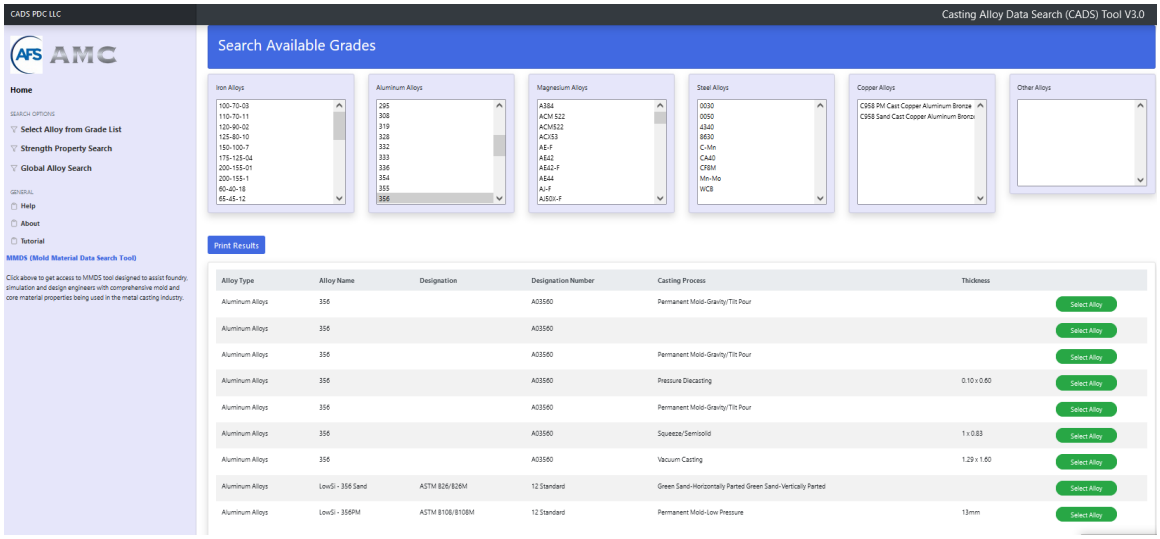


Figure 3: Down selected 356 under Alluminum Alloys listing available various data sets for various processes and section thickness.

User then choses an alloy of interest by clicking on the Select Alloy button in green on right. Figure 4 below is the display of list of available properties in alphabetical order for Low Si 356 alloy selection.

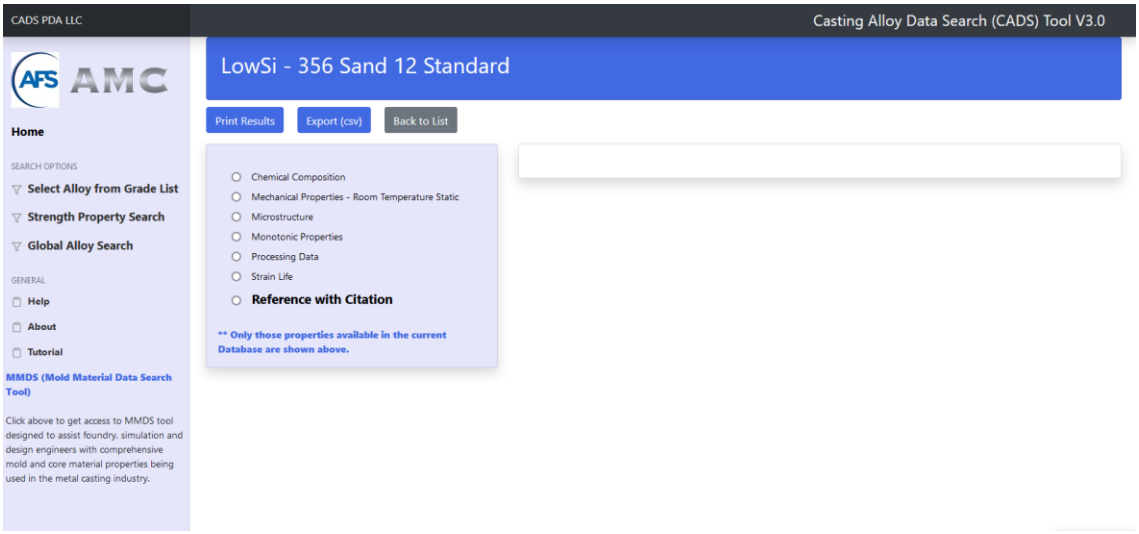


Figure 4: Selected Alloy Low Si 356 with the list of available data alphabetically including refrences with citation at bottom

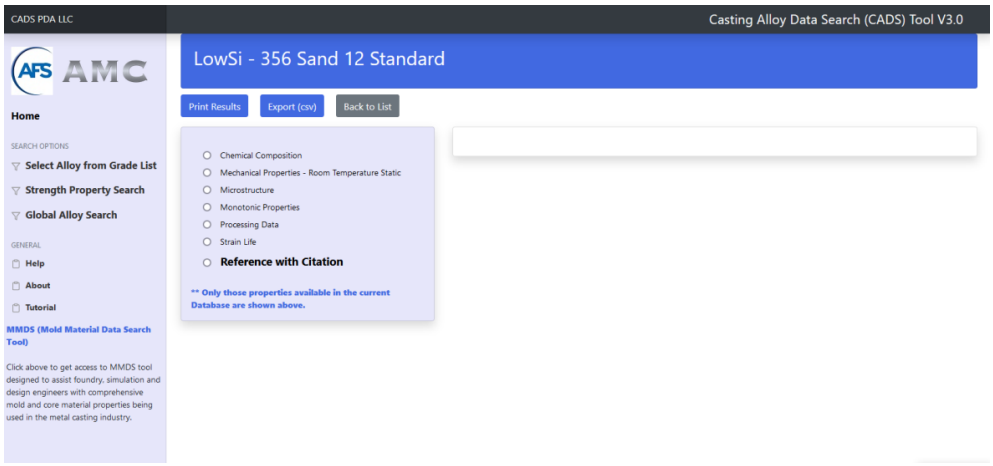


Figure 5: Low Si 356 selected alloy showing available properties

User has the option to choose one from the available data sets as shown in Figure 5 above. If user chooses, for example as shown in Figure 6 below, **Room Temp Static Mech Props** (room temperature static mechanical properties) properties by clicking into the box on left. All properties will be listed on the right side of the window with **Property Name** and the **Property Value**.

