Zanardi
Fonderie

AUSTEMPERED DUCTILE IRON GEAR FATIGUE PROPERTIES

#4

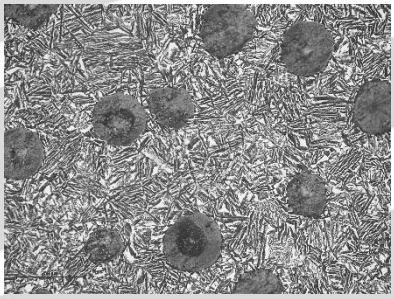
Introduction

This document is designed to familiarize the designer with **gear fatigue properties for ADI materials**. It is a reference document, not to be referred to as a standard.
The data in this document are taken from Zanardi research database, international standards, and technical papers. The content of this informational sheet has to be considered "for information only". The real component design shall be based only upon international standards and/or contractual agreements.

1 Material notes

Austempered Ductile Iron (ADI)

Austempered Ductile Iron (ADI) is obtained by heat-treating an alloyed ductile iron, casted with a special preconditioning of the metal bath. The matrix structure consists predominantly of ferrite and acicular austenite. The obtained matrix is called "ausferritic" which offers the combination of high fatigue resistance, toughness, wear resistance, lightness and extensive freedom in designing components together with significant machining properties.



2 Gear fatigue properties

Standard allowable stress numbers

The values are chosen for 99% probability of survival; statistical analysis enables adjustment of these values in order to correspond to other probabilities values.

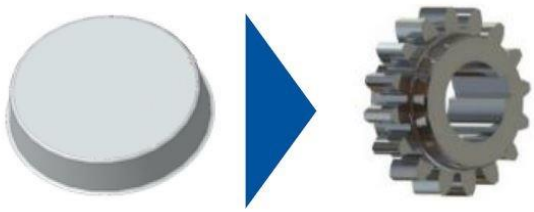
- Allowable stress number (bending), σ_{FE}: the allowable stress number for bending (for definition see ISO 6336-3), is the basic bending strength of the un-notched test piece, under the assumption that the material condition (including heat treatment) is fully elastic. For most materials, 3×10^6 stress cycles are considered to be the beginning of the long-life strength range (see life factor in ISO 6336-3);
- Allowable stress number (contact), $\sigma_{H\,lim}$: the allowable stress number is derived from a contact pressure that may be sustained for a specified number of cycles without the occurrence of progressive pitting. For some materials, 5×10^7 stress cycles are considered to be the beginning of the long-life strength range (see life factor in ISO 6336-2).

Tooth root bending resistance

Tooth root bending stress tests were performed by means of pulsator on following ADI grades: ADI JS/800-10, ADI JS/1050-6 and ADI JS/1200-3. Test gears have been obtained by hobbing with cutting tools and process parameters optimized for ADI. Gear quality inspection according to ISO 1328, load capacity assessment according to ISO 6336.

