Environmentally conscious off-grid Laundry Machine Design Report

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Summary

This project was to design a human-powered washing machine for camping in UK. It will be used once a week for a summer period of 3 months. It has to be portable. Power input is required to produce an output speed of 70 rmp for agitate and 700 rpm for spinning. The design process includes designing several concept ideas. Mechanisms were chosen in order to solve some engineering problems. Various components were chosen after calculations and different considerations. Ergonomic design was considered by using the anthropometric data to generate a more comfortable design to users.

Contents

Introduction

Engineering products facilitated human's life a lot. People nowadays can easily wash their clothes by putting them with detergent into a washing machine. In this report, a human-powered laundry machine for camping in the UK will be designed and discussed. It could be operated without the access of electricity. It promotes healthy lifestyle and raise people awareness of environmentally conscious. The washing cycle would be:

1) Washing with detergent and warm water and agitate for 10 minutes
2) Drain water
3) Rinse with clean warm water and agitate for 5 minutes
4) Drain water
5) Spinning at 700 rpm for 4 minutes

The washing machine has a minimum payload of 10 soaking wet t-shirt or 2 soaking wet pairs of jeans. It would be used once per week for a summer period of 3 months. It should be portable for campers to move and a mechanism should be applied to agitate the machine.

Requirement Specification

Design Specification			Date:
Product: Environmentally Conscious off-Grid Laundry Machine			10/11/2015
D/W	Wt	REQUIREMENTS	KEYWORD
		PERFORMANCE	
D	H	- Minimum required payload is 10 soaking wet t-shirts or 2 soaking wet pairs of jeans	payload
D	H	- It has to be portable – it should fit into the boot of a family saloon/estate or the trunk of a motorhome	portable
D	H	- Machine's drum is to be filled with clothes, preheated water and detergent	filled
D	H	- 1) wash for 10 minutes	wash
D	H	- 2) agiate rinse for 5 minutes	rinse
D	H	- 3) 700 rpm spinning for 4 minutes	spin
D	H	- Drain manually	drain
W	M	- It could be moved with wheels below it	wheel
D	H	- It will allow users to exercise	exercise
		ENERGY	
D	H	- All cycles have to be foot- and/or hand-powered	Hand/foot-powered
		ENVIREMENT	
D	H	- Temperature operation range: 0 - 40	temperature
W	L	- Not too much noise	noise
W	M	- No excessive vibration	vibration

		LIFE IN SERVICE	
D	H	- The machine is to be used in a frequency of once per week for a summer period of 3 months	frequency
		MATAINANCE	
W	M	- It should be easy to maintain and find replacement parts	maintain, replacement
		PRODUCTION	
D	H	- £50 Factory transfer price	price
D	M	- Batch production of 10,000	10,000
		QUANTITY	
W	M	- Can have various of components	components
		SIZE	
D	M	- Should be small enough to carry because it should be portable	small
		WEIGHT	
D	M	- Should be light enough to carry because it should be portable	light
		AESTHTICS	
W	L	- Attractive to look at	attractive
		SAFETY	
D	H	- Relative moving parts designed so unlikely to trap limbs	trap
D	H	- Correct posture to move the machine as it should be portable	posture
D	H	- Wear a comfortable and suitable shoe to ride eg. No flip flops	suitable
D	H	- Chain should be clean, free of debris and able to turn	chain
		INSTALLATION	
D	M	- Easy to assemble and disassemble	assemble
		DOCUMENTATION	
W	M	- Include clear instructions to the user on operation	instructions
		DISPOSAL	
W	M	- Material used can be recycled	recycle

Other design considerations

The design considered ergonomics so that users can operate the machine more comfortably. Anthropometrics data was used to design components that users will interact with. For example, the height of the bike seat from the pedal. And the distance from the bike seat to the handle.

Since the machine was designed to be portable. The whole machine could be separated to several parts when it is moved. Frame joint connecting method was used to assembly different parts together and no screws and nuts were used at all. This allows the machine to be easily assembled and disassembled for maintenance and moving around.

Conceptual Design

A morphological charted was created listing possible ways of different elements to build a laundry machine. This includes the washing methods, the mechanism of agitating and human power input etc. The concept designs are basically different combinations of the elements from each section of the chart, which is shown in Appendix 1.

Alternative Concepts

Basically, for the first concept idea, the spinning of the drum harnesses the rotating motion of the rear wheel of the bicycle to drive it. The wheels have to be elevated in order to keep the whole system steady. Moreover, the rear wheel has to be specially designed to match the friction belt on the drum. With a smaller radius extrusion on the drum, a faster angular velocity could be attained when they are switched. This design emphasizes the portability of the whole system which the drum could be attached on to the bicycle and makes the transportation of the machine easy and simple with no noticeable disadvantage against other designs.

The second concept idea is totally different from the first one. With the implementation of a spring, a back and forth motion can be attained. When the handle is pulled, the thread spin the drum in a clockwise motion. This also creates an extension in the spring and tension is built up and forcing the system into an opposite direction (anti-clockwise). As soon as the user releases the handle bar, the drum reverse its direction due to the high tension force built up because of extension. By repeating this process, an "agitating " motion can be obtained.

The third concept design utilise the working mechanism of a bicycle, by transferring power from the pedal to a gear system and finally to the drum. The gear system used here is specifically designed to create a 2-way rotating motion on the drum to achieve an agitating system. Another highlight of the design is that the assemble of the machine requires no bolts and nuts, only frame joining all the parts which has a great advantage on easy assembly and disassembly, especially for camping use.

Concept Evaluation and selection

Selection							
		Concept 1		Concept 2		Concept 3	
Criteria	**Weighting**	**Score**	**Weight Score**	**Score**	**Weight Score**	**Score**	**Weight Score**
Fit 5 T-shirts or 2 jeans	3	Y	3	Y	3	Y	3
Washing cycle(agitate)	3	N	-3	Y	3	Y	3
Portable	3	Y	3	Y	3	Y	3
Use once per	3	Y	3	Y	3	Y	3

week							
Spin at 700 rpm	3	Y	3	N	-3	Y	3
Human powered	2	Y	2	Y	2	Y	2
Used by ages 16 – 65	1	Y	1	N	-1	Y	1
Batch produced	2	Y	2	Y	2	Y	2
			14		12		20

Table 1 - Concept selection scoring chart

Evaluation							
		Concept 1		**Concept 2**		**Concept 3**	
Criteria	**Weighting**	**Score**	**Weight Score**	**Score**	**Weight Score**	**Score**	**Weight Score**
Size	2	-2	-4	2	4	2	4
Durability	2	1	2	-1	-2	1	2
Maintenance	2	2	4	0	0	0	0
Assembly	2	2	4	1	-2	1	2
Cost	2	-2	-4	2	4	2	4
Stability	2	0	0	-1	-2	1	2
			2		2		14

Table 2 - Concept evaluation scoring chart

Embodiment Design- Design analysis

It is assumed that the mass of 10 soaking wet T-shirt is 5kg. Hence, the mass of the drum was assumed to be 6kg. The rpm for washing and rinsing was set to be 70 rpm and 700 rpm was required for spinning. By applying equation 1, 2 and 3, the power input by human and power output to the drum could be calculate. **[Appendix 2]**

$$T=I\frac{\omega}{t} \qquad (1)$$

$$I=\frac{m}{2}(r_1 ¿¿ 2+r_2{}^2)¿ \qquad (2)$$

$$P=T\omega \qquad (3)$$

, where T = torque, I = moment of inertia, ω = angular speed, r_1 and r_2 are the inner and outer radius of the drum.

The service factor was considered in the calculation which obtained by using **Technical Data Supplement [TDS1] & Appendix 3**.

The forces acting on the shaft is calculated as shown in **Appendix 4 & 5**. It is done by first drawing the free body diagram and distinguishes the force acting at various points of the shaft. Simple moment calculations were applied. After that, Macaulay's notation was applied to obtain the shear stress and bending moment diagram as shown in **Appendix 6 & 7 & 8**.

Nodes are identified throughout the shaft. **[Appendix 9]** The moment at each node calculated, torque, moment of inertia, bending stress, second moment of area, torsional stress and combined stress were then be compare with the allowable stress of materials in order to choose a suitable and cost effective material for the shaft. **[Appendix 10]** Safety factors will also be considered and the stress concentration factor was calculated by using **TDS 3**.

Power Transmission

Since the power input and output were calculated for 70 and 700 rpm, the speed ratio was calculated to be 3:1. **[Appendix 11]** Hence, suitable gear ratio **[TDS 2]** could be selected with in order to step the power input into the power output required for the drum to operate in the required speed. Taper lock sprockets selected under the 10B T/L group are:

Taper lock sprocket	026C0119	026C0157
Teeth	19	57

Table 3 - Taper lock sprocket selected **[See TDS4]**

Bearings, Components and Material Selection

The overall static bearing forces at bearing A, B, C and D are calculated as shown in **Appendix 12**.

The overall dynamic bearing forces at bearings are then calculated by using the equation $L=¿$, where: L = Life = 530 million revs, C = Dynamic Load Rating, P = Applied Load, and P = Life Factor

$$\text{For a ball bearing } C=P\times L^{\frac{1}{3}} \quad (4)$$

, the results are

Bearing	A	B	C	D
C /kN	0.518	0.417	0.417	0.753

Table 4 - Dynamic load for bearings

Bearings would then be chosen in the catalogue in order to match with other components and the diameter of the shaft. **[TDS5 & 6 & 7]** Those bearings chosen are required to be strong enough to withstand the Dynamic load, C calculated here in order to make to shaft work.

