Industry Best Practice Data Driven Design Allowable Properties for some Common Alloys in CADS (Casting Alloy Data Search) Online Tool

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ABSTRACT

A project funded by the Defense Logistics Agency (DLA) and managed by the American Foundry Society (AFS) as part of the American Metalcasting Consortium (AMC) led to the development of a web-based casting alloy data search tool for design and simulation engineers. The search tool provides engineering properties and in most cases fatigue properties with the supporting pedigreed data, such as chemistry, mold material, casting process, section thickness, type of test bar and heat treatment, etc. in contrast to the typical handbook static properties data with no or little supporting pedigree information. The improved data will enable better casting part designs capable of delivering several long-term objectives, i.e., longer service life, lower scrap, lighter weight, and better performance.

The Casting Alloy Data Search (CADS) online tool provides current and qualified information generated using the latest methods and disseminates this information in a user-friendly format to both users and manufacturers of castings. The latest effort presented in this paper is focused on developing industry best practice-data-driven design allowable property values using standard Metallic Materials Properties Development and Standardization (MMPDS) methods for 24 new alloys (two copper-base, four aluminum-base, six iron-base, and twelve steel-base grades) from more than 10 foundries. The AFS foundry members provided the data while this paper's author, Shah, performed the data analysis using the established statistical method which considers heat and lot variability within a foundry as well as from one foundry to another, for the same alloy grade.

Keywords: mechanical properties database, Casting Alloy Data Search, CADS, dynamic and static material properties, Metallic Materials Properties Development and Standardization, MMPDS

INTRODUCTION

Preliminary engineering design properties that reflect the capability of cast metals are not readily available in a convenient searchable form from a recognized source. In most cast alloys, properties are highly impacted by the chemistry and local cooling rate, which is mainly controlled by the section thickness and the type of mold media or casting process used. Along the same lines, qualified data is vital for design engineers to effectively design more sophisticated parts and components. The need for lightweighting often results in more highly stressed parts due to thinner section thicknesses. Castings are becoming even more complex with the advent of 3D sand printing and its capabilities to cast lower density parts that need to be validated by simulation using accurate data.

When this project started, handbooks contained material properties which are generally inadequate, in a printed format vs. electronic, and/or generated with dated test methods. Moreover, the available handbook data nearly unanimously lacked the requisite pedigree information such as process, chemistry, mold/core media, section thickness, etc. The data also often lacked strain life fatigue data, which is becoming critically important in developing and optimizing casting design(s). Due to a continuously decreasing number of metalcasters, these critical design properties are difficult to find or unavailable. The absence of this data often results in substantial delays in the procurement of castings.

Lack of design allowable data leads to the casting alloy and process selection using an ad-hoc casting knock-down factor attributed to anticipated variability over the minimum mechanical properties as specified by the relevant standards. Accordingly, castings become less competitive in the design engineer's selection of alloys and processes over wrought counterparts. This is especially true in aerospace and military applications where the net effect of the knock-down factors detrimentally affects the calculations. Design allowable determination is a statistical method that factors the lot-to-lot and heat-to-heat variability in properties data, meeting the minimum required with a reasonable sample universe.

The MMPDS organization under the direction of the Federal Aviation Administration (FAA) has developed a statistical computation tool to derive design allowable values factoring sample lot and heat variability.

Per FAA Regulations (FARS, CFR 14) SECTION 23-613, (a) Material strength properties must be based on enough tests of material meeting specifications to establish design values on a statistical basis; and (b) Design values must be chosen to minimize the probability of structural failure due to material variability. Selecting design values that ensure material strength with the following probability: (1) Where applied loads are eventually distributed through a single member within an assembly, the failure of which would result in loss of structural integrity of the component; 99 percent probability with 95 percent confidence. [T99, also known as A-Basis Design Allowable] and (2) For a redundant structure, in which the failure of individual elements would result in applied loads being safely distributed to other load-carrying members; 90 percent probability with 95 percent confidence. [T95, also known as B-Basis Design Allowable].

The use of design allowable values results in more realistic casting design configurations when compared to ad-hoc casting knockdown factors over the minimum called out by American Society for Testing and Materials (ASTM) specifications, Aerospace Material Specification (AMS), and the U.S. Military Standards (MIL-STDs).

Best practice data from the quality metalcasters for various alloys using separately cast test bars properties represent the realistic variability and statistically derived design allowable values, and using that data is more valuable and meaningful than minimums provided in applicable standards, specifications, and handbooks published data. Hence, a task is dedicated to generating such data in the last year of the project in place of generating strain life fatigue data for just one alloy.

This project was undertaken to address the above-listed need for creating a repository of the pedigreed data generated in government-funded projects like the American Metalcasting Consortium (AMC) Casting Source Readiness (CSR), its successor Innovative Casting Technologies (ICT), and via industrial partnerships. It is an online database search and retrieval tool to benefit design engineers and foundry process engineers alike, that utilize Finite Element Analysis (FEA) based validations for new product development, design optimization, and process simulation validations.

A dedicated, open-access website (http://www.AFSCADS.com) was designed and launched for the CADS V1.0 (Version 1.0) and Mold Material Data Search (MMDS) V1.0 tools in 2016. Most of the data was leveraged from other author-involved research projects. These projects include a funded project to develop a Fatigue Properties Database (circa 2010), a United States Automotive Materials Partnership/United States Consortium of Automotive Research (USAMP/USCAR) funded light metals materials database (circa 2012), and finally, a society-funded research project on strain life fatigue data for Compacted Graphite Iron (CGI) Grade 400 and a High-alloy Class 40 Gray Iron (circa 2014).

CADS is a readily searchable database of alloy-centric properties. The recent CADS V3.0 (Version 3.0, circa 2021) greatly enhances the user experience and is the first version to offer a copy/paste citation field and direct link to the AFS online digital library where the pedigreed data reports reside.

EXPERIMENTAL PROCEDURE

Task 1: CADS Upgrade to V3.0

For better access by the metalcasting industry professionals, CADS V3.0 is currently linked through the main AFS website (www.AFSINC.org), under the sub-menu of "Designers and Buyers" as shown in Figure 1. Also, a separate landing page and dedicated website were designed and launched under the weblink at www.AFSCADS.com, to get additional users, and to facilitate searching/identification via common search engines. Figure 2 shows the landing page with a link to CADS V3.0.

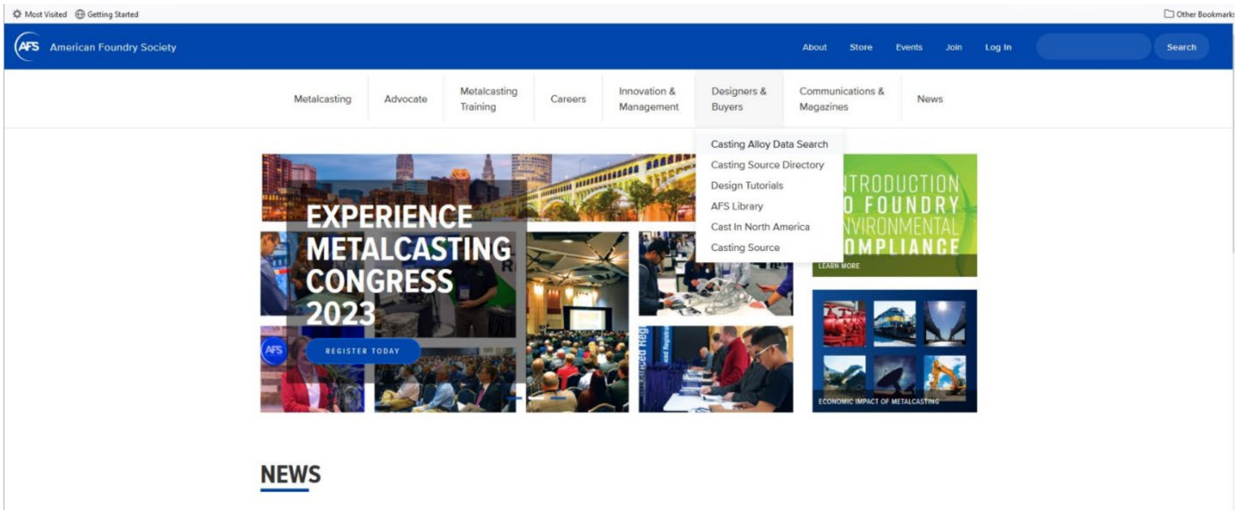

Figure 1. CADS interface from AFS main website (www.afsinc.org).