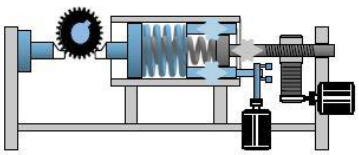
Picture 1

a) cast blank (rel. w.t 45 mm) to machined test gear



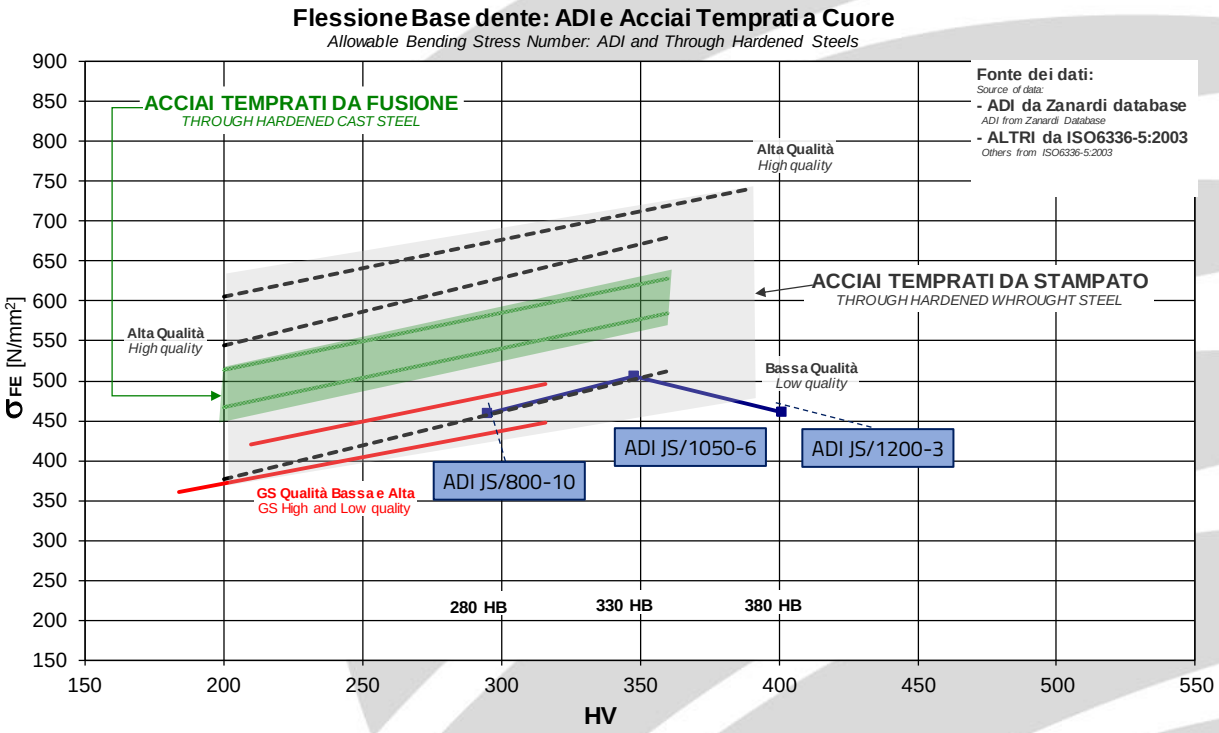
b) test conditions

- **Geometry**
  - m_n = 5 mm
  - z = 18
  - α_n = 20°
  - β = 0°
  - d_a = 104.45 mm
- **Material properties**
  - E_{ADI} = 160000 N/mm²
  - ν_{ADI} = 0.27
- **Pulsator**
  - Schenck PHT 010 N

