Table 4. Cycles before fracture at various stress levels. Test stopped at 10 million cycles.

Stress, MPa	Cycles before fracture		
	Bumax DX	**Bumax 88**	**A4-80**
400±50	10 million	10 million	10 million
400±50	10 million	10 million	1.4 million
400±55	10 million	10 million	0.4 million
400±55	10 million	10 million	0.4 million
400±60	10 million	4.2 million	0.5 million
400±60	10 million	5.6 million	0.3 million
400±70	10 million	1.9 million	
400±70	10 million	1.8 million	
400±80	10 million	0.7 million	
400±80	10 million	0.4 million	
400±85	10 million		
400±85	2.6 million		
400±90	5.1 million		
400±90	0.6 million		
400±95	0.4 million		
400±95	0.3 million		

Bufab is one of a few fastening companies that actually has tested the fatigue strength of Duplex fasteners and compared it with austenitic stainless steel fasteners. Fatigue testing has been performed on Bumax DX, Bumax 88 and competitor A4-80 material at an external laboratory up to 10 million cycles. Table 4 shows testing result from longitudinal fatigue loading on M6x50 ISO 4017 bolts, Wöhler curve (S-N curve) can be received on request. The bolts were pre-stressed to 400 MPa, which is the stress obtained on a typical preloading of M6 class 80 bolts.

QUALITY AND ENVIRONMENT

The majority of our fasteners are manufactured using our unique processes in our own facilities in Sweden where stainless fasteners have been made since 1926. The BUMAX process gives a superior product with increased strength, grain flow and improved fatigue resistance.

Raw material is sourced from premium suppliers in Europe with rigid specifications regarding chemical composition with low content of trace elements as well as low inclusion and slag content. All our products are delivered with full traceability and 3.1 certificate.

STOCK

We keep Bumax SDX stock in strength class 10.9 on the most common types of screws, nuts and washers. Contact your local Bumax sales representative or visit www.bumax.se for more information.

SERVICE

Bumax Duplex products are manufactured in our own factories and we can therefore keep a very high service level on these products. Thanks to our own manufacturing, we can offer sizes other than those presented in our stock range enabling us to produce "special" products according to each customer needs. We can produce products having even higher strength than the ones presented in this brochure. In these cases, it is the limitations on the steel itself deciding how far we can reach in terms of strength and other properties. We are continuously working on improving the properties of our products.

Marking

The Bumax SDX fasteners held in stock consisting of hexagon head screws, hexagon socket screws, nuts and washers that are marked in accordance with the figure below.

We also have the possibility of individual marking or according to special customer requests.

Packing

Our products are packed in high quality sturdy boxes and are marked according to a colour coded system. We guarantee full traceability for all our products in unbroken boxes. On our labels all data for full traceability is given.

BUMAX®
THE WORLDS STRONGEST STAINLESS STEEL BOLT

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BUMAX® A BUFAB GROUP BRAND

BUMAX®
THE WORLDS STRONGEST STAINLESS STEEL BOLT

Bumax is Bufab's registered trademark, known as the strongest stainless steel fastener in the world.
Bumax is manufactured in Bufab's own plants in Sweden and meets the requirements of high demanding customers when it comes to quality, corrosion resistance, high strength, fatigue strength, traceability and heat resistance. We deliver safety and reliability.

Some of the products in the Bumax family are completely unique that cannot be found anywhere else on the market. All products have full traceability (3.1 certificates available for each item) and are sourced solely from premium European stainless steel manufacturers according to rigid specifications.

INTRODUCTION to Duplex Stainless Steel

Duplex Stainless Steel, also known as Ferrite-Austenitic Stainless Steel, is a family of stainless steel that have two-phase microstructure containing Ferrite and Austenite. The picture below shows the austenitic grains embedded in a ferritic phase (dark grey grains). It is important that the mix of ferritic and austenitic phase is roughly 50/50, a too high content of any structure can lead to reduced corrosion resistance and mechanical properties.

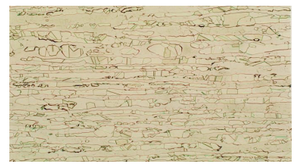

Fig 1. Duplex stainless steels have a two-phase microstructure of austenite and ferrite grains.

Duplex stainless steel offers many attractive properties:

Strength: Dual phase prevents grain growth during annealing and a much higher strength can be achieved after strain hardening compared to ordinary austenitic stainless steel.

