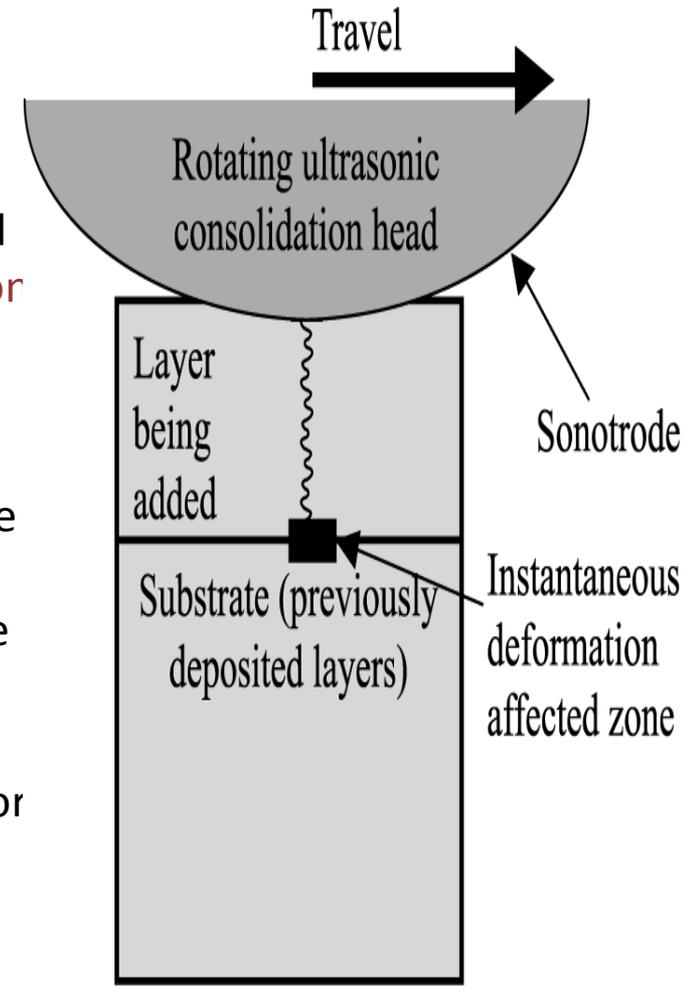
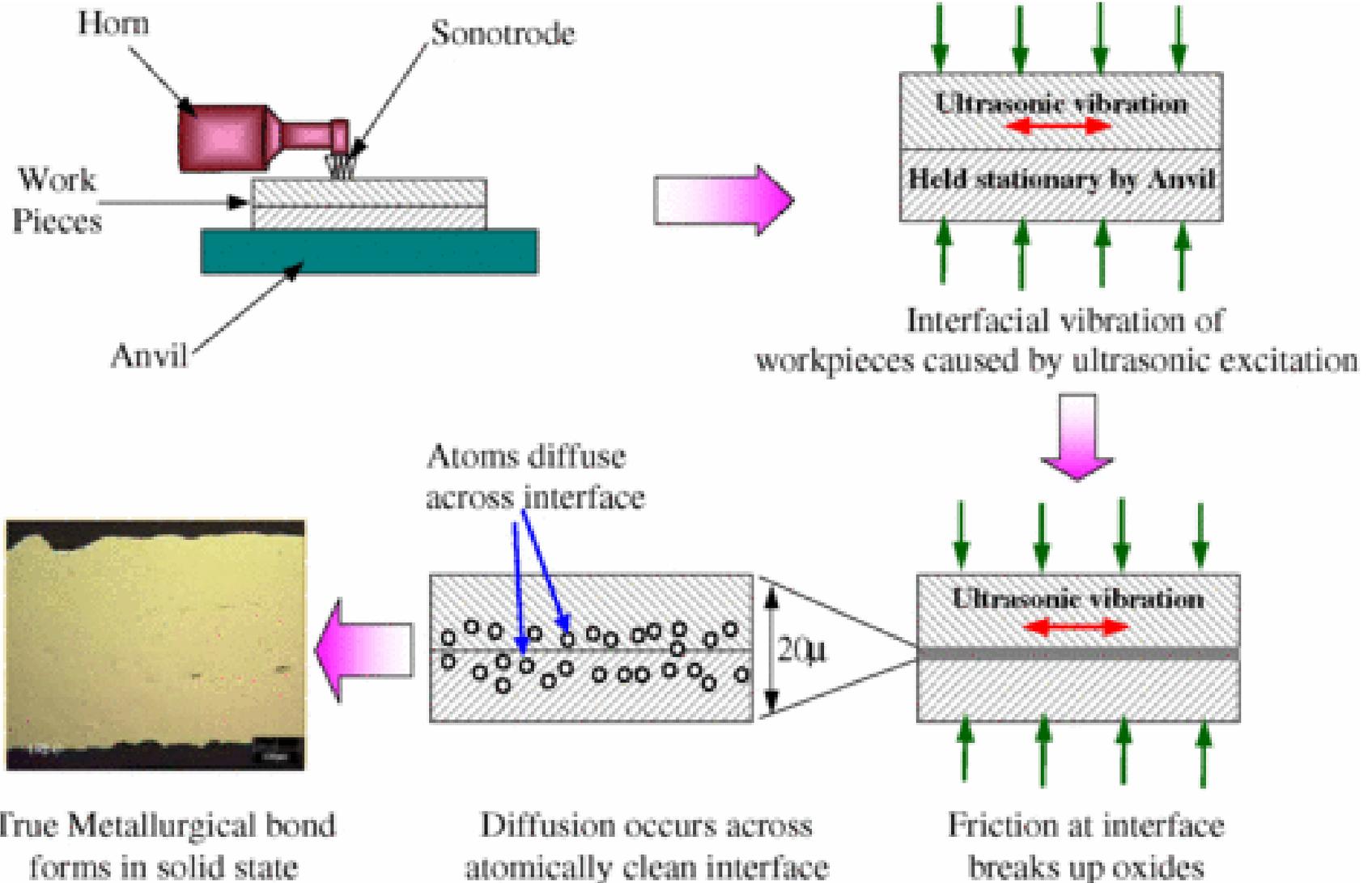