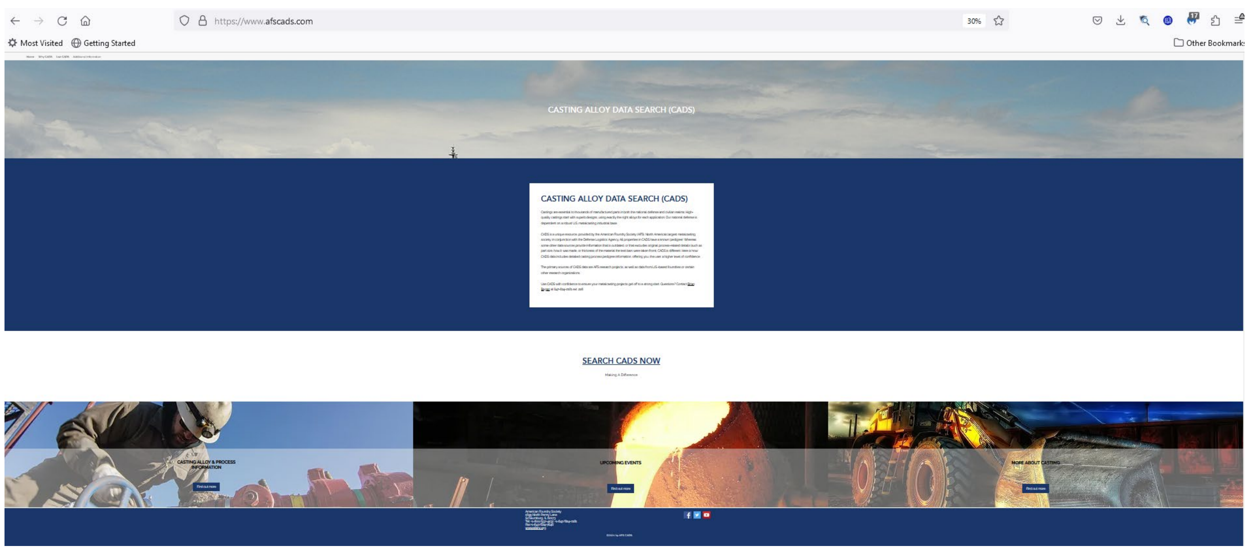

Figure 2. Dedicated landing site for CADS on the AFS website (www.afscads.com).

The CADS V3.0 user interface was radically improved from the previous version to enhance the use and adoption by foundry process and design engineers. A screenshot of the main CADS home page appears in Figure 3. On this screen, three main navigation options appear on the left sidebar menu: Select Alloy from Grade List, Strength Property Search, and Global Alloy Search. By selecting the first menu option (Select Alloy from Grade List) on the left sidebar menu, a scrolling list of available grades categorized by alloy (e.g., iron, aluminum, magnesium, steel, copper and other alloys) appears. A screenshot of the 356 Aluminum Alloys grade is provided in Figure 4.

Similarly, by selecting the second menu option (Strength Property Search) from the left sidebar menu, moveable slide bars can be used to select the desired mechanical properties combination for ultimate tensile strength (UTS) in ksi, yield strength (YS) in ksi, and elongation % (E).

The resulting screenshot after using the slide bars to select mechanical property value of 31 ksi UTS, 11 ksi YS and 3% E is presented in Figure 5. The result is a list of all combinations of alloys, castings processes, and section thickness maximums that will achieve or exceed the combination of targeted mechanical properties.

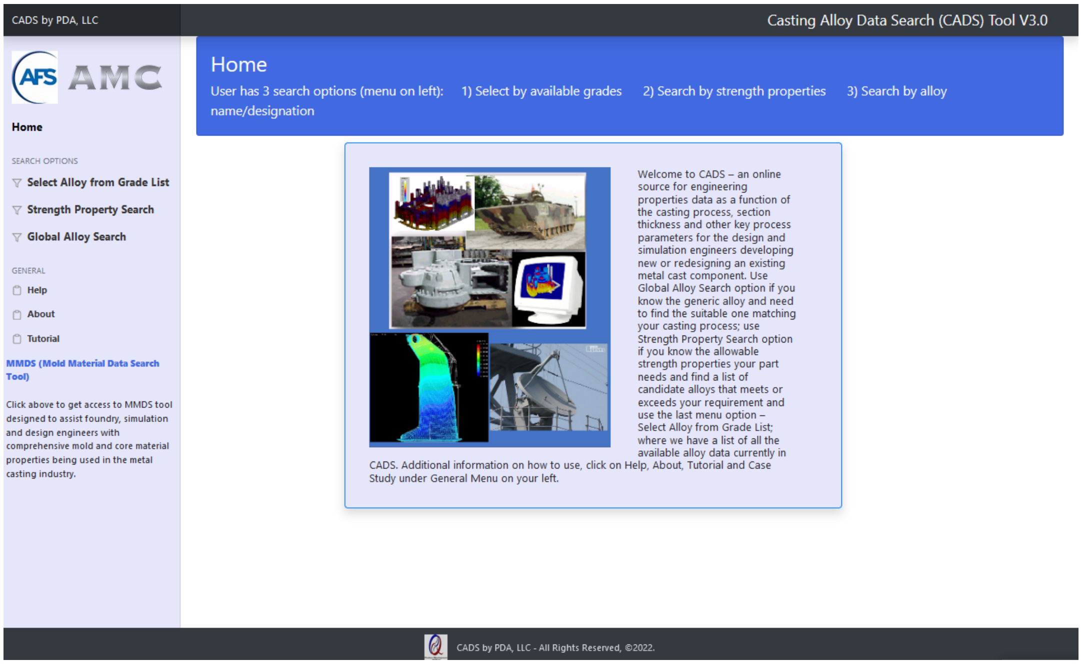

Figure 3. Display of main menu of CADS V3.0 user interface.