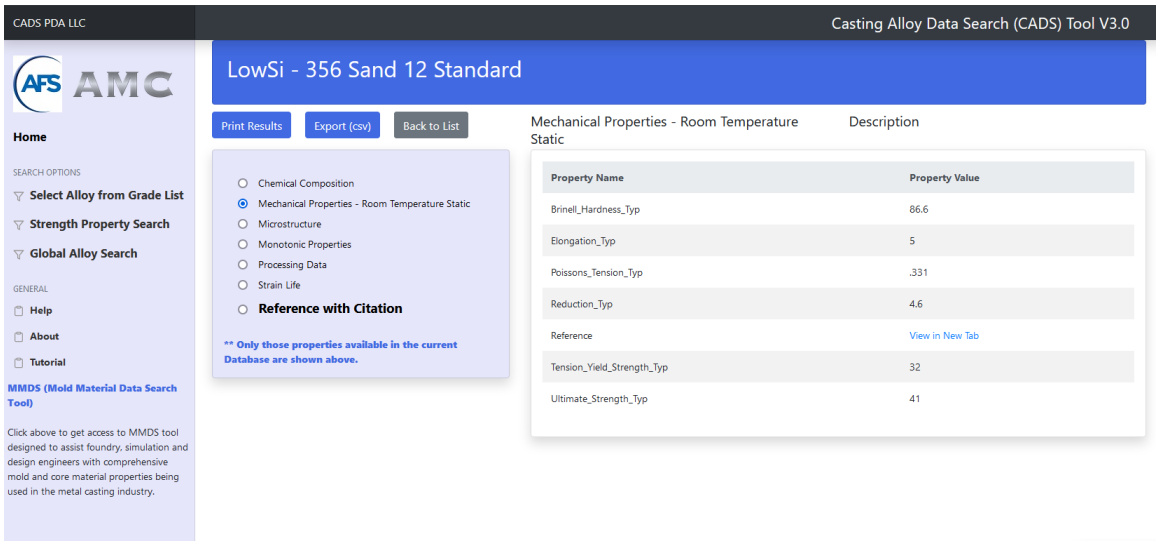


Figure 6: Low Si 356 Sand Cast Room Tempeature Mechanical properties

All refrences with citation for this data set can be seen by clicking on Refrencce with Ctation button and output will see like one below in Figure 7.

