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OPTIMIZING SPLINED HUB OF AUTOMOTIVE FRICTION CLUTCH

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Summary: *This article deals with modification of splined hub joined with clutch shaft. At first these modifications are performed on the external hub surfaces, secondly also on internal ones. Under torsion loading contact pressures, shaft and hub stresses are calculated using finite element analysis (FEM). Especially new forms of external hub surfaces resulted in cutting-down of both pressures and stresses. At the same time the weight of hub was considerably reduced.*

1. Introduction

Automotive accessories producers offer wide range of clutch discs with splined hubs. The first figure depicts partial cross section of one chosen hub (together with piece of shaft) in its standard heavy-duty version, destined for a commercial vehicle. Fig.1 shows shaft and hub comprised in the whole, as the structure created for finite element analysis.

Both parts are linked only by means of contact elements placed on the key and groove sides. Due to precise machining and close production limits of these surfaces usual practice, subsisted in import of suitable structure co-ordinate data from some routine three-dimensional software for modeling (ProEngineer, for example) proved to be useless. Creating appropriate program file directly from FEM software commands solved this problem.

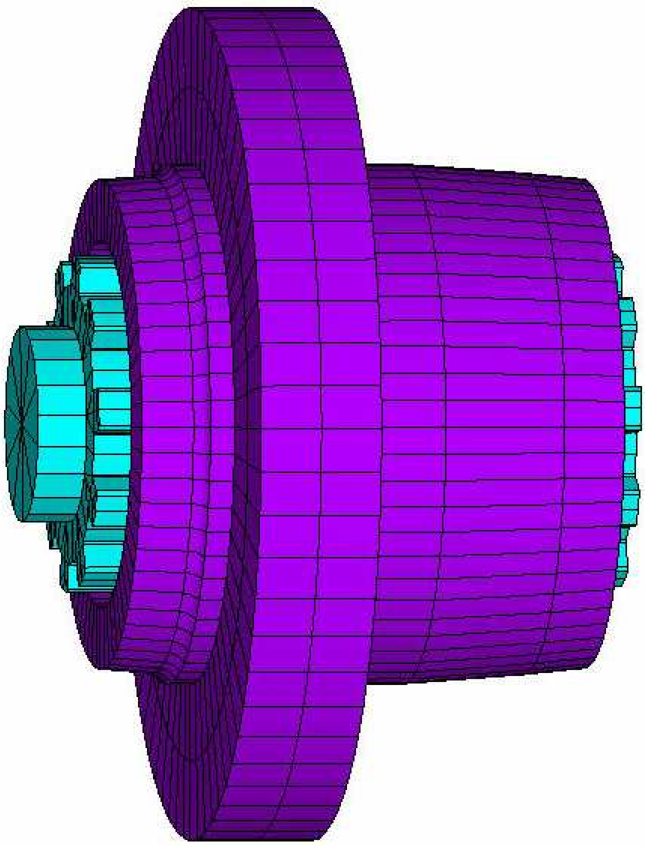

Fig. 1: Major parts of shaft and hub model - current design

Relatively large flange width **s** (Fig. 2) enables the installation of clutch disc torsion damper between two plates. They are centered on cylindrical surfaces A and fastened by means of rivets, disposed along pitch circle having diameter $\mathbf{d_r}$. External tangential forces, forming rated average torque 990 Nm, take place in structure nodes being placed just on radial distance $\mathbf{d_r/2}$ from symmetry axis. Proper constraints are introduced on the right shaft end. Characteristic

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loading torque, supplied by commonly used vehicle internal combustion engine, may, however, easily get over quadruple amount of its rated average value. Moreover, complement torsion vibrations present in drive velocity range, or vehicle starts add substantial raise to resulted peak value.

Suppose that only rated nominal low-level torque 660 Nm is applied. Then average contact pressure, determined by well-known actual formula for splined joint in question, amounts roughly 17 MPa,. On the other hand, resulted contact pressure from FEM analysis for the same torque value (see Fig. 3) appeared extremely non-uniform, with its peak pressure come out at 96 MPa. This primary but crucial and unfavourable post-processing contour seems to be made better, by means of hub shape modification, for instance.