# Ultrasonic Consolidation (Ultrasonic Additive Manufacturing)

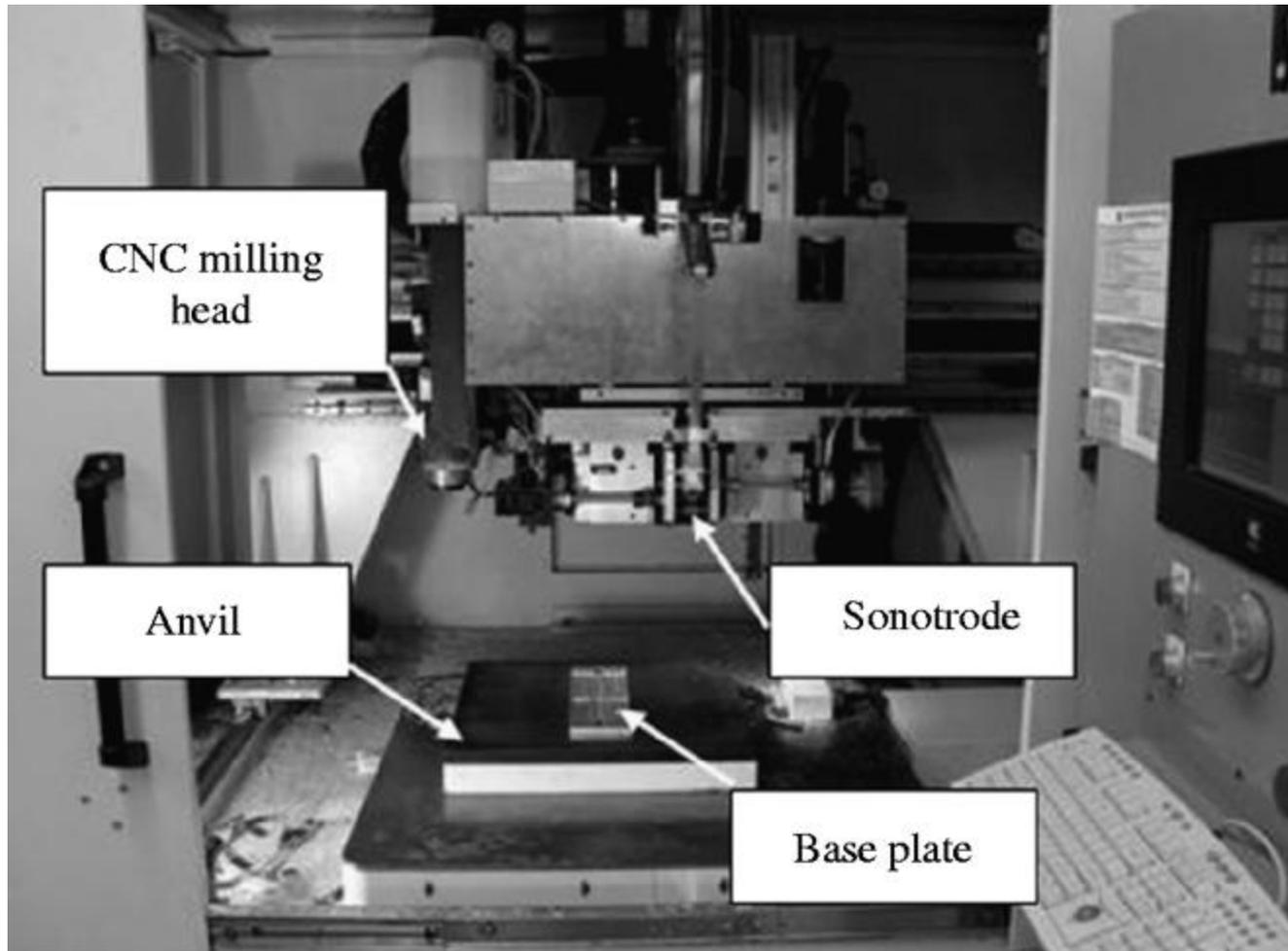
The mechanism of bond formation during the ultrasonic welding of metals has been widely studied. O'Brien et al. (1987) states that bonding formation is initiated by a combination of compression under moderate pressure and scrubbing of metal caused by ultrasonic motion. **The motion cleans off surface oxides through friction and leveling of surface asperities. This allows direct contact of pure metal resulting in atomic bonding.** Shear vibration produces heat through friction and by plastically deforming asperities. The heat and plastic deformation promote diffusion and crystallization of material between layers resulting in a true metallic bond. The process maybe aided by the passage of ultrasonic energy into the metal, which effectively may act similarly to localized heating, reducing the stress needed for plasticity