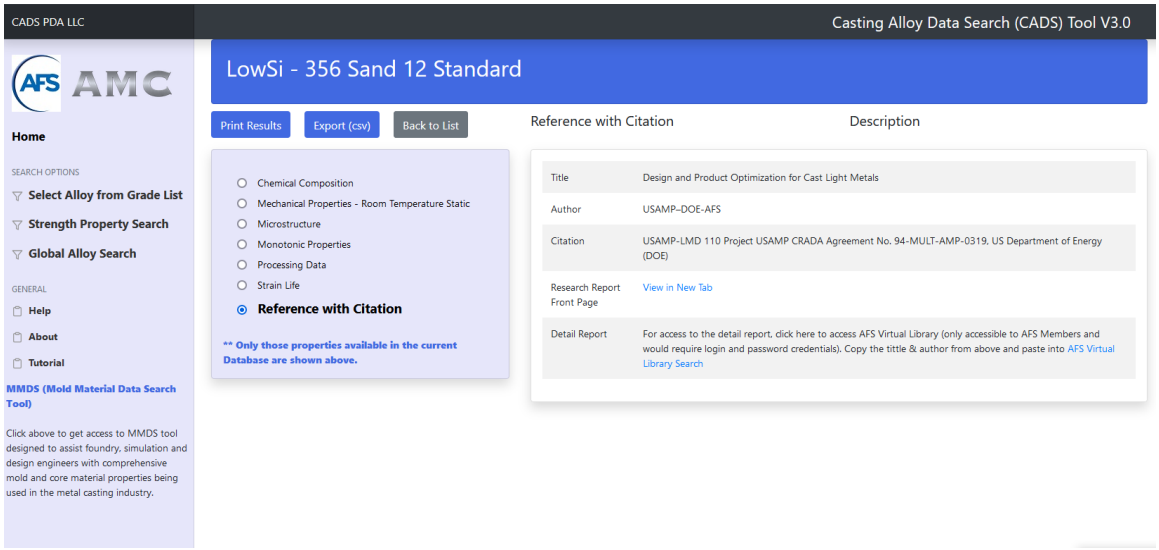
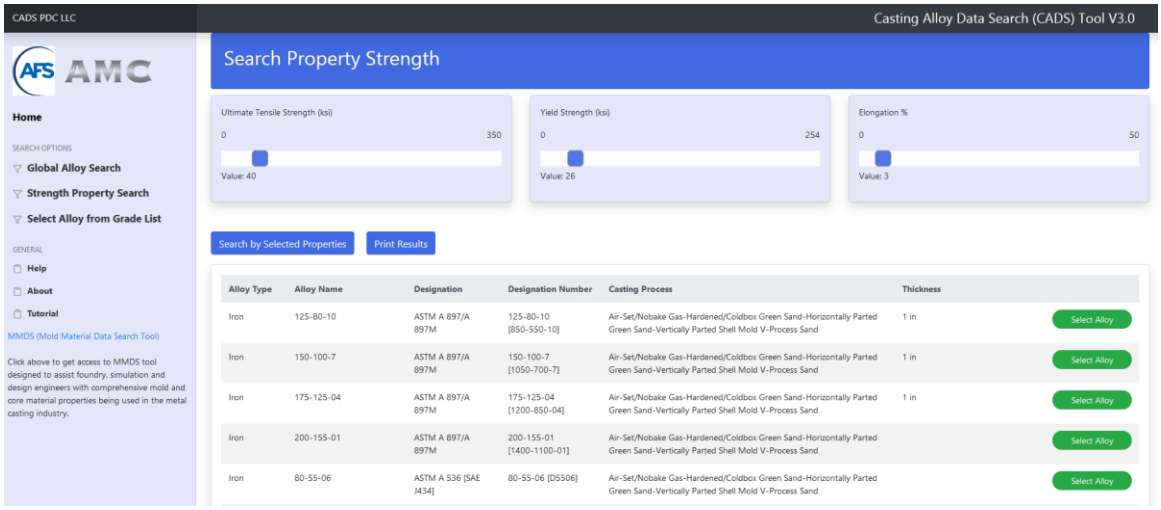
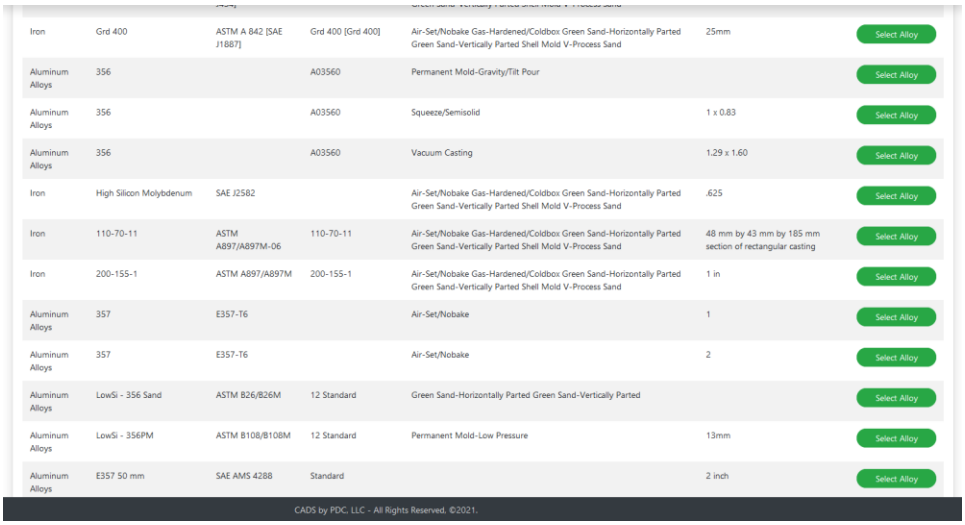


Figure 7: Reference with Citations for Low Si 356 -Sand alloy data

2. **Strength Property Search:** This search option is for design engineers looking for appropriate cast alloy grade that exceeds the minimum strength requirements for a cast product design. These are room temperature ultimate tensile strength, yield strength and elongation properties. User can choose either all 3 or any two or only one, using the blue colored slider bar as shown in Figure 8 below. In the example, user is looking for all the alloys that exceed ultimate tensile strength of 40 ksi; yield strength of 26 ksi and an elongation of 4%. Once the sliders are positioned to the desired values, click on **Search by Selected Properties** button in blue. A list of candidate alloys will be listed below as shown in Figure 8.

   User picks LowSi-356-Sand cast alloy by clicking on the dark green colored button, Select Alloy and the output looks like as shown in Figures 9 through 7. Use can print the search results listing all the candidate alloys.





Iron	Grd 400	ASTM A 842 [SAE J1887]	Grd 400 [Grd 400]	Air-Set/Nobake Gas-Hardened/Coldbox Green Sand-Horizontally Parted Green Sand-Vertically Parted Shell Mold V-Process Sand	25mm	Select Alloy
Aluminum Alloys	356		A03560	Permanent Mold-Gravity/Tilt Pour		Select Alloy
Aluminum Alloys	356		A03560	Squeeze/Semisolid	1 x 0.83	Select Alloy
Aluminum Alloys	356		A03560	Vacuum Casting	1.29 x 1.60	Select Alloy
Iron	High Silicon Molybdenum	SAE J2582		Air-Set/Nobake Gas-Hardened/Coldbox Green Sand-Horizontally Parted Green Sand-Vertically Parted Shell Mold V-Process Sand	.625	Select Alloy
Iron	110-70-11	ASTM A897/A897M-06	110-70-11	Air-Set/Nobake Gas-Hardened/Coldbox Green Sand-Horizontally Parted Green Sand-Vertically Parted Shell Mold V-Process Sand	48 mm by 43 mm by 185 mm section of rectangular casting	Select Alloy
Iron	200-155-1	ASTM A897/A897M	200-155-1	Air-Set/Nobake Gas-Hardened/Coldbox Green Sand-Horizontally Parted Green Sand-Vertically Parted Shell Mold V-Process Sand	1 in	Select Alloy
Aluminum Alloys	357	E357-T6		Air-Set/Nobake	1	Select Alloy
Aluminum Alloys	357	E357-T6		Air-Set/Nobake	2	Select Alloy
Aluminum Alloys	LowSi - 356 Sand	ASTM B26/B26M	12 Standard	Green Sand-Horizontally Parted Green Sand-Vertically Parted		Select Alloy
Aluminum Alloys	LowSi - 356PM	ASTM B108/B108M	12 Standard	Permanent Mold-Low Pressure	13mm	Select Alloy
Aluminum Alloys	E357 50 mm	SAE AMS 4288	Standard		2 inch	Select Alloy

Figure 8: Search by minimum Strength properties of ultimate strength of 40 ksi, yield strength of 26 ksi and elongation of 3%.