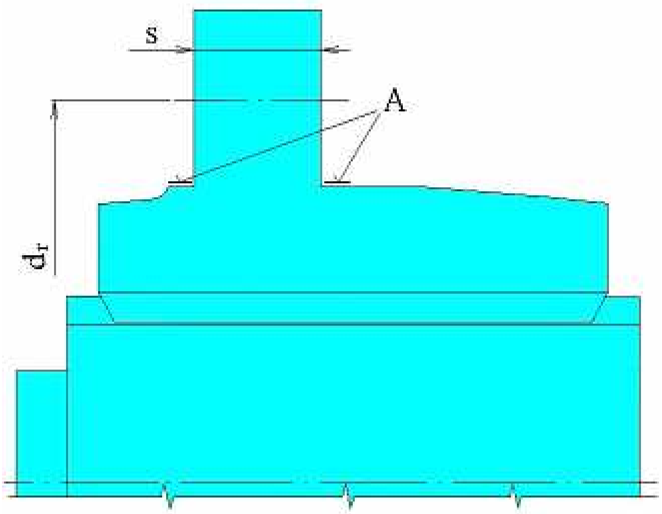

Fig. 2: Longitudinal section of researched clutch – current design

Additional contour (Fig. 4) deals with gap, which remains between sides of

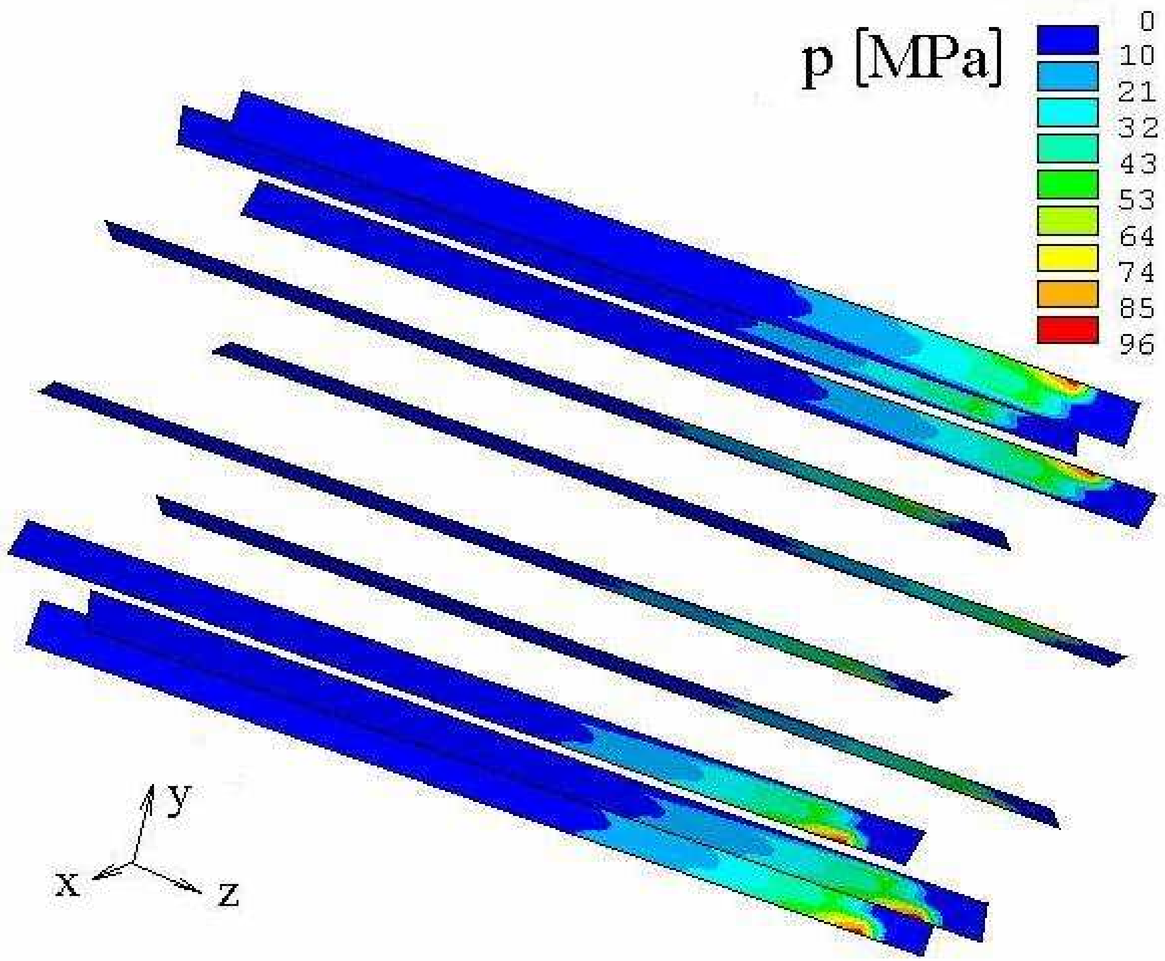

Fig. 3: Contact pressure in splined joint loaded by rated average torque – current design

grooves and keys in contact. Without any loading, nominal gap value amounts 0,039 mm. Silver ends of strips denote the areas, where there are no target elements against contact ones. Naturally, the greatest value of gap is placed on the opposite side, in comparison with previous figure.

In following two pictures (Fig. 5 and 6) stresses in shaft and hub, respectively, were shown. Cumulative HMH stress values were chosen, which probably enable us to compare satisfactorily the results with subsequent ones.