The bearings chosen are:

Bearing	A & D	B & C
Reference Number	62/22	61807-2RSR

Table 5 - Bearings chosen

After that, relative circlips were chose according to the $r_{a\ max}$ value stated in the catalogue. Circlips chosen are:

Bearing	62/22	61807-2RSR
Circlip	A22	A35

Table 6 - Circlips chosen **[See TDS8 & 9]**

Taper locks, TB3020, with 40mm bore size were chose to connect the inner drum to the shaft. **[See TDS10 & 11]**

Different materials were selected for different components of the washing machine. For example, the frame of the washing machine will be made of mild steel as this is strong and cheap. It is weldable and, hence recyclable. **[5]** Besides, the drum will be manufactured by polypropylene. It is light and it has long service life as exposed membrane guaranteed. **[6]**

Final Design Description

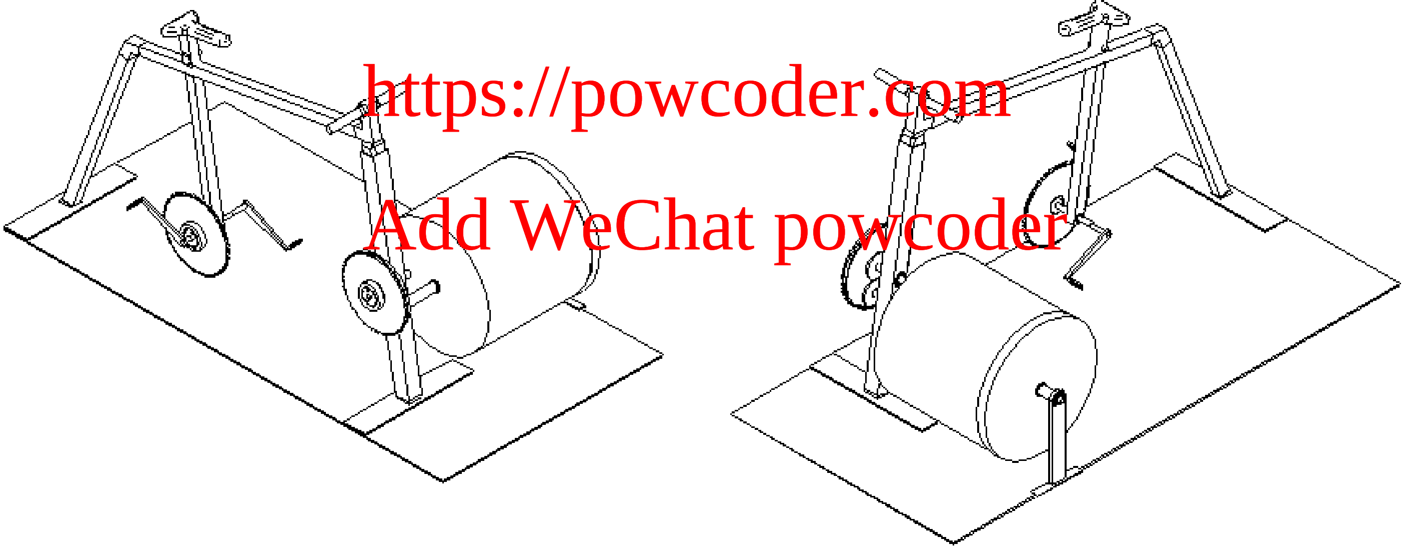


Figure 1 – Whole assembly

The final design of the washing machine is from the third concept idea with a little adjustment made on the body frame. This whole assembly is shown on **Figure 1**. In **Figure 2**, the drum is shown, with an inner core of 0.4 meter diameter cylinder covered with holes evenly distributed and an outer drum of 0.5 meter diameter separated into 2 parts, the cover and the body. The inner core has a depth of 0.4 meter and the outer has 0.5 meter. These dimensions are proved to be able to withhold more than 10 wet T-shirts plus sufficient water to operate the washing cycle. **Figure 3** shows the body frame of the machine. The base plates that support the frame at the bottom have wide extension to steady the body frame. The frame would

be manufactured by lengths of steel hollow square sections and frame joint together to achieve easy disassembly.
To switch the washing cycles into spinning cycles, manual gear changing is required. This is because a gearbox would not be necessary to perform such an easy operation and in addition the budget is low that cannot possibly include a gearbox in the system. For the washing cycle, the drum would be turning in both ways. This is all attributed to the specifically design gear system shown in **Figure 4**.
The dimensions of the body frame were designed based on data from anthropometric resources to meet the ergonomic requirements that it would be suitable for 90% of users. The length from the seat to the pedal, distance from seat to handles and the angle of the seat frame made with the vertical were all taken into account and the final overall dimensions are shown in attachment 1.