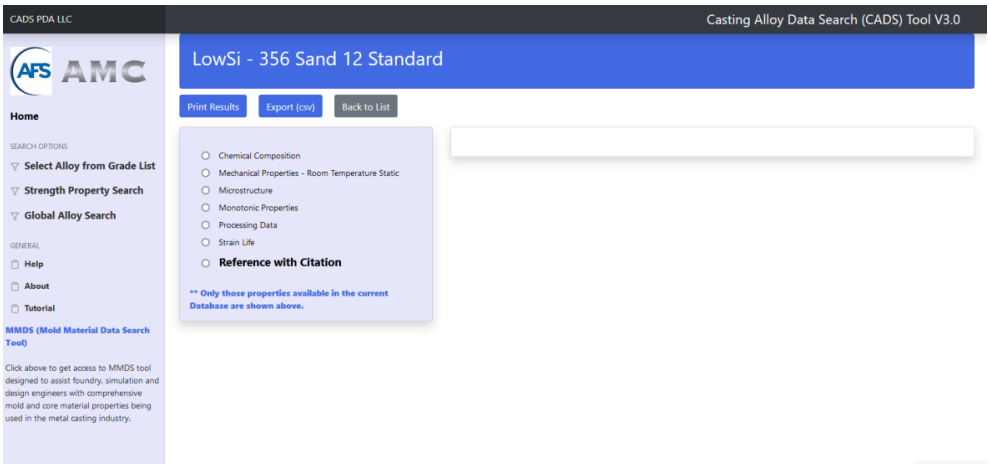


Figure 9: Low Si 356 selected alloy showing available properties

User has the option to choose one from the available data sets as shown in Figure 9 above. If user chooses, for example as shown in Figure 10 below, **Room Temp Static Mech Props** (room temperature static mechanical properties) properties by clicking into the box on left. All properties will be listed on the right side of the window with **Property Name** and the **Property Value**.

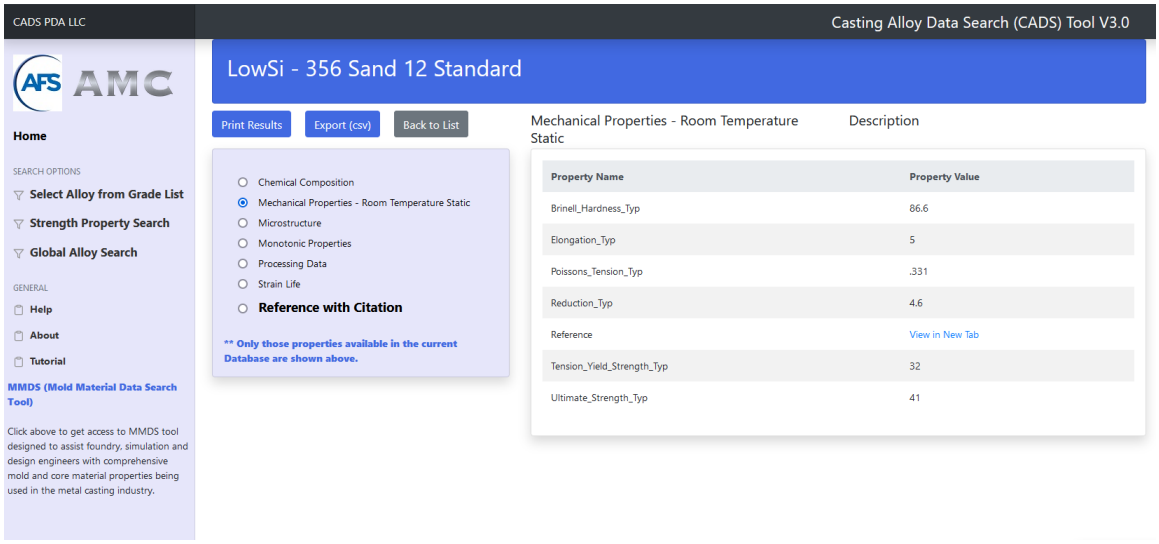


Figure 10: Low Si 356 Sand Cast Room Tempeature Mechanical properties

All refrences with citation for this data set can be seen by clicking on Refrencce with Ctation button and output will see like one bwlow in Figure 11.