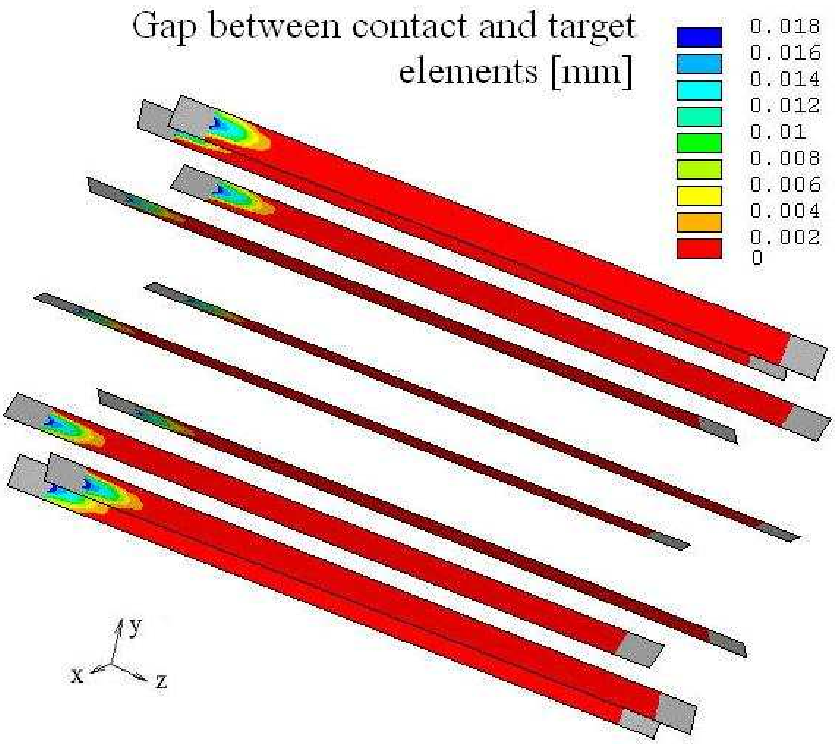

Fig. 4: Forming the gaps in loaded point – current design

2. Optimizing clutch hub on its external surfaces

Some external hub surfaces must remain unchanged in order to hold circular position of rivets and axial position of two plates for clutch discs torsion damper mentioned above. Other surfaces were, in successive steps, placed some near to the axis of shaft rotation.

Main aim of this process was to decrease clutch hub torsion stiffness. Longitudinal section of hub after four optimizing steps is seen

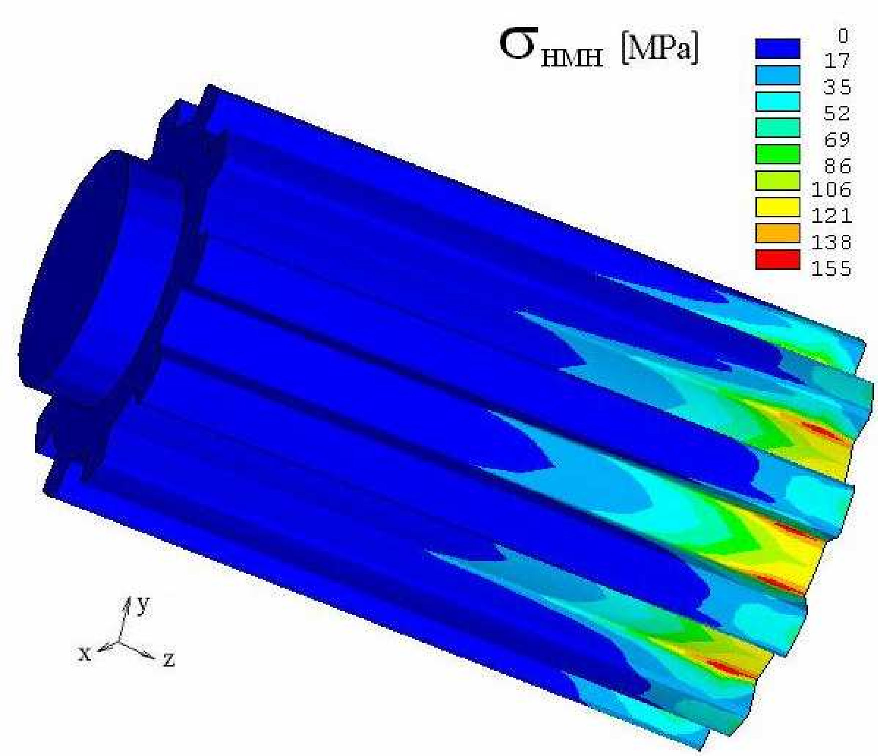

Fig. 5: Cumulative HMH stress in clutch shaft – current design

in Fig. 7. Diameter of cylindrical surfaces **B** for riveted parts was made considerably lowered. Therefore guiding bush during assembly could help according to usual practice.

In Fig. 8 contours of the first computed result – contact pressure – using modified model are shown. Comparing with Fig. 3 we can state, that the hub shape modification idea proved to be effective - the peak contact stress reached only the 60 MPa level. This means the cut-down by more than 37 per cent. Moreover, pressure distribution seems to be more acceptable.

As for shaft stress (Fig. 9), computed results are also favourable – peak value of HMH cumulative stress amounts 146 MPa. As in previous case, stress distribution contour, compared with Fig. 5, occurs better too.