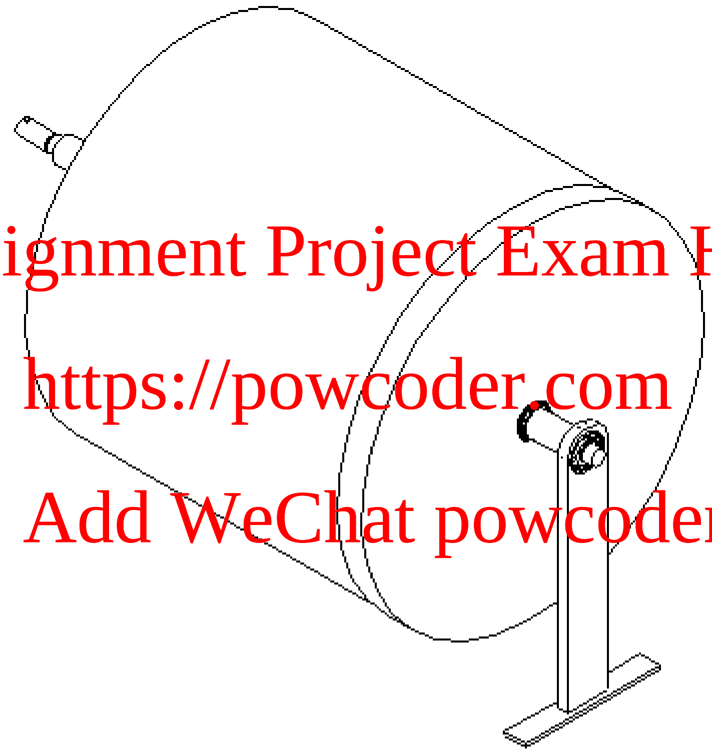


Figure 2 – Drum assembly

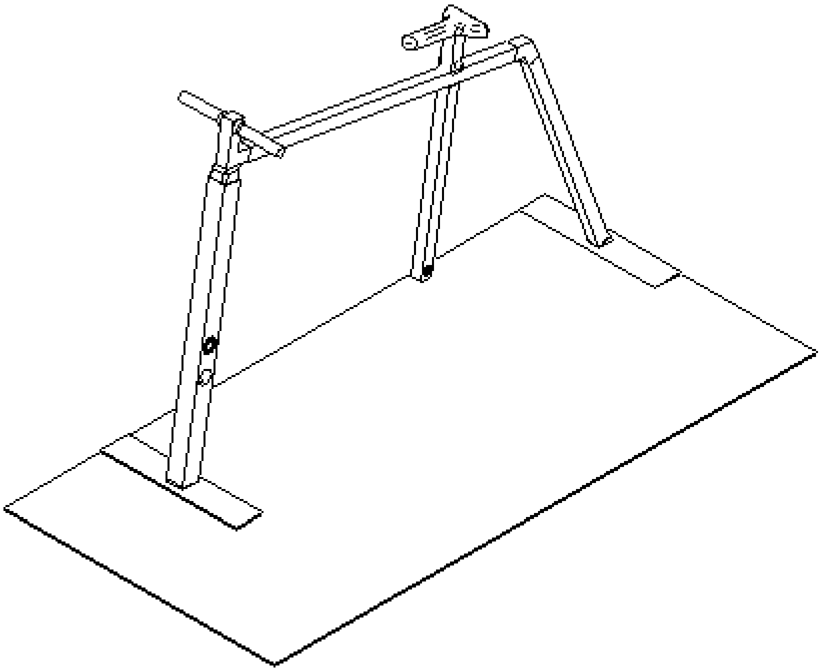


Figure 3 – Body Frame assembly

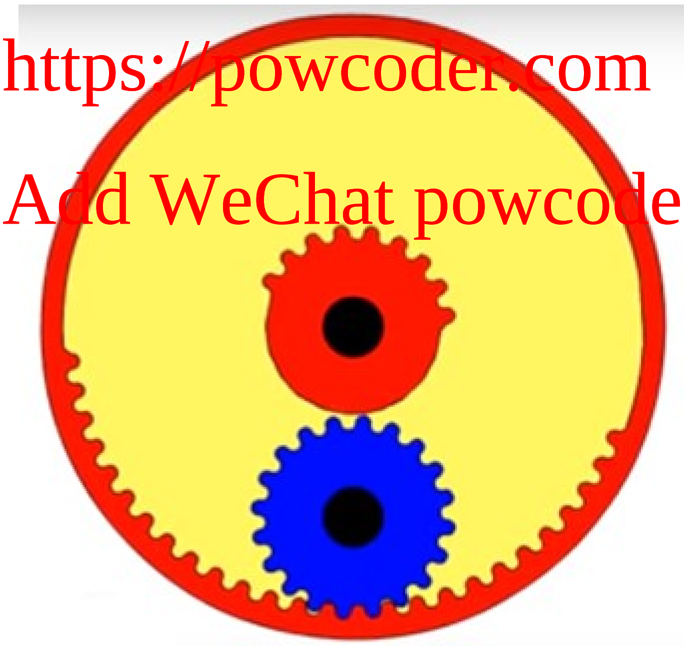
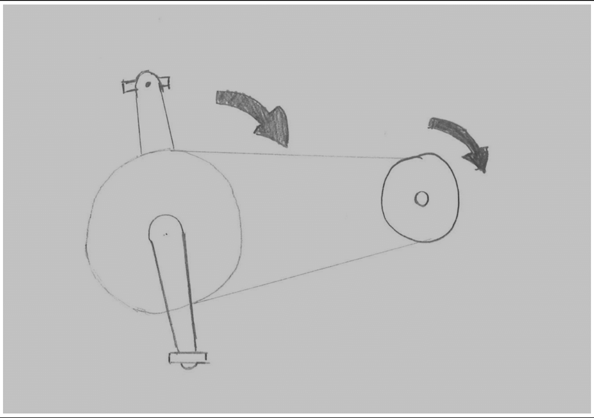
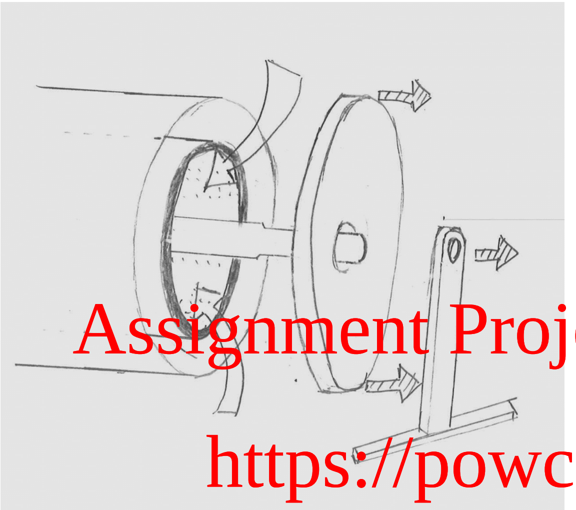
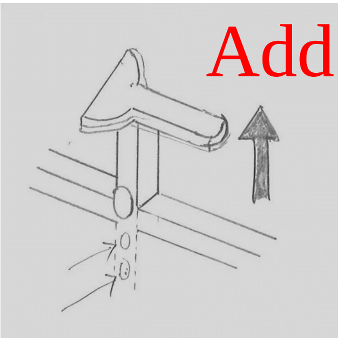
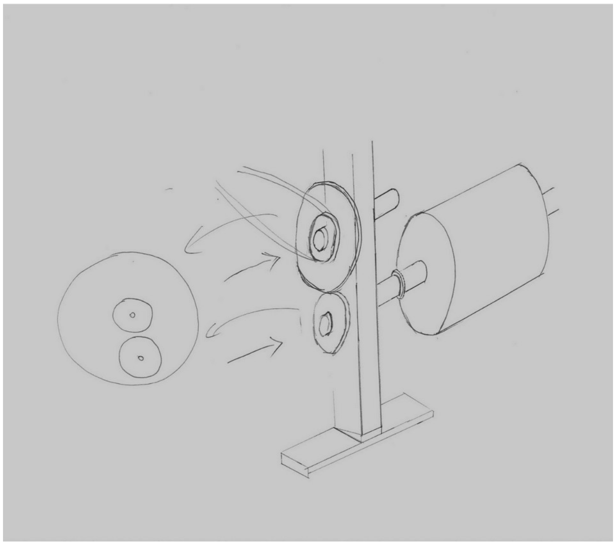


Figure 4 – Agitate mechanism

Method of Operation

	The user cycles the pedals to spin the sprocket and rotate the drum.
	The drum can easily be loaded by removing the shaft end support and the covering lid and resealed simply by assemble back the parts. No bolts or nuts needed, easy and simple.
	The seat has an adjustable height for different users of different height and leg length, simply by unplugging the pin and adjusts to the desirable height then inserts the pin back.

	Manual gear changing is required when changing rinsing cycle to spinning cycle. The driving sprocket has a teeth number of 57 and the driven one has 19, of which another 57-teeth sprocket is on the driven sprocket shaft. On the shaft connecting the drum, a 19-teeth sprocket is to be used. This has a total angular velocity step up of 9 times the pedal angular velocity.

Safety

Safety is an essential issue of engineering design. It is one of the most important factor that customers concern. There are some safety changes that could be made for the washing machine.

1) A derailleur could be added to change the gear instead of using hands to do so
2) Guards could be added to the taper lock sprocket to avoid user injured by it directly
3) Add a clear instruction on how to use and move the machine

Solution Specification

- Power Required (Spin Cycle) – 14W
- Power Required (Agitation Cycles) – 42W
- Load Capacity – 5kg
- Spin Cycle Speed – 700 rpm (Cycling Speed Required – 78rpm, Force Required – 25N)
- Agitation Cycle Speed – 70rpm (Cycling Speed Required – 70rpm, Force Required – 34N)
- Dimensions – 1583 X 1082 X 1077 mm
- Ergonomically designed features such as the seat, grip and position of the pedal and gear changer
- Adjustable seating position to allow people of different heights to use comfortability

Reference

Other concepts

[1] Zinn, L. (2012) Technical FAQ: Crankarm length versus BB height, long-spindle Eggbeaters,

perspective and more, Retrieved 29 November 2015, from
http://velonews.competitor.com/2012/12/bikes-and-tech/technical-faq/technical-faq-crankarm-length-versus-bb-height-long-spindle-eggbeaters-perspective-and-more_269831

[2] Marinoff, S. (11th Jan 2015) A little bit of everything but (probably) mostly bicycles, Retrieved 29 November 2015, from
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Calculations

[3] N.A. (10th Dec 2015) List of moments of inertia, Retrieved 29 November 2015, from
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[4] N.A. (N.D.) Angular Motion – Power and Torque, Retrieved 29 November 2015, from
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[5]Knapman, A. (25th Nov 2014) Top 5 Advantages of Mild Steel, Retrieved 29 November 2015, from
http://www.austenknapman.co.uk/blog/2014/11/25/top-5-advantages-of-mild-steel/

[6]N. A. (25th Oct 2014) The Polypropylene advantage, Retrieved 29 November 2015, from
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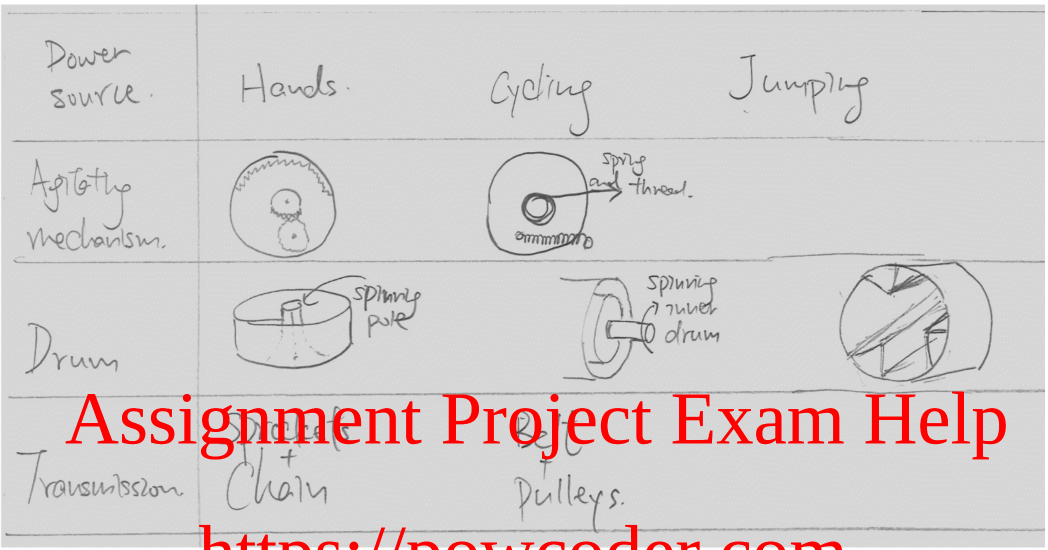
Appendices



App

endix 1 – Morphological Approach

$m = 6\,kg$ Drum radius : $0.2\,m$

$$I = \frac{m}{2}(r_1^2 + r_2^2)$$
$$= \frac{6}{2}(0.2^2 + 0.195^2)$$
$$= 0.234075.$$

70rpm, $\omega = 70 \times \frac{2\pi}{60} = 7.33\ rads^{-1}$

$$T = Fr$$
$$= 6(9.81)(0.2) = 11.772.$$

$$P = I\frac{\omega^2}{t}$$
$$= \frac{0.234075(7.33)^2}{1}$$ % assume it takes 1s from 0 to 70rpm.
$$= 12.5766.$$

Pout for 700 rpm $= 12.6 \times 1.1 = 13.8$
(with service factor)