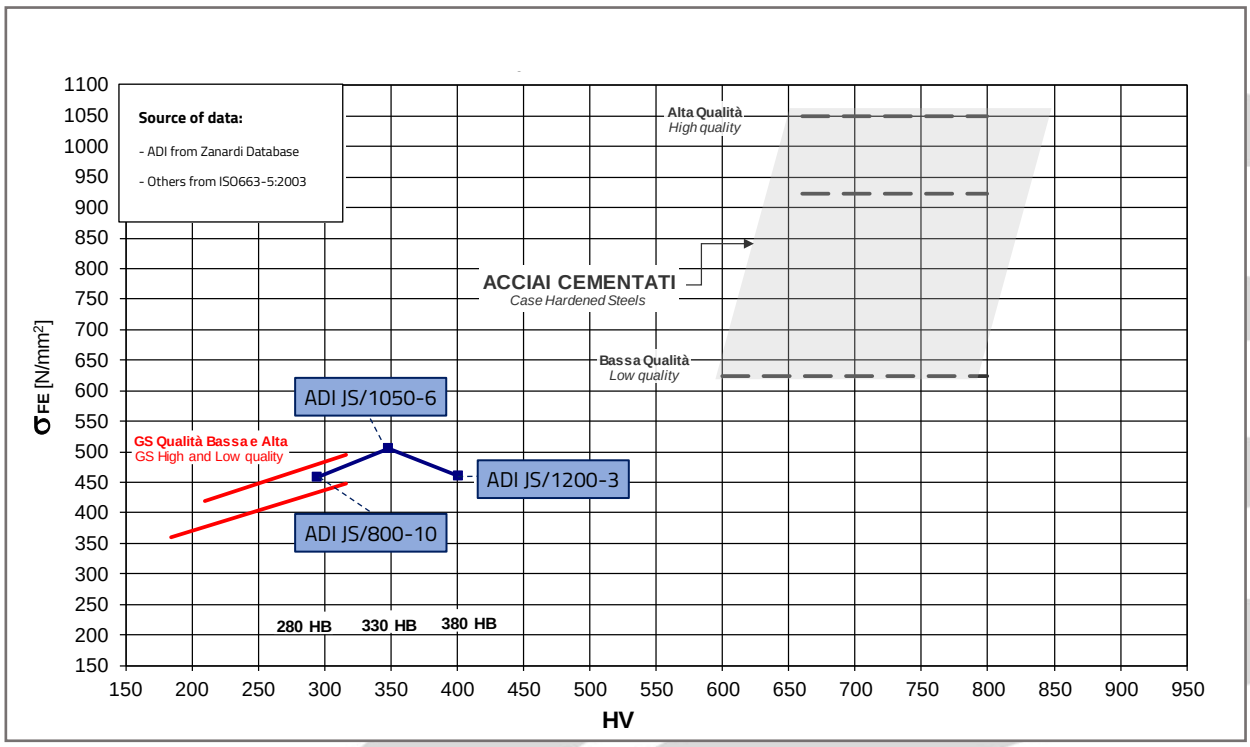


Following diagram show that ADI's represent the natural extension of DI's according to hardness increase. ADI JS/1050-6 (HB 330) is the material grade showing the highest tooth root bending resistance (σ_{FE}). Starting from the grade ADI JS/1200-3 we enter in the field of existence of lower ausferrite.
In general, when the design requirement is the tooth root bending resistance, it is evident that ADI can compete with common construction steel only.
If design requirement is wear and tooth root bending resistance has a secondary role, ADI is a valid alternative to steels. In case of applications where integration of several components is required, ADI could be the winning choice. Experimental data were carried out by Zanardi and WZL - Aachen University.