On the other hand, in the case of hub stress, the situation is slightly different. Maximum value of HMH cumulative stress (see Fig. 10) reaches the value, which is higher

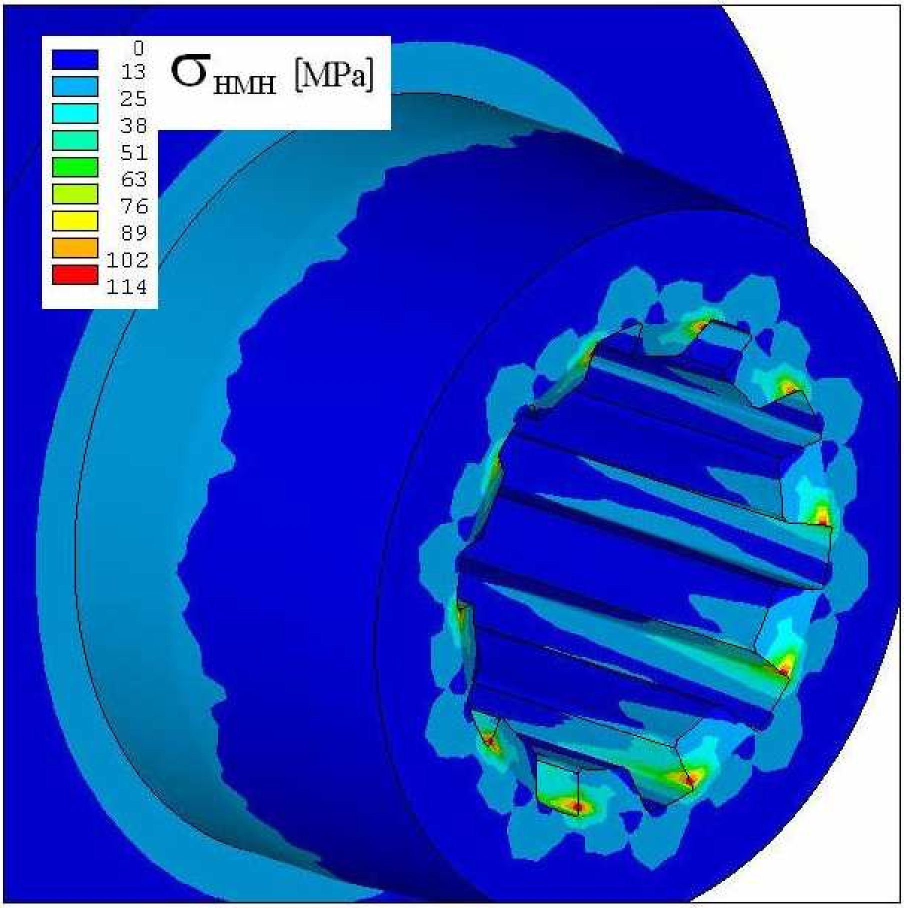

Fig. 6: Cumulative HMH stress in clutch hub – current design

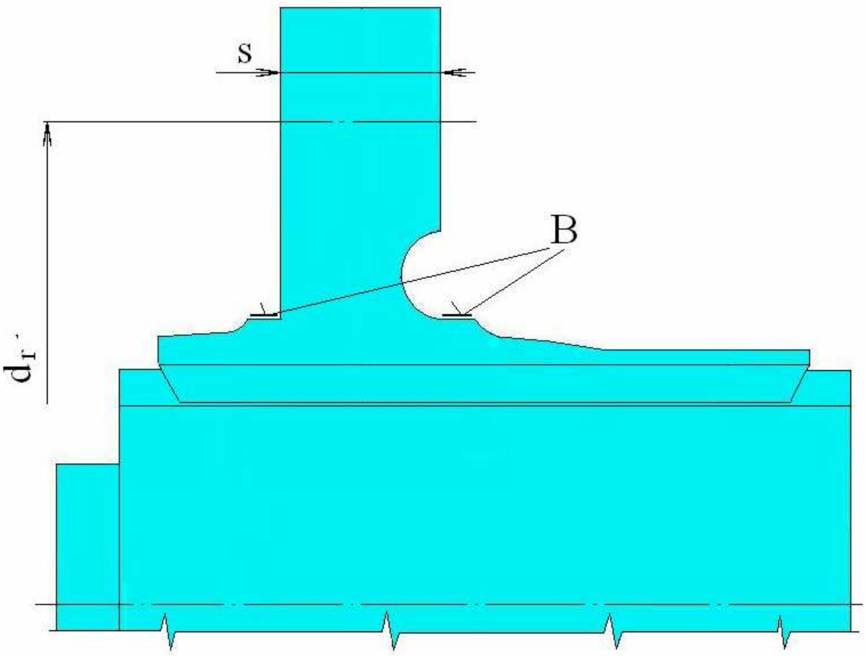

Fig. 7: Longitudinal section of researched clutch – version after four steps of modifications on its external surfaces

