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Augmenting Machine Design textbooks by Integrating vendor-supplied resources

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Rungun Nathan, a professor and program chair for the mechanical engineering department, joined the faculty at Penn State Berks in 2007 as an assistant professor and was promoted in 2012 to associate professor. He has over 25 combined years of increasing responsibilities in industry and in academia, including at the Centre for Development of Telematics (C-DOT), a telecommunications technology arm of the Indian government, the Indian Institute of Science (IISc.), Bangalore, and Villanova University, PA. Nathan received his BS from the University of Mysore, a postgraduate diploma from the Indian Institute of Science, an MS from Louisiana State University, and a PhD from Drexel University. He worked in electronic packaging in C-DOT and then as a scientific assistant in the robotics laboratory at IISc. in Bangalore, India, and as a postdoc at the University of Pennsylvania in haptics and virtual reality. His research interests are in the areas of brain traumatic injury, unmanned vehicles, particularly flapping flight and Frisbees, mechatronics, robotics, MEMS, virtual reality, and haptics, as well as teaching with technology. He has ongoing research in brain traumatic injury, flapping flight, frisbee flight dynamics, lift in porous material, and wound therapy. He is an active member of APS (DFD), ASEE, ASME, and AGMA, and is a reviewer for several ASME, IEEE, ASEE, and FIE conferences and journals. He is co-editor for ASEE publication Computers in Education. Nathan has been a very active member of both the Mechanics and Mechanical Engineering Divisions of ASEE since 2006. He started as a member at large and then rose to chair the Mechanics Division in 2012–2013. He currently is chair of the Mechanical Engineering Division after starting as member at large in 2017. Nathan also has been an active member of ASEE's Engineering Technology, Computers in Education, Educational Research Methods, Multidisciplinary Engineering, Experimentation and Laboratory-Oriented Studies, and Systems Engineering Divisions. He is also one of the organizers for MEEd held annually by ASME. He volunteers as a Program Evaluator for ABET.

Augmenting Machine Design textbooks by Integrating vendor-supplied resources.

Abstract

A course in Design of Machine Elements (aka Machine Design in some programs) is a required part of most Mechanical Engineering curricula in the world. Textbooks for this course are usually divided into two halves: 1) development of failure theories, and 2) design, analysis, and selection of individual machine components such as bearings, flexible power elements (belts, chains), gears, shafts, springs, threaded members, etc. Analytical methods for these individual components are presented at a very general level to provide the student with a broad understanding of the technical issues involved. While this broad understanding provides a good starting point, there is not enough technical detail to facilitate the selection of an actual component from a vendor. In engineering practice, detailed information regarding selection and application of a particular machine component often comes from engineering guides that are supplied by component vendors. A good example of this is the selection of rolling-element bearings. Machine design textbooks present a general description of bearing types, present a few mounting strategies, and give basic bearing life calculations. In practice, roller element bearings are manufactured in a wide number of variations that are intended for specific conditions of use and specific mounting geometry. Engineering guides from the major bearing vendors contain extensive information on proper mounting, allowable loads, and load types, sealing and lubrication, and allowable environment. In practice, engineers use these guides to learn the details involved in selection and application of roller bearings. The author contends that effective use of vendor-supplied engineering guides is a significant skill in engineering practice, in addition to the fundamentals of Machine Design, and is a big missing piece in many curricula.

Since the 1950's, a course in Design of Machine Elements has been a required course in mechanical engineering curricula around the globe. The roots of this course have been the research in solid mechanics, mechanisms, and machine elements. The course mostly focuses on load, analysis of loads, calculations of stresses, static and fatigue failure theories, applying correction factors looked up from data in textbooks and the derivation and application of methods used to analyze individual machine elements such as shafts, bearings, gears, and other elements [1]. Practice of machine design requires different and diverse types of knowledge and using vendor catalog is one among the many diverse knowledge. Liu and Brown have observed that newly graduated mechanical engineers have difficulty dealing with ambiguity and uncertainty when they are faced with real-world machine design problems [2]. Another experience-based skill required by engineers is to move forward amidst ambiguity and uncertainty. Liu and Brown also suggest that including active and project-based learning has the potential to develop this experience-based skills in undergraduate students. Monterrubio and Sirinterlikci implement this active learning approach into the curriculum of a Machine Design course by including a semester-long laboratory in which students design and construct an injection-mold [3]. The authors found increased student engagement and high achievement of experience-based outcomes such as effective use of industrial and manufacturing tools such as CAM, CAE, DFM, DFA and quality tools. Several other authors have published results that support the idea that active, project-based learning is an effective approach to teaching experience-based skills in machine design [4],[5],[6].

Shapiro has pointed out that one of the valuable skills that academia must develop is to "source items" based upon design specification from vendor catalogs [7]. Morales in his work presents how to develop machine design expertise in students by examining components of existing machinery. In the process of examination, the students compare size information from vendor catalog of bearings and gears, instead of being limited to what is present in the textbook [8]. Morales uses the SAE Baja auto on campus as the existing machine. Shooter incorporated designing a machine using a specific vendor's catalog in his machine design course [9]. For each component, the students were required to provide a figure, list it with a description, stock number, page reference and price if available. Kundu used a problem from an axle manufacturer for testing bearing in his design class and students had look up to catalog to obtain parts and costs based on their design [10]. Like many of the previous authors, Pierce, Stone, and Kaul, [11] have introduced elements of selecting components from vendor catalog after performing a typical design calculation. Pierce spent time in their lab delving deeper into catalogs than most of the others. Their work was more related to selecting the component than to incorporate it into the whole design process which this paper intends to do.

To provide context for this paper, the author was taught Machine Design as an undergraduate in Mechanical Engineering from Shigley's textbook [12] along with a Design Data Handbook [13]. The handbook contained the necessary design equations, stress factors charts and tables, correction factors, application factors etc. that are commonly used in designing mechanical components. The handbook was permitted as a reference material in final exams just like the NCEES Exam Reference Handbooks are allowed for FE and PE exams. From this introduction, the author went on to design many anthropomorphic and mobile robots, robotic grippers for which data from [12] and [13] was used and then finalizing the component using vendor catalog and/or discussion with sales engineers from major vendors and catalogs. Later working as an Electronics Packaging Engineer, the author used vendor catalog extensively for selecting components when designing telephone exchange equipment for landlines and private automatic telephone exchanges. These components included mechanical hardware like screws, nuts and bolts, rivets, packaging materials, several types of electrical connectors, card cages to house printed circuit boards, heat sinks on printed circuit boards, card ejectors mounted on printed circuits, and many other related components. Dependence on first designing and then reaching out vendors to supply the need was the typical approach in the industry the author worked.

As an instructor, the author has been teaching ME 367 - Machine Design since spring 2014 (offered once in the academic year) and started by using only the textbook and data provided in the book by Shigley [12] for the first two years and afterwards Norton [14]. Grading used quizzes and exams for assessing the course outcome. The author who also teaches the two semester Capstone design course ME 448/449 noticed that students struggled selecting components from vendor catalog. They could design components and size them based on their sixth semester ME 367 - machine design course but demonstrated struggle in selecting and specifying components from catalogs which was required for their design and build in capstone projects. This struggle shown by students inspired the change in the machine design course from the more traditional quizzes and exams to design project driven course implementation and project-based assessment.

In spring 2016, Machine design ME 367 was restructured to have three projects based on the problems from Shigley [12]. Project 1 involved the design of a shaft and components like the keyways and circlips. Project 2 was the design of a gear set. Project 3 was the design of sleeve bearings, and a selection of roller element bearings. In the first year the students were asked to select data and components from what is available in the textbook. The same approach was applied in spring 2017 but the project scope was expanded to have less details, so students had to make choices as the design proceeded. For example, project 1 started with a given material and uniform diameter. After this the project called for a slope and deflection to be met while the diameter was still constant. After the slope and deflection design was completed, the students were required to change the design to have features like change in diameter for the gears to be seated against and bearings to be held between a step in the shaft and a circlip making the design more realistic.