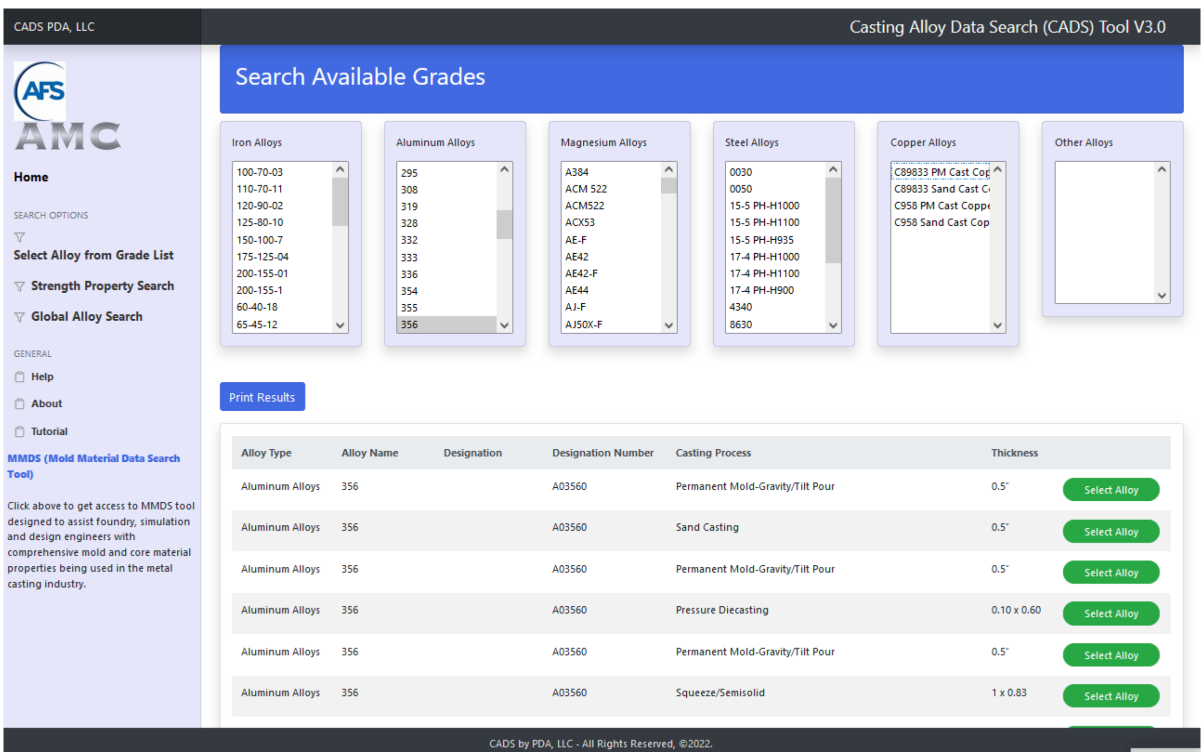

Figure 4. First search option by available alloy grades in the dataset, 356 is selected.

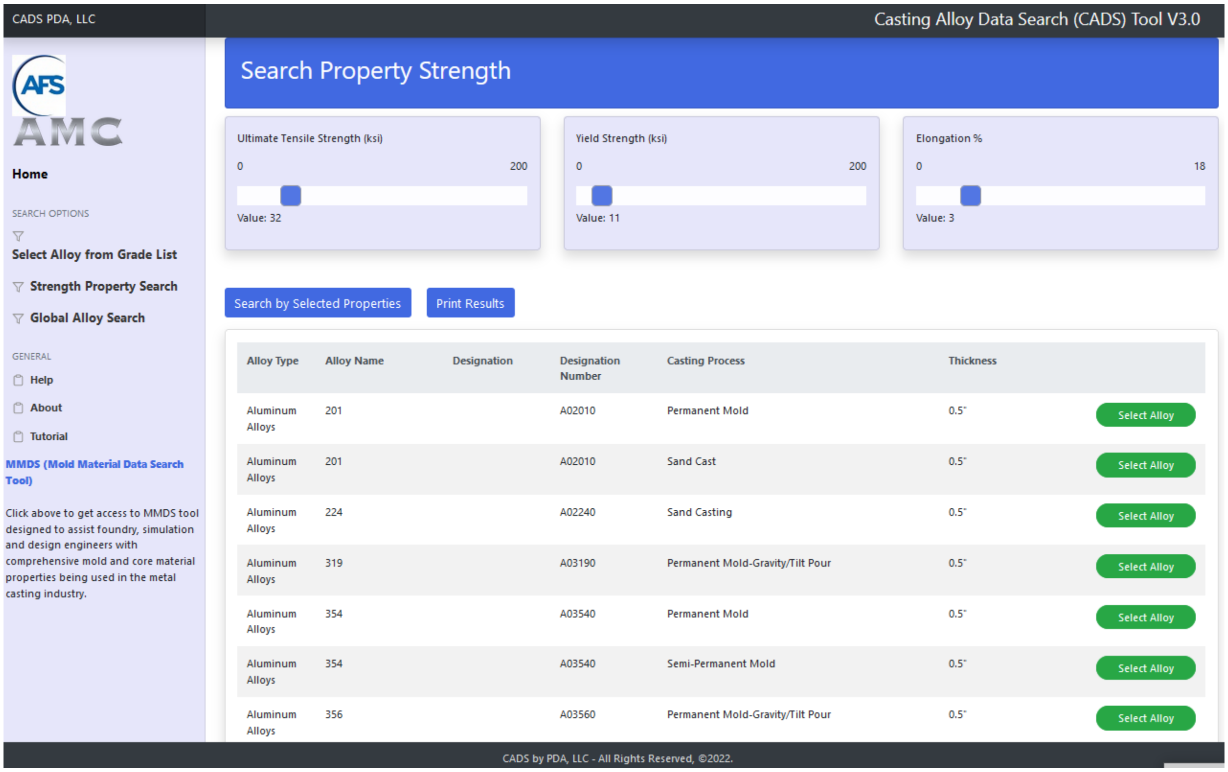

Figure 5. Display of output from second menu choice of designer choosing desired properties.

By selecting the third menu choice (Global Alloy Search) from the left sidebar menu, the designer can search for all of the property listings of a known alloy grade. The resulting screenshot after inputting 356 into the "Search For" field from the Global Alloy Search page appears in Figure 6. One might wonder how selecting 356 from the Global Alloy Search page differs from selecting 356 alloy from the scrolling alloy grade list (Select Alloy from Grade List).

The difference is the scrolling alloy grade list may have multiple listings for a single alloy (e.g., 356), based on the number of datasets with different conditions (e.g., tempers, thicknesses, molding media, etc.) whereas the Global Alloy Search identifies every reference of that alloy in every condition.

The CADS database provides casting process and design guidance for quality and performance. The properties within a casting differ as the cooling rate and/or chemical composition differ, so now it becomes important to realize the differences in properties as a function of cooling rate controlled by section thickness, type of mold media, and casting process used. Local cooling rates in most alloys drive the microstructure evolution during solidification and cooling, which in turn drive the local properties in a casting. To address these differences in properties, CADS upgraded to V3.0 highlights thickness and casting process as a top-level search. Examples of top-level search conditions are shown in Figures 4 through 6. Additionally, and unique to CADS V3.0, search results can be printed by selecting the blue "Print Results" button at any stage in the search process.