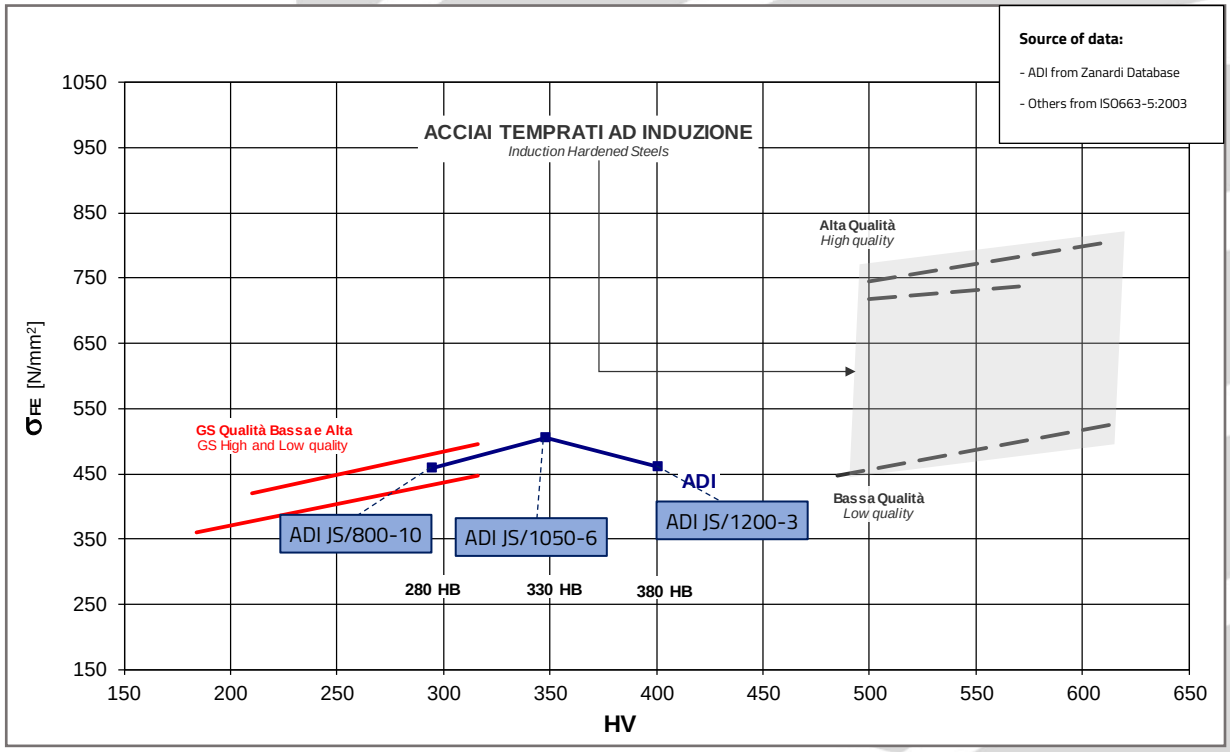
Graphic 1 - Tooth root bending stress number: ADI vs through hardened steels



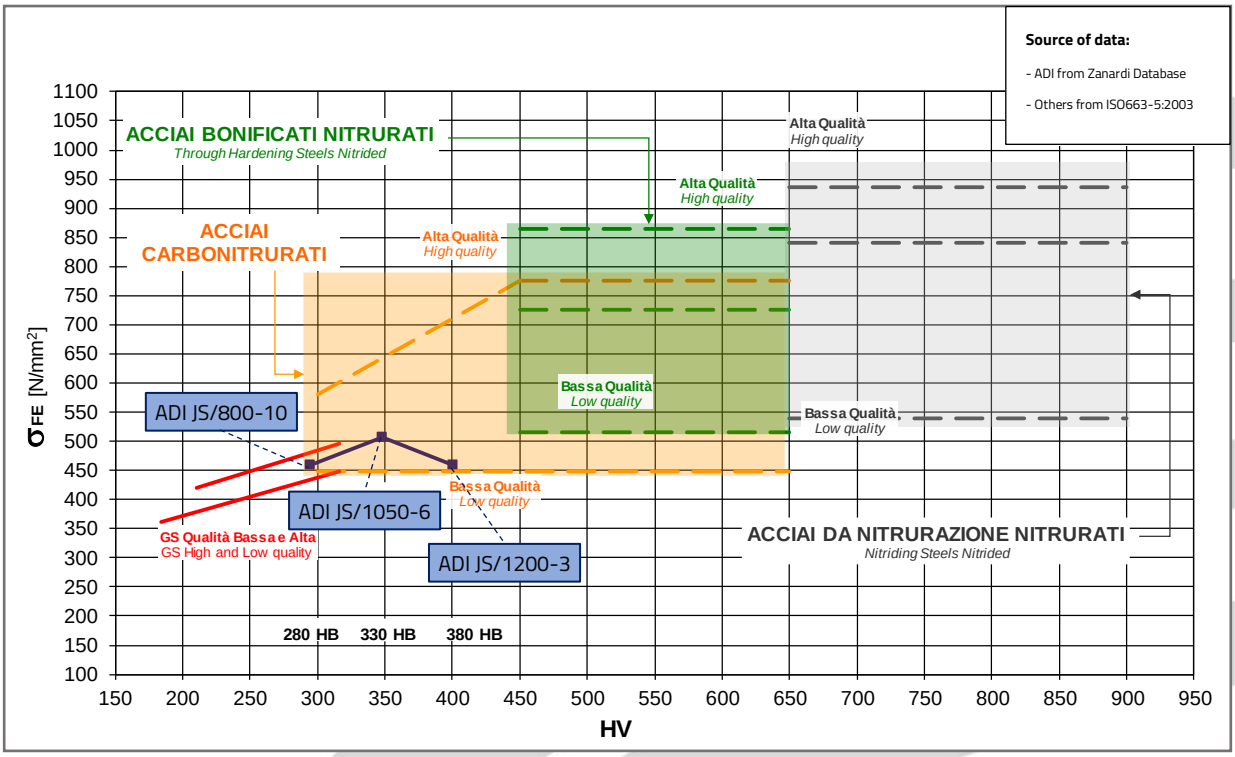
Graphic 2 - Tooth root bending stress number: ADI vs case hardened steels