In spring 2018, a brief introduction in the lecture was given to using a bearing calculator from SKF [15]. The tool at that time was not the same as it is now, but helped to get more data for the bearings that were selected from the required class textbook by Norton [14]. If one creates a free account on the SKF website, one could generate a technical report of the selected bearing, and this was also demonstrated in class. It provided additional information that was not in the textbook and the students had the option of using it for the roller element bearing selection part of their project. A sizable number of students used the vendor website for their project and created and submitted the technical report from the vendor. The use of SKF tool was further developed and used in the Spring 2019 semester. See appendix A for instructions given in class to use vendor provided bearing selection tool. Anecdotally the students in 2018 and 2019 from machine design had better comfort in Capstone class when selecting components, particularly bearings. (12 Capstone projects in 2 sections in 2018-2019 and 8 Capstone projects in 2 sections in 2019-2020)

With the success seen in student comfort with using vendor catalog in component selection, Spring 2020 added more details, and it was required for all students to only use vendor catalog and website in the selection of bearing for project 3. The project also added the requirement that students had to select the fit based on vendor catalog recommendation and incorporate it in their project with proper reference to ANSI B4.1 and the page number where it is in the standard. The students were introduced to typical finishes that could be obtained from various machining processes [16] as part of the lecture. Instruction on how to read the fits in ANSI B4.1 was also provided in the class. In the project it was required for students to specify the machining process for the housing and shaft in which the bearing would be used based on their design. Students were also required to obtain the technical report that some of the bearing vendors provided, and it had to be attached to the project report. A sample report from SKF is attached as Appendix B. Also required was for the students to obtain a price for the bearing from industrial suppliers like McMaster Carr or Grainger to name two. The Spring 2020 class of ME 367 - machine design was surveyed in Spring 2021 when they were enrolled in second semester of capstone design ME 449. In spring 2021 some more vendor's websites for bearings were included and demonstrated in class as examples problems were solved. Students had the choice of using any vendor for the project and then later for their capstone design projects. Similar demonstrations of vendor catalogs use were done for gears which is not part of this paper.

Three cohorts of students were anonymously surveyed, and the results are included in this paper. The Capstone class ME 449 in spring 2021, 2023 and 2024 was surveyed and they would have been introduced to vendor catalogs in their ME 367 - Machine Design class in Spring 2020, Spring 2022, and Spring 2023, respectively.

The survey questions included the following questions among others that are not used in this paper. They are:

1. Before taking ME 367 - Machine Design, have you used manufacturers catalog in any course for component selection?
2. Did you use any Bearing Manufacturer's catalog/website for bearing selection? (Yes or No answer).
3. If you answered "Yes" to question 2, using a scale of 1 – 5; rate its usefulness.
4. Did you use any of the guidelines provided by the manufacturer's catalog/website in addition to your calculations? (Yes OR No answer)
5. Introduction of manufacturer's catalog/website was a very useful tool for my understanding and then for Capstone Design? (Likert scale of 1 – 5)

Based on an anonymous survey of the students in Penn State Berks (one of 24 campuses of Penn State University which offers 4-year degree programs), about 56% are employed during the school year. Of these 56% employed, 26% are employed in engineering and related fields. (see figure 1 and figure 2). As the students are employed in engineering related fields some of these have seen and used vendor/manufacturer's catalog at their workplace.

Figure 3 is the results from the question "Have you used Manufacturer's catalog before ME 367class?". It is seen that about 30% over all the years have seen and used catalogs. Some of these are those employed in engineering related jobs. The other contributing factor is because students have another project in junior first semester in which students are required to build adaptive devices to help people with needs. During the prototype development for adaptive devices, some of the students who are actively involved in component selection tend to use manufacturer's catalog and come seeking the author's help. They typically end up using the catalog to buy the component but may not be making full use as taught in the ME 367 class.

Figure 4 shows how many students use the bearing manufacturer's catalog and about 75% of students over all the years use them. 25% probably belong to the teams that do not have bearings or could be from the students that are not directly involved in component selection for their team. Figure 5 shows that of the 75% that use the bearing manufacturer's catalog, 61% use the guidelines. Figure 6 shows that over 66% find the bearing catalog and guidelines very useful or somewhat useful for their Capstone projects. In Capstone projects, where bearing selection is involved, it has been observed that students are now better equipped. The drawings made for manufacturing of the build parts are far better specified for machining and the tolerance needed for the bearings to fit on the shaft and housing – a direct consequence of using the vendor catalog, as the curriculum does not have fits and tolerances anywhere else in the program. Students have extended the use of vendor's catalog and guidelines in the process of selection of other components also.

When students were asked about the usefulness of the introduction and use of vendor catalog and guidelines in ME 367 and the preparation for two semester Capstone design ME 448/449, 74% strongly agree or agree with this statement.

The survey also included a place for students to give any comments about the use of catalogs/manufacturer's website etc. and are reproduced here. The comments are grouped under three catagories. The first set of comments are more general, the second set of comments show how students felt it was useful for the jobs they held after taking ME 367 – Machine Design and before graduating. The last set of comments show the impact students felt on their Capstone Design ME 448/449.

> "*Most if not all courses should use catalogs in their projects. The concepts seem straightforward, but students need guidance when sifting through the details of each component specifically when comparing their calculations to actual parts. This practice would become natural with repetition and the transition from schoolwork to the workforce would be easier.*"

> *"Although I have used manufactures catalogs outside. I never fully understood how to use them properly or how effective they could be until I took machine design ME 367."*

> *"SKF bearing selection was useful and provided a large catalog and critical information for bearing selection."*

> *"I liked how it was more like a real-world scenario where we had to match a real product to our design specifications. I would say that it was very impactful and, in my opinion, it should definitely stay in the course!"*

> *"Covering broader and addition catalog topics may be beneficial for machine design ME 367 or ME 345W (Instrumentation, Measurements, and Statistics) such as electrical components."*

"If I remember correctly, I had problems with using manufacturer catalogs in ME 367 because after I finished my calculations, the parts that matched my solutions did not exist. I could change the specifications of my part to match one of the options from the catalog, but the change in material or size or some aspect of the threading on that one part resulted in one of the other parts no longer being compatible." "I do believe that learning to use a catalog more effectively is a useful skill, but it made the machine design projects far more difficult than they already were."

"The catalogs were somewhat daunting to read over and navigate. Once I was able to figure it out, it helped with picking out a proper bearing, though there were still some challenges with gears."

"Being exposed to catalogs and purchase requests is useful because it is something we will use in future positions in the workforce."

"No comments, the manufacturer's catalog was explored efficiently in ME 367."

"The inclusion of choosing gears and bearings from a manufacturer's catalog helped to identify common pricing trends for characteristics of machine design, such as finding a balance between size and number of teeth on a gear. We learned to design perfect mechanisms, and used the catalogues to change certain values to match a commonly manufactured part that would still fit requirements while minimizing price."

"It would be helpful to have more examples in class that help exhaust the process of using a manufacturer's catalog. It would be very helpful to go through the process of selecting a part, re-evaluating, and reselecting components until you have a satisfactory design. This process was covered in ME 367, but once set on our own it proved to be very difficult and more content on these subjects would be beneficial. Overall, manufacturer's catalogs were a useful addition to the course."

"I am very thankful for the inclusion of the Manufacturer's catalog/website in our class. I never used something like this, and it really opened my eyes to the real world of manufacturing. I really wish professor would include this sort of teaching early in a student's college career to ease them into it and get them used to taking information from the catalog/website and using it."

"Provided real-life experience in being able to read and interpret manufacturer's catalog/website, a skill that will be useful in an engineer's career. It is important to include lessons in college that will be used in our careers, rather than always focusing on just theory and textbook teachings."

Comments indicating the usefulness of vendor catalog in the jobs students held after the class and before graduation.

"I used different catalogs at work, not those specific ones we used in ME 367."