Ductility: Duplex stainless steels are unique in its kind of combining super high strength with excellent ductility and elongation. Even at very high strength levels such as 12.9, Duplex stainless steel is equally good or has better elongation than A4-80.

Fatigue resistance: Duplex microstructure together with low inclusion content, excellent strength and ductility results in superior fatigue resistance.

Corrosion resistance: Depending on Duplex grade, ranging from grades equivalent to A2/A4 to highly resistant austenitic stainless steel and Nickel base alloys.

Thermal expansion: Duplex stainless has lower expansion in elevated temperature than an austenitic stainless steel. The coefficient of thermal expansion is approximately 25% lower because of the ferrite phase in Duplex stainless steel.

Nickel price stability: Duplex stainless steels have generally lower nickel and molybdenum contents than their austenitic counterparts of similar corrosion resistance. Due to the lower alloying content, Duplex stainless steels can offer lower alloy surcharge and better price stability over time.

APPLICATIONS

Bumax Duplex fasteners are used in many demanding applications that require better corrosion resistance and mechanical properties than Bumax 88/109 (316L, A4).

High alloyed Duplex grades such as Bumax SDX and Bumax HDX are mainly used in the oil/gas, chemical, pulp and paper industries, subsea or other types of applications that are working in tough corrosive environments.

Bumax LDX is mainly used in applications that require similar corrosion resistance as A2/A4, but where it is beneficial with higher strength and better fatigue resistance. Typical applications are large construction projects such as bridges, wind turbines and storage tanks.

BUMAX DUPLEX GRADES

Duplex Stainless Steel fasteners are widely used for critical applications that demands a combination of excellent corrosion resistance and high strength. The material has very high strength, even in annealed condition, and is therefore difficult to cold form. That is the reason why nearly all Duplex fasteners up till now has either been machined or hot forged. What makes Bumax Duplex grades unique is our production process that offers many advantages compared to machined or hot forged Duplex fasteners, such as:

- Higher strength and better fatigue resistance due to our special Bumax production process. Duplex fasteners are offered in strength class 80, 8.8, 10.9 or 12.9, depending on customer demands. Machined fasteners have only the same strength as the procured annealed bar and can therefore not be produced in higher strength class than 8.8.
- All Bumax Duplex fasteners are thread rolled. Thread rolling induces compressive stresses and thereby higher surface hardness and improved fatigue resistance. Cut threads have the disadvantage of sharp edges and not a proper grain flow, which can affect galling and fatigue life length.
- Super Duplex and Hyper Duplex are very sensitive to all forms of high temperature processes. Structural changes can occur in Duplex stainless steel at temperatures that exceeds 600ºC, a temperature that is exceed in hot forged duplex production. Formation of inter-metallic phase or non-balanced microstructure with too high ferrite content is very critical as it will reduce corrosion resistance and decrease ductility which can lead to fractures. Bumax Duplex fasteners and bar turned bolts are not affected as they are produced in much lower temperature.

Bumax offers a complete product range of Duplex fasteners, from Lean Duplex to Hyper Duplex stainless steel.

Bumax Lean Duplex (LDX) offers an economical solution for high strength fasteners in medium corrosive environments. Bumax LDX is not a stock item but we can offer competitive prices on large volume orders.

Bumax Duplex (DX) is characterized by excellent strength, ductility and fatigue resistance in combination with good general crevice, pitting and stress corrosion properties. Bumax DX is a non-stock product.

Bumax Super Duplex (SDX) is characterised by excellent mechanical properties and very good corrosion resistance. Excellent resistance to general crevice, pitting and stress corrosion in chloride bearing medias. Most common fastener types and dimensions of Bumax SDX in strength class 10.9 are stock product.

Bumax Hyper Duplex (HDX), a groundbreaking alloy used in the most demanding applications. Suited for use in severe corrosive environments such as hot chlorinated sea-water and for aggressive acidic chloride containing media in chemical, oil/gas, marine and petrochemical industry. Bumax HDX is a non-stock item but can be manufactured on request to a maximum dimension of M8.

