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Properties

High-strength DILLIMAX offers more than just outstanding material and processing qualities. Its properties and performance are also impressive under operating conditions in the component.

The information on the properties and processing of DILLIMAX has been developed in accordance with Dillinger's best knowledge and experience. It is intended to support manufacturers in developing their own processing procedure for DILLIMAX.

Our wide product portfolio at a glance

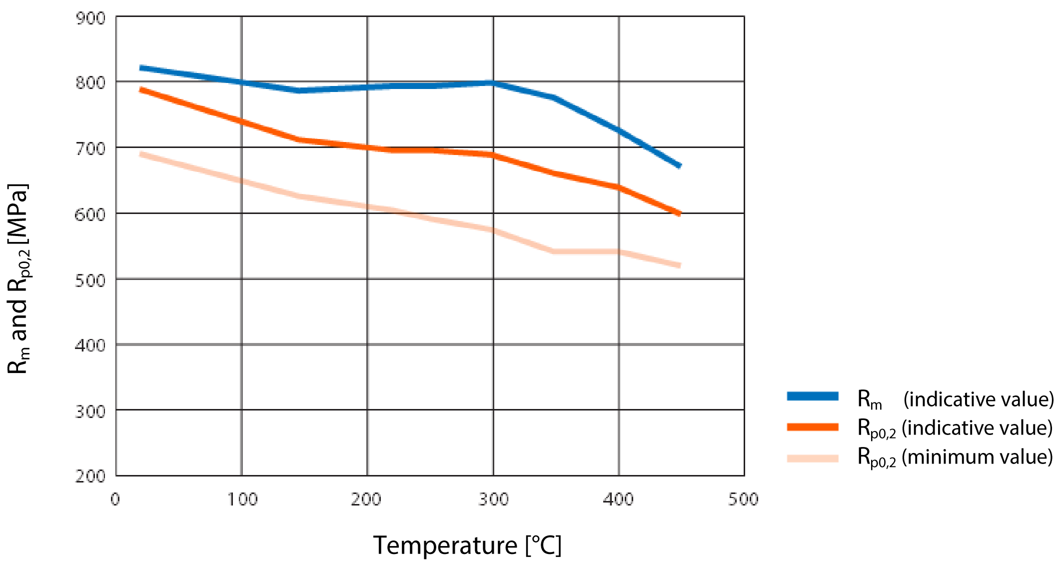
	Nominal minimum yield strength [MPa] (ksi)	Notched impact strength [°C] (°F)	Plate thickness [mm]	Designation EN 10025-6
DILLIMAX 690	690 (100)	B/T/E -20/-40/-60 (-4/-40/-76)	6 - 290[a]	S690
DILLIMAX 890	890 (130)		6 - 160	S890
DILLIMAX 965	960 (140)			S960
DILLIMAX 1100	1100 (160)	-40 (-40)	8 - 40	n.a.

[a] DILLIMAX 690 E: up to 200 mm

Heat resistance

The selective use of alloying elements and the particular quenching and tempering treatment give DILLIMAX 690 steels and above good heat resistance up to 500 °C.

Effect of temperature on the strength properties of DILLIMAX 690 (plate thickness ≤50 mm)