"Utilizing vendor catalogs during class was extremely helpful during my summer internship."

"I think the introduction of catalogs was very useful within this course. I had to do very similar things during my internship the following summer as I was finding parts that fit the equipment I was working on. This class put me a step ahead of most engineers as they did not expect me to be able to understand how to read these data sheets and find what I needed on them."

"Using catalogs and getting comfortable with how to pick parts out of a catalog or website helped me at my internship that I started after taking the class."

"It was nice to get exposure to the industry design process and then to put it to use in my internship."

"The addition of using manufacturer's catalogs gave the course a real-world scenario that will transition directly into a working environment. Developing custom components is not a feasible option (time and money wise) when the components already exist. Being able to leverage off the shelf components to design and build projects is a huge boon in any engineering field."

Comments that talk about the impact of introducing vendor catalog on Capstone Project.

"Using a manufacturer's catalog for selecting gears and bearings in ME 367 - Machine Design was useful in determining what types of components are commercially available and what would need to be custom made. Designing a component such as a gear to meet a parameter and then finding a commercially sold product that satisfies or exceeds parameters is a useful comparison skill that I use in Capstone to determine the best option for a component that requires purchase while taking cost, availability, durability and replaceability into account in design."

"It was very helpful to be exposed to component selection, as it was a large part of our capstone design process."

"I remember thinking "this is a pain" while in ME 367, looking up manufacturer's catalog/website. I now see the importance of the class now. Something engineers make an ideal design on paper but if manufacturers do not have the appropriate dimensions/size to accommodate the design, the design must be modified to reach desire output. For my Capstone project - belt driven bike we used manufacturer catalog to select groove belt, sleeve bearing, and flange bolt that are compatible with the design."

"I remember the bearing catalog and logistics were the hardest to understand in my opinion. During my final project I had an easier time going through the bearing catalog and finding a bearing that would fit onto the design."

As student comments have pointed out, the introduction and use of vendor catalog in ME 367 – Machine design had dramatically changed how students select components for their build in Capstone projects. Even though data was not collected, the number of wrong orders from vendors has been reduced in Capstone Projects. Students are able to get better estimates for components in Capstone Projects and work well in staying under the budget. More Capstone projects have reached successful build with working prototypes in the past few years.

Conclusion: The introduction of vendor's catalogs has been very useful and has improved the instruction in the class as applicable for machine design. The added benefit is that students are now better equipped to make use of these catalogs and guidelines in making component selection in Capstone Projects.

Acknowledgement: Thanks to the students for constant feedback and their willingness to be part of my pedagogy experiments. Thanks to the reviewers who pointed out some important points that vastly improved the final paper.

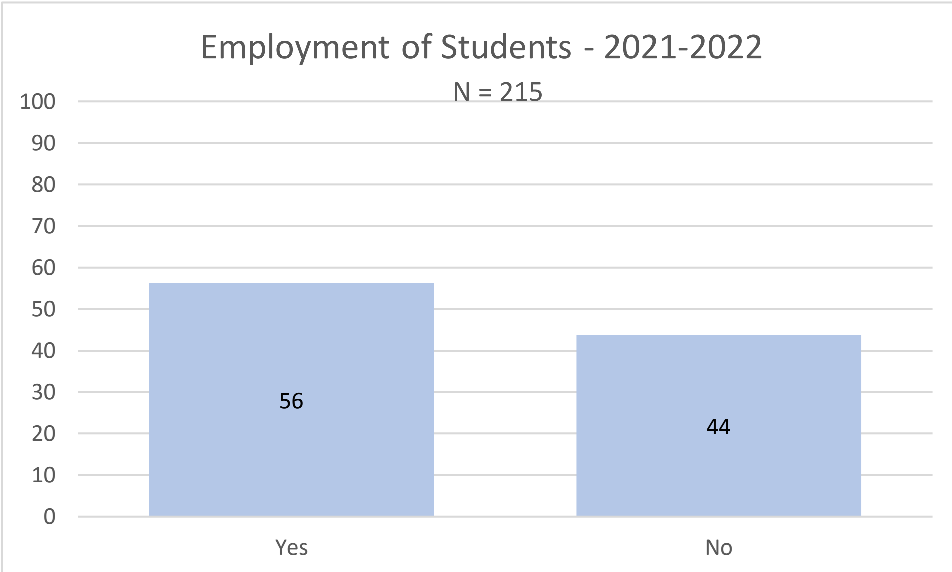

Figure 1. Employment status of 2021-2022 cohort

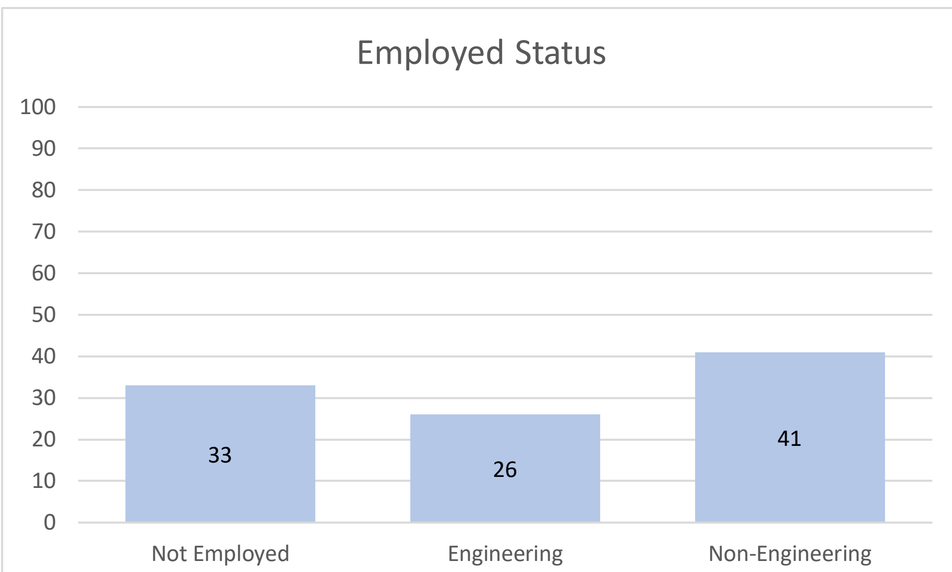

Figure 2. Field of employment of cohort in 2021-2022

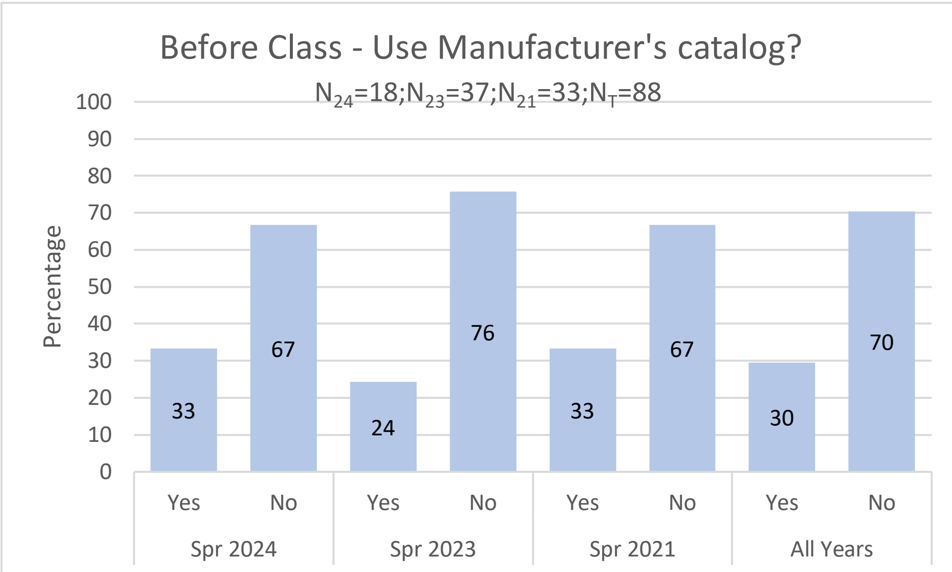

Figure 3. Use of Manufacturer's catalog before ME 367 class?