Graphic 3 - Tooth root bending stress number: ADI vs induction hardened steels



Graphic 4 - Tooth root bending stress: ADI vs nitride / nitrocarburized steels

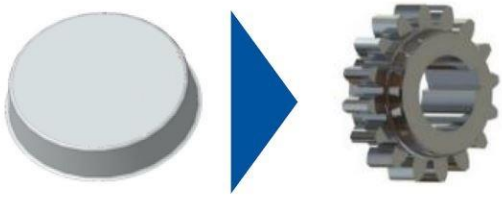


Contact fatigue resistance

Back-to-back tests were carried out by means of FZG machine on ADI JS/900-8 e ADI JS/1200-3 grades. Test gears have been obtained by hobbing with cutting tools and process parameters optimized for ADI, then grinded. Gear quality inspection according to ISO 1328, load capacity assessment according to ISO 6336.

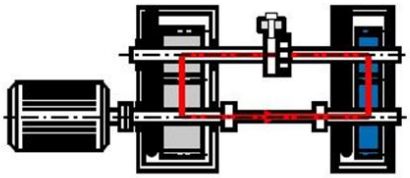
Picture 2

a) cast blank (rel. w.t 45 mm) to machined test gear



b) test conditions

- **Gear Geometry**
  - M_n = 5 mm
  - $z_{1/2}$ = 17 / 18
  - B = 10 mm
  - α_n = 20°
  - β = 0°
  - $d_{a,1/2}$ = 99,75 / 104,45 mm
- **Material Properties**
  - ν = 0,27
  - E = 160.000 N/mm²
- **Operating Conditions**
  - Splash Lubrication
  - Oil: FVA 3A, 4% Anglamol
  - T_{Oil} = 90 °C
  - n_1 = 3000 min^{-1}
  - N_G = 50 ·10^6 L.C.