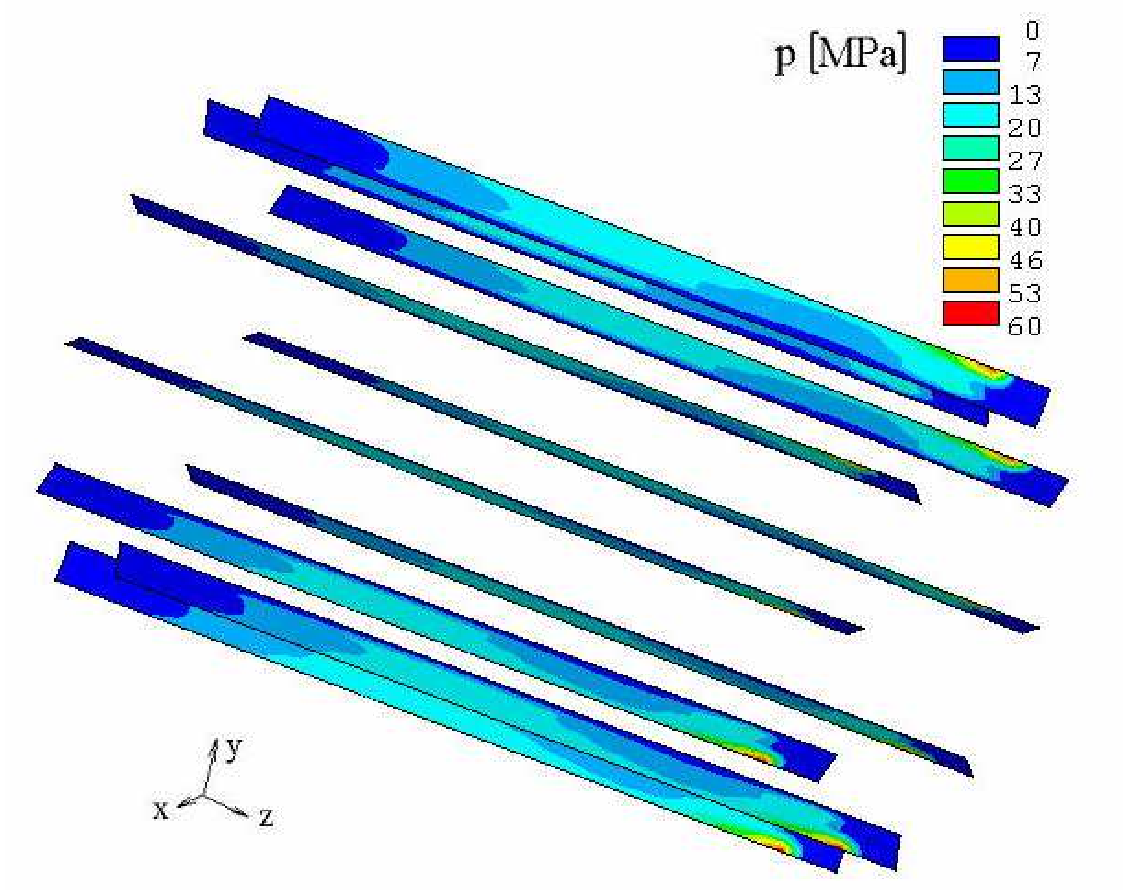

Fig. 8: Contact pressure in splined joint loaded by rated average torque – version after four steps of clutch hub modifications on its external surfaces

than before. Again, three aspects are positive, however. Contour stress level is broadly considered as moderate, contour stress distribution is more favourable than before and places of peak stress are removed more widely into the hub depth. The latter matter of fact is largely appreciated as measure against initiation of possible crack damages.

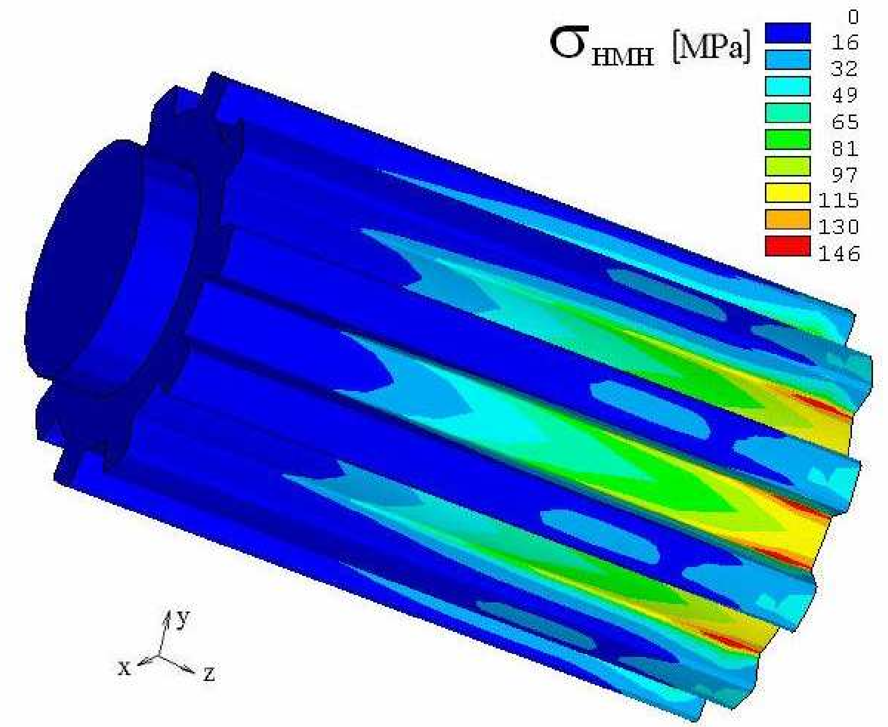

Fig. 9: Cumulative HMH stress in clutch shaft – version after four steps of clutch hub modifications on its external surfaces

3. Optimizing clutch hub on its internal surfaces

External hub shape forming described above can be adopted as appropriate and capable of competing. Therefore its last step may serve as starting level of forming hub internal shape.