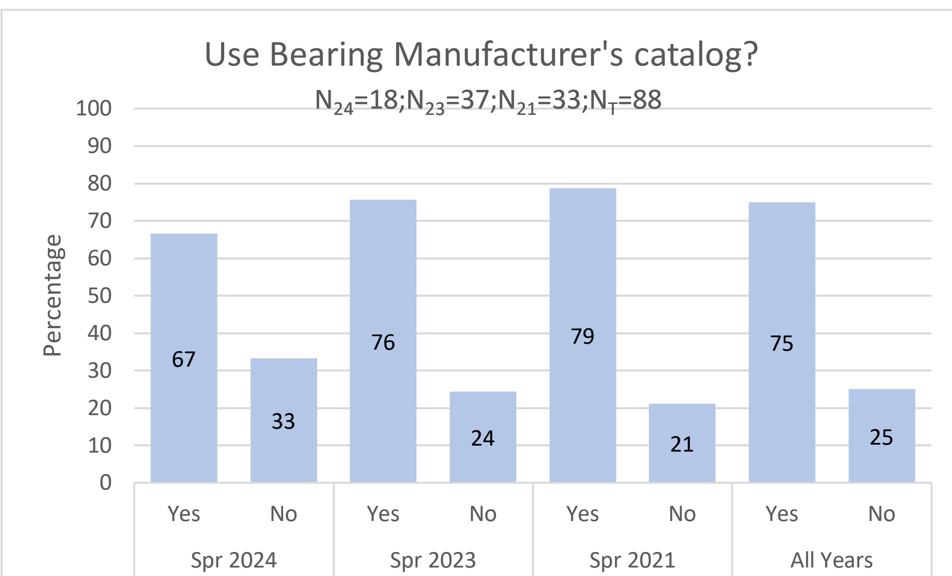

Figure 4. Did you use any Bearing manufacturer's catalog for bearing selection?

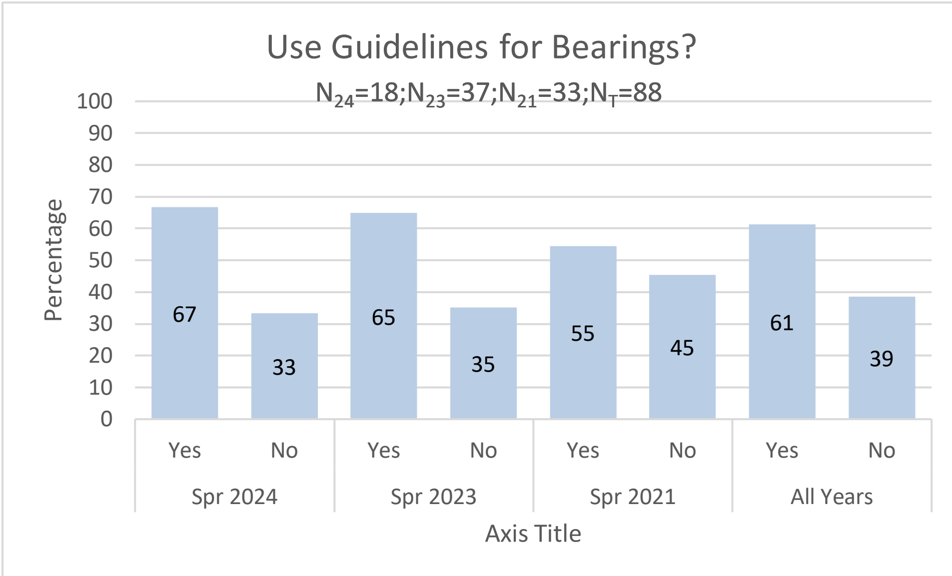

Figure 5. Did you use guidelines provided by Bearing Manufacturers?

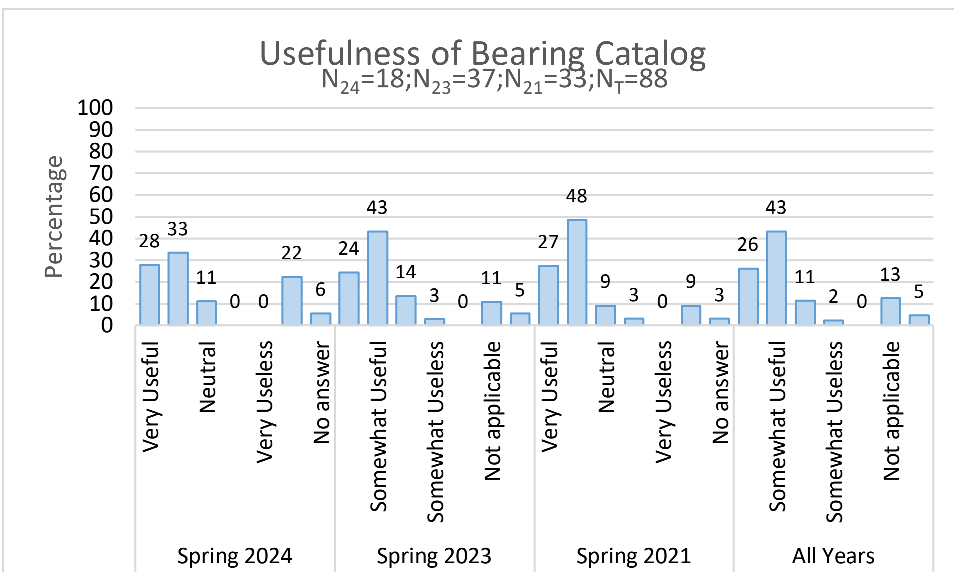

Figure 6. Usefulness of Bearing Catalog/guidelines?

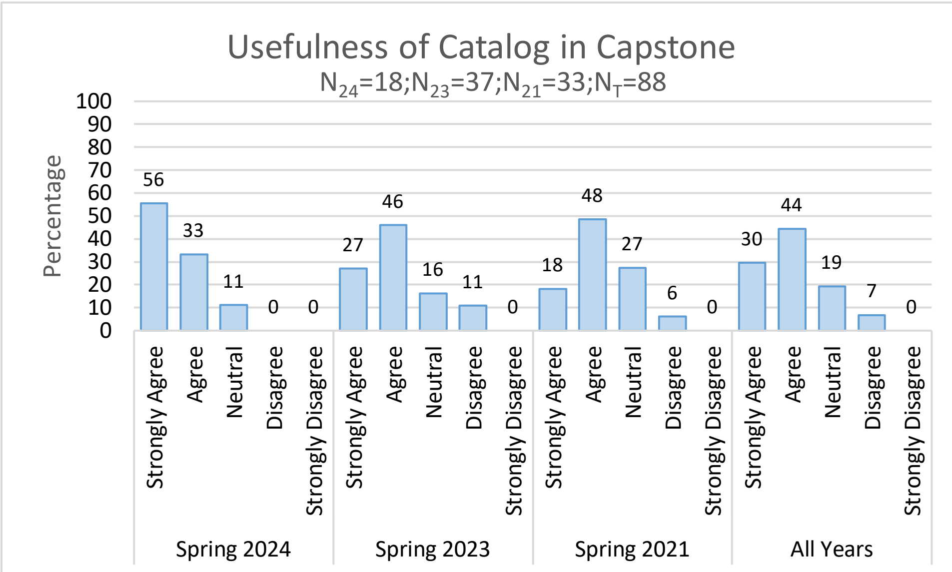

Figure 7. Usefulness of manufacturer's catalog for ME 367 and then Capstone?