700rpm, $\omega = 700 \times \frac{2\pi}{60} = 73.3\ rads^{-1}$

$$P = I\frac{\omega^2}{t} = \frac{0.234075(73.3)^2}{30}$$

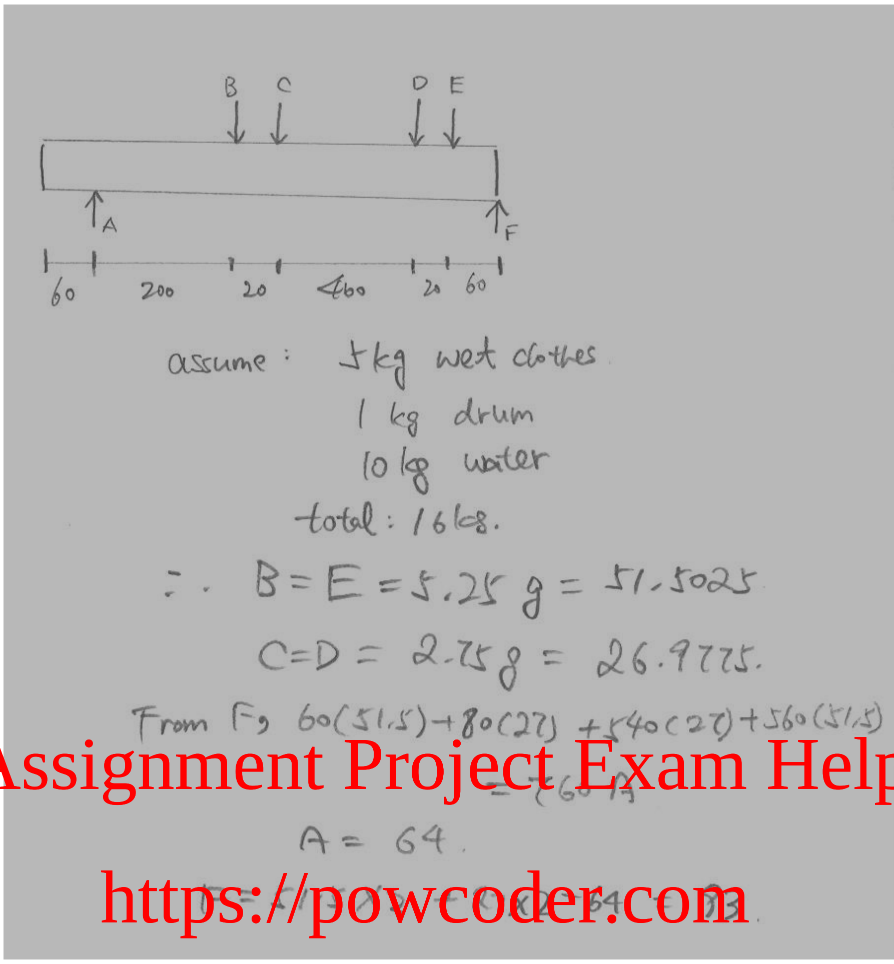
% assume it takes 30s from 0 to 700rpm.

$$= 41.922.$$

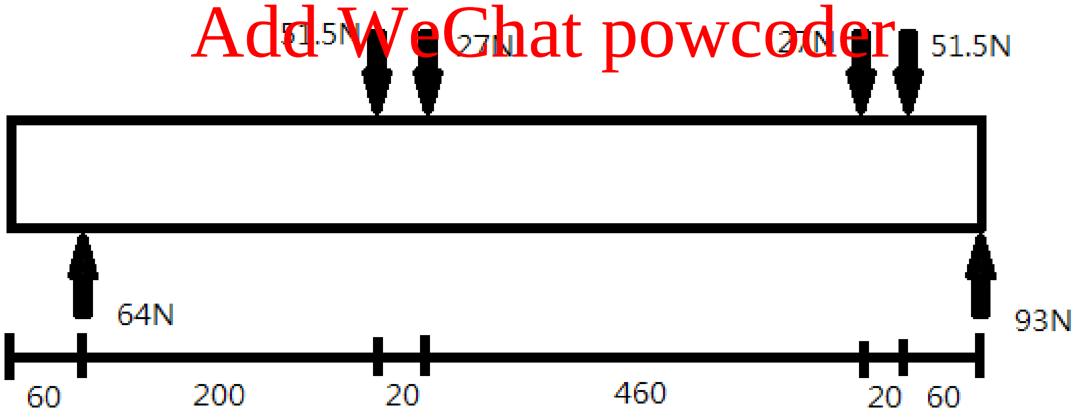
Appendix 2 - Power calculation

Pout for 700 rpm $= 12.6 \times 1.1 = 13.8$
(with service factor)

Appendix 3 - Service factor considered



Appendix 4 - Force acting on shaft



Appendix 5 - Force distribution on shaft

Force: at 0, $x = 0\langle x\rangle^0 = 0$

at 0.06, $x = 64\langle x-0.06\rangle^0 = 64$

at 0.26, $x = 64 - 51.5\langle x-0.26\rangle^0 = 12.5$

at 0.28, $x = 12.5 - 27\langle x-0.28\rangle^0 = -14.5$

at 0.74, $x = -14.5 - 27\langle x-0.74\rangle^0 = -41.5$

at 0.76, $x = -41.5 - 51.5\langle x-0.76\rangle^0 = -93$

Moment: at 0, $x = 0\langle x\rangle^1 = 0$

at 0.06, $x = 64x + 3.84 = 7.68$

at 0.26, $x = 64x + 3.84 - 51.5x + 13.39 = 12.5x + 17.23 = 20.48$

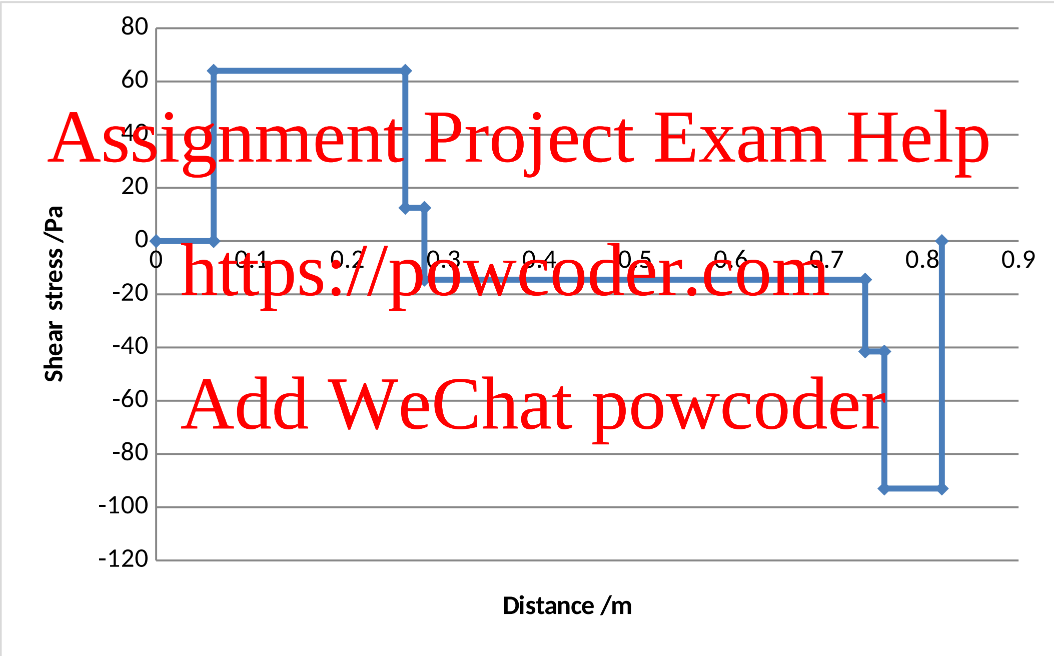
at 0.28, $x = 12.5x + 17.23 - 27x + 7.56 = -14.5x + 24.79 = 20.73$

at 0.74, $x = -14.5x + 24.79 - 27x + 19.98 = -41.5x + 44.77 = 14.06$

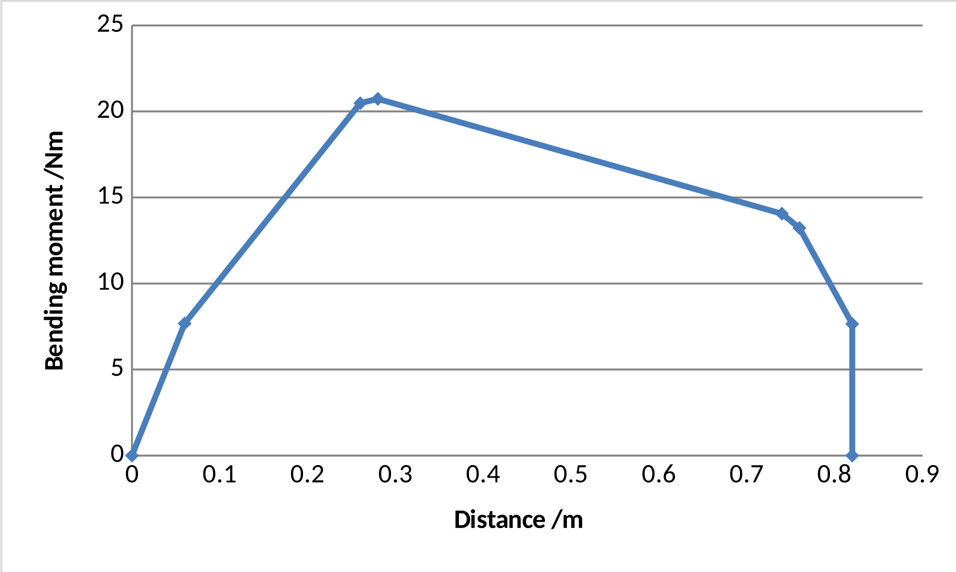
at 0.76, $x = -41.5x + 44.77 - 51.5x + 39.14 = -93x + 83.91 = 13.23$

0.82, $x = -93x + 83.91 + 93x - 76.26 = 7.65$

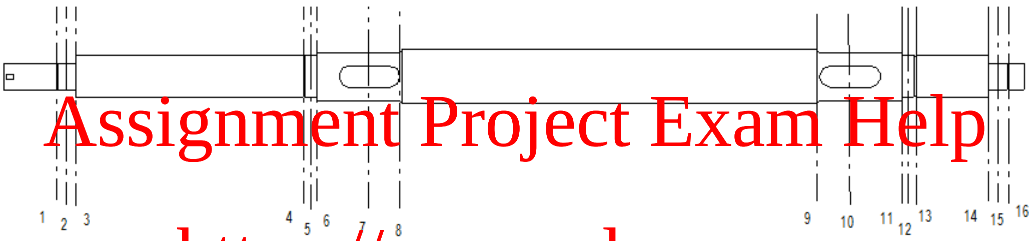
Appendix 6 - Calculation of Macaulay's natation