# Ultrasonic Consolidation (Ultrasonic Additive Manufacturing)



# Ultrasonic Consolidation (Ultrasonic Additive Manufacturing)



# Ultrasonic Consolidation (Ultrasonic Additive Manufacturing)

## Fundamental Questions and Conflicting results

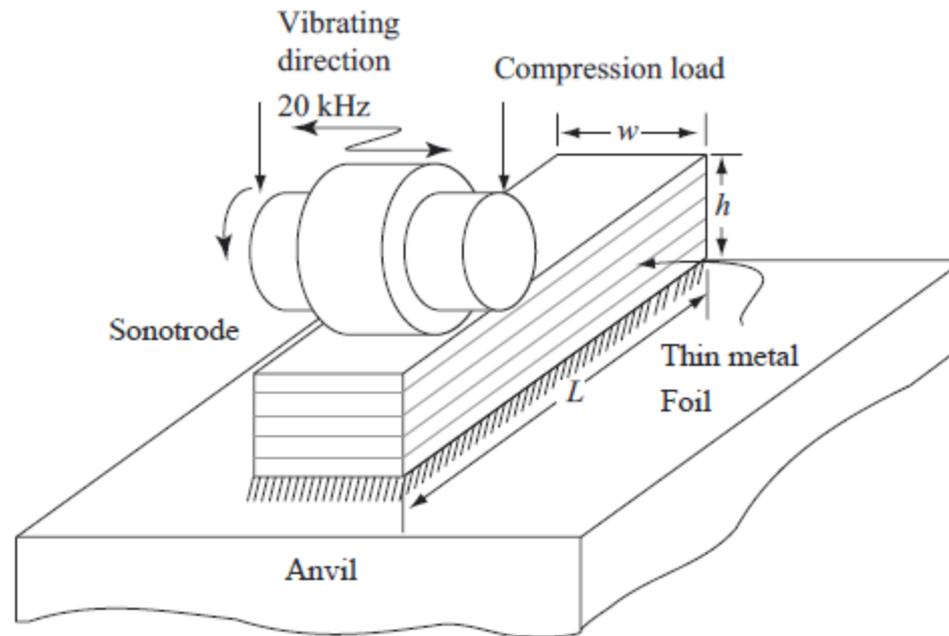
- Transducer amplitude vs. normal force
- Transducer slip on top tape?
- Slip or stick of top tape on build structure?