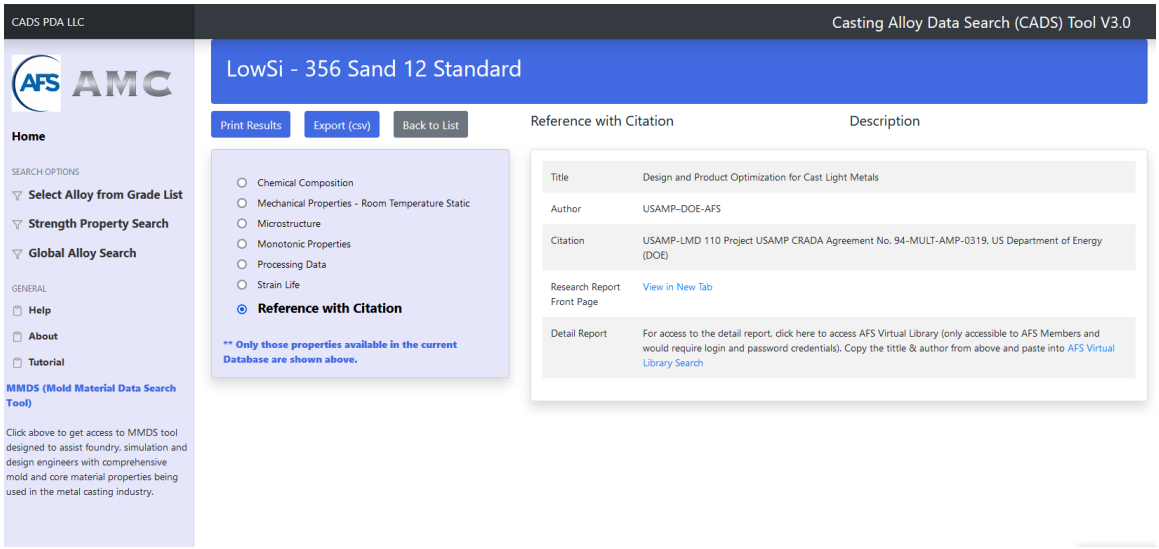


Figure 11: Reference with Citations for Low Si 356 -Sand alloy data

3 **Global Alloy Search:** By clicking on global alloy search button, the following menu shows up as shown in Figure 12. As shown as an example, a user is looking for 356 alloy grades for the available data for various processes with pedigree information, such as section thickness. A list of available data for 356 alloy grades under various processes and available section thickness shows up below. The search result can be printed by clicking on **Print Results** button.

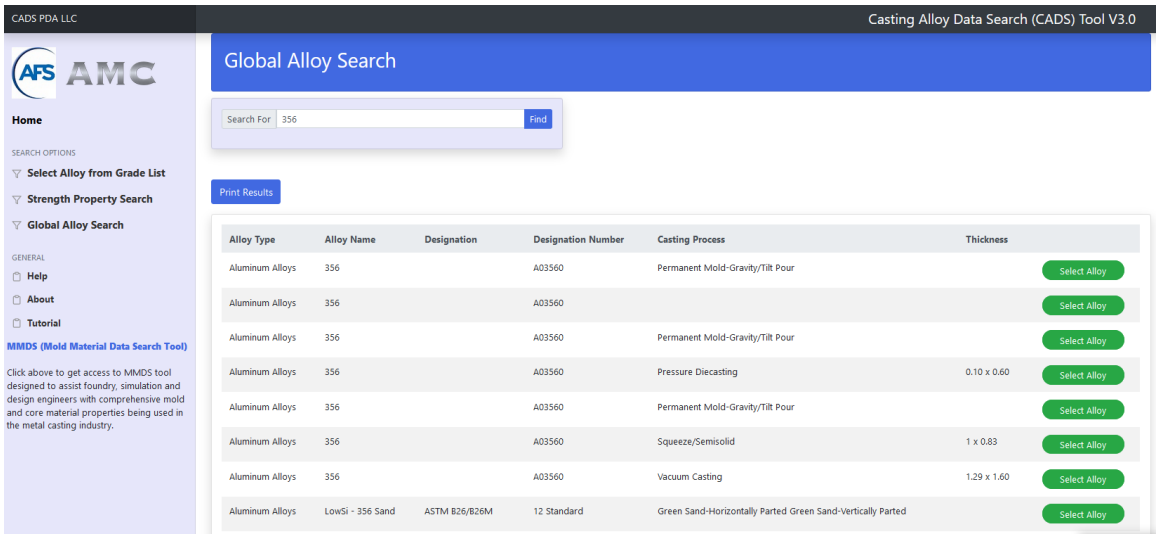


Figure 12: Global Alloy Search Menu for 356

Then, click on **Select Alloy** (dark green colored) button for the detail data. For example, here, 8th entry under **LowSi-356 Sand** is chosen by the user and Figure 13 displays the output as shown below.

The output for the selected alloy property data can be printed or exported into Excel (CSV) formats by clicking **Print Results** and **Export (csv)** buttons respectively as shown in Fig 13. If user wants to go back and look at the list of alloys, can do so by clicking **Back to List** button.

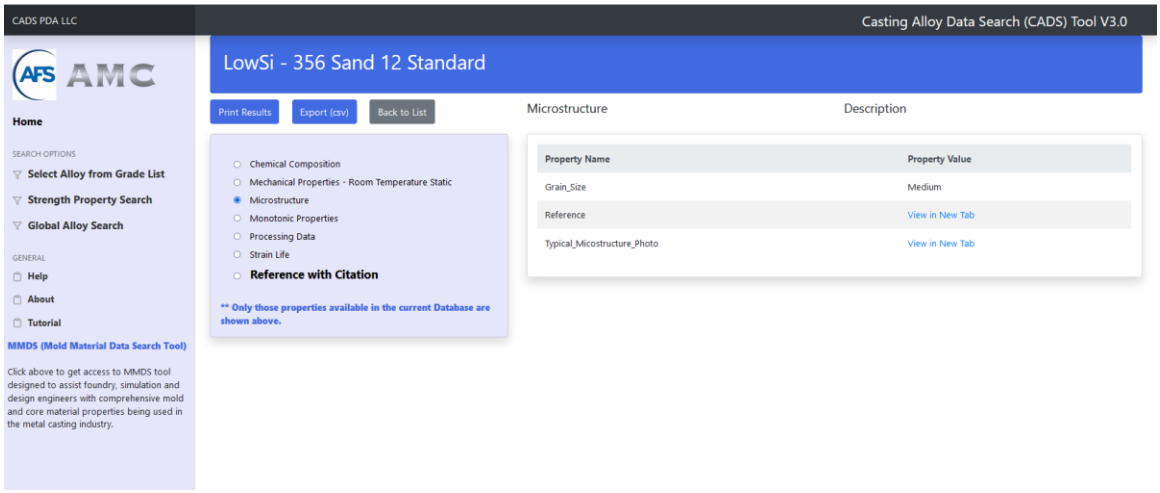


Figure 13: LowSi-356-Sand Property Outputs - Microstructure

Other property option, for example, **Microstructure**, if any micrographs are available, will be shown highlighted in blue as shown in Figure 6 above and by clicking **View in New Tab**, another window will open showing the JPEG image of the microstructure as shown below in Figure 14. Similarly, any **Reference** documents if any linked to the data, is hyperlinked and highlighted in blue and will open another window showing the PDF document page.

