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Opinion

Curvature and Branching as Effects of Deformation Fronts Stabilization

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Opinion

Despite the fact well-known in Combustion community that a combustion front curvature leads to the front stabilization (Markstein solution of the one dimensional thermal diffusion problem (1DTDP) [1,2]) etc, a transfer of similar ideas and results to deformation waves meets great difficulties. The reason is that plane fronts of deformations are thermally unstable at the conditions of hot forging (with the temperatures strongly different from that of surrounding) (see Figure 1, range 0: $D_{ee}/D_{ss} \cong 0$; $Z_e > 2+\sqrt{5}$) and are hydrodynamically/diffusionally unstable in the range1 of curved deformation fronts: $D_{ee}/D_{ss} > 1$; $Z_e > 2+\sqrt{5}$ (see Figure 1). Since the elastic-plasticity invariant Z` introduced in [3-5] has the extremely low value ($\approx 10^{-5}$-10^{-4} m/s) the actual thermal instability of plane deformations needs a huge time to be developed. Therefore, unstable fronts of flat deformations will acquire more stable, curved shapes (with the higher coefficient of diffusion) much faster than they will be registered and recognized as developed unstable front shapes. From a purely mathematical point of view, the one-dimensional model of plastic deformations (1DMPD) based on the theory of thermally activated moving dislocations (see the refs inside) differs from 1DTP in Combustion just by the second diffusion equation for the field of deformations instead of the equation of thermal diffusion in 1DTDP . Therefore, the instability areas of plane combustion fronts presented early [2] in terms: Lewis number (Le) – Zeldovich number (Ze) may be represented for deformation fronts certainly in the same way and form in terms: relative diffusion coefficient (D_{ee}/D_{ss}) - Ze (see Figure 1).

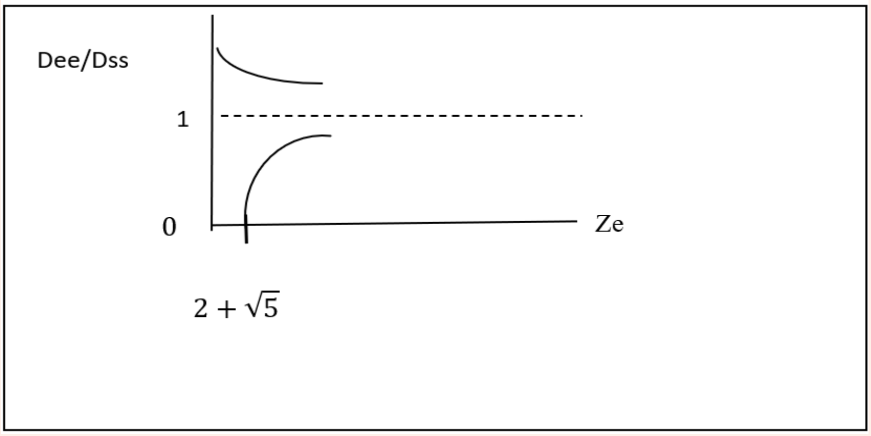

Figure 1: Parametric areas of unsteady state plane solutions of 1DMPD in [3-5].

Therefore, at high temperatures strongly different from the temperature of surrounding atmosphere plane fronts of the dislocations are certainly unstable at the conditions of hot forging. Correspondingly, the ancient Russian technology of the sword steel production ("Russian bulat") may be explained just mechanistically: by stabilization of plane front deformations and the consequensive steel hardening at the temperature equal to that of the surrounding (see Figure 2). Unfortunately, the authors [3-5] have not investigated the stability of their 1DMPD solutions. They preferred to generalize a huge volume of contradictory experimental data existing instead of the data logical and physical explanation. In my opinion, in the ancient technology of creating Damascus steel, the main goal was to obtain a fairly smooth and sharp front of deformations that coincides with the cutting edge of the future sword and its timely rapid hardening at the low room temperatures at which it becomes stable (see Figures 1 & 2). Without cooling to the room temperature in a liquid (oil, water), you cannot get a high-quality sword, but only a saw as an imperfect or low-quality sword. In agreement with the elastic theory [6] deformation isolines in a spherical shell are always curved. Therefore, the deformation structure of materials produced by mechanoactivation in a planetary mill is not plane (see Figures 3 & 4).One can inspect the conclusion I made from Figures 1 & 2 experimentally by the data of mechano activation presented on Figures 3 & 4. They prove my above conclusion that a curvature and branching of deformation isolines are the conditions sufficient for a deformation front stabilization (Figure 5), [7].