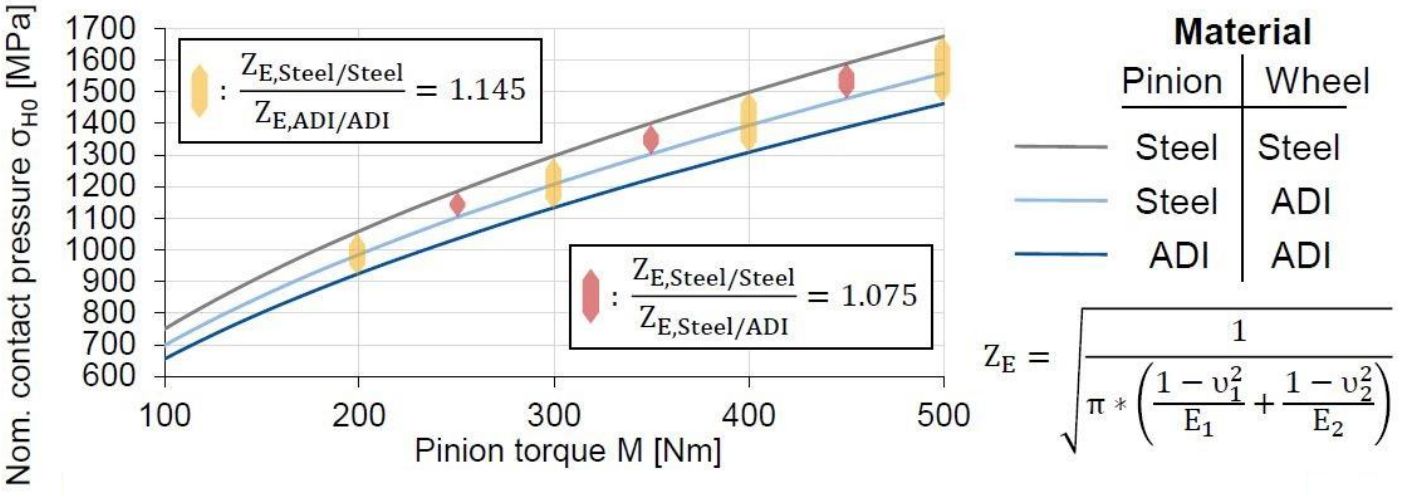


Following diagram show that ADI JS/900-8 e ADI JS/1200-3 contact fatigue resistance is comparable to of Through Hardened steel and Nitrided/NitroCarburized steels.

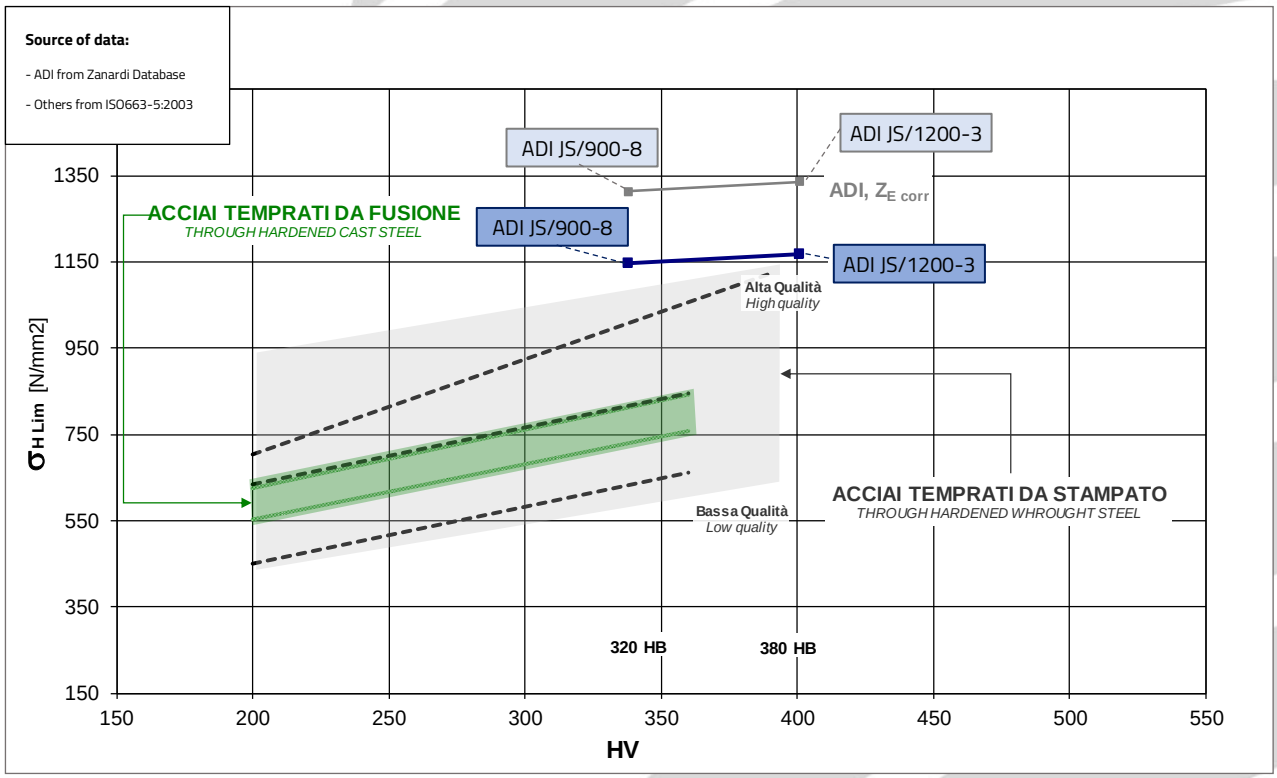
It is worth noting that one-to-one comparison to steel should be done by compensating the $\sigma_{H\,lim}$ through the Z_E loading factor that accounts for the different E and ν of ductile iron compared to steel: for a given pinion torque, ADI-ADI gears pair undergoes lower Hertzian pressure than the equivalent steel-steel gears pair. According to this evidence, ADI's can compete with induction hardening steel as well, provided that tooth root bending resistance requirements are fulfilled too.