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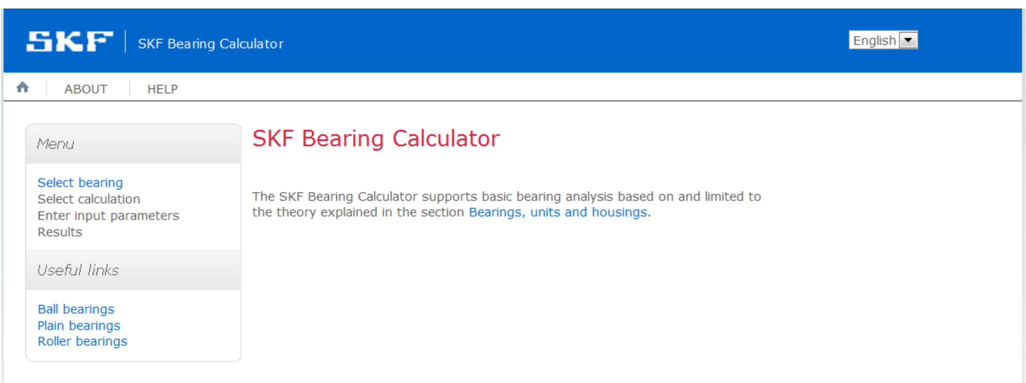
SKF Bearing Calculator

English

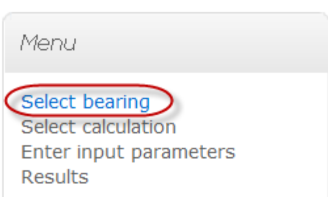
User manual for SKF Bearing Calculator

1. Home page [top]



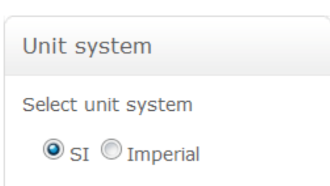
SKF Bearing Calculator is currently available in English.

2. Select bearing [top]



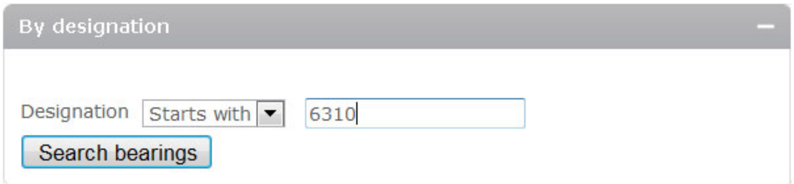
Click on ‘Select bearing’ to search for or add a bearing.

2.1 Unit system



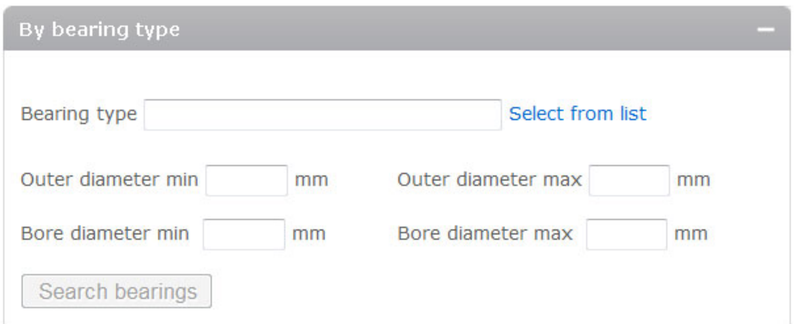
The unit system can be set to either SI or Imperial.
The unit system can be set only on the ‘Select bearing’ page.
The unit system section becomes read only on the other pages.

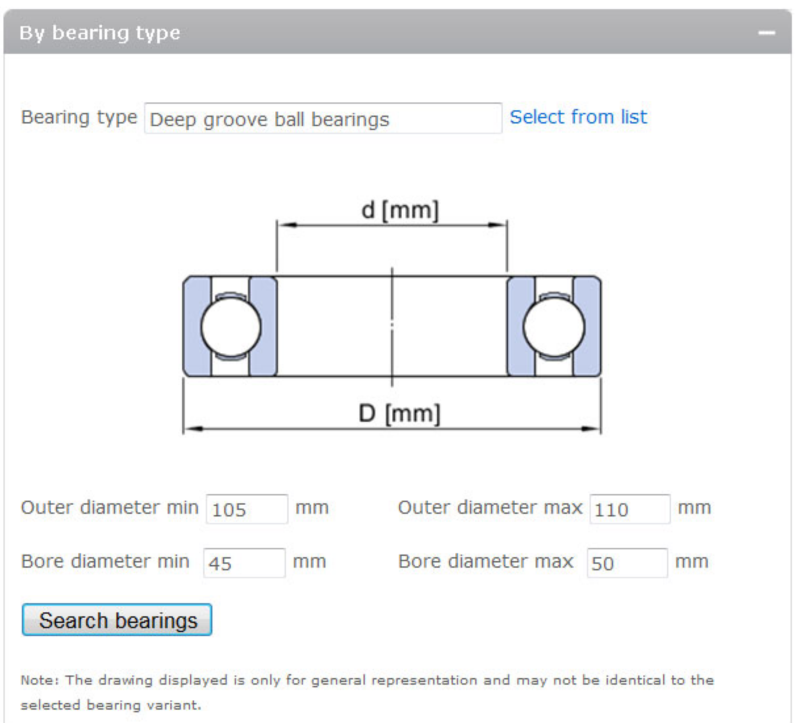
2.2 By designation



The bearing can be searched by SKF designation. The bearing designation can be typed in the search box with the ‘Starts with’ or ‘Contains’ or ‘Ends with’ option. The ‘Search bearings’ button becomes active when three or more characters are typed in the designation search box.

2.3 By bearing type



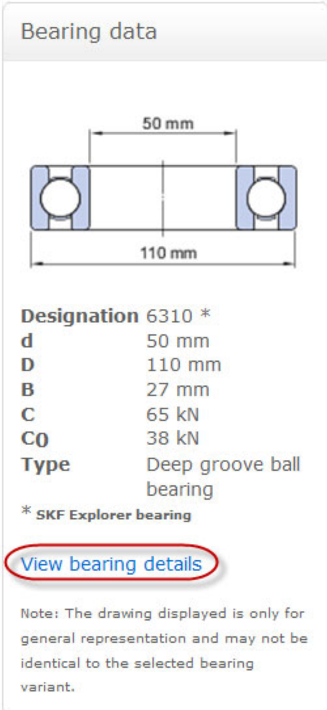


The bearing type can be selected by clicking on the ‘Select from list’ hyperlink. When you select a bearing type from the list, the bearing cross-sectional drawing gets updated on the page. The minimum and maximum values of bearing outer and bore diameters can be provided in the search box.

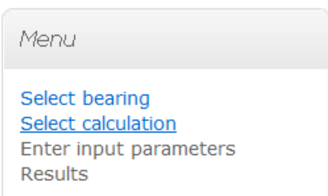
The ‘Search bearing’ button becomes active when bearing type and outer diameter or bore diameter inputs are provided. The ‘Search bearings’ button should be clicked to get the bearing designation list.

When a bearing designation is selected from the search result list, the bearing data gets updated on the right hand side in the ‘Bearing data’ section and the ‘Select calculation’ page opens. The detailed product information can be obtained from the ‘View bearing details’ hyperlink.

Note: The drawing displayed is only a general representation and may not be identical to the selected bearing variant.



3. Select calculation [top]



The underline on the ‘Select calculation’ page shows that the user is currently on the ‘Select calculation’ page.