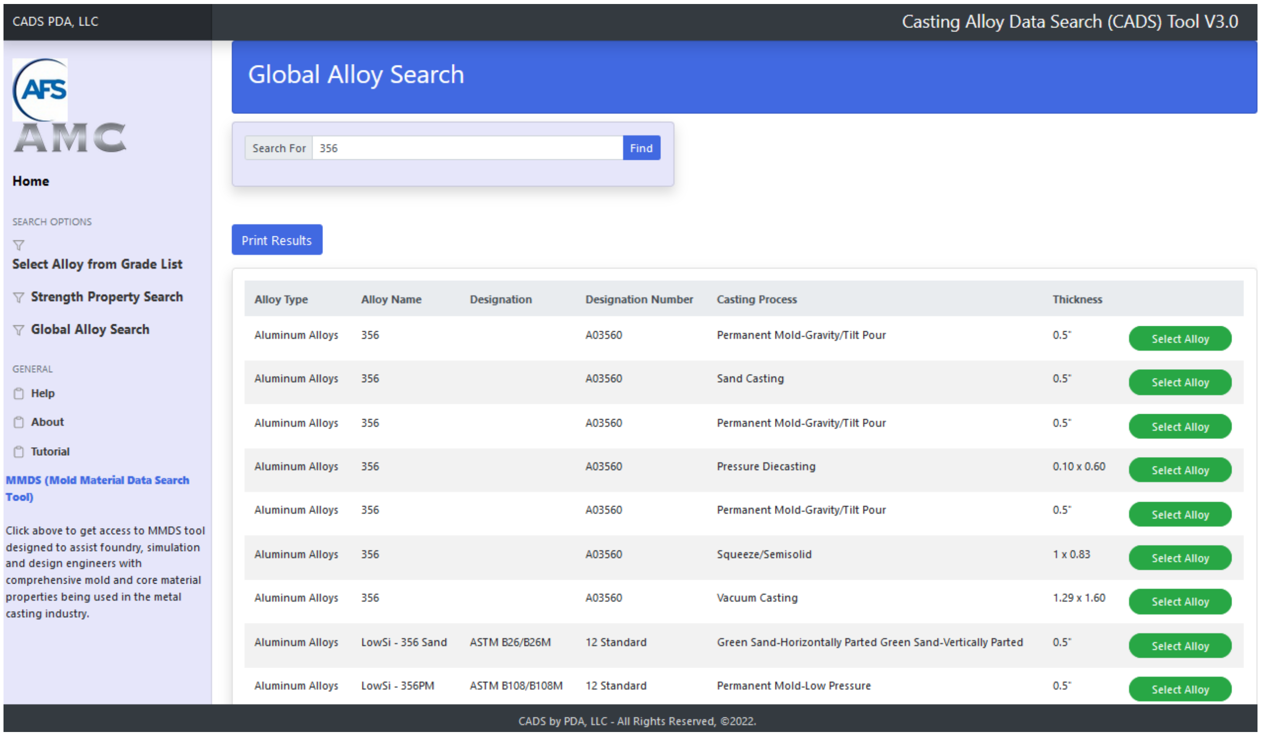

Figure 6. Global alloy search output display for aluminum"356."

A detailed tutorial incorporating the use and applicability of the above three search options is incorporated into the online V3.0 documentation and can be easily accessed by clicking "Tutorial" on the left sidebar menu. A "Help" and "About" menu have also been added on the left sidebar menu along with the Tutorial under a "General" heading as seen in Figures 3 through 6.

In CADS V3.0, the provisions for temperature-dependent physical and mechanical properties are incorporated into an existing database. Other improvements in this version are inclusion of MMPDS driven design allowables for alloys A206-T4, A206-T7, E357-T6, 17-4 PH and 15-5PH developed in the prior AMC/AFS Cast High-integrity Alloy Mechanical Properties Standards (CHAMPS) program. Just like CADS V2.0, allowance of the typical or actual chemistry with minimum and maximum limits with all key chemical elements including trace elements have been added.

Figure 7 shows a detailed output screenshot for 356 properties in the permanent mold casting process with chemistry details supporting the data. Figure 8 shows the processing pedigree information for the same property dataset contained in CADS referenced in Figure 7. Other enhancements in V3.0 include additional fields within the aluminum alloys such as Secondary Dendrite Arm Spacing (SDAS) and grain size. There are also links to the strain life fatigue data in either an MS-Excel file format (when available) or graphically with figures or tables, for the various iron, aluminum, copper and steel grade alloys where this data exists.
Another improvement in CADS V3.0 is to show only the available properties where data exists in the database. When a property does not exist for a certain alloy, that property is not listed as a selectable item as it had been in CADS V2.0. Accordingly, time is not spent selecting properties where datasets do not exist.

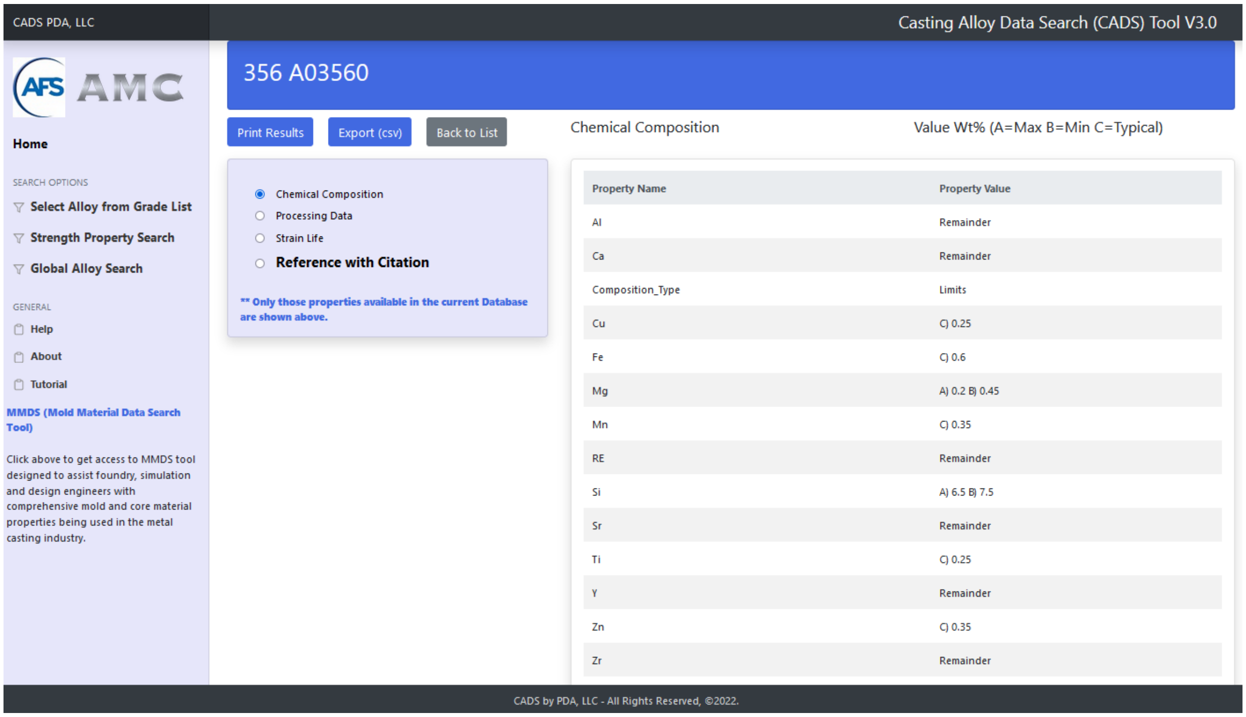

Figure 7. Screenshot of 356, 0.5" thick, permanent mold chemical composition output display on CADS.