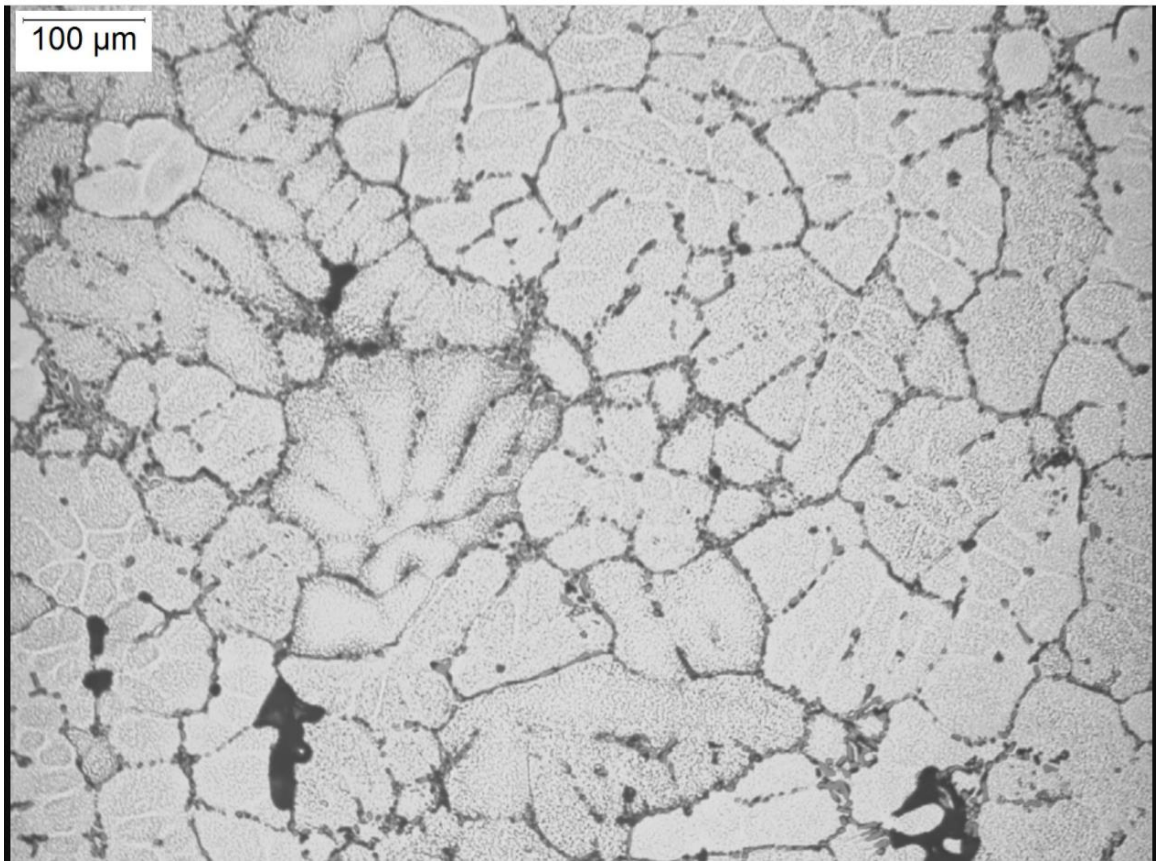


Figure 14: LowSi-356-Sand Typical Microstructure Image

3.**Data Structure, Processes and Properties Definitions:**

1. **Alloy Types:** Current CADS database is structured per the following broad alloys:

1. Ferrous
    a. Iron
        i. Gray Iron
        ii. Ductile Iron
        iii. Compacted Graphite Iron
        iv. Austempered Ductile Iron
        v. Malleable Iron
        vi. Abrasion Resistant Iron
        vii. Corrosion Resistant Iron
        viii. Heat Resistant Iron
    b. Steel
        i. Carbon Steels
        ii. Low Alloy Steels
        iii. Corrosion-Resistant Steels
        iv. Heat-Resistant Steels
        v. Manganese Steels

2. Nonferrous
    a. Aluminum Alloys
        i. Aluminum-Copper (200 series)
        ii. Aluminum-Silicon (300 Series)
        iii. Aluminum-Silicon (400 Series)
        iv. Aluminum-Magnesium (500 Series)

    b. Copper Alloys
        i. Red/Yellow Brass/Tin-Bronze
        ii. High Copper Alloys
    c. Zinc-Base
    d. Lead Alloys
    e. Magnesium Alloys

3. Superalloys

    a. Nickel-Base
    b. Titanium
    c. Cobalt-Base
    d. Other Superalloys

2. **Casting / Molding Processes:** Following processes are considered for capturing the pedigree information

    1. Sand Casting (Green Sand, Horizontal and Green Sand, Vertical, Air Set, No-bake, CO2, Cold Box,)
    2. Shell Molding
    3. Lost-Foam (EPC, Full-Mold)
    4. Vacuum Casting
    5. Investment Casting
    6. Ceramic Molding
    7. Plaster Casting
    8. Permanent Mold (Gravity/Tilt Pour, Low Pressure)
    9. Die Casting (High pressure)
    10. Squeeze Casting
    11. Centrifugal Casting

3. **Chemical Composition –** Database has captured maximum, minimum and typical compositions abbreviated as **A**, **B** and **C** in the output, all elements are listed in the first column under **Property Name**. Please see Figure 15 below.