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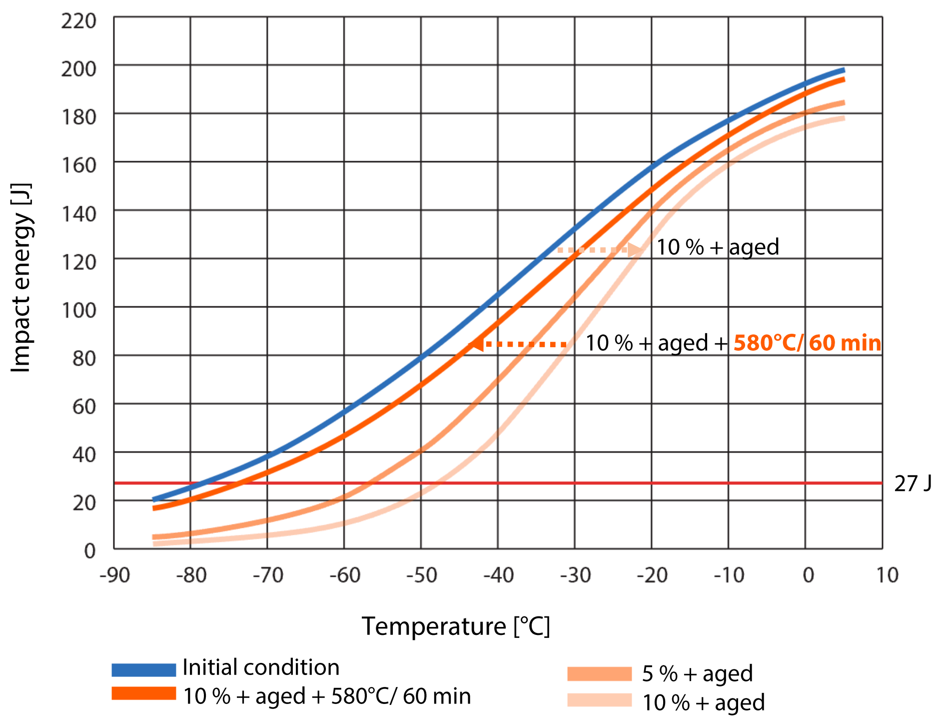
The values for the yield strength at elevated temperature of DILLIMAX 890 and DILLIMAX 965 are similar to the curve in the diagram for DILLIMAX 690, just around 200 MPa higher for DILLIMAX 890 and around 350 MPa higher for DILLIMAX 965. Minimum values for the yield strength at elevated temperature can be guaranteed if required and stated in the material certificate.
If hot forming is carried out at more than 560 °C, the original tempering condition as well as the mechanical properties may be impaired. In this case, re-tempering is necessary. The general rule of thumb here is to stay approx. 40 °C below the actual tempering temperature. To counteract this, a higher temperature can be agreed before ordering and/or the tempering temperature can be specified in the certificate. Please also refer to our processing information– forming.

Ageing

Over a period of time, cold-formed steels are subject to an embrittlement phenomenon known as ageing. While this process can take years at room temperature, it occurs much faster at elevated temperatures. Ageing can also be accelerated when welding in cold-formed areas. The proof of ageing resistance can be provided on request when ordering.
Welding in cold-formed areas can also accelerate ageing. The reserves of toughness shown in the initial state, the degree of cold forming and the lowest application temperature of the component are, therefore, the decisive criteria for the resistance of a cold-formed steel to brittle fracture.
Annealing in the stress relieving temperature range carried out after forming reduces aging-induced embrittlement.

Effect of cold forming, ageing and stress relieving on the Charpy impact transition curves of DILLIMAX 690 T (plate thickness 30 mm)



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Flame straightening

Flame straightening of plates is a process frequently used in steel construction to shape complex components and achieve flat cross-sections. All DILLIMAX steels up to DILLIMAX 965 can be flame straightened. However, certain boundary conditions must also be observed while processing conventional steels. A distinction must be made between flame straightening with heat paths, flame straightening with heat points and heat wedges. Flame straightening of DILLIMAX 1100 is not permitted.

Operational tests have shown that a localised reduction in the strength properties and notch impact properties of DILLIMAX 690 during linear flame straightening up to 800 °C only occurs on the heat paths. However, this is negligible for the entire plate, depending on the application. If these areas cannot be tolerated in the application or if the entire cross-section is heated, the maximum straightening temperature must be limited to 40 °C below the tempering temperature. This also applies to hot straightening with heat spots and heat wedges. It should generally be noted that a reduction in the strength and toughness properties of DILLIMAX steels is to be expected in case of high heat input.

Indicative carbon equivalent

The following carbon equivalents[a,b] are reference values. They are based on experience and average values. They may deviate in individual cases. The values agreed in the order are binding.