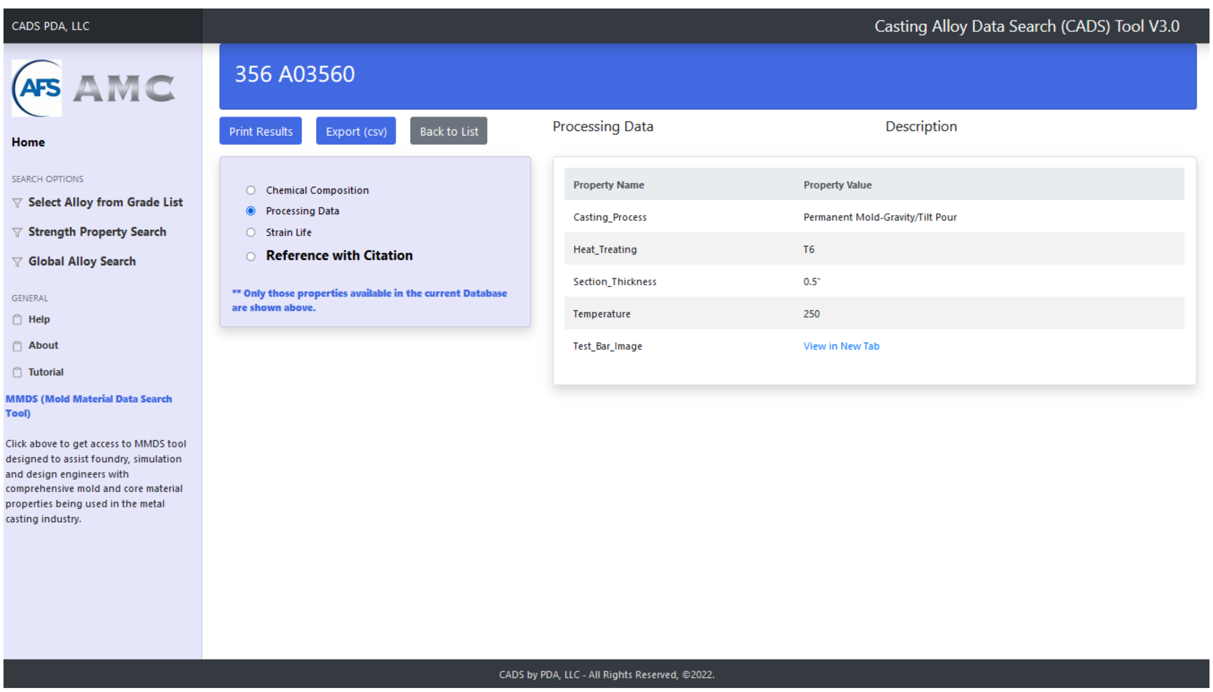

Figure 8. The 356, 0.5" thick, permanent mold processing data output display.

Significant effort was spent during the latest project properly storing all the reference research reports and test report documents for every dataset into the digital AFS Library. The AFS Library was chosen as the pedigree repository, so CADS users can view the title, citation, front cover, and file name of the reference document for data searched. CADS V3.0 has a direct link to the AFS Library, which is accessible only to those with an AFS membership login, thereby keeping the detail reports secured under controlled access but readily retrievable to those with a login. Figure 9 is a screenshot of a search output for 356 permanent mold process with 0.5" thickness when clicked on the "Reference with Citation" button. To accomplish a direct link to the AFS Library, the entire CADS V2.0 database had to be imported into the V3.0 database and relocated/reprogrammed under a secured AWS server for stability and versatility. This transition required periodic minimal software upgrades to keep the open-access database live during migration

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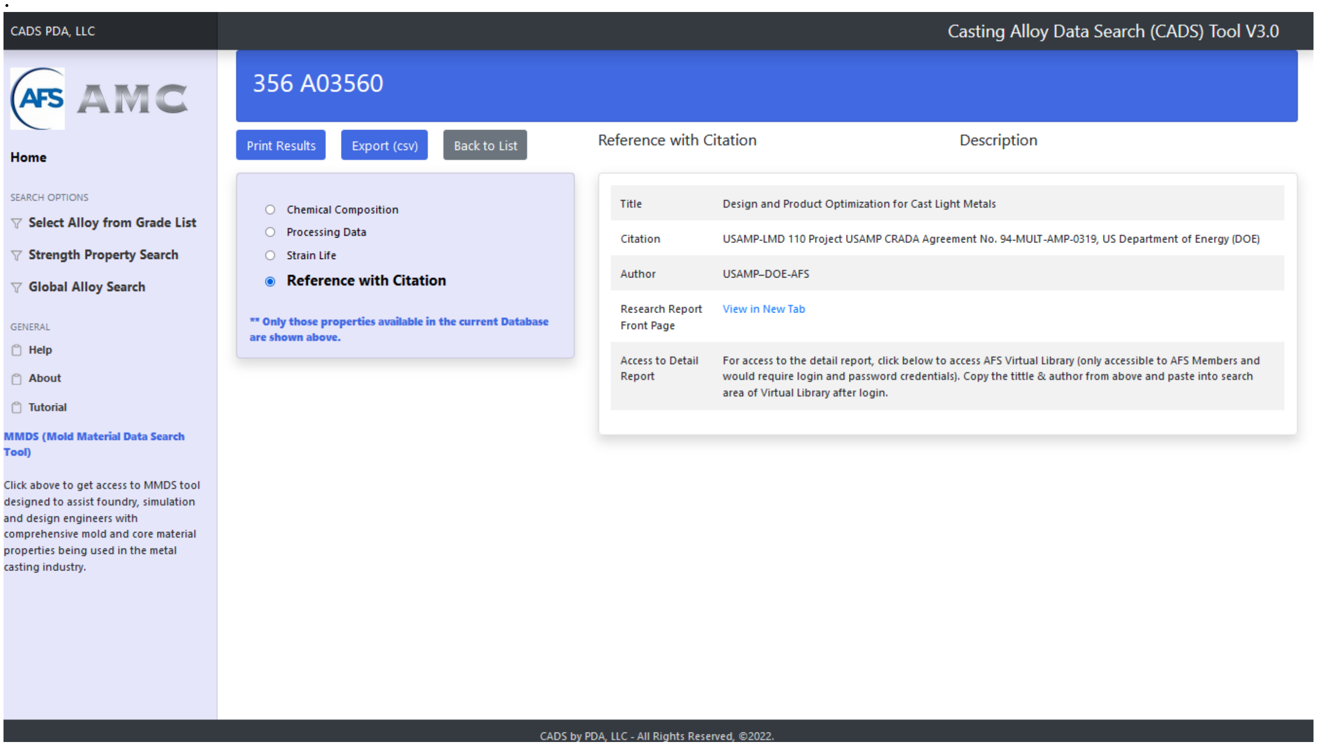

Figure 9. Screenshot of new reference with citation link in CADS V3.0 (example is 356 permanent mold, 0.8" alloy).

Task 2: Best Practice-Driven Design Allowable

The authors worked with the member foundries to develop T99 (A-Basis) and T95 (B-Basis) design allowable values for 24 cast alloys using methods followed and approved by the MMPDS. A graphical illustration of the latest T99 and T95 normal set is provided in Figure 10. Several participating foundries provided the multiple heats- and lots-qualified data required to calculate the T99 and T95 values and the results were added into CADS V3.0.

Tables 1 and 2 show a total of 24 datasets with Table 1 containing dataset information for the 12 steel alloys and Table 2 containing the same dataset information for the various non-steel alloys (four aluminum, six iron, and two copper alloys). These tables were generated using datasets provided by AFS member foundries from separately cast test bars data over multiple heats. Each dataset is reviewed and only acceptable lots meeting the minimum required properties are taken into the calculation for design allowable values using the MMPDS methodology

A typical output from the MMPDS tool showing T99 and T95 values as highlighted in yellow appears in Table 3. This dataset was from the A206-T4 best practice data with 586 datasets/heats. Furthermore, a Pearson Probability Plot for the same alloy appears in Figure 11.