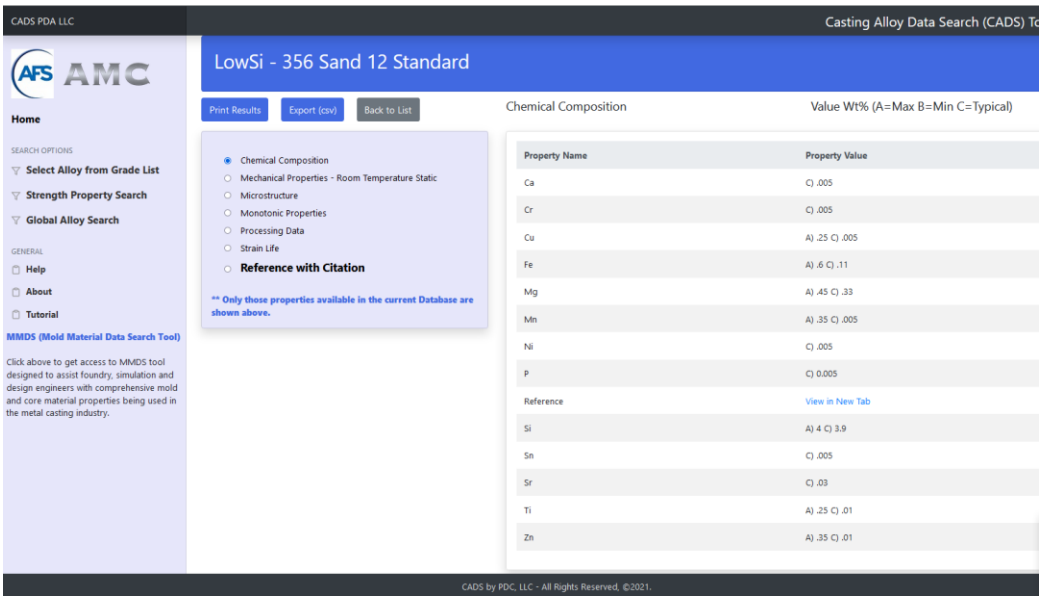


Figure 15: Chemcal compisition typical out put (example LowSi-356-Sand)

4. **Section Thickness** – The critical cross-section thickness, which will correspond to the test bar thickness, from which the mechanical properties have been derived. The section thickness in most alloys impact the cooling rates and final microstructure and properties.

5. **Service Temperature** – In the data base, there are Room Temperature or Elevated Temperature options available. The database has minimum, maximum and typical properties as available.

    1. **Room Temperature Properties:**
        a. Brinell Hardness (500 kg load on 10 mm ball)
        b. Compressive Yield Strength (set at 0.2% off-set) in ksi
        c. Elongation in % in 2-inch dia.
        d. Hardness in HRC
        e. Poisson's Ratio
        f. Reduction in area, %
        g. Shearing Strength, ksi
        h. Tension Yield Strength (set 0.2% or 0.5%), ksi
        i. Ultimate Tensile Strength, ksi
        j. Young's Modulus, ksi

    2. **Elevated Temperature Properties:** tensile or compressive strength in ksi

6. **Fatigue Strength:** Strain-life fatigue-based values are provided for iron, aluminum and steel family of various grades. Some of the data are in a graphical form as PDF or JPEG, or tables and others are listed with values. The following is the list of all the fatigue related properties captured into CADS; only select alloys have some of these properties:
    1. Cyclic Strain Hardening Exponent (n')
    2. Cyclic Strength Coefficient (K') in ksi
    3. Cyclic Yield Strength in ksi
    4. Elastic Modulus in ksi
    5. Endurance Limit / Fatigue Limit in ksi
    6. Fatigue Ductility Exponent ©
    7. Fatigue Strength Coefficient (s'f) in ksi
    8. Fatigue Strength Exponent (b)
    9. Strain Curve
    10. Strength Coefficient (K) in ksi
    11. Strain Hardening Exponent (n)
    12. True Fracture Ductility
    13. True Fracture Strength in psi
    14. True Yield Strength in psi
    15. Cyclic Strength Coefficient (K') in ksi

7. **Impact Property:** For desired room or operating temperature, Charpy in inch-lbs min and maximum and typical values are contained in the database.

8. **Flexural Strength:** From the desired room temperature compression or tension strength in ksi min and maximum, values

9. **Design Allowable:** There are two sources for design allowable properties: MMPDS (Metallic Material Properties Development & Standardization; an organization maintaining the material data derived using statistical methods of A, B and S allowable, mainly used by the aircraft and aerospace community as well as Military. The second source is derived by AFS using MMPDS methods using member foundries provided production historical test bar properties

data with significant number of heats or lots. Below Figure 16 shows an example for Aluminum Alloy E357 data, listing Design Allowables. By clicking Design Allowables button, the display of the available properties is displayed as shown in Figure 17 below.