	DILLIMAX 690		DILLIMAX 890		DILLIMAX 965		DILLIMAX 1100	
Plate thickness	CEV Indicative	CEN EN 10025-6	CEV Indicative	CEV EN 10025-6	CEV Indicative	CEV EN 10025-6	CEV Indicative	CEV EN 10025-6
10	0.45	0.65	0.57	0.72	0.57	0.82	0.57	-
25	0.45	0.65	0.50	0.72	0.50	0.82	0.77	-
50	0.51	0.65	0.54	0.72	0.54	0.82	-	-
100	0.59	0.77	0.66	0.82	0.66	0.85	-	-
175	0.71	0.83	-	-	-	-	-	-

	DILLIMAX 690	DILLIMAX 890	DILLIMAX 965	DILLIMAX 1100
Plate thickness	CET indicative	CET indicative	CET indicative	CET indicative
10	0.34	0.35	0.35	0.35
25	0.34	0.34	0.34	0.37
50	0.34	0.35	0.35	-
100	0.36	0.39	0.39	-
175	0.41	-	-	-

[a] CEV = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15

[b] CET = C + (Mn+Mo)/10 + (Cr+Cu)/20 + Ni/40

Galvanising

High strength steels can tend to crack during pickling or galvanising. However, the crack-resistance during hot-dip galvanising depends not only on the choice of material but also on the design, the residual stresses, the composition of the zinc bath and the galvanising process. The use of high-strength quenched and tempered steels in hot-dip galvanised structures should therefore be treated with particular caution.

If galvanising or pickling is planned, this should be communicated at enquiry stage. In any case, the steel manufacturer and the hot-dip galvaniser should always be consulted in advance.

Corrosion resistance

The corrosion behaviour of DILLIMAX does not differ from that of conventional steel grades. They must therefore be protected by a coating system adapted to the ambient medium - normally with a multi-layer coating.

Component properties

The most important characteristic is fatigue strength.

Weldable, fine grained structural steels in the upper strength range such as DILLIMAX 690 to DILLIMAX 1100 are preferred for components whose weight is to be kept to a minimum (e.g. constructions in the conveying plants and hoisting equipment sectors). The high tensile properties of DILLIMAX steels are particularly of advantage for constructions subjected to a low number of load cycles, and thus designed assuming quasi-static conditions (mobile cranes for instance). Cyclical loads during service life can be decisive for the design of a component.

DILLIMAX steels are strong against cyclical loading. However, welds are subjected to much higher fatigue than the base material, and can thus lead to component failure.

In accordance with e.g. Eurocode 1993-1-9, fatigue strength is determined for welded components irrespective of the material´s yield strength, and solely by the fatigue strength of the present notch detail. The cost effective use of high strength steels in welded structures, if the fatigue analysis is crucial, is therefore not possible, at least on the basis of current design rules. In such cases, the engineer is unable to fully benefit from the potentially higher static strength.

In order to use high-strength steels economically in fatigue-stressed components, attention must therefore be paid above all to fatigue adapted design. This can be achieved by taking measures to reduce the notch sharpness of the welded details, but also by modifying fatigue-critical residual stresses. This can significantly increase the fatigue strength of high-strength steels. Suitable post-weld-treatment methods for increasing fatigue strength are higher-frequency hammering processes (e.g. HiFIT or UIT). This can be explained by the fact that these processes lead to both an improved residual stress condition due to the imprinting of compressive stresses and to weld seam transitions that are less critical to fatigue.