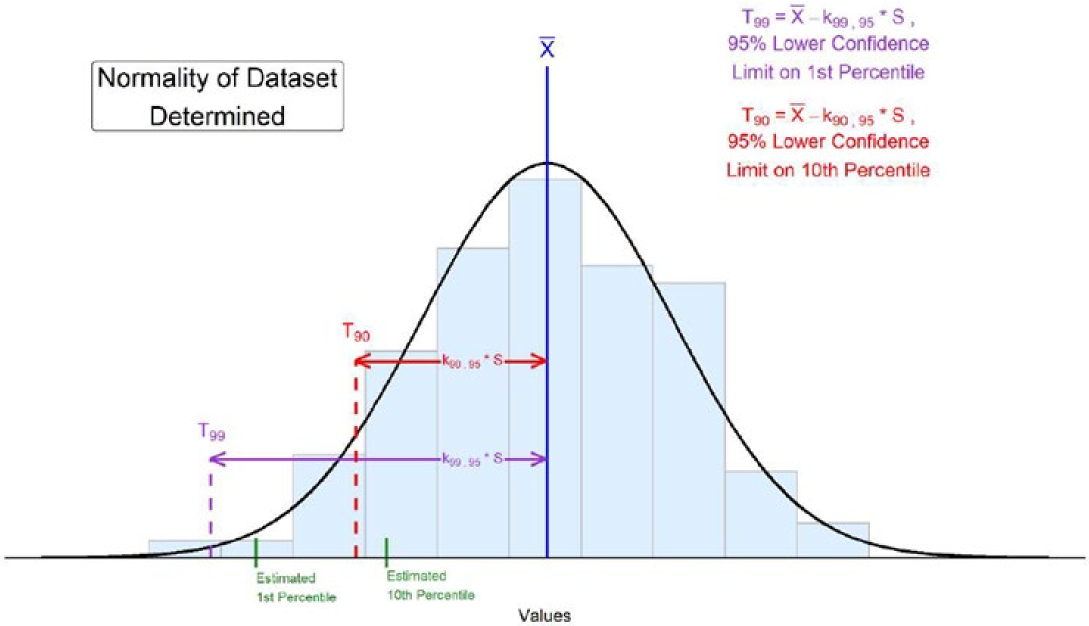

Figure 10. Calculation of T99 and T95 values for a small single dataset.

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Table 1. Best Practice Industry Data to Derive Design Allowable Values (T99 and T95)−Steel Alloys

	Steel											
Grades	WCB	CF8M	CF8	CF8C	CF3	CF3M	CA6NM	17-4 PH H925	17-4 PH H1000	17-4 PH H1150	WC9	WC6
Process	Sand Casting (CB, shell)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Investment Cast	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)
ASTM /SAE/AMS Referenced	A216	A351	A351	A351	A351	A351	A487	A747	AMS 5343E	A747	A217	A217
H/T	N	SA	SA	SA	SA	SA	SA	H 925	H 1000	H 1150	N	N
(UT-ksi,Y -ksi,%E)	70-95, 36, 22%, 25%	70,30,35%	70,30,35%	70,30,30%	70,30,35%	70,30,30%	100,75,17%, 35%	175,150,5%	150,130,4%	125,97,10%	70 to 95, 40, 20%, 35%RA	70 to 95, 40, 20%, 35%RA
Test Bar section thickness	1"	1"	1"	1"	1"	1"	4"	1"	0.25"	1"	1"	1"
Machined gauge dia	0.5"	0.5"	0.5"	0.5"	0.5"	0.5"	0.5"	0.5"	0.2"	0.5"	0.5"	0.5"
Keel Block	1" dia test bar with top riser	1" dia test bar with top riser	1" dia test bar with top riser	1" dia test bar with top riser	1" dia test bar with top riser	1" dia test bar with top riser	4"x4"x10"	1" dia test bar with top riser	Cast Integral Test Bar of 0.25" Gauge Dia	1" dia test bar with top riser	4"x4"x10"	4"x4"x10"

Table 2. Best Practice Industry Data to Derive Design Allowable Values (T99 and T95)−Non-steel Alloys

	Aluminum					Iron						Copper Alloys	
Grades	A206-T7	A206-T4	A356-T6	A356-T6	E357-T6	D8036 /N550/80-55-06	D10036/N700 /100-70-03	D65	60-40-18	65-45-12	80-55-06	C83600 (Red Brass)	C89833 (Bi Red Brass)
Process	Sand Casting (CB)	Sand Casting (CB)	Sand Cast - Unchilled	PM	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)
ASTM /SAE/AMS Referenced	B686	B686	B686	B108	B686	ASTM 536	ASTM 536	ASTM 536	SAE D4018 Mod	SAE D4512 Mod	SAE D5506	B584	B584
H/T	T7	T4	T6	T6	T6								
(UT-ksi,Y -ksi,%E)	(50,40,3)	(50,30,10)	(38,26,5)	(38,26,5)	(45,3)	(80,55,06)	(100,70,03)	(65,45,12)	(60, 40, 10%, 4.4 mm BHN 187 Max)	(65,45,7%; 4.1-4.8 mm BHN 156-217)	(75,50,6%, 3.8-4.4 mm - BHN 187-255)	(30, 14, 20%)	(30, 14, 16%)
AMS Spec	4235B	4236B											
	(50,40,3)	(50,30,10)	(38,26,5)	(38,26,5)									
						SAEJ434	SAEJ434						
Test Bar section thickness	1/2 "	1/2 "	1/2 "	1/2 "	1/2 "	1"	1"	1"	1.57"	1.57"	1.57"	0.7"	0.7"
Machined gauge dia	as-cast	as-cast	as-cast	as-cast	as-cast	1/2" dia	1/2" dia	1/2" dia	0.5"	0.5"	0.5"	As-cast (B208 Fig4)	As-cast (B208 Fig4)
Keel Block	NA	NA	NA	NA	NA	modified keel block with 1" dia TB	modified keel block with 1" dia TB	modified keel block with 1" dia TB	145x45x90 mm block	145x45x90 mm block	145x45x90 mm block	NA	NA

Table 3. A206-T4 Design Allowable from Best Practice Industry Data

Supplier: Alloy - Temper	ALL: - A206			ALL: - A206			ALL: - A206		
Product Form	T4			T4			T4		
Property(Orientation)	TUS	(ALL)		TYS	(ALL)		ELG	(ALL)	
Thickness Min / Max	0.5	0.5	in	0.5	0.5	in	0.5	0.5	in
Sample Size	596			596			596		
Sample Mean	60.061		ksi	37.122		ksi	14.502		%
Sample Std. Dev	2.826		ksi	1.725		ksi	2.663		%
Sample Skewness	-0.774		ksi	-0.509		ksi	0.108		%
COV	4.706		%	4.646		%	18.362		%
Sample Min / Max	48.4	66.6	ksi	29.5	43.9	ksi	10	26	%
Number of Heats / Lots	596	596		596	596		596	596	
Method	T99	T90	Status	T99	T90	Status	T99	T90	Status
Weibull	50.001	55.849	Accepted	31.4	34.535	Lower 50% Subtracting 0.148 units	9.284	10.454	Lower 50% Subtracting 0.290 units
Pearson	51.12	55.889	Accepted			Rejected			Rejected
NonParametric	49.4	56		30.2	34.8		10	10.5	
Normal Method	53.1	56.17	Not normal	32.874	34.748	Not normal	7.944	10.836	Not normal
50 % Censored Normal	51.546	55.562	$R^2 = 0.976$	32.03	34.431	$R^2 = 0.956$	7.894	10.649	$R^2 = 0.966$
Best Fit	Pearson			Weibull			Sample min meets spec min		
Rounded	51	56	kis	31	35	ksi	10		%
See Notes									
preliminary A-Basis (T99)	51			31			10		
Preliminary B-Basis (T95)	56			35			10		
Preliminary S-Basis	45			30			10		