Appendix 7 - Shear stress diagram



Appendix 8 - Bending moment diagram



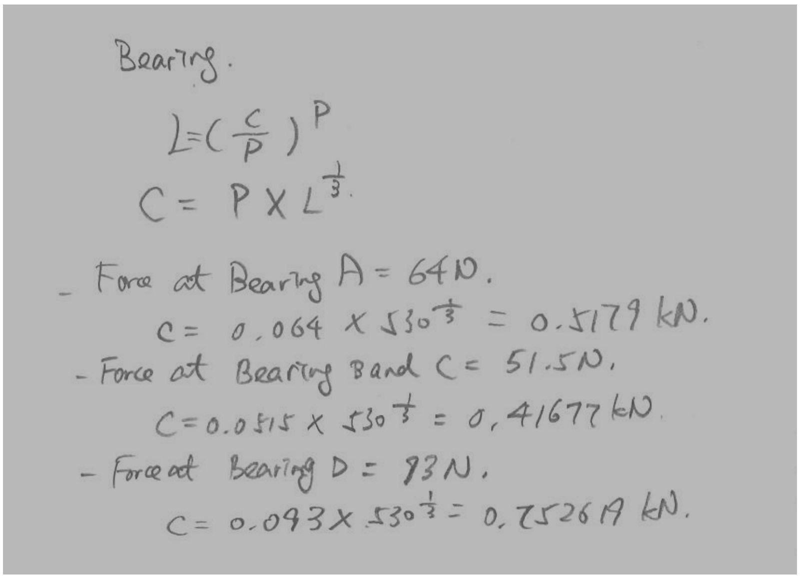
Appendix 9 - Nodes on shaft

	circlip	Bearing A	radius	circlip	Bearing B	radius	taper lock A	radius	radius	taper lock B	radius	Bearing C	circlip	radius	Bearing D	circlip
Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dia. (mm)	21	22	23	33	35	35.3	40	42	42	40	35.3	35	33	23	22	21
Mv	0	7.68	0	0	20.48	0	20.73	0	0	14.06	0	13.23	0	0	7.65	0
Mh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mc (N/m2)	0.00	7.68	0.00	0.00	20.48	0.00	20.73	0.00	0.00	14.06	0.00	13.23	0.00	0.00	7.65	0.00
Torque (Nm)	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772	11.772
I	9.54E-09	1.15E-08	1.37E-08	5.82E-08	7.36E-08	7.62E-08	1.26E-07	1.53E-07	1.53E-07	1.26E-07	7.62E-08	7.36E-08	5.82E-08	1.37E-08	1.15E-08	9.54E-09
Bending stress	0.00E+00	7.35E+06	0.00E+00	0.00E+00	4.87E+06	0.00E+00	3.30E+06	0.00E+00	0.00E+00	2.24E+06	0.00E+00	3.14E+06	0.00E+00	0.00E+00	7.32E+06	0.00E+00
J	1.91E-08	2.30E-08	2.75E-08	1.16E-07	1.47E-07	1.52E-07	2.51E-07	3.05E-07	3.05E-07	2.51E-07	1.52E-07	1.47E-07	1.16E-07	2.75E-08	2.30E-08	1.91E-08
Torsional stress	6.48E+06	5.63E+06	4.93E+06	1.67E+06	1.40E+06	1.36E+06	9.37E+05	8.10E+05	8.10E+05	9.37E+05	1.36E+06	1.40E+06	1.67E+06	4.93E+06	5.63E+06	6.48E+06
a1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
a2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
a3	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
b.c.d	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
k	2	1	1.7	2	1	1.8	1	1.28	1.28	1	1.8	1	2	1.7	1	2
Nu (b,c,d *k*a)	10.8a	5.4a	9.18a	10.8a	5.4a	9.72a	5.4a	6.912a	6.912a	5.4a	9.72a	5.4a	10.8a	9.18a	5.4a	10.8a
Combined Stress at node	6.48E+06	6.73E+06	4.93E+06	1.67E+06	2.81E+06	1.36E+06	1.90E+06	8.10E+05	8.10E+05	1.46E+06	1.36E+06	2.10E+06	1.67E+06	4.93E+06	6.72E+06	6.48E+06
Allowable stress material 1	2.04E+07	4.07E+07	2.40E+07	2.04E+07	4.07E+07	2.26E+07	4.07E+07	3.18E+07	3.18E+07	4.07E+07	2.26E+07	4.07E+07	2.04E+07	2.40E+07	4.07E+07	2.04E+07
Allowable stress material 2	2.50E+07	4.99E+07	2.94E+07	2.50E+07	4.99E+07	2.77E+07	4.99E+07	3.90E+07	3.90E+07	4.99E+07	2.77E+07	4.99E+07	2.50E+07	2.94E+07	4.99E+07	2.50E+07
Allowable stress material 3	6.30E+07	1.26E+08	7.41E+07	6.30E+07	1.26E+08	7.00E+07	1.26E+08	9.84E+07	9.84E+07	1.26E+08	7.00E+07	1.26E+08	6.30E+07	7.41E+07	1.26E+08	6.30E+07

Appendix 10 - Comparison to choose the best material

$$\text{Speed ratio} = \frac{42}{13.8} = 3.04 \therefore 3:1$$

Appendix 11 - Calculation on speed ratio


Bearing.

$L = \left(\frac{C}{P}\right)^{P}$

$C = P \times L^{\frac{1}{3}}$

- Force at Bearing A = 64N.

$C = 0.064 \times 530^{\frac{1}{3}} = 0.5179\ kN.$

- Force at Bearing B and C = 51.5N.

$C = 0.0515 \times 530^{\frac{1}{3}} = 0.41677\ kN.$

- Force at Bearing D = 93N.

$C = 0.093 \times 530^{\frac{1}{3}} = 0.75261\ kN.$

Appendix 12 - Calculation on the dynamic load rating of bearings

Bought in components	**£15.00**
Material cost	£33.33
Manufacturing	£10.00
Total cost	£58.33

Technical Data Supplements

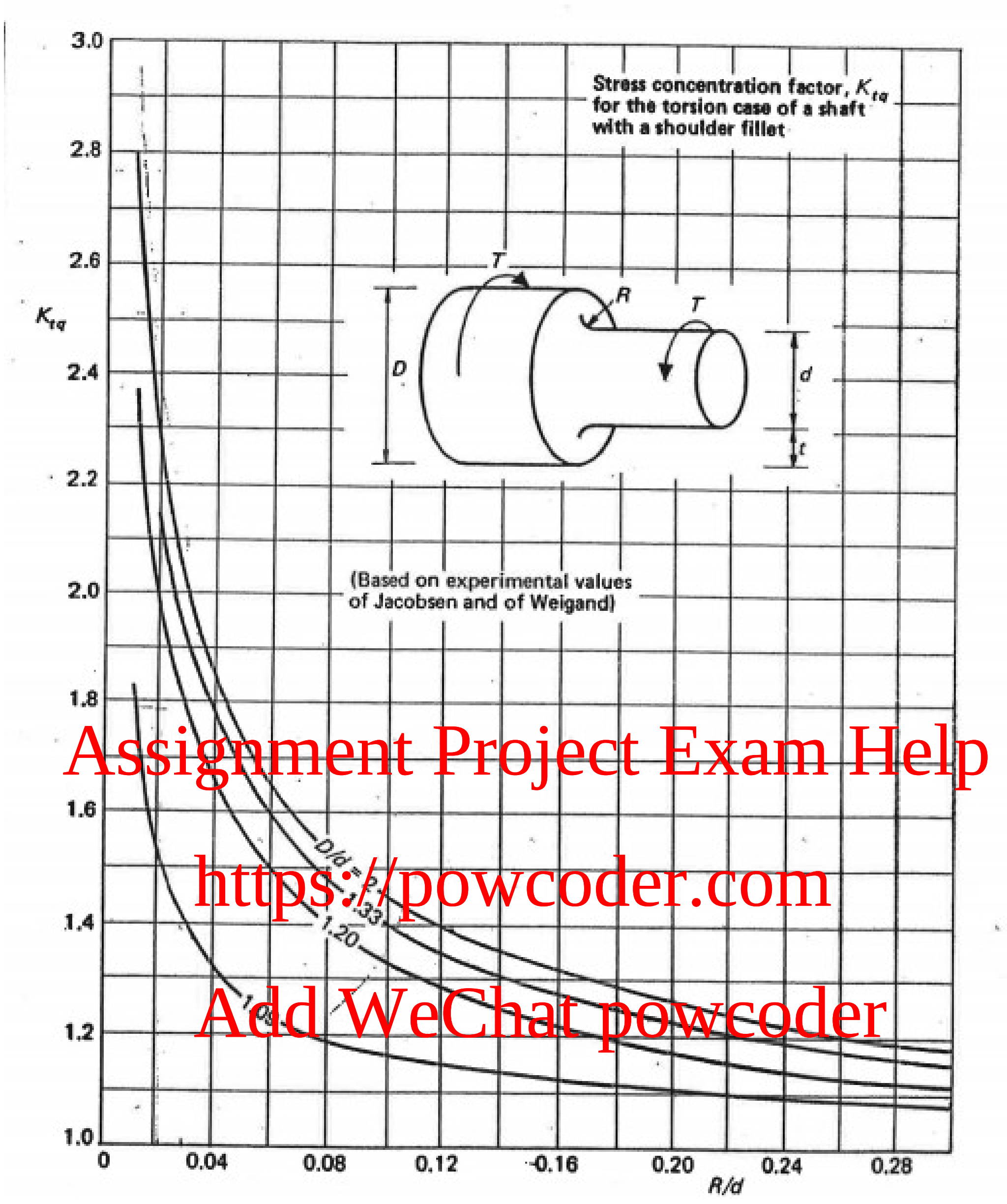
	TYPES OF PRIME MOVER					
	'Soft' starts			'Heavy' starts		
	Electric motors: A.C. – Star-delta start D.C. – Shunt wound Internal combustion engines with 4 or more cylinders. All prime movers fitted with centrifugal clutches, dry or fluid couplings.			Electric motors: A.C. – Direct-on-line start D.C. – Series and compound wound. Internal combustion engines with less than 4 cylinders.		
	Hours per day duty					
TYPES OF DRIVEN MACHINE	10 and under	Over 10 to 16	Over 16	10 and under	Over 10 to 16	Over 16
Light Duty Agitators (uniform density), Belt conveyors (uniformly loaded).	1.0	1.1	1.2	1.1	1.2	1.3
Medium Duty Agitators and mixers (variable density). Belt conveyors (not uniformly loaded), Kilns, Laundry machinery, Lineshafts, Machine tools, Printing machinery, Sawmill and woodworking machinery, Screens (rotary).	1.1	1.2	1.3	1.2	1.3	1.4
Heavy Duty Brick machinery, Bucket elevators, Conveyors (heavy duty), Hoists, Quarry plant, Rubber machinery, Screens (vibrating), Textile machinery.	1.3	1.4	1.5	1.5	1.6	1.7