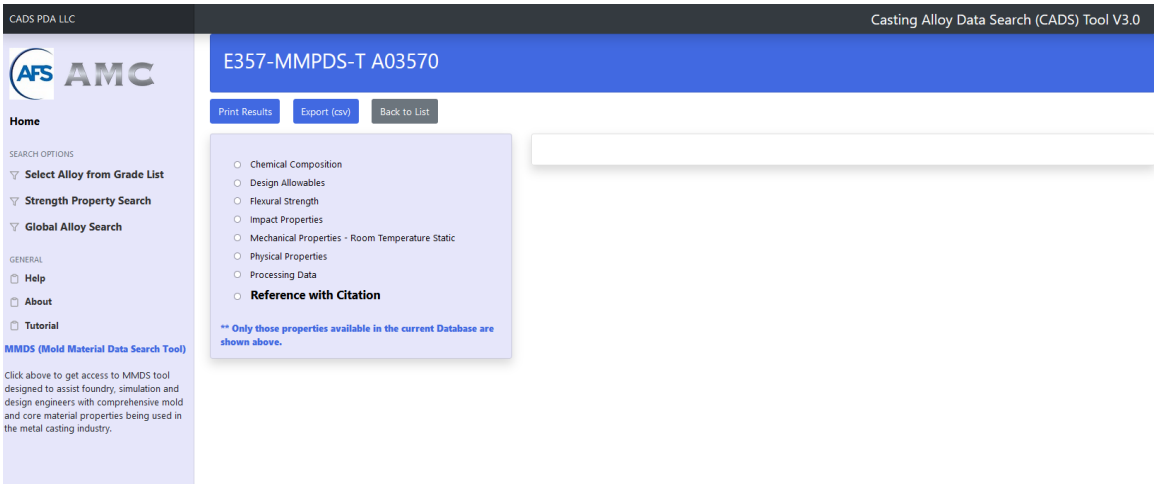


Figure 16 Listing of all available data including Design Allowable for Aluminum E357

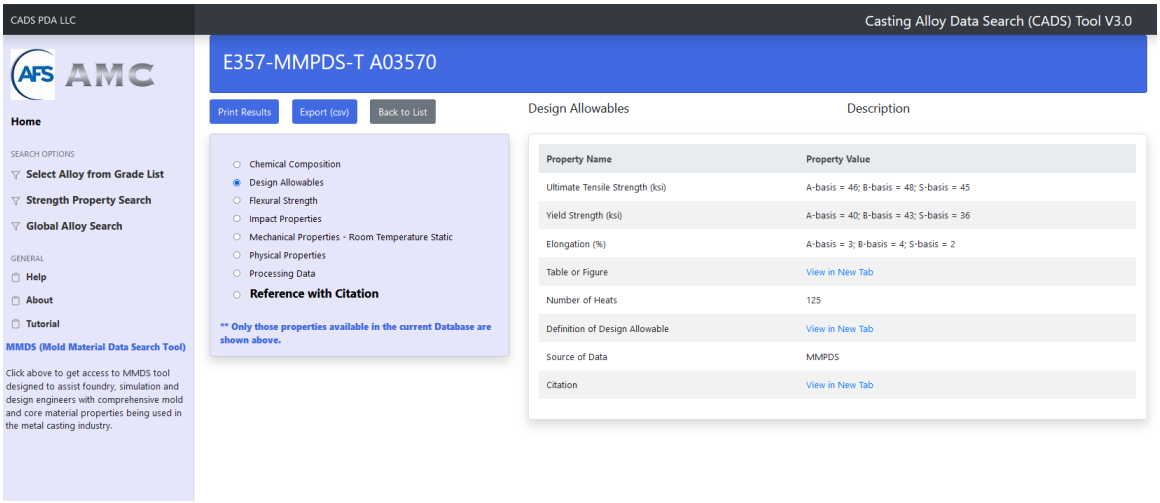


Figure 17 Display of Design Allowable for Aluminum E357

By clicking on Table or Figre, additional design allowable properties as cntained in MMPDS handbook get dsiplayed in another windwo of your browser. Fogre 18 below shows an example of such table.

Table 3.9.7.0(c). Design Mechanical and Physical Properties of E357.0 Aluminum Alloy Casting

Specification	AMS 4288				
Form	Investment Casting[a]		Sand Casting[b]		
Temper	T6				
Thickness, in.	...	...	0.500-2.500		...
Location Within Casting	Designated area	Non-Designated area	Designated area		Non-Designated area
Basis	S	S	A	B	S
Mechanical Properties:					
F_{tu}, ksi	50	45	46	48	45
F_{ty}, ksi	40	36	40[c]	43	36
F_{cy}, ksi	41	37	42	44	36
F_{su}, ksi	33	30	32	34	31
F_{bru}[d], ksi:					
(e/D = 1.5)	75	67	...	...	...
(e/D = 2.0)	98	88	78	86	...
F_{bry}[d], ksi:					
(e/D = 1.5)	59	53	61	65	52
(e/D = 2.0)	69	62	75	78	64
e, percent (S-Basis)	3	2	3	...	2
E, 10^3 ksi	10.4		10.6		
E_c, 10^3 ksi	10.5		10.8		
G, 10^3 ksi	3.9		3.9		
μ	0.33		0.33		
Physical Properties:					
ω, lb/in.^{3}	0.097				
C, Btu/(lb)(°F)	0.23 (at 212°F)				
K, Btu/[(hr)(ft^2)(°F)/ft]	88 (at 77°F)				
α, 10^{-6} in./in./°F	12.0 (68°F to 212°F)				

Issued: Apr-2005, MMPDS-02, Item 02-02. Last revised: July 2016, Item 13-40.

a Properties were determined from investment cast plates.
b Properties were determined from step geometry.
c A-Basis is specification minimum. The rounded T_{99} = 42 ksi.
d Bearing values are "dry pin" values per Section 1.4.7.1.

Figure 18 Design Allowble properties as contained in MMPDS Handbook