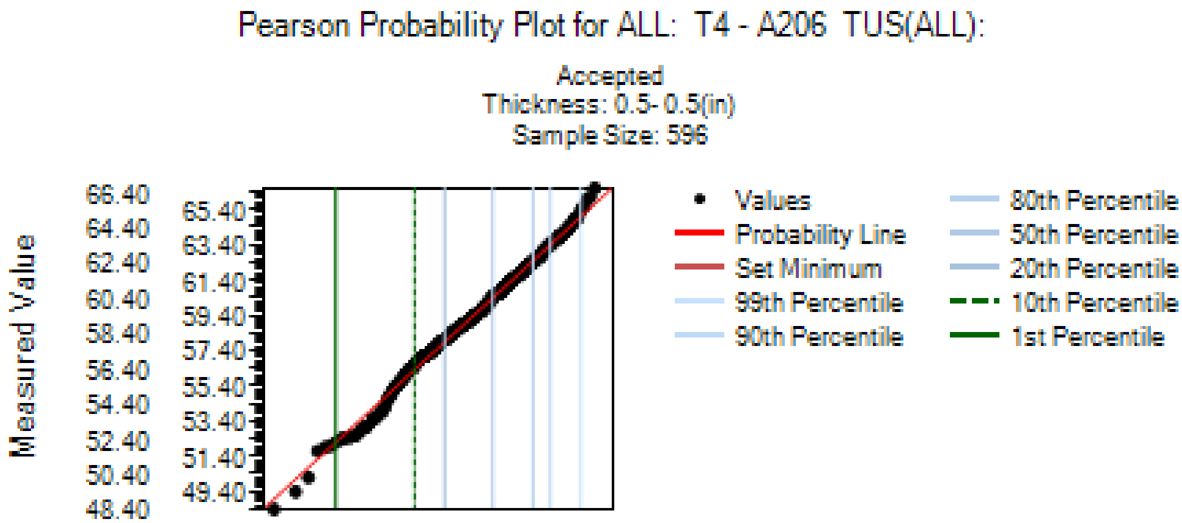

Figure 11. Probability plot for ultimate tensile strength using best practice industry data for A206-T4.

RESULTS AND DISCUSSION

A user-friendly, open-access database tool, Casting Alloy Data Search (CADS), was developed as an online casting material database to assist the Department of Defense (DoD), Original Equipment Manufacturers (OEMs), and metalcasters with easy accessibility to critical design properties on a digital format. This database has been designed so that the material properties can be imported into Computer Aided Engineering (CAE) and Finite Element Analysis (FEA) tools along with casting process simulation programs. CADS assists the casting design engineer with the latest datasets for engineering properties including strain life fatigue values determined using the latest test methods available. This database includes an updated tutorial with detailed instructions along with both a help function and a case study for navigation.

The datasets from CADS V2.0 remain in CADS V3.0. Tables 4 and 5 show the T99 (equivalent to A-Basis per MMPDS latest method), T95 (equivalent to B-Basis per MMPDS latest method) and S-basis (minimum allowable per the corresponding standard) for various steel and non-steel (iron, aluminum and copper) alloy grades, respectively. In most alloys, the T99 and T95 strength values either exceed or are very close to the minimum required by the applicable standards. Data from 14,542 heats were reviewed and analyzed and the full report with detailed information on methodology, along with the various probability distribution graphs outputs for each alloy grade by the MMPDS tool, appears in Reference #8.

The CADS V3.0 database continues to grow with the addition of several alloys each year and now has over 400 datasets including various irons grades (e.g., Austempered Ductile Iron (ADI), Solution Strengthened Ferritic Ductile Iron (SSFDI), and High Silicon Molybdenum Iron (HiSiMo)), various grades of common cast steels (e.g., WCB steel, 4330 steel, 8630 steel, CF8M (316) stainless steel, and 420 (CP40) stainless steel), numerous aluminum and magnesium alloys imported from USCAR/USAMP research projects, and two newly-generated copper alloys (C95800 and C89833). Other datasets added include 17-4PH and 15-5PH steel data, 357-T6 (0.5” to 2” thickness) and A206 (T4 and T7) aluminum MMPDS data from the CHAMPS project.

Photomicrographs at 50x, 100x, and/or 500x (both etched and/or un-etched) were incorporated when available into the CADS V3.0 datasets; including several of the iron and aluminum alloys. The photomicrographs can be retrieved under the “microstructure” selection under the alloy listing. For example, Figure 12 is the search result for SSF-500-14 grade of ductile iron and Figure 13 is an example of the SSF-500-14 microstructure at 100x.

Table 4. Best Practice Industry Data Derived Design Allowable Values ((T99, T95 and S-basis) −Steel Alloys)

	Steel											
Grades	WCB	CF8M	CF8	CF8C	CF3	CF3M	CA6NM	17-4 PH H925	17-4 PH H1000	17-4 PH H1150	WC9	WC6
Process	Sand Casting (CB, shell)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Investment Cast	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)
ASTM /SAE/AMS Referenced	A216	A351	A351	A351	A351	A351	A487	A747	AMS 5343E	A747	A217	A217
H/T	N	SA	SA	SA	SA	SA	SA	H 925	H 1000	H 1150	N	N
(UT-ksi,Y -ksi,%E)	70-95, 36, 22%, 25%	70,30,35%	70,30,35%	70,30,30%	70,30,35%	70,30,30%	100,75,17%,35%	175,150,5%	150,130,4%	125,97,10%	70 to 95, 40, 20%, 35%RA	70 to 95, 40, 20%, 35%RA
AMS Spec												
Test Bar section thickness	1"	1"	1"	1"	1"	1"	4"	1"	0.25"	1"	1"	1"
Total No. of Heats	5084	1378	69	45	37	1201	94	31	31	24	7	24
UTS - ksi T99 (A Basis)	72	70	69	73	69	70	94	171	147	123		70
T95 (B Basis)	76	74	73	75	74	74	101	174	155	128		70
S Basis	70	70	70	70	70	70	100	175	150	125	70	70
YS-ksi T99 (A Basis)	42	33	31	17	28	35	76	145	137	98		31
T95 (B Basis)	47	38	36	27	34	39	76	151	145	99		41
S Basis	36	30	30	30	30	30	75	150	130	97	40	40
E % T99 (A Basis)	23	36	39	40	36	36	16	2		7		13
T95 (B Basis)	25	44	49	46	46	44	18	5		11		21
S Basis	22	30	30	30	30	30	17	5	4	10	20	20
Hardness - BHN T99 (A Basis)		108	120	125	138	138		340		284		
T95 (B Basis)		132	138	140	151	151		357		284		
S Basis								375		269		
RA % T99 (A Basis)	36						38					35
T95 (B Basis)	41						51					48
S Basis	35						35		12		35	35

Table 5. Best Practice Industry Data Derived Design Allowable Values ((T99, T95 and S-basis) − Non-steel Alloys)