TDS1 - Service factor

TABLE 4 – SPEED RATIOS

Number of teeth – Driven Sprocket	Number of teeth – Driving Sprocket: 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	27	30
10	1.00																	
11	1.10	1.00																
12	1.20	1.09	1.00															
13	1.30	1.18	1.08	**1.00**														
14	1.40	1.27	1.17	1.08	1.00													
15	1.50	1.36	1.25	**1.15**	1.07	**1.00**												
16	1.60	1.45	1.33	1.23	1.14	1.07	1.00											
17	1.70	1.55	1.42	**1.31**	1.21	**1.13**	1.06	**1.00**										
18	1.80	1.64	1.50	1.38	1.29	1.20	1.13	1.06	1.00									
19	1.90	1.73	1.58	**1.46**	1.36	**1.27**	1.19	**1.12**	1.06	**1.00**								
20	2.00	1.82	1.67	1.54	1.43	1.33	1.25	1.18	1.11	1.05	1.00							
21	2.10	1.91	1.75	**1.62**	1.50	**1.40**	1.31	**1.24**	1.17	**1.11**	1.05	**1.00**						
22	2.20	2.00	1.83	1.69	1.57	1.47	1.38	1.29	1.22	1.16	1.10	1.05	1.00					
23	2.30	2.09	1.92	**1.77**	1.64	**1.53**	1.44	**1.35**	1.28	**1.21**	1.15	**1.10**	1.05	**1.00**				
24	2.40	2.18	2.00	1.85	1.71	1.60	1.50	1.41	1.33	1.26	1.20	1.14	1.09	1.04	1.00			
25	2.50	2.27	2.08	**1.92**	1.79	**1.67**	1.56	**1.47**	1.39	**1.32**	1.25	**1.19**	1.14	**1.09**	1.04	**1.00**		
26	2.60	2.36	2.17	2.00	1.86	1.73	1.63	1.53	1.44	1.37	1.30	1.24	1.18	1.13	1.08	1.04		
27	2.70	2.45	2.25	**2.08**	1.93	**1.80**	1.69	**1.59**	1.50	**1.42**	1.35	**1.29**	1.23	**1.17**	1.13	**1.08**	**1.00**	
28	2.80	2.54	2.33	2.15	2.00	1.87	1.75	1.65	1.56	1.47	1.40	1.33	1.27	1.22	1.17	1.12	1.04	
29	2.90	2.64	2.42	2.23	2.07	1.93	1.81	1.71	1.61	1.53	1.45	1.38	1.32	1.26	1.21	1.16	1.07	
30	3.00	2.73	2.50	2.31	2.14	2.00	1.88	1.76	1.67	1.58	1.50	1.43	1.36	1.30	1.25	1.20	1.11	1.00
38	3.80	3.45	3.17	**2.92**	2.71	**2.53**	2.38	**2.24**	2.11	**2.00**	1.90	**1.81**	1.73	**1.65**	1.58	**1.52**	1.41	1.27
57	5.70	5.18	4.75	**4.38**	4.07	**3.80**	3.56	**3.35**	3.17	**3.00**	2.85	**2.71**	2.59	**2.48**	2.38	**2.28**	2.11	1.90
76	7.60	6.91	6.33	**5.85**	5.43	**5.07**	4.75	**4.47**	4.22	**4.00**	3.80	**3.62**	3.45	**3.30**	3.17	**3.04**	2.81	2.53
95	9.50	8.64	7.92	**7.31**	6.79	**6.33**	5.94	**5.59**	5.28	**5.00**	4.75	**4.52**	4.32	**4.13**	3.96	**3.80**	3.52	3.17

TDS2 - Speed ratio



TDS3 – Stress concentration factor, k

10B T/L SPROCKET $^{5}/_{8}$" (15.9mm) PITCH

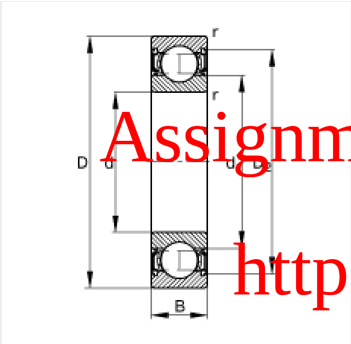
Tooth Width

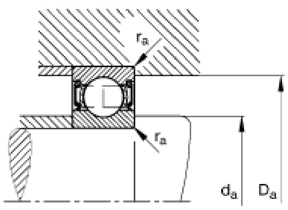
B_1	9.1mm
b_1	9.0mm
B_2	25.5mm
B_3	42.1mm

No.of Teeth	Pitch	Outer Dia	Dia Over Chain	Simplex Taper Lock						Duplex Taper Lock						Triplex Taper Lock					
				Product code	Desig-nation	Bush No.	Type	Length Bore	Hub Dia	Product code	Desig-nation	Bush No.	Type	Length Bore	Hub Dia	Product code	Desig-nation	Bush No.	Type	Length Bore	Hub Dia
	d_p mm	d_e mm	A mm					L mm	N mm					L mm	N mm					L mm	N mm
13	66.34	73	81	026C0113	**51–13**	1008	1	22.2	47												
15	76.35	83	91	15	**51–15**	1210	1	25.4	60	026C0215	**52–15**	1210	3	25.4		026C0315	**53–15**	1210	5	42.1	
17	86.39	93	101	17	**51–17**	1610	1	25.4	71	17	**52–17**	1610	3	25.4		17	**53–17**	1210	5	42.1	
19	96.44	103	111	19	**51–19**	1610	1	25.4	75	19	**52–19**	1610	3	25.4		19	**53–19**	1615	5	42.1	
20	101.49	108	116	20	**51–20**	1610	1	25.4	76												
21	106.50	114	122	21	**51–21**	1610	1	25.4	76	21	**52–21**	1610	3	25.4		21	**53–21**	1615	5	42.1	
23	116.59	124	132	23	**51–23**	1610	1	25.4	76	23	**52–23**	1610	3	25.4		23	**53–23**	2012	5	42.1	
25	126.67	134	142	25	**51–25**	2012	1	32.0	90	25	**52–25**	2012	2	32.0	90	25	**53–25**	2517	4	45.0	105
27	136.75	144	152	27	**51–27**	2012	1	32.0	90	27	**52–27**	2012	2	32.0	90	27	**53–27**	2517	4	45.0	110
30	151.87	159	167	30	**51–30**	2012	1	32.0	90	30	**52–30**	2012	2	32.0	90	30	**53–30**	2517	4	45.0	120
38	192.23	200	208	38	**51–38**	2012	1	32.0	100												
45	227.58	235	243	45	**51–45**	2012	6	32.0	100												
57	288.19	296	304	57	**51–57**	2012	6	32.0	110												
76	384.15	392	400	76	**51–76**	2012	6	32.0	110												

Taper Lock bushes supplied as a separate item

TDS4 - Taper lock sprocket





d	35 mm	
D	47 mm	
B	7 mm	
D_2	44,3 mm	
$D_{a\,max}$	45 mm	
d_1	39 mm	
$d_{a\,min}$	37 mm	
$r_{a\,max}$	0,3 mm	
r_{min}	0,3 mm	
m	0,03 kg	Mass
C_r	4050 N	Basic dynamic load rating, radial
C_{0r}	3000 N	Basic static load rating, radial
n_G	7300 1/min	Limiting speed
C_{ur}	153 N	Fatigue limit load, radial