Such a modification is performed in hub grooves area (see Fig. 11). The first step can be represented, for example, by deleting the part of hub analysed structure in the form of a ring. The width of this ring amounts roughly one fifth of the total mutual contact length.

Figure referred above depicts at its right side one of optional location of deleted volumetric structure.

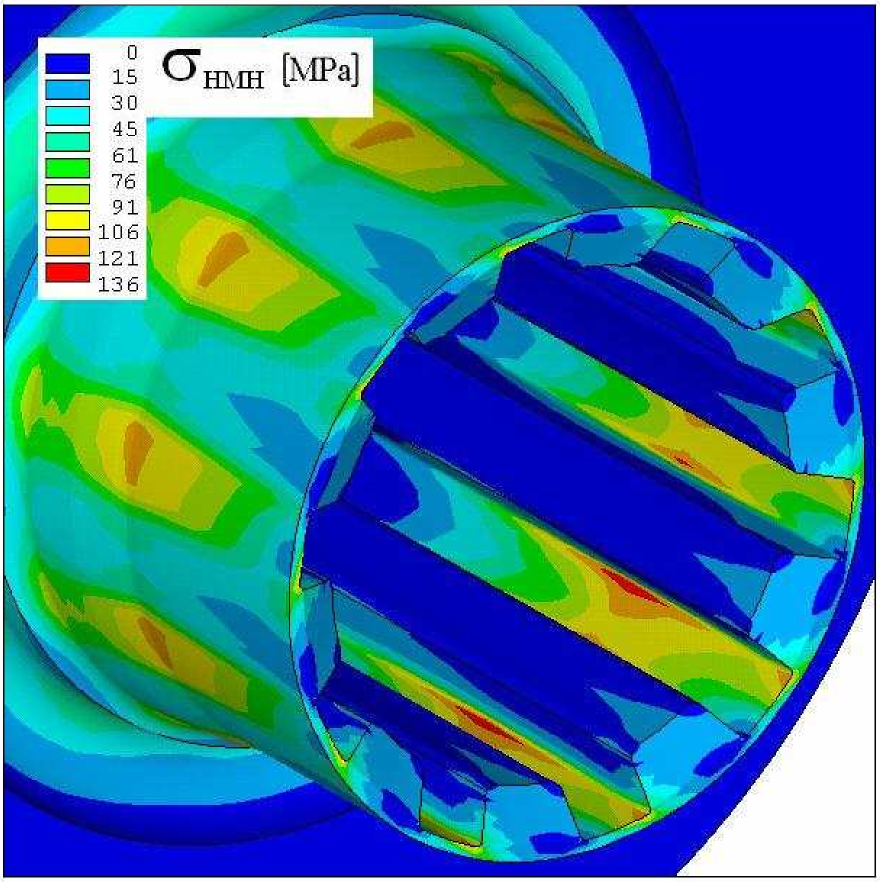

Fig. 10: Cumulative HMH stress in clutch hub – version after four steps of clutch hub modifications on its external surfaces

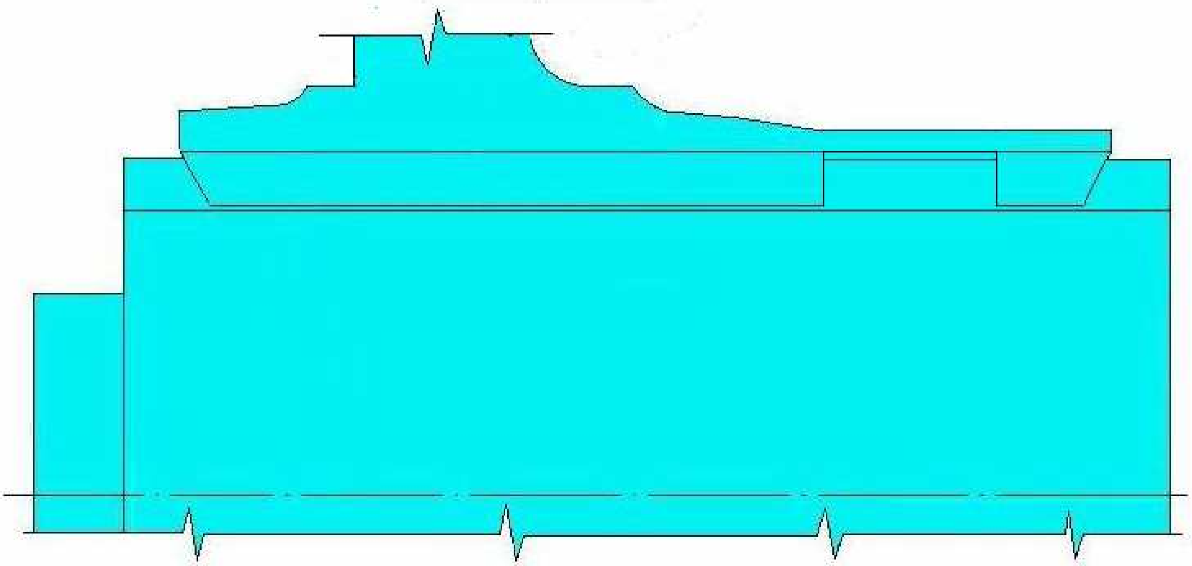

Fig. 11: Enlarged detail of researched clutch longitudinal section – version after the first step of modifications on its internal surfaces