Potentials for improvement of the fatigue strength of weld details

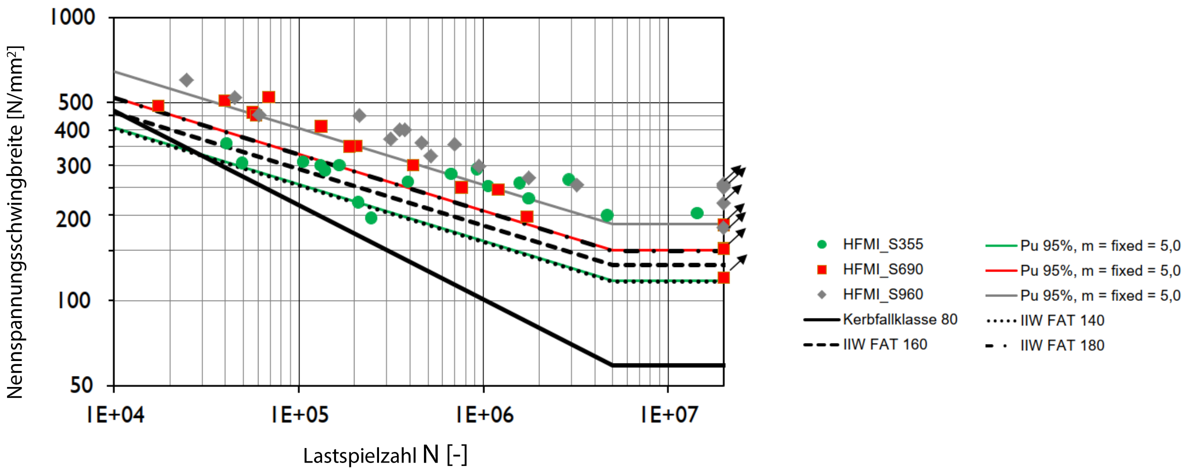
Reduction of notch acuity

- High frequency impact treatment (HiFIT, UIT)
- Grinding of weld transitions
- Appropriate selection of welding technology
- Remelting of weld transitions

Modification of residual stresses

- High frequency impact treatment (HiFIT, UIT)
- Shot blasting
- Post weld heat treatment
- Hammering/Needling

The effectivenes of such post weld treatment methods has been demonstrated in the most diverse range of research projects (e.g. REFRESH). Thus, the test results shown in the following graph[1] (evaluation according to the nominal stress concept) validate or exceed the FAT classes proposed by IIW and DASt for the HFMI post-treated welded joint. The results of the samples from S690 and S960 are significantly higher than the proposed FAT 160 (for S690) and FAT 180 (for S960).[1]



1 J. Schubnell, M. Farajian, S. Gkatzogiannis, P. Knödel, IGF-Vorhaben Nr. 19227 N Rechnergestütztes Bewertungstool zum Nachweis der Lebensdauerverlängerung von mit dem Hochfrequenz-Hämmerverfahren (HFMI) behandelten Schweißverbindungen aus hochfesten Stählen, Fraunhofer IWM, KIT (VAKA), 2020

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Information for these procedures and other useful literature:

DIN EN 1993-1-9, Eurocode 3: Design of steel structures - Teil 1-9: Fatigue. Standard, 2010

FKM Forschungskuratorium Maschinenbau e.V.: FKM-Richtlinie; Analytical Strength Assessment for Machine Components - 7th Edition, 2020

DASt Deutsche Ausschuss für Stahlbau: DASt - Guideline 026 -Ermüdungsbemessung bei Anwendung höher-frequenter Hämmerverfahren, 2019

Marquis, G.B., Barsoum, Z. : IIW Recommendations on High Frequency Mechanical Impact (HFMI) Treatment for Improving the Fatigue Strength of Welded Joints, Singapore: Springer, 2016

D. Schäfer, V. Rinaldi, D. Beg, P. Može, R. Lacalle, J. Portilla, D. Ferreño, J. A. Álvarez, R. Willms, J. Schütz; European Commission EUR 25120 — Optimisation and improvement of the flame straightening process (Optistraight), 2012

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Disclaimer

The information and data provided concerning the quality and/or applicability of materials and/or products constitute descriptions only. Any and all promises concerning the presence of specific properties and/or suitability for a particular application shall in all cases be deemed to require separate written agreements.

This processing information is updated at irregular intervals. The current version is relevant. The latest version is available from the mill or as download at www.dillinger.de.

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Issue 02/2024