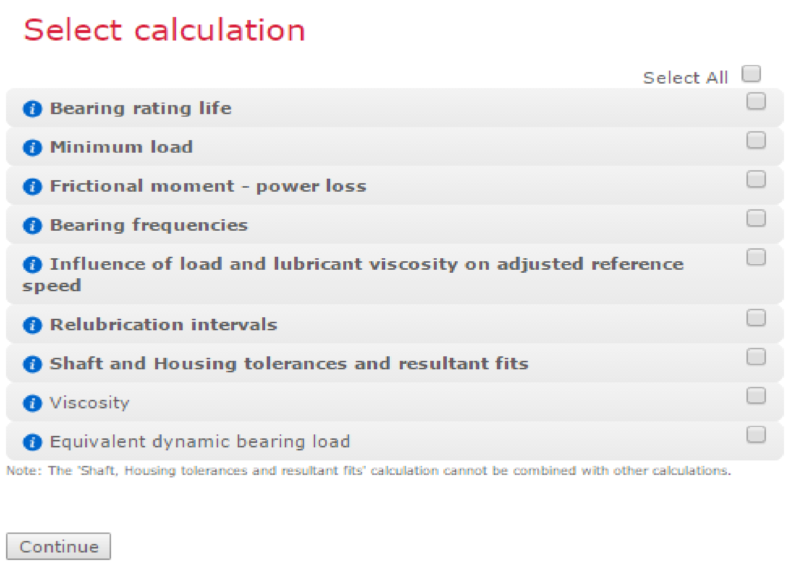
The ‘Select calculation’ list gets updated based on the bearing type selected on the ‘Select bearing’ page.

Single or multiple calculations can be selected.

The ‘i-button’ before each calculation gives more information about the theory behind the calculation.

Click on the ‘Continue’ button to move on to ‘Enter input parameters’.

Appendix A: 2019 Bearing Selection



The following calculations are available in the SKF Bearing Calculator.

Rolling bearings:

1. Bearing rating life
2. Minimum load
3. Frictional moment - power loss
4. Bearing frequencies
5. Influence of load and lubricant viscosity on adjusted reference speed
6. CARB displacement misalignment
7. CARB permissible displacement
8. CARB calculating the free space required on both sides of the bearing
9. CARB bearing reduction of internal radial clearance
10. Dynamic axial load carrying capacity for cylindrical roller bearings
11. Relubrication intervals
12. Grease life for capped deep groove ball bearings
13. Shaft and Housing tolerances and resultant fits
14. Viscosity
15. Equivalent dynamic bearing load

Spherical plain bearings:

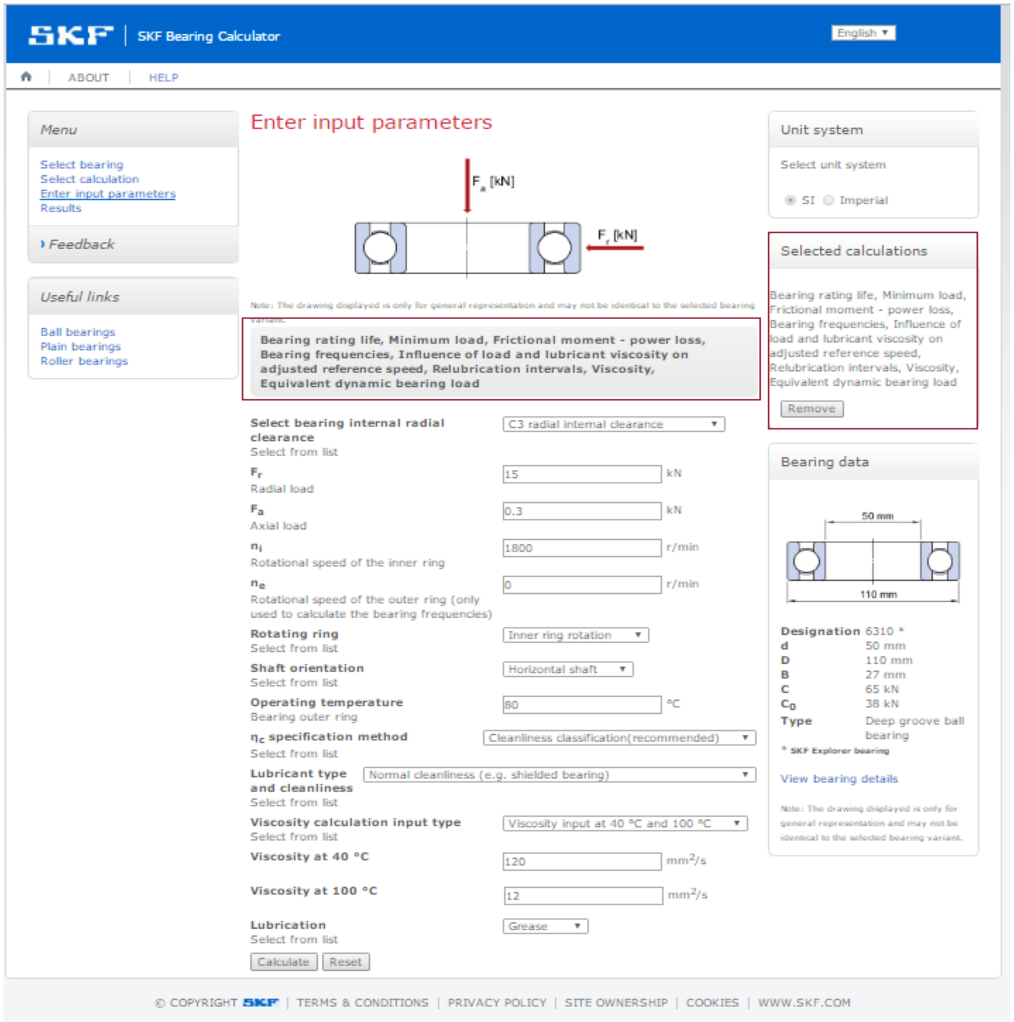
1. Basic rating life for spherical plain bearings and rod ends
2. Frictional moment for spherical plain bearings and rod ends

Composite dry sliding bushings

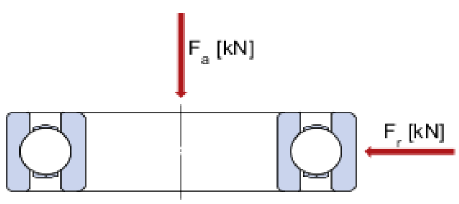
1. Basic rating life for composite dry sliding bushings

Note: The ‘Shaft and Housing tolerances and resultant fits’, spherical plain bearing and composite dry sliding bushing calculations cannot be combined with other calculations.

4. Enter input parameters [top]



The selected calculations are listed just below the bearing drawing and in the 'Selected calculations' section on the right hand side.



Note: The drawing displayed is only for general representation and may not be identical to the selected bearing variant.

Bearing rating life, Minimum load, Frictional moment - power loss, Bearing frequencies, Influence of load and lubricant viscosity on adjusted reference speed, Relubrication intervals, Viscosity, Equivalent dynamic bearing load

Selected calculations

Bearing rating life, Minimum load, Frictional moment - power loss, Bearing frequencies, Influence of load and lubricant viscosity on adjusted reference speed, Relubrication intervals, Viscosity, Equivalent dynamic bearing load

Remove

The selected calculations can be removed by pressing the 'Remove' button.