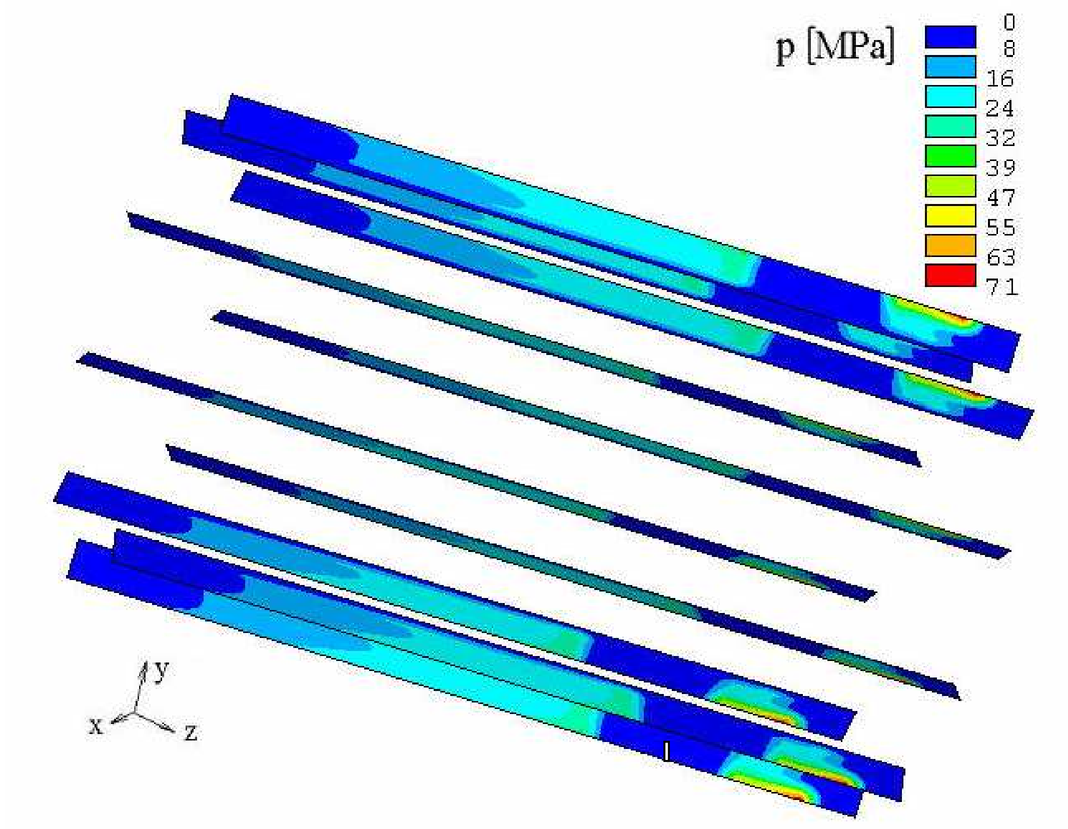

Fig. 12: Contact pressure in splined joint loaded by rated average torque – version after the first step of clutch hub modifications on its internal surfaces