# Ultrasonic Consolidation (Ultrasonic Additive Manufacturing)

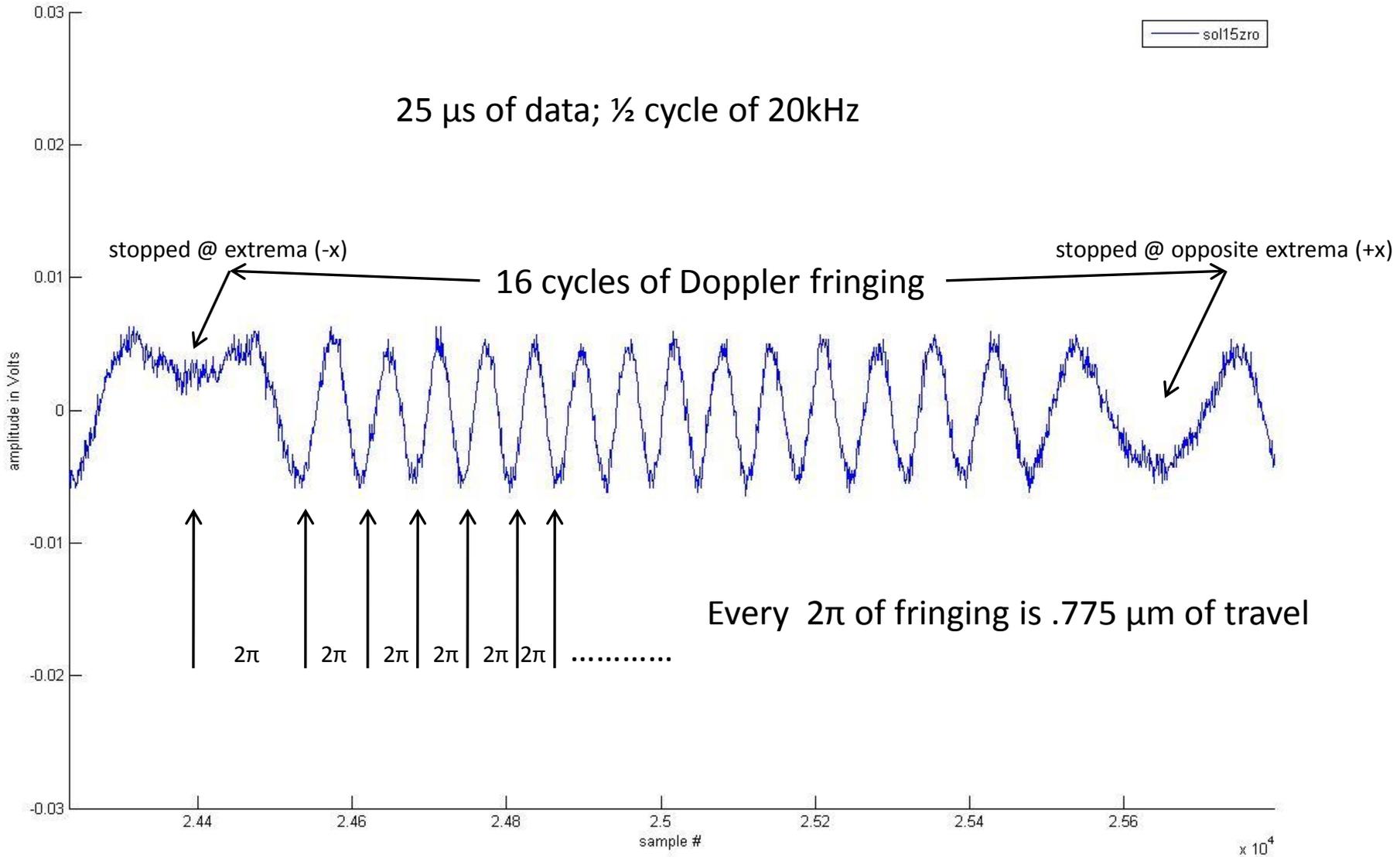
Effect of height to width ratio on the dynamics of UC