Table 2. Difference in chemical composition

Grade	EN	UNS	Chemical composition, weight-%				
			Cr	Ni	Mo	Other	PRE[1)]
Bumax LDX	1.4162	S32101	21.5	1.5	0.3	M 0.22, Mn 5	26
Bumax DX	1.4462	S31803,S32205	22	5.2	3.2		36
Bumax SDX	1.4410	S32750	25	7	4		42
Bumax HDX	1.4658	S32707	27	6.5	4.8	Co	49

[1)] PRE = %Cr + 3.3x%Mo + 16x%N

CORROSION RESISTANCE

Duplex Stainless Steel offers very good resistance to general and pitting corrosion due to the high content of chromium, nitrogen and molybdenum. The Duplex microstructure itself gives high resistance to stress corrosion cracking.

Bumax Duplex grades exhibits great corrosion resistance, ranging from Bumax LDX that has approximately the same corrosion resistance as A4 (ASTM 316) to Bumax SDX and HDX that can substitute very expensive nickel base alloys or even Titanium in some environments. The Pitting Resistance Equivalent number, PRE is based on a well-known formula and gives a good indication of the pitting and crevice corrosion resistance as a function of the alloying content. The higher PRE number, the more resistant is the steel against pitting corrosion in seawater and chloride induced corrosion.

Table 2. Corrosion guideline

Condition		A4	Bumax LDX	Bumax DX	Bumax SDX	Bumax HDX
Saltwater		O	O	◌	◌	◌
Hydrochloric acid, HCl	1% at 50ºC	●	●	O	◌	◌
	2% at 50ºC	●	●	●	◌	◌
	3% at 50ºC	●	●	●	●	◌
Nitric acid, HNO_3	65% at 70ºC	◌	◌	◌	◌	◌
	65% at 90ºC	●	◌	◌	◌	◌
Suplhuric acid, H_2SO_4	1% at 50ºC	◌	◌	◌	◌	◌
	10% at 50ºC	◌	◌	◌	◌	◌
	30% at 50ºC	●	●	●	◌	◌

◌ No risk of corrosion under normal conditions

O Possible risk of corrosion, but the steel grade might be suitable depending on requirement, environment, design and maintenance

● Not suitable, corrosion is likely to occur

MECHANICAL PROPERTIES

Bumax Duplex grades can be offered in different strength classes depending on customer request, dimension and fastener type. Table 3 shows the Bumax Duplex grades dimension range and mechanical properties. Bufab can also offer bar turned Super Duplex fasteners with complex geometry and dimension larger than M30. Machined Super Duplex grades have lower strength and can be offered in strength class 80, 8.8 or according to a specific standard such as NORSOK or NACE0175.

Bumax Super Duplex (SDX) fastener in strength class 10.9 is held in stock, visit www.bumax.se for information regarding stock product range.

Table 3. Bumax duplex grades dimension range and strength class

Product	Strength Class	Dimension, mm	Tensile strength R_m, min		Yield strength $R_{p0.2}$, min		Elongation, min [1)]
			MPa	psi	MPa	psi	
Bumax LDX	10.9	M8 – M30	1000	145 000	900	130 500	0.4 d
	12.9	On request	1200	174 000	1080	156 500	
Bumax DX	10.9	M3 – M30	1000	145 000	900	130 500	0.4 d
	12.9	On request	1200	174 000	1080	156 500	
Bumax SDX	10.9	M3 – M30	1000	145 000	900	130 500	0.4 d
	12.9	On request	1200	174 000	1080	156 500	
Bumax HDX	12.9	M3 – M8	1200	174 000	1080	156 500	0.3 d

[1)] According to ISO 3506

Bumax Duplex fasteners are always coated with our special tailor made wax, suitable for duplex fasteners and guarantees low friction and minimizing the risk of galling. Recommended preload and tightening torque data can be found at www.bumax.se

FATIGUE RESISTANCE

Fatigue fracture occurs when a fastener is subjected to repeat cyclic loading. Even maximum stresses below the materials yield point can lead to the formation of microscopic cracks that eventually lead to a failure. The starting point of a fatigue fracture is often stress concentration in inclusions, slags or surface defects.

It is well known that Duplex grades exhibits extraordinary fatigue resistance, far better than any standard austenitic fastener such as A2, A4 etc. The reasons for the high fatigue resistance on Bumax Duplex grades are:

- High strength fasteners with compressive stresses due to thread rolling
- Excellent elongation
- Low amount of inclusions
- Dual phase that prevent crack propagation