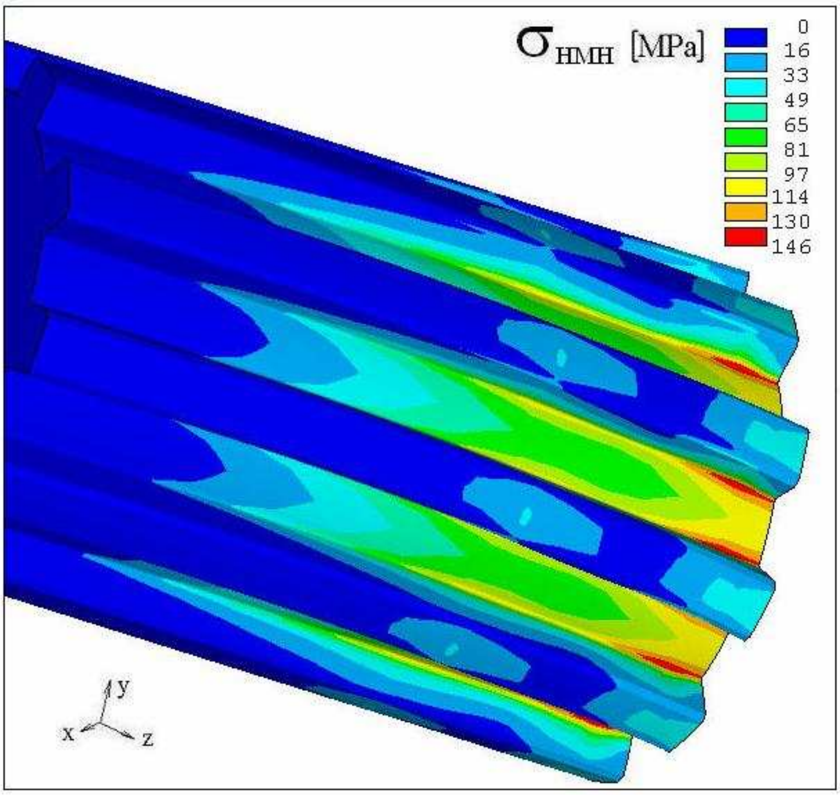

Fig. 13: Cumulative HMH stress in clutch shaft – version after the first step of clutch hub modifications on its internal surfaces

For this case, Fig. 12 shows distribution of shaft surface contact pressure. There are clearly pointed out (at right side) deep blue parts of strips, where, naturally, contact between shaft and hub come not on.

In following Fig. 13 and Fig. 14 cumulative HMH stresses for shaft and hub are depicted, respectively.

All peak numerical values of contact stress and cumulative stresses for joint current design, last computed step of hub modifications on its external surfaces and modification on its internal surfaces are assembled in Tab. 1.

It must be noted, that increase of contact press (see the last row in the table) is less than we may expect, because reduced effective length of splined joint is in this case relatively higher.

Table values in two last rows (the third column) are identical. This is a mere random, because two contours in Figs. 9 and 13 are different.

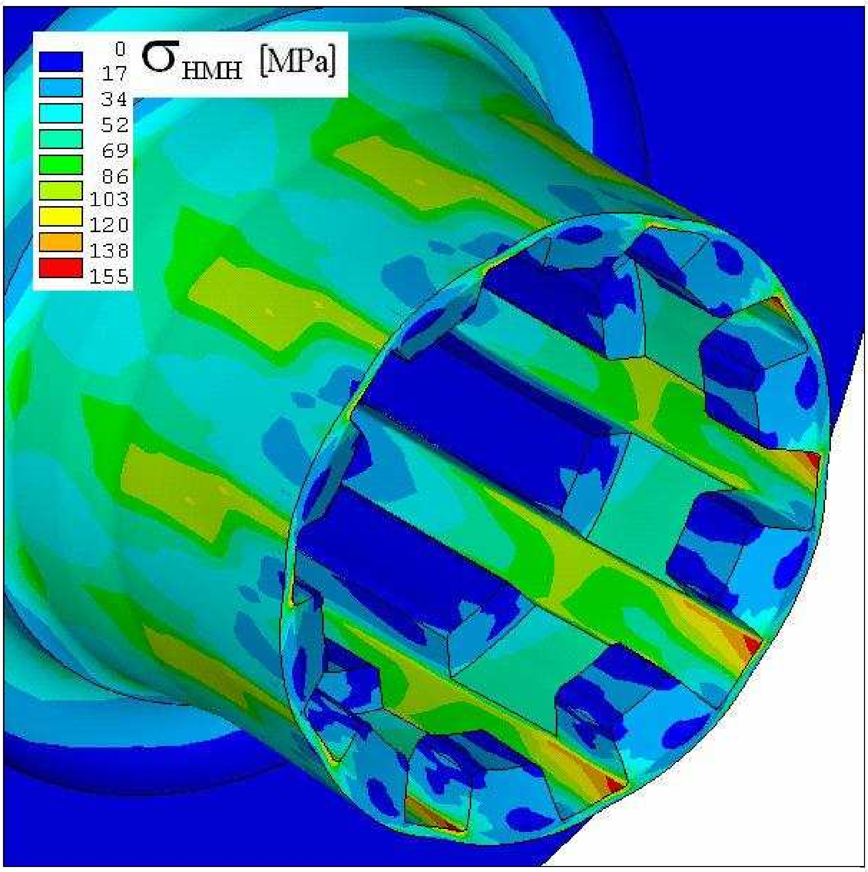

Fig. 14: Cumulative HMH stress in clutch hub – version after the first step of clutch hub modifications on its internal surfaces

4. Conclusions

Described optimizing process confirmed, that suggested hub shape modifications may considerably cut down the stress in parts of automotive clutch joint. It is apparent, that resumption in this process may earn another useful piece of knowledge. Nevertheless, before starting following steps it is at best necessary to inspect carefully an thoroughly automotive service centres reports dealing with fails dealing with the joint in question.

Tab. 1: Basic results of calculation for friction clutch splined joint

	Contact press [MPa]	%	HMH shaft stress [MPa]	%	HMH hub stress [MPa]	%
Current design	96	100	155	100	114	100
Version after the fourth step of hub external modification	60	62,5	146	94,2	136	119,3
Version after the first step of hub internal modification	71	74,0	146	94,2	155	136,0

Acknowledgement

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