*James M. Gibert, Eric M. Austin and Georges Fadel*

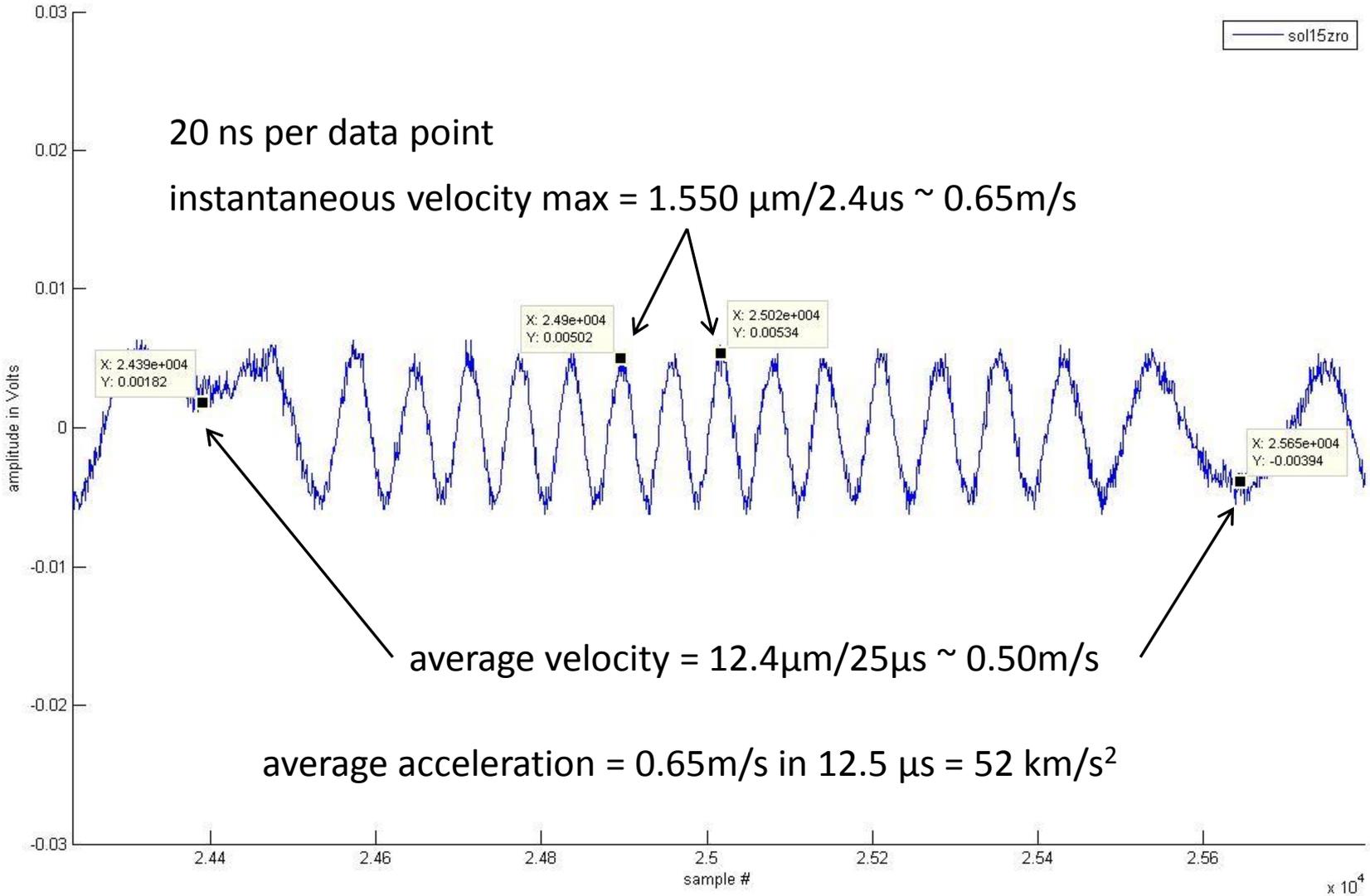
**Figure 1**



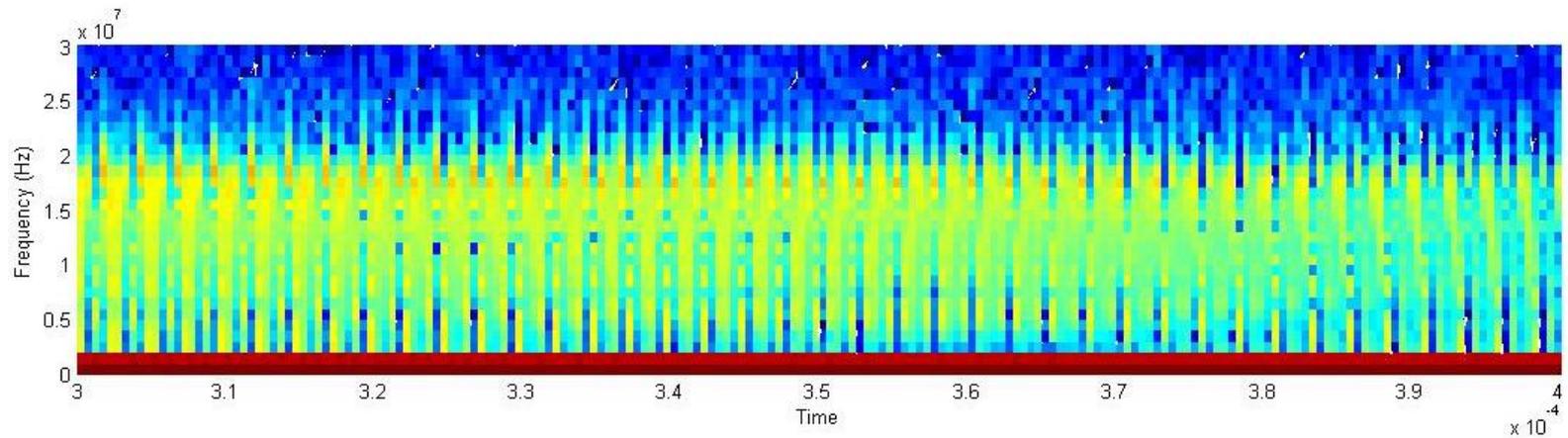
PDV raw data - solidica 15  