Experimental data were carried out by WZL - Aachen University.

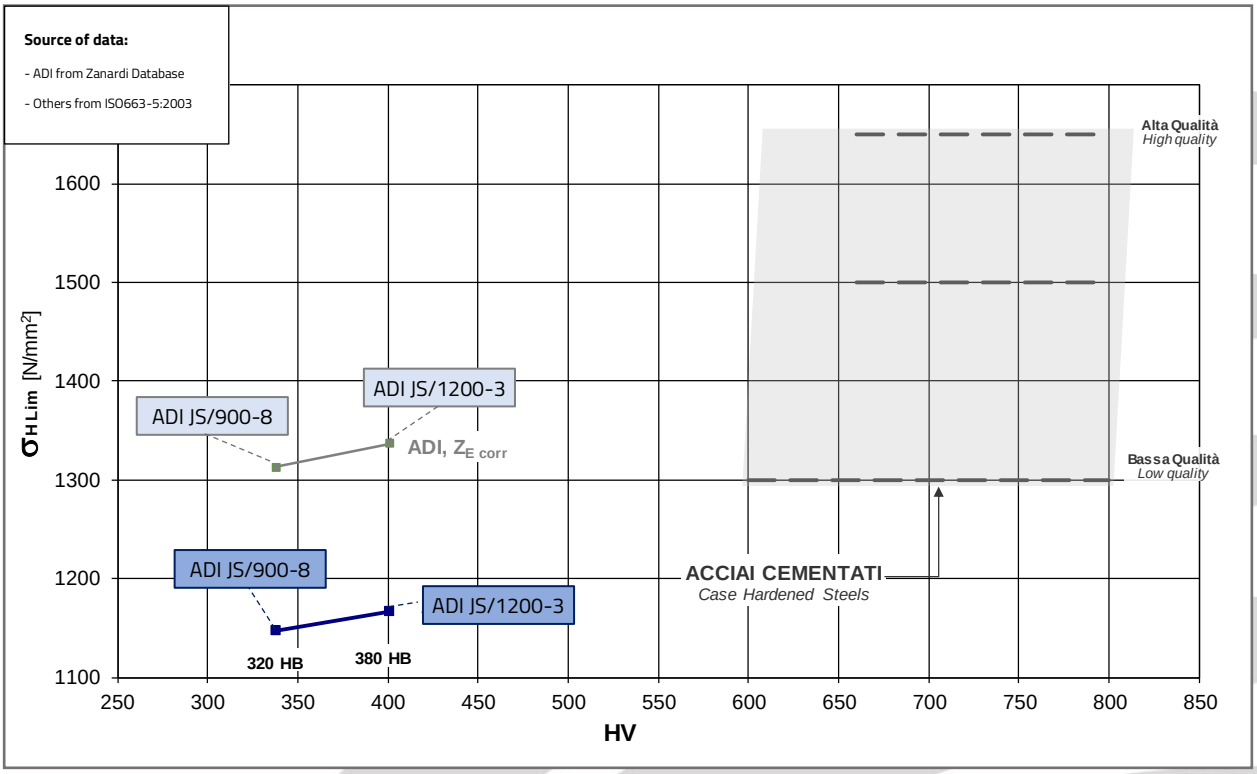
Graphic 5 – Load capacity comparison under consideration of power density



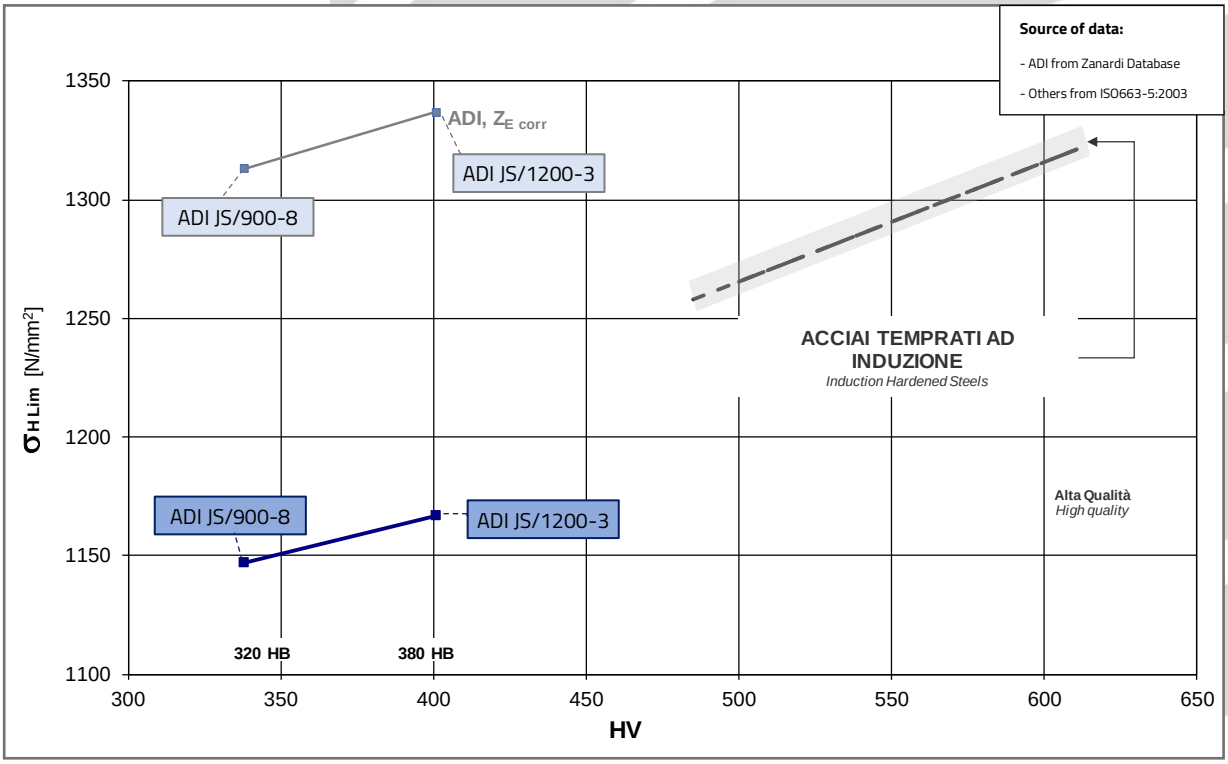
Graphic 6 – Contact stress number: ADI versus through hardened steels



Graphic 7 – Contact stress number: ADI versus case hardened steels



Graphic 8 – Contact stress number: ADI versus induction hardened steels



Graphic 9 – Contact stress number: ADI versus nitride / nitrocarburized steels