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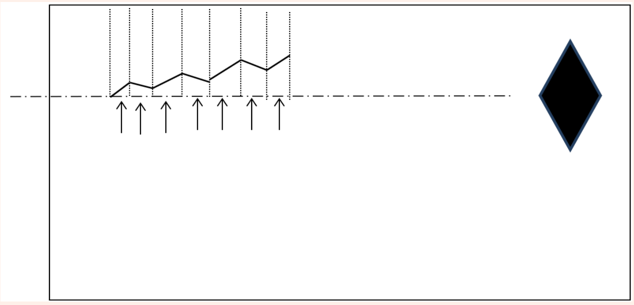

Figure 2: Ancient technology of Damascus steel edged weapons. Stage 1: forging a hot sample using local deformations (represented by a broken line, $D_{ee}/D_{ss}\approx 0$, $Ze>2+\sqrt{5}$). Stage 2: Alignment of the hot deformation front represented by a broken line to a flat and sharp edge and hardening at the lower ambient temperature ($D_{ee}/D_{ss}\approx 0$, $Ze\equiv 0$).

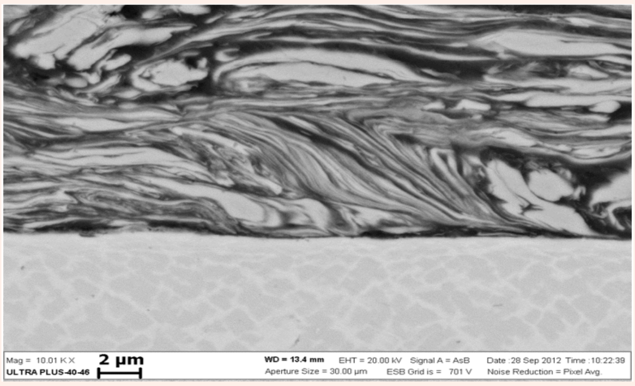

Figure 3: Deformation structure of the NiAl layers after mechanoactivation of their blends in a planetary mill. No plane deformations.

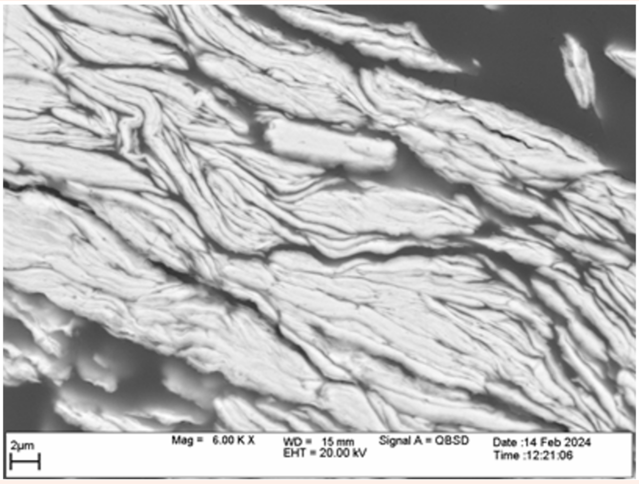

Figure 4: Deformation structure of Ni-Cu layers in a planetary mill. No plane deformations.

Figure 5: Size of the balls covered by the products of mechanoactivation in a planetary mill (corresponding to Figures 3 & 4).

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References

1. AZeldovich YB, Barenblatt GI, Librovich VB, Makhviladze GM (1980) Mathematical theory of combustion and explosion. Moscow, Nauka, Russia, p. 253.
2. Merzhanov AG (2000) Solid flame Combustion. Chernogolovka, ISMAN, Russia, p. 127.
3. Zuev LB, Physics of macroscopic localization of plastic flow.
4. Zuev LB, Autowave plasticity. Localization and collective mods.
5. Zuev LB, Khon YA (2021) Plastic flow as a process of the formation of spatio-temporal structures. Part I. Qualitative and quantitative patterns. Physical Mesomechanics 24(6): 5-14.
6. Landau LD, Lifshitz EM (1987) Theory of elasticity. Theoretical Physics, Nauka, Moscow, Russia, p. 247.
7. Rogachev AS, Moskovskikh DO, Powder Technology 274(215): 44-52.

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