expanded centered subset  
~1200 samples



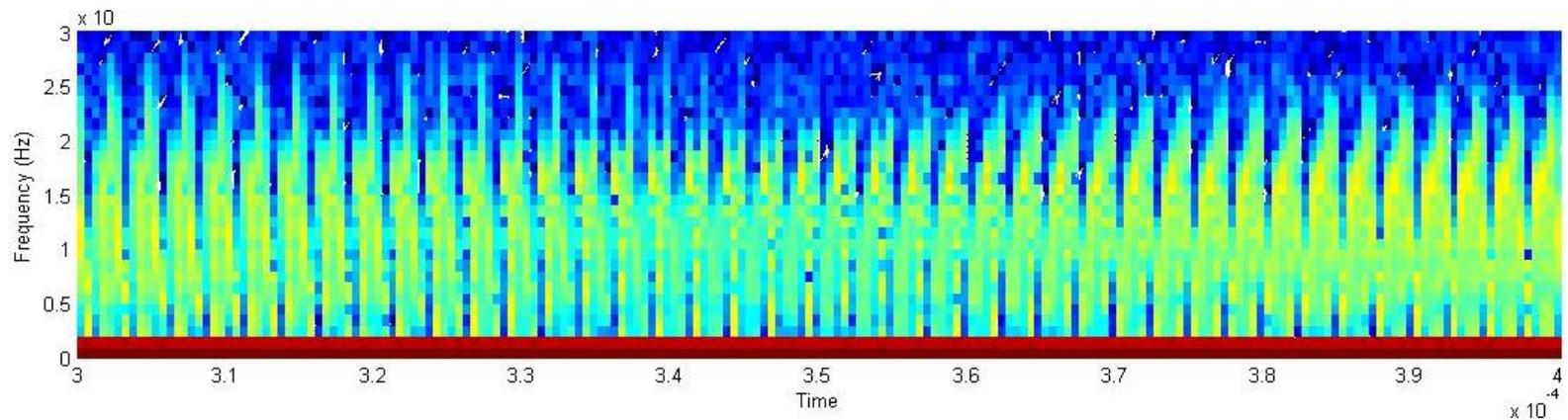
PDV raw data - solidica 15  
expanded centered subset  
~1200 samples