	Aluminum					Iron						Copper Alloys	
Grades	A206-T7	A206-T4	A356-T6	A356-T6	E357-T6	D8036 /N550/80-55-06	D10036/N700 /100-70-03	D65	60-40-18	65-45-12	80-55-06	C83600 (Red Brass)	C89833 (Bi Red Brass)
Process	Sand Casting (CB)	Sand Casting (CB)	Sand Cast - Unchilled	PM	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)	Sand Casting (CB)
ASTM /SAE/AMS Referenced	B686	B686	B686	B108	B686	ASTM 536	ASTM 536	ASTM 536	SAE D4018 Mod	SAE D4512 Mod	SAE D5506	B584	B584
H/T	T7	T4	T6	T6	T6								
(UT-ksi,Y -ksi,%E)	(50,40,3)	(50,30,10)	(38,26,5)	(38,26,5)	(45,3)	(80,55,06)	(100,70,03)	(65,45,12)	(60, 40, 10%, 4.4 mm BHN 187 Max)	(65,45,7%; 4.1-4.8 mm BHN 156-217)	(75,50,6%, 3.8-4.4 mm - BHN 187-255)	(30, 14, 20%)	(30, 14, 16%)
AMS Spec	4235B	4236B											
	(50,40,3)	(50,30,10)	(38,26,5)	(38,26,5)									
						SAEJ434	SAEJ434						
Test Bar section thickness	1/2 "	1/2 "	1/2 "	1/2 "	1/2 "	1"	1"	1"	1.57"	1.57"	1.57"	0.7"	0.7"
Total No. of Heats	324	596	669	263	132	1544	470	1010	12	176	272	366	683
UTS - ksi T99 (A Basis)	49	51	34	38	34	88	111	66		65		30	30
T95 (B Basis)	54	56	36	40	36	94	116	68		67		33	31
S Basis	50	50	34	38	40	80	100	65	60	65	65	30	30
YS-ksi T99 (A Basis)	38	31	24	25	24	54	70	45		40	56	13	13
T95 (B Basis)	43	35	27	28	27	56	70	45		42	59	15	16
S Basis	40	30	24	26	34	55	70	45	40	45	55	14	14
E % T99 (A Basis)	3	10	3.5	3.3	1	6	3	11		9	3	14	17
T95 (B Basis)	3	10	3.5	5.4	2	7	4	14		12	4	20	19
S Basis	3	10	3.5	5	1	6	3	12	18	12	6	20	16
Hardness - BHN T99 (A Basis)			71	71	89	197	240	156		216	295		
T95 (B Basis)			78	81	94	212	250	163		193	279		
S Basis			80	80	88								

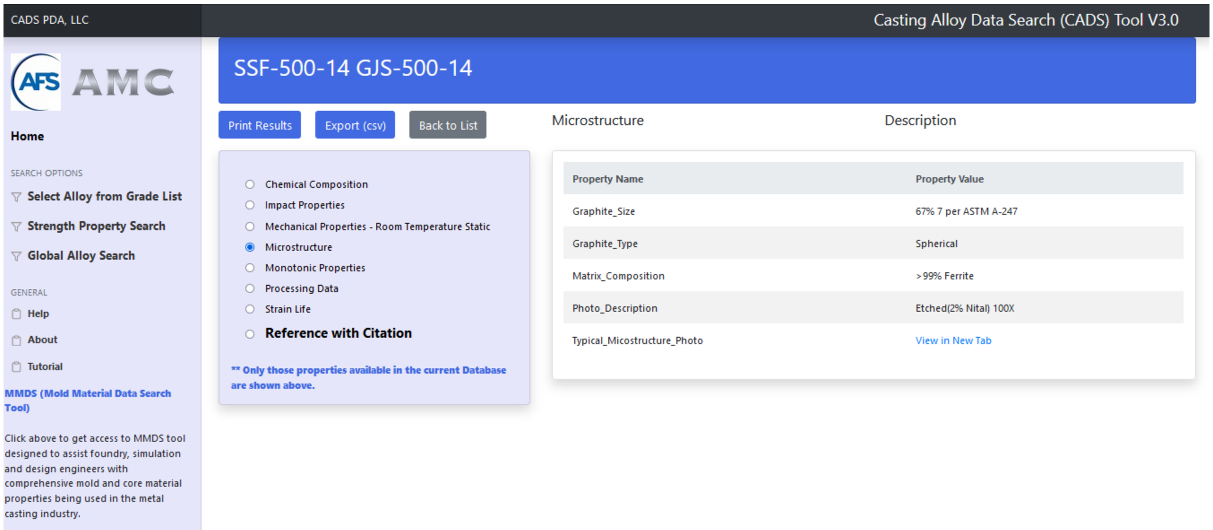

Figure 12. The SSF-500-14 grade of ductile iron in CADS.

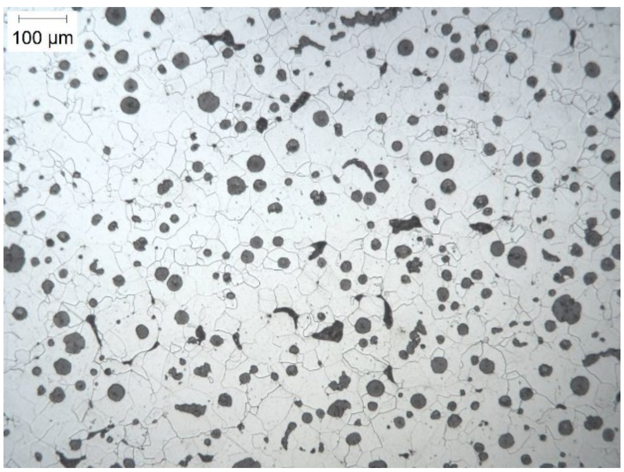

Figure 13. Photomicrograph of SSF-500-14 ductile iron.

TRANSITION TO INDUSTRY

One of the primary objectives of AFS is the transfer of technology into industry and there are several ways in which this was accomplished at AFS. There are more than 900 corporate members and 7000 individual AFS members. This footprint makes reaching a multitude of industry partners and their OEM customers possible. Many industry foundries supplied data and/or in-kind for this project working through the various AFS Technical Committees on Iron, Aluminum & Light Metals (Aluminum, Magnesium), Steel, Copper, and Molding. These technical committees have a vested interest in this database and provide invaluable support and oversight. This information has also been distributed to multiple industry OEMs via presentations and live demonstrations at the annual AFS Metalcasting Congress to an average attendance of 25 people each over the past 10 years. A dedicated CADS webinar was organized by AFS as well and is available on demand on the AFS website. Finally, CADS has been incorporated into the AFS Institute's "Casting Design" course and was promoted on the AFS website and in AFS publications.

CONCLUSION

The CADS tool is continuously being upgraded with more data and more data fields and is maintained on a secure server. The new CADS V3.0 database contains over 400 datasets. The AFS digital library is available to AFS members including active military email accounts using a .mil or .civ email address.

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REFERENCES

1. Tartaglia, John, "Strain-Life Fatigue Data for Two Casting Types of Cast Copper Aluminum Bronze C958," Element Materials Technology (Feb. 7, 2019). (Link last accessed 01-16-25.)
2. Tartaglia, John, "Tensile Data for Two Casting Types of Cast Bismuth Red Brass C89833," Element Materials Technology (May 28, 2019). (Link last accessed 01-16-25.)
3. Shah, Jiten, "Aluminum Alloys Best Practice Separately Cast Test Bar Properties Design Allowable with Computation Methodology," Report Prepared for AFS by PDA LLC (2023). (Link last accessed 01-16-25.)
4. Tuttle, R., Ravi, S., "Thermophysical Properties of Green Sands," *AFS Transactions*, Paper 17-084, AFS Metalcasting Congress, pp. 243-255 (2017). (Link last accessed 01-16-25.)
5. Shah, Jiten, "Final Report On The Measurement Of Thermo-Physical Properties Of Shell Resin Bonded Silica Sand," Report Prepared for AFS by PDA LLC (2018). (Link last accessed 01-16-25.)
6. Shah, Jiten, "Final Report on the Measurement of Thermo-physical Properties of 3D Printed Phenolic Bonded Ceramic Sand," Report prepared for AFS by PDA LLC (2020). (Link last accessed 01-16-25.)
7. Giese, Scott, "Influence of Ceramic Aggregate on Cast Iron Properties," *AFS Transactions*, Paper 25-067, AFS Metalcasting Congress (2025).
8. Shah, Jiten; "Best Practice Separately Cast Test Bar Properties Design Allowable Computation Methodology." Report prepared for AFS by PDA LLC (2023). (Link last accessed 01-16-25.)