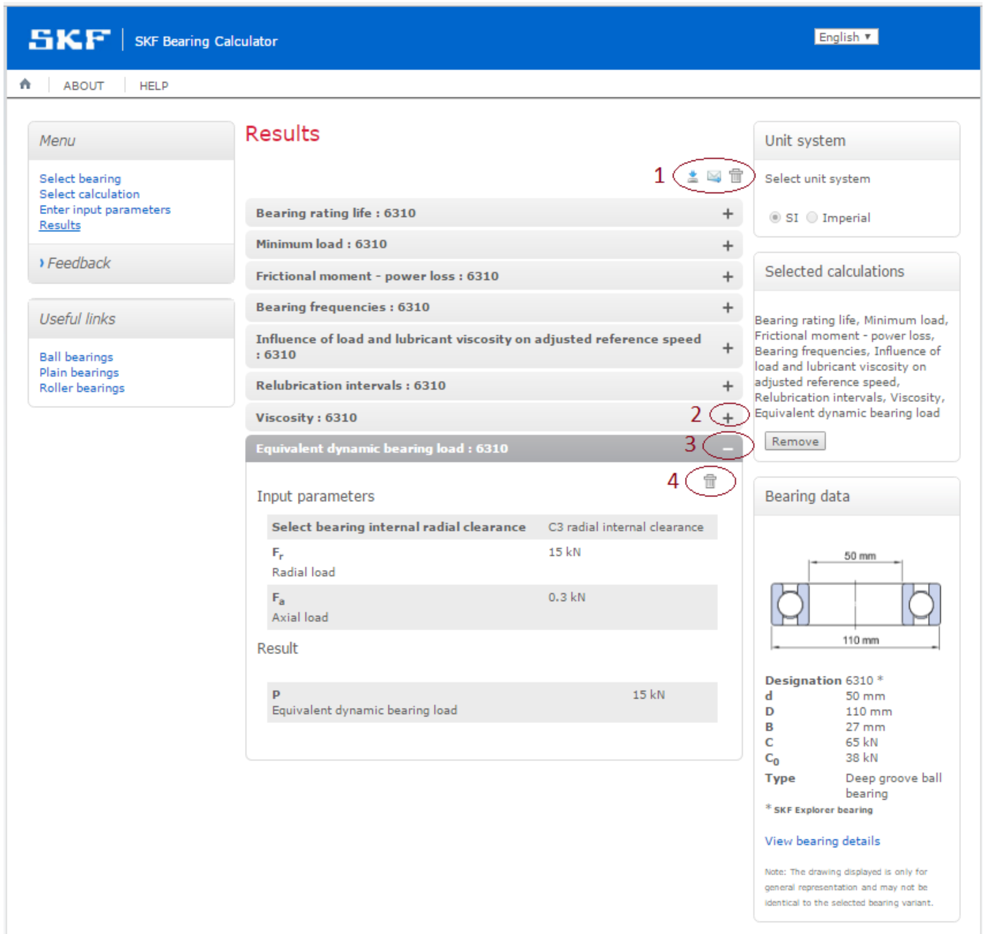
The input parameters (e.g. Radial load, Axial load, Speed, etc) for the selected calculations are provided on this page.

The input parameter list gets updated based on the type of bearing selected on the 'Select bearing' and calculation(s) selected on the 'Select calculation' page.

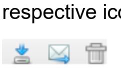
Click on the 'Calculate' button to calculate the results for the selected calculations.
After pressing the 'Calculate' button, the 'Results' page appears.

Click on the 'Reset' button to reset the input parameters on the 'Enter input parameters' page.

5. Results [top]



The detailed output results are shown on this page.
The results can be downloaded, sent by email or deleted by clicking on the respective icons shown by number 1 in the above snapshot.



The result for each calculation can be expanded by clicking on the ' + ' icon on the right hand side of the respective calculation shown by number 2 in above snapshot.

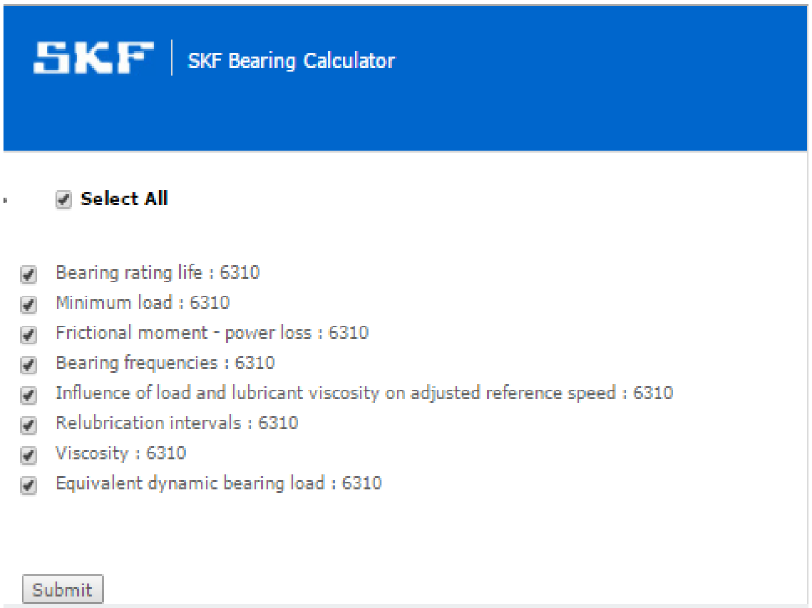
The result of an individual calculation can be collapsed by clicking on the ' - ' icon on the right hand side of the respective calculations shown by number 3 in above snapshot.

The result of an individual calculation can be deleted by clicking on the delete icon on the right hand side of the respective calculation shown by number 4 in above snapshot.

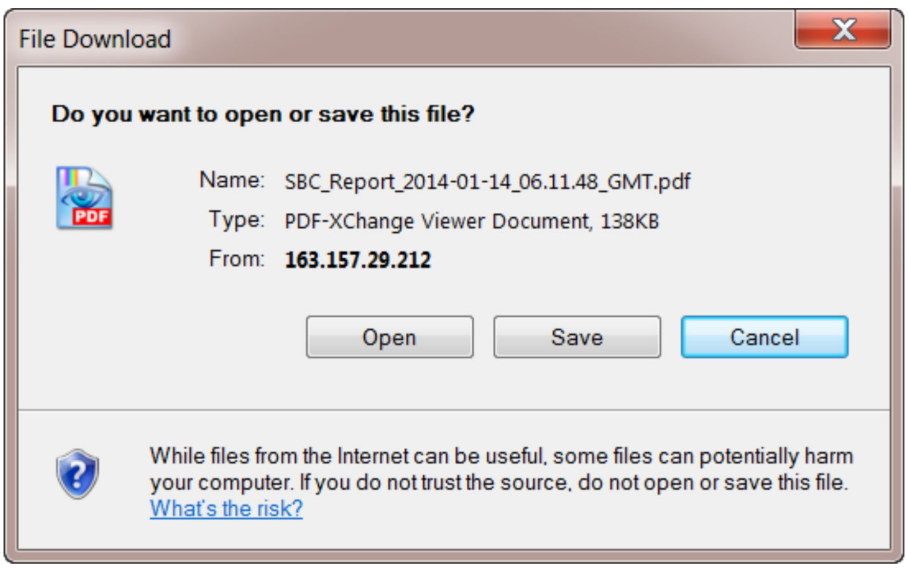
5.1 Download report as .pdf file:

Click on the download icon  to download the report in the .pdf format.

The result of a single calculation or multiple calculations can be selected in the report. The check box can be selected to add the calculation result in the report.



Click the ‘Submit’ button to download the report.

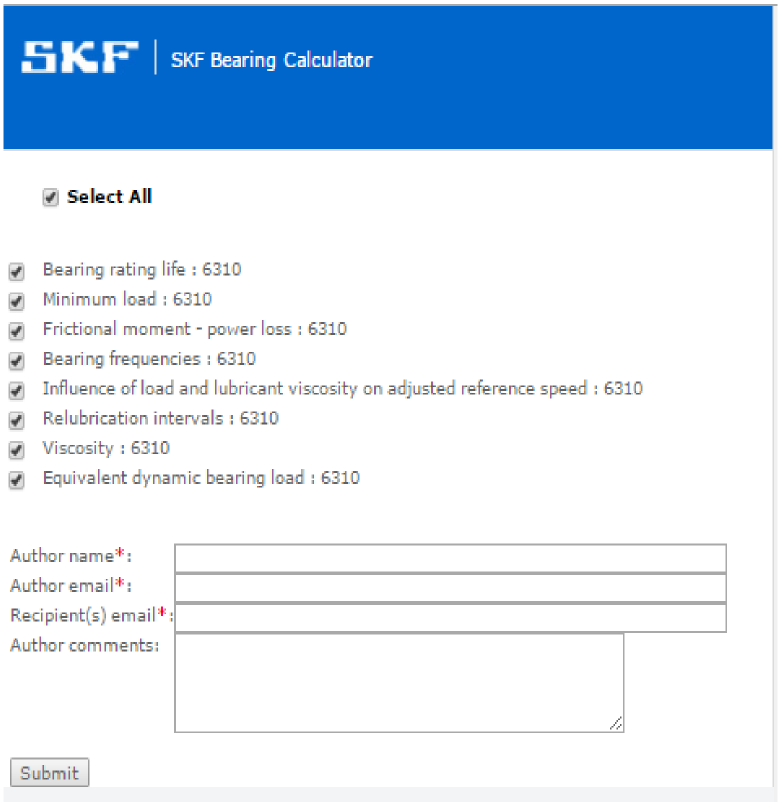


The report can be opened, saved or cancelled by clicking on the respective buttons.