# Transducer amplitude vs. normal force

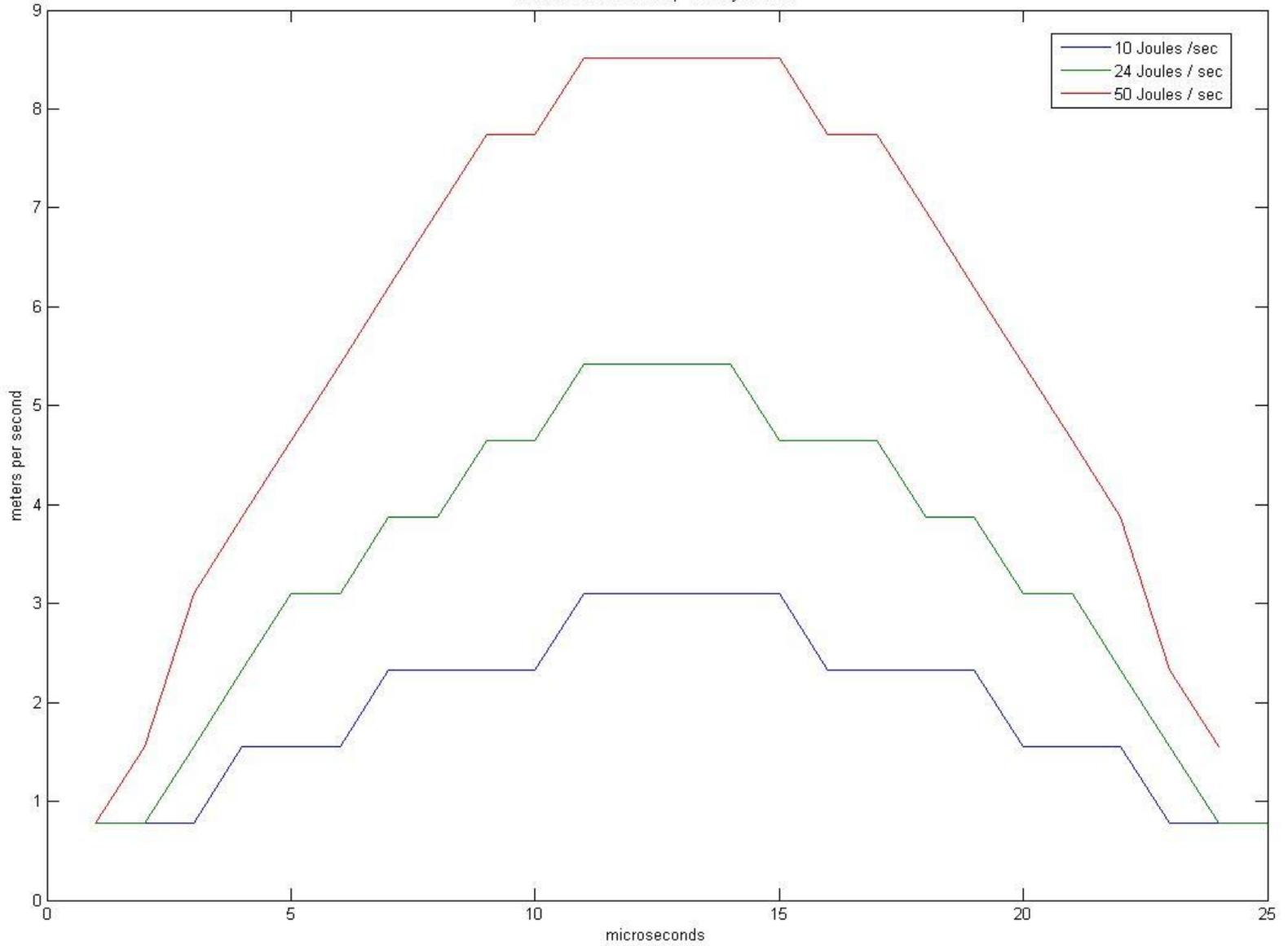


2000N normal force



500N normal force

Ultrasonic tranducer tip velocity vs time