TDS5 - Bearing B & C

Principal dimensions			Basic load ratings		Fatigue load limit	Speed ratings		Mass	Designation
			dynamic	static		Reference speed	Limiting speed		
d	D	B	C	C_0	P_u				
mm			kN		kN	r/min		kg	–
12	21	5	1,74	0,915	0,039	70 000	43 000	0,0063	61801
	24	6	2,91	1,46	0,062	67 000	40 000	0,011	61901
	28	8	5,4	2,36	0,1	60 000	38 000	0,021	* 6001
	30	8	5,07	2,36	0,1	60 000	38 000	0,026	16101
	32	10	7,28	3,1	0,132	50 000	32 000	0,037	* 6201
	37	12	10,1	4,15	0,176	45 000	28 000	0,06	* 6301
15	24	5	1,9	1,1	0,048	60 000	38 000	0,0065	61802
	28	7	4,36	2,24	0,095	56 000	34 000	0,016	61902
	32	8	5,85	2,85	0,12	50 000	32 000	0,03	* 16002
	32	9	5,85	2,85	0,12	50 000	32 000	0,03	* 6002
	35	11	8,06	3,75	0,16	43 000	28 000	0,045	* 6202
	42	13	11,9	5,4	0,228	38 000	24 000	0,082	* 6302
17	26	5	2,03	1,27	0,054	56 000	34 000	0,0075	61803
	30	7	4,62	2,55	0,108	50 000	32 000	0,016	61903
	35	8	6,37	3,25	0,137	45 000	28 000	0,038	* 16003
	35	10	6,37	3,25	0,137	45 000	28 000	0,038	* 6003
	40	12	9,95	4,75	0,2	38 000	24 000	0,065	* 6203
	40	12	11,4	5,4	0,228	38 000	24 000	0,064	6203 ETN9
	47	14	14,3	6,55	0,275	34 000	22 000	0,11	* 6303
	62	17	22,9	10,8	0,455	28 000	18 000	0,27	6403
20	32	7	4,03	2,32	0,104	45 000	28 000	0,018	61804
	37	9	6,37	3,65	0,156	43 000	26 000	0,037	61904
	42	8	7,28	4,05	0,173	38 000	24 000	0,05	* 16004
	42	12	9,95	5	0,212	38 000	24 000	0,067	* 6004
	47	14	13,5	6,55	0,28	32 000	20 000	0,11	* 6204
	47	14	15,6	7,65	0,325	32 000	20 000	0,098	6204 ETN9
	52	15	16,8	7,8	0,335	30 000	19 000	0,14	* 6304
	52	15	18,2	9	[illegible]	30 000	19 000	0,14	6304 ETN9
	[illegible]	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6404
22	50	14	14	7,65	0,325	30 000	19 000	0,13	62/22
	56	16	18,6	9,3	0,39	28 000	18 000	0,18	63/22

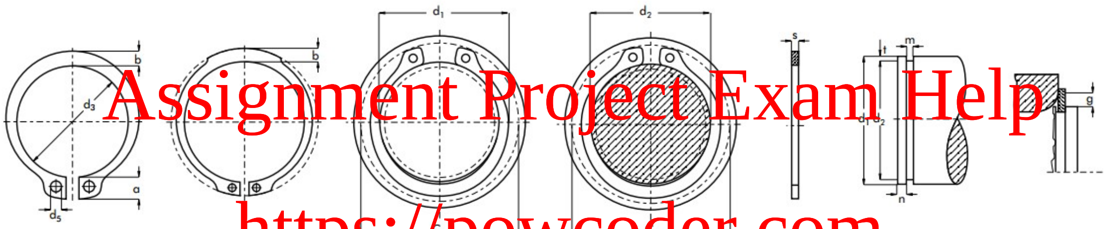
TDS6 - Bearing A & D

Dimensions					Abutment and fillet dimensions			Calculation factors	
d	d_1 ~	D_1 ~	D_2	$r_{1,2}$ min.	d_a min.	D_a max.	r_a max.	k_r	f_0
mm					mm			–	
12	14,8	18,3	–	0,3	14	19	0,3	0,015	13
	16	20,3	–	0,3	14	22	0,3	0,02	15
	17	23,2	24,8	0,3	14	26	0,3	0,025	13
	17	23,4	24,8	0,3	14,4	27,6	0,3	0,025	13
	18,4	25,7	27,4	0,6	16,2	27,8	0,6	0,025	12
	19,5	29,5	31,5	1	17,6	31,4	1	0,03	11
15	17,8	21,3	–	0,3	17	22	0,3	0,015	14
	18,8	24,2	25,3	0,3	17	26	0,3	0,02	14
	20,5	26,7	28,2	0,3	17	30	0,3	0,02	14
	20,5	26,7	28,2	0,3	17	30	0,3	0,025	14
	21,7	29	30,4	0,6	19,2	30,8	0,6	0,025	13
	23,7	33,7	36,3	1	20,6	36,4	1	0,03	12
17	19,8	23,3	–	0,3	19	24	0,3	0,015	14
	20,4	26,6	27,7	0,3	19	28	0,3	0,02	15
	23	29,2	31,2	0,3	19	33	0,3	0,02	14
	23	29,2	31,2	0,3	19	33	0,3	0,025	14
	24,5	32,7	35	0,6	21,2	35,8	0,6	0,025	13
	24,5	32,7	–	0,6	21,2	35,8	0,6	0,03	12
	26,5	37,4	39,6	1	22,6	41,4	1	0,03	12
	32,4	46,6	48,7	1,1	23,5	55,5	1	0,035	11
20	23,8	28,3	–	0,3	22	30	0,3	0,015	15
	25,5	31,4	32,7	0,3	22	35	0,3	0,02	15
	27,3	34,6	–	0,3	22	40	0,3	0,02	15
	27,2	34,8	37,2	0,6	23,2	38,8	0,6	0,025	14
	28,8	38,5	40,6	1	25,6	41,4	1	0,025	13
	28,2	39,6	–	1	25,6	41,4	1	0,025	12
	30,3	41,6	44,8	1,1	27	45	1	0,03	12
	30,3	42,6	–	1,1	27	45	1	0,03	12
	37,1	54,8	–	1,1	29	63	1	0,035	11
22	32,2	41,8	44	1	27,6	44,4	1	0,025	14
	32,9	45,3	–	1,1	29	47	1	0,03	12

TDS7- Bearing A &D

																DATA							
d_1	DIN 471 D1400 A	s	Δ	d_3	Δ	a max.	b ≈	d_5 min.	C_1	C_2	(kg/1000)	d_2	Δ	m min.	t	n	FN (kN)	FR (kN)	g	FRg (kN)	AN (mm^2)	B	$n_{det.}$ x1000 (rpm)
3	A3	0.40	-0.05	2.7	+0.04 -0.15	1.9	0.8	1.0	7.0	6.6	0.017	2.8	-0.04	0.50	0.10	0.3	0.1	0.47	0.5	0.27	0.9	2.06	360
4	A4	0.40		3.7		2.2	0.9	1.0	8.6	8.2	0.022	3.8		0.50	0.10	0.3	0.2	0.50	0.5	0.30	1.2	1.93	211
5	A5	0.60		4.7		2.5	1.1	1.0	10.3	9.8	0.066	4.8		0.70	0.10	0.3	0.2	1.00	0.5	0.80	1.5	7.38	154
6	A6	0.70		5.6		2.7	1.3	1.2	11.7	11.1	0.084	5.7		0.80	0.15	0.5	0.4	1.45	0.5	0.90	2.8	10.40	114
7	A7	0.80		6.5	+0.06 -0.18	3.1	1.4	1.2	13.5	12.9	0.121	6.7	-0.06	0.90	0.15	0.5	0.5	2.60	0.5	1.40	3.2	14.70	121
8	A8	0.80		7.4		3.2	1.5	1.2	14.7	14.0	0.158	7.6		0.90	0.20	0.6	0.8	3.00	0.5	2.00	4.9	14.20	96
9	A9	1.00	-0.06	8.4		3.3	1.7	1.2	16.0	15.2	0.300	8.6		1.10	0.20	0.6	0.9	3.50	0.5	2.40	5.5	30.00	85
10	A10	1.00		9.3	+0.10 -0.36	3.3	1.8	1.5	17.0	16.2	0.340	9.6	-0.11	1.10	0.20	0.6	1.0	4.00	1.0	2.40	6.2	28.20	84
11	A11	1.00		10.2		3.3	1.8	1.5	18.0	17.1	0.410	10.5		1.10	0.25	0.8	1.4	4.50	1.0	2.40	8.4	26.10	70
12	A12	1.00		11.0		3.3	1.8	1.7	19.0	18.1	0.500	11.5		1.10	0.25	0.8	1.5	5.00	1.0	2.40	9.2	24.00	75
13	A13	1.00		11.9		3.4	2.0	1.7	20.2	19.2	0.530	12.4		1.10	0.30	0.9	2.0	5.80	1.0	2.40	11.9	23.20	66
14	A14	1.00		12.9		3.5	2.1	1.7	21.4	20.4	0.640	13.4		1.10	0.30	0.9	2.1	6.40	1.0	2.40	12.9	22.90	58
15	A15	1.00		13.8		3.6	2.2	1.7	22.6	21.5	0.670	14.3		1.10	0.35	1.1	2.6	6.90	1.0	2.40	16.1	21.60	50
16	A16	1.00		14.7		3.7	2.2	1.7	23.8	22.6	0.700	15.2		1.10	0.40	1.2	3.2	7.40	1.0	2.40	19.6	21.00	45
17	A17	1.00		15.7		3.8	2.3	1.7	25.0	23.8	0.820	16.2		1.10	0.40	1.2	3.4	8.00	1.0	2.40	20.8	21.60	41
18	A18	1.20		16.5		3.9	2.4	2.0	26.2	24.8	1.110	17.0		1.30	0.50	1.5	4.5	17.00	1.5	3.75	27.5	37.10	39
19	A19	1.20		17.5		3.9	2.5	2.0	27.2	25.8	1.220	18.0		1.30	0.50	1.5	4.8	17.00	1.5	3.80	29.1	36.40	35
20	A20	1.20		18.5	+0.13 -0.42	4.0	2.6	2.0	28.4	27.0	1.300	19.0	-0.13	1.30	0.50	1.5	5.0	17.10	1.5	3.85	30.6	36.30	32
21	A21	1.20		19.5		4.1	2.7	2.0	29.6	28.2	1.420	20.0		1.30	0.50	1.5	5.3	16.80	1.5	3.75	32.2	35.40	29
22	**A22**	**1.20**		**20.5**		**4.2**	**2.8**	**2.0**	**30.8**	**29.4**	**1.500**	**21.0**		**1.30**	**0.50**	**1.5**	**5.6**	**16.90**	**1.5**	**3.80**	**33.8**	**35.40**	**27**
23	A23	1.20		21.5		4.3	2.9	2.0	32.0	30.6	1.630	22.0	-0.15	1.30	0.50	1.5	5.9	16.60	1.5	3.80	35.4	34.70	25
24	A24	1.20		22.2		4.4	3.0	2.0	33.2	31.7	1.770	22.9	-0.21	1.30	0.55	1.7	6.7	16.10	1.5	3.65	40.5	33.40	27
25	A25	1.20		23.2	+0.21 -0.42	4.4	3.0	2.0	34.2	32.7	1.900	23.9		1.30	0.55	1.7	7.0	16.20	1.5	3.70	42.3	33.40	25
26	A26	1.20		24.2		4.5	3.1	2.0	35.5	33.9	1.960	24.9		1.30	0.55	1.7	7.3	16.10	1.5	3.70	44.0	32.90	24
27	A27	1.20		24.9		4.6	3.1	2.0	36.7	34.8	2.080	25.6		1.30	0.70	2.1	9.6	16.40	1.5	3.80	57.8	33.40	22
28	A28	1.50		25.9		4.7	3.2	2.0	37.9	36.0	2.920	26.6		1.60	0.70	2.1	10.0	32.10	1.5	7.50	60.0	65.00	21
29	A29	1.50		26.9		4.8	3.4	2.0	39.1	37.2	3.200	27.6		1.60	0.70	2.1	10.3	31.80	1.5	7.45	62.0	64.00	20
30	A30	1.50		27.9		5.0	3.5	2.0	40.5	38.6	3.320	28.6		1.60	0.70	2.1	10.7	32.10	1.5	7.65	64.0	64.20	19
31	A31	1.50		28.6		5.1	3.5	2.5	41.7	40.9	3.450	29.3		1.60	0.85	2.6	13.4	31.50	2.0	5.60	81.0	62.80	18
32	A32	1.50		29.6		5.2	3.6	2.5	43.0	40.7	3.540	30.3	-0.25	1.60	0.85	2.6	13.8	31.20	2.0	5.55	83.0	61.80	17
33	A33	1.50		30.5	+0.25 -0.50	5.2	3.7	2.5	44.0	41.7	3.690	31.3		1.60	0.85	2.6	14.3	31.60	2.0	5.65	86.0	62.20	17
34	A34	1.50		31.5		5.4	3.8	2.5	45.4	43.1	3.800	32.3		1.60	0.85	2.6	14.7	31.30	2.0	5.60	88.0	61.30	16
35	A35	1.50		32.2		5.6	3.9	2.5	46.8	44.2	4.000	33.0		1.60	1.00	3.0	17.8	30.80	2.0	5.55	107.0	60.10	16
36	A36	1.75		33.2		5.6	4.0	2.5	47.8	45.2	5.000	34.0		1.85	1.00	3.0	18.3	49.40	2.0	9.00	110.0	95.80	15
37	A37	1.75		34.2		5.7	4.1	2.5	49.0	47.0	5.370	35.0		1.85	1.00	3.0	18.8	50.00	2.0	9.15	113.0	96.40	14