5.2 Send report to email

Click on the send icon to send the report to an email.

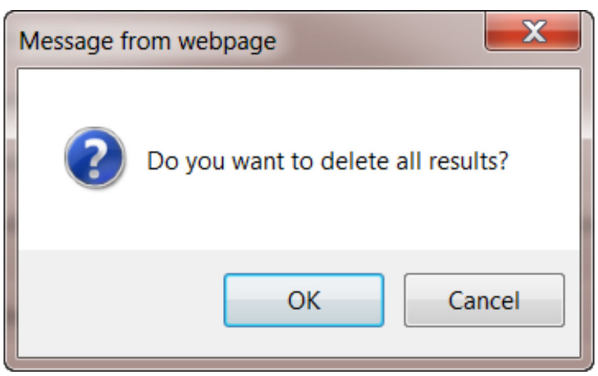
The result of a single calculation or multiple calculations can be selected in the report. The check box can be selected to add the calculation result in the report.
The details on the Author’s name and email, Recipient’s email and the Author’s comments can be added before clicking the ‘Submit’ button. The fields marked with *are mandatory.



After clicking the ‘Submit’ button, the ‘Email sent successfully’ message will be displayed.

5.3 Delete the complete report

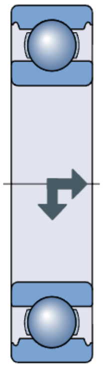
Click on the delete icon to delete the all results. The following warning message will appear.



Click on the ‘OK’ button to delete all results. Click ‘Cancel’ to cancel if it is not necessary to delete the report.

1. Abstract

Calculation overview



Deep groove ball bearing

SKF Explorer

	Bearing rating life		Static safety factor	Frictional moment	Power loss
Designation	Basic	SKF life		Total	
	L_{10h} (h)	L_{10mh} (h)	S_0	M (lbfft)	P_{loss} (ftlbf/s)
6007	420	1600	2.04	0.21	33

Error

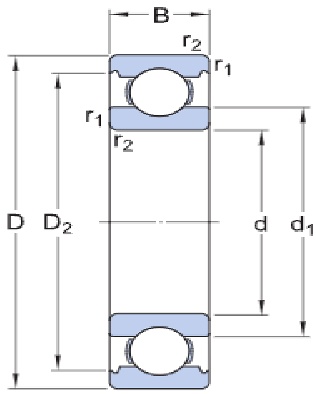
The C/P value is too low. Calculation result is invalid. More info

Consideration

High viscosity ratio k, no asperity contact. k>4 will no further increase bearing rating life but result in higher viscous frictional losses. Operating temperature must be given more attention More info

2. Input

2.1. Bearing data



		Principal dimensions			Basic load ratings		Fatigue load limit	Speed ratings		Clearance class
Designation	Bearing type				Dynamic	Static		Reference	Limiting	
		d (inch)	D (inch)	B (inch)	C (lbf)	C_0 (lbf)	P_u (lbf)	n_{ref} (r/min)	n_{lim} (r/min)	
6007	Deep groove ball bearing	1.378	2.441	0.551	3776.791	2293.052	98.916	24000.0	15000.0	Normal

2.2. Loads, Speed and Temperature

Shaft orientation	Horizontal
Rotating ring	Inner ring rotation

	Forces		Speed	Temperature		Case weight
	Radial (F_r) (lbf)	Axial (F_a) (lbf)	(r/min)	Inner ring (°F)	Outer ring (°F)	
LC1	1125.0	100.0	1500.0	158	149	1

Maximum temperature is used for calculating the actual viscosity, kappa, a_{SKF} and SKF rating life.

Mean temperature is used for calculating bearing friction and power loss.

2.3. Lubrication

	Lubricant			Effective EP additives	Contamination	
Designation	Type	Method	Name		Method	Cleanliness / Factor
6007	Grease	ISO VG (3448)	ISO VG 1000	False	Detailed guidelines	Normal cleanliness

2.4. CO_2 emissions settings

Designation	Input energy mix manually	Geographical location	Period of interest [Years]	Time operational [%]
6007	False	European Union	1	100

2.5. Fits and tolerances

	Requirements	Tolerance Class		Calculated interference	Include Smoothing
Designation	Guidance	Housing	Shaft		
6007	False	N7	s6	True	True

3. Results

3.1. Loads & static safety

	Load ratio	Static safety factor	Equivalent dynamic load	Equivalent static load
Designation	C/P	S_0	P (lbf)	P_0 (lbf)
6007	3.36	2.04	1125.0	1125

3.2. Bearing minimum load

	Reaction forces		Minimum load	
Designation	Radial	Axial		Requirements
	F_r (lbf)	F_a (lbf)	F_{rm} (lbf)	met?
6007	1125.0	100.0	55	yes

3.3. Adjusted reference speed

Designation	Adjusted reference speed	Adjustment factors	
		For bearing load P	For oil viscosity
	n_{ar} (r/min)	f_p	f_v
6007	8790	0.43	0.86

3.4. Lubrication conditions

Designation	Operating viscosity			Viscosity ratio
	Actual	Rated	Rated @ 104 °F	
	ν (cSt)	ν_1 (cSt)	ν_{ref} (cSt)	κ
6007	178	13.9	42.6	12.8

3.5. Grease life and relubrication interval

Error

The C/P value is too low. Calculation result is invalid. More info

3.6. Bearing rating life

Designation	Bearing rating life		SKF life modification factor	Contamination factor
	Basic	SKF		
	L_{10h} (h)	L_{10mh} (h)	a_{skf}	η_c
6007	420	1600	3.81	0.64

Consideration

High viscosity ratio k, no asperity contact. k>4 will no further increase bearing rating life but result in higher viscous frictional losses. Operating temperature must be given more attention More info

3.7. Bearing friction & power loss

Designation	Frictional moment		Friction sources				Power loss
	Total	At start 68-86°F and zero speed	Rolling	Sliding	Seals	Drag loss	
	M (lbfft)	M_{start} (lbfft)	M_{rr} (lbfft)	M_{sl} (lbfft)	M_{seal} (lbfft)	M_{drag} (lbfft)	P_{loss} (ftlbf/s)
6007	0.21	0.34	0.09	0.11	0	0	33

3.8. Bearing frequencies

	Rotational frequencies				Frequency of over-rolling		
Designation	Inner ring	Outer ring	Rolling element set & cage	Rolling element about its axis	Point on inner ring	Point on outer ring	Rolling element
	f_i (Hz)	f_e (Hz)	f_c (Hz)	f_r (Hz)	f_{ip} (Hz)	f_{ep} (Hz)	f_{rp} (Hz)
6007	25.0	0.0	10.454	74.327	160.005	114.995	148.655

3.9. Fits and tolerances

Note

Typically, it is not sufficient to use an interference fit alone to axially locate a bearing ring on a cylindrical seat.

3.9.1. Tolerances

	Shaft outer diameter		Bearing bore		Bearing outer diameter		Housing bore		Smoothing	
Designation	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Shaft and bearing bore	Bearing outer ring and housing
	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)
6007	43	59	-12	0	-13	0	-39	-9	8	14

Consideration

For the tolerances calculation, the normal tolerance for the bearing bore and outer diameter is used.

3.9.2. Fits, Probable Interference (+) / Clearance (-)

	Shaft			Housing		
Designation	Probable minimum	Middle	Probable maximum	Probable minimum	Middle	Probable maximum
	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)
6007	39	49	59	-13	3	20