Half cycle displacement ultrasonic transducer - normal to tip

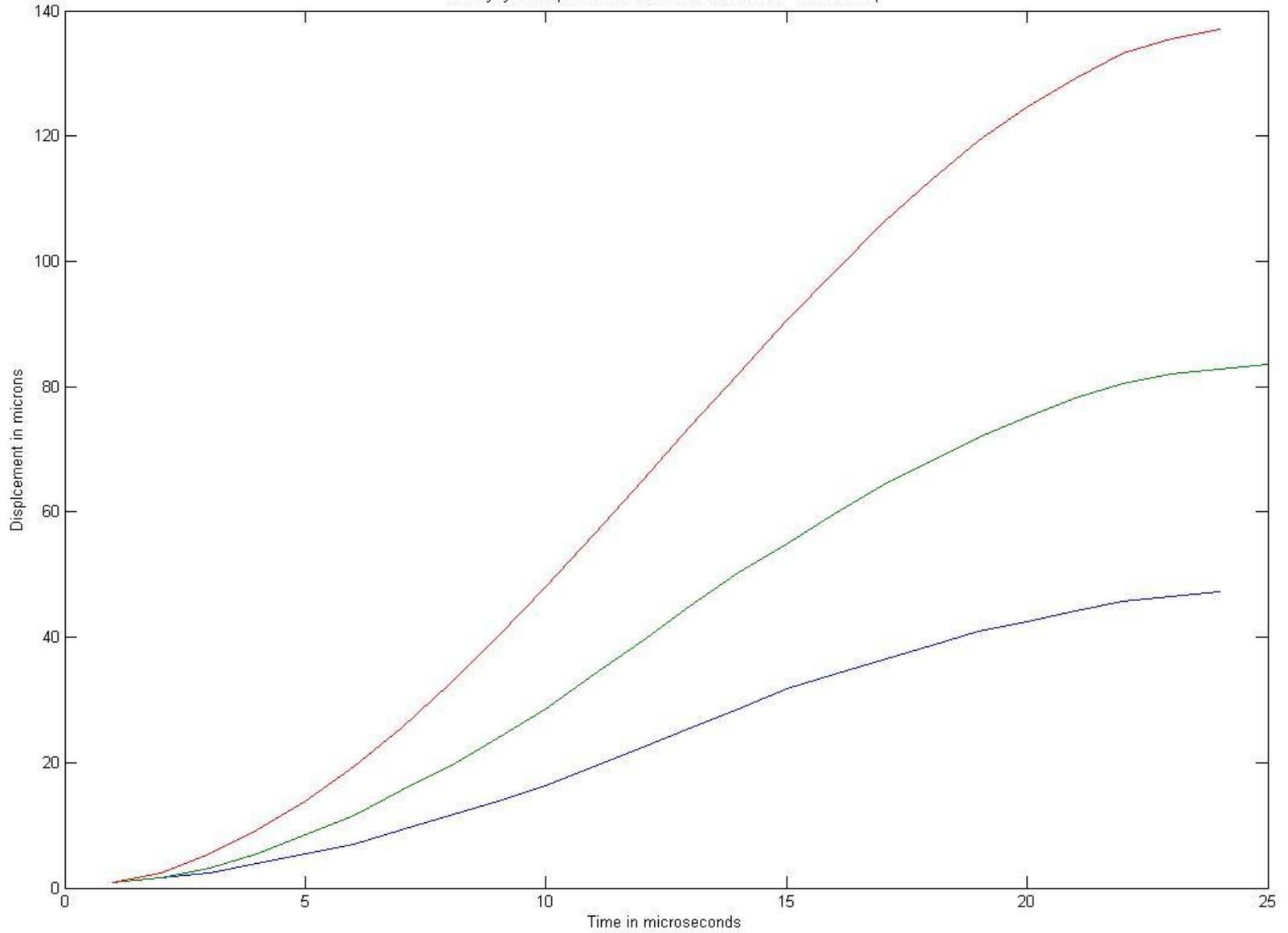
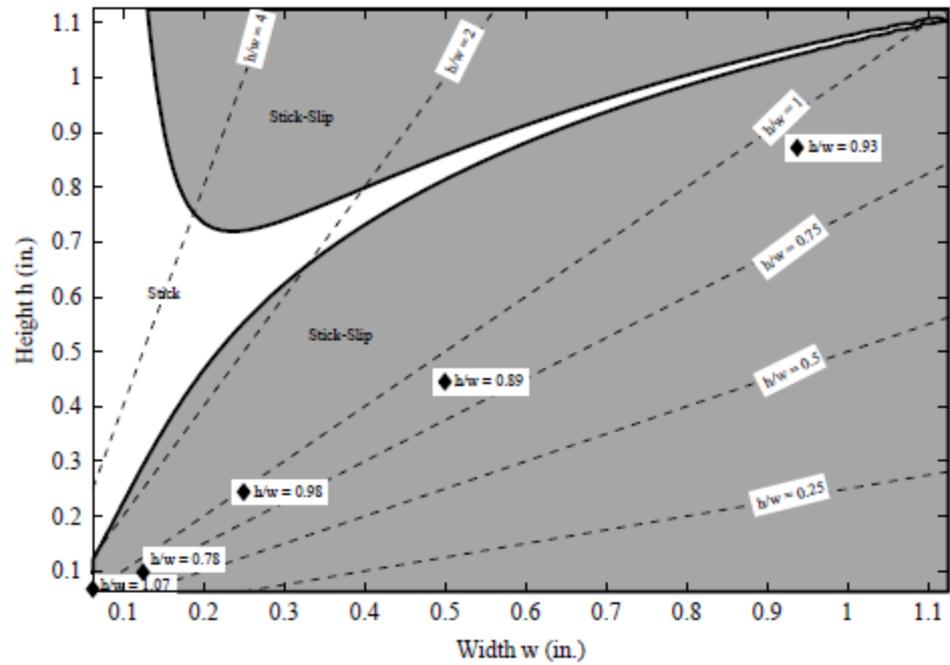