TDS8 -



TDS9 -

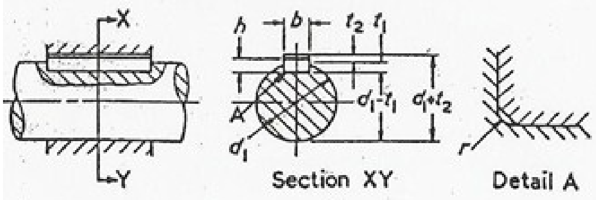
Bush No.	Available Bore Sizes - Metric mm																		
TB1008	9	10	12	14	16	18	19	20	22	24	25								
TB1210	11	12	14	16	18	19	20	22	24	25	28	30	32						
TB1215	11	12	14	16	18	19	20	22	24	25	28	30	32						
TB1610	14	16	18	19	20	22	24	25	28	30	32	35	38	40	42				
TB1615	14	16	18	19	20	22	24	25	28	30	32	35	38	40	42				
TB2012	14	16	18	19	20	22	24	25	28	30	32	35	38	40	42	44	45	48	50
TB2017	18	19	20	22	24	25	28	30	32	35	38	40	42	45	48	50			
TB2517	16	18	19	20	22	24	25	28	30	32	35	38	40	42	45	48	50	55	60
TB2525	19	20	22	24	25	28	30	32	35	38	40	42	45	48	50	55	60		
TB3020	25	28	30	32	35	38	40	42	45	48	50	55	60	65	70	75			
TB3030	35	38	40	42	45	48	50	55	60	65	70	75							
TB3535	35	38	40	42	45	48	50	55	60	65	70	75	80	85	90				
TB4040	40	42	45	48	50	55	60	65	70	75	80	85	90	95	100				

TDS10 - Taper lock

Bush size		1008	1108	1210	1610	1615	2012	2517	3020	3030	3525	3535	4030	4040	4535	4545	5040	5050
Screw tightening torque (Nm)		5.6	5.6	20.0	20.0	20.0	30.0	50.0	90.0	90.0	115.0	115.0	170.0	170.0	190.0	190.0	270.0	270.0
Screw details	qty	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3
	size (BSW)	1/4"	1/4"	3/8"	3/8"	3/8"	7/16"	1/2"	5/8"	5/8"	1/2"	1/2"	5/8"	5/8"	3/4"	3/4"	7/8"	7/8"
	Hex. socket size (mm)	3	3	5	5	5	6	6	8	8	10	10	12	12	14	14	14	14
Large end dia. (mm)		35.0	38.0	47.5	57.0	57.0	70.0	85.5	108.6	108.0	127.0	127.0	146.0	146.0	162.0	162.0	178.0	178.0
Bush length (mm)		22.3	22.3	25.4	25.4	38.1	31.8	44.5	50.8	76.2	63.5	89.0	76.2	102.0	89.0	114.0	102.0	127.0
Approx mass (kg)		0.1	0.1	0.2	0.3	0.5	0.7	1.5	2.7	3.6	3.8	5.0	5.6	7.7	7.5	10.0	11.1	14.0

TDS11 - Taper lock (2)

Dimensions and Tolerances of Keyways



Shaft: Diameter (1) d – Above	Shaft: Diameter (1) d – to and including	Key (1): Section b×h	Keyway: Width b – nom.	Width b tolerance: Sliding keys – shaft H9	Sliding keys – hub D10	Normal keys – shaft (N9)	Normal keys – hub (JS9)	Fitted keys shaft and hub (P9)	Depth (2): shaft: t – nom.	shaft: t – tol.	hub: t_1 – nom.	hub: t_1 – tol.	Radius r – max.	Radius r – min.
6	8	2× 2	2	+0.025	+0.060	−0.004	+0.0125	−0.006	1.2		1		0.16	0.08
8	10	3× 3	3	0	+0.020	−0.029	−0.0125	−0.031	1.8		1.4		0.16	0.08
10	12	4× 4	4						2.5	+0.1	1.8	+0.1	0.16	0.08
12	17	5× 5	5	+0.030	+0.078	0	+0.015	−0.012	3	0	2.3	0	0.25	0.16
				0	+0.030	−0.030	−0.015	−0.042						
17	22	6× 6	6						3.5		2.8		0.25	0.16
[illegible]	30	8× 7	8	+0.036	[illegible]	0	[illegible]	[illegible]	4		3.3		0.25	0.16
[illegible]	[illegible]	[illegible]	[illegible]	0	+0.040	[illegible]	[illegible]	−0.051	[illegible]		[illegible]		[illegible]	[illegible]
38	44	[illegible]	12						5		3.3		0.40	[illegible]
44	50	14× 9	14	+0.043	+0.120	0	+0.0215	−0.018	5.5		3.8		0.40	0.25
50	58	16×10	16	0	+0.050	−0.043	−0.0215	−0.061	6	−0.2	4.3	+0.2	0.40	0.25
58	65	18×11	18						7	0	4.4	0	0.40	0.25
65	75	[illegible]	[illegible]						[illegible]		[illegible]		0.60	0.40
75	85	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]		[illegible]		0.60	0.40
85	95	25×14	25	0	[illegible]	−0.052	−0.026	−0.074	9		5.4		0.60	0.40
95	110	28×16	28						10		6.4		0.60	0.40
110	130	32×18	32						11		7.4		0.60	0.40
130	150	[illegible]	36	[illegible]	[illegible]	0	[illegible]	[illegible]	12		[illegible]		1.00	0.70
150	170	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		1.00	0.70
170	200	[illegible]	45						15		[illegible]		1.00	0.70
200	230	50×28	50						17	+0.3	11.4	+0.3	1.00	0.70
230	260	56×32	56						20	0	12.4	0	1.60	1.20
260	290	63×32	63	+0.074	+0.220	0	+0.037	−0.032	20		12.4		1.60	1.20
290	330	70×36	70	0	+0.100	−0.074	−0.037	−0.106	22		14.4		1.60	1.20
330	380	80×40	80						25		15.4		2.50	2.00
380	440	90×45	90	+0.087	+0.260	0	+0.0435	−0.037	28		17.4		2.50	2.00
440	500	100×50	100	0	+0.120	−0.087	−0.0435	−0.124	31		19.5		2.50	2.00

TDS12 - Dimension and tolerance of keyway