Statement of the German Spring Manufacturers Association (VDFI - Verband der Deutschen Federnindustrie e.V.) and the Machine Elements Group at the Ilmenau University of Technology on the questions raised in Hexagon's Infobrief 195 https://www.hexagon.de/info195/index_d.htm on the results of the research project IGF 19693

- ***Hexagon: "DH according to EN 10270-1, TD according to EN 10270-2, VD according to EN10270-2, 1.4310 according to EN 10270-3, 1.4568 according to EN 10270-3".***
  Comment: the applicable standard DIN EN 13906-1 (2013), which represents the state of the art, contains 10 diagrams for cold-formed springs:

FD or TD	VD	**DH or SH**	1.4310	1.4568
10^6, ks (fig. 14) 10^7, ks (fig. 17) 10^7, nks (fig. 18)	10^7, ks (fig. 19) 10^7, nks (fig. 20)	10^6, ks (fig. 13) 10^7, ks (fig. 15) 10^7, nks (fig. 16)	10^7, nks (fig. 21)	10^7, nks (fig. 22)

- ***Hexagon: "Strange that FDSiCr is tested for fatigue strength, although this material is only intended for static applications according to EN 10270"***
  Comment: it is correct, VD is the stress crack tested variant of FD wires.
  2 aspects spoke for the consideration of FDSiCr in the fatigue tests:
  1st: PA members asked for the tests as FD is being used for springs subjected to cyclic loading due to cost.
  2nd: The Goodman diagrams of standard 13906-1 define the state of the art and show the relevance of the FD grades for cyclic stresses.

- ***Hexagon: "According to the determined, almost identical fatigue strength diagrams from IGF 19693, FDSiCr and VDSiCr are equally well suited for cyclic loading"***
  Comment: According to EN 10270-2, only slightly different mechanical properties result for FD and VD. With otherwise identical calculations, these lead to similar fatigue strengths.
  The differences would become clearer if safety factors were determined separately for wire types (greater scatter to be expected for FD).

- ***Hexagon: "Strange also that the newly determined Goodman diagrams of VDSiCr are compared with the old ones of VD (without SiCr)"***
  Comment: in a survey before the start of the project, it emerged that mainly SiCr alloyed oil tempered wires are used today. FD and VD are considered obsolete. FD/TD and VD (without SiCr) are known to the users as state of the art due to the standard. It is therefore obvious to compare the newly determined fatigue strengths of the SiCr-alloyed materials with those in the standard.

- ***Hexagon: "Comparable and almost identical, however, are the newly determined Goodman diagrams for VDSiCr of 2021 with those from Bosch's Kraftfahrtechnisches Taschenbuch from 1995, which are used in HEXAGON FED."***
  Comment: there are numerous projects and publications in which fatigue data can be found (e.g. also Goodman diagrams by Kaiser 2002 (TU Darmstadt)).
  The non-detailed and, above all, incomplete information on the determination and calculation of the fatigue data from the known factories (including those mentioned

here by HEXAGON FED) was not satisfactory for the project and thus not a reliable reference. Therefore, it was decided to compare only the (legally) binding state of the art (applicable standard DIN EN 13906-1) in addition to the springs newly manufactured in own projects, which were completely measured, tested and documented in all parameters regarding manufacture and testing, in order to be able to transparently present the procedure for creating the diagrams.

- ***Hexagon: "The fatigue strengths (N=1E7) of VDSiCr made from HEXAGON FED (with setting tauoz=tauz) are almost identical to the newly determined IGF data, both shot-peened and non-blasted. However, there are clear differences in the fatigue strength (N=1E6), thus the calculated life for overstressed springs becomes significantly lower."***
  Comment: This is based on other slope exponents of the Wöhler line.
  How can a service life become shorter if it is specified for N=1E6? This probably refers to the fatigue strength, which is lower. Otherwise see above: HEXAGON FED does not represent the legally binding state of the art.

- ***Hexagon: "In the case of spring steel wire 1.4310, there is no mention of whether the grade 1.4310-NS or 1.4310-HS was examined"***
  Comment: it is 1.4310 NS. This is documented in the final research report.

- ***Hexagon: "The permissible shear stress in the new Goodman diagram is thus even worse than for 1.4310-NS. The permissible stroke stresses for non shot peened springs are lower for tauk1=0 than according to EN 13906-1 (320 instead of 380 MPa for d=3mm) and higher from tauk1=300MPa onwards".***
  Comment: the insufficient fit of the standard diagram for 1.4310 was communicated by various project committee members. It was reported that the standard diagram was not conservative enough and springs could fail below the permissible upper stress. This information from spring manufacturers was confirmed during the fatigue tests in the project.

- ***Hexagon: "For shot-peened springs, on the other hand, the newly determined permissible shear stresses are all higher than before."***
  Comment: as of 2013, the standard does not contain a Goodman diagram for shot peened springs made of 1.4310.

- ***Hexagon: "Even for spring steel wire of grade 1.4568, not shot peened, the newly determined fatigue strength values are much lower than according to EN 13906-1"***
  Comment: The strengths are based on fatigue test data, calculations and a safety concept. For the standard diagrams, almost all data is missing; here, too, it was confirmed in the project monitoring committee that the standard diagrams are critical.

Summary:
Nearly nothing is known about the diagrams in the standard. No geometries, no manufacturing data, no surfaces, no residual stresses, no statistical evaluation and above all: no probability and safety data. All this is included in the new diagrams and documented in a comprehensible way. Just by "playing" with the pre-selected safety factors, the characteristic curves can be shifted and thus the actual comparison, both with the standard and with Hexagon, can be "shaped". The safety factors were chosen in the project in such a way that the diagrams are conservative for the vast majority of practical requirements. The final report also documents a method for adjusting the safety factors for special requirements and converting the fatigue strengths to other spring geometries, manufacturing parameters and conditions of use.

Before the publication of the info letter we would have wished for consultation on the questions mentioned - in this way the IGF project and the 35 PA members (associations (VDFI, FSV and

ESV), SMEs to corporations, wire manufacturers, spring manufacturers and spring users), thus ultimately also HEXAGON FED customers, were discredited and the readers of the info letter were unsettled.
The questions raised could have been resolved very easily and completely; this is now done in this joint statement by the VDFI and the research group at TU Ilmenau. We thank all those who contributed to the project.

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Currently, the charts are being further validated nationally and in Europe; so far, all submitted fatigue results fit the new charts. The inclusion of the new diagrams in the standard is being driven by the VDFI and the research group.

Three small notes on the FD/VD issue:

1. In addition to the tensile strength of the material, there are also effects on the fatigue strength due to the chemical composition. FDSiCr and VDSiCr wires differ in terms of permissible P, S and Cu contents.
2. Surface crack testing has its limits at 40µm. The test can therefore probably only exclude very early fractures due to surface cracks. However, most fractures occur with much smaller surface cracks that are not detected by the crack detection. This again suggests that FD and VD have similar behaviour in terms of cyclic properties.
3. FD, TD and VD are, in our view, only material classifications. FD includes FDC, FDCrV, FDSiCr and FDSiCrV.

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Ilmenau and Hagen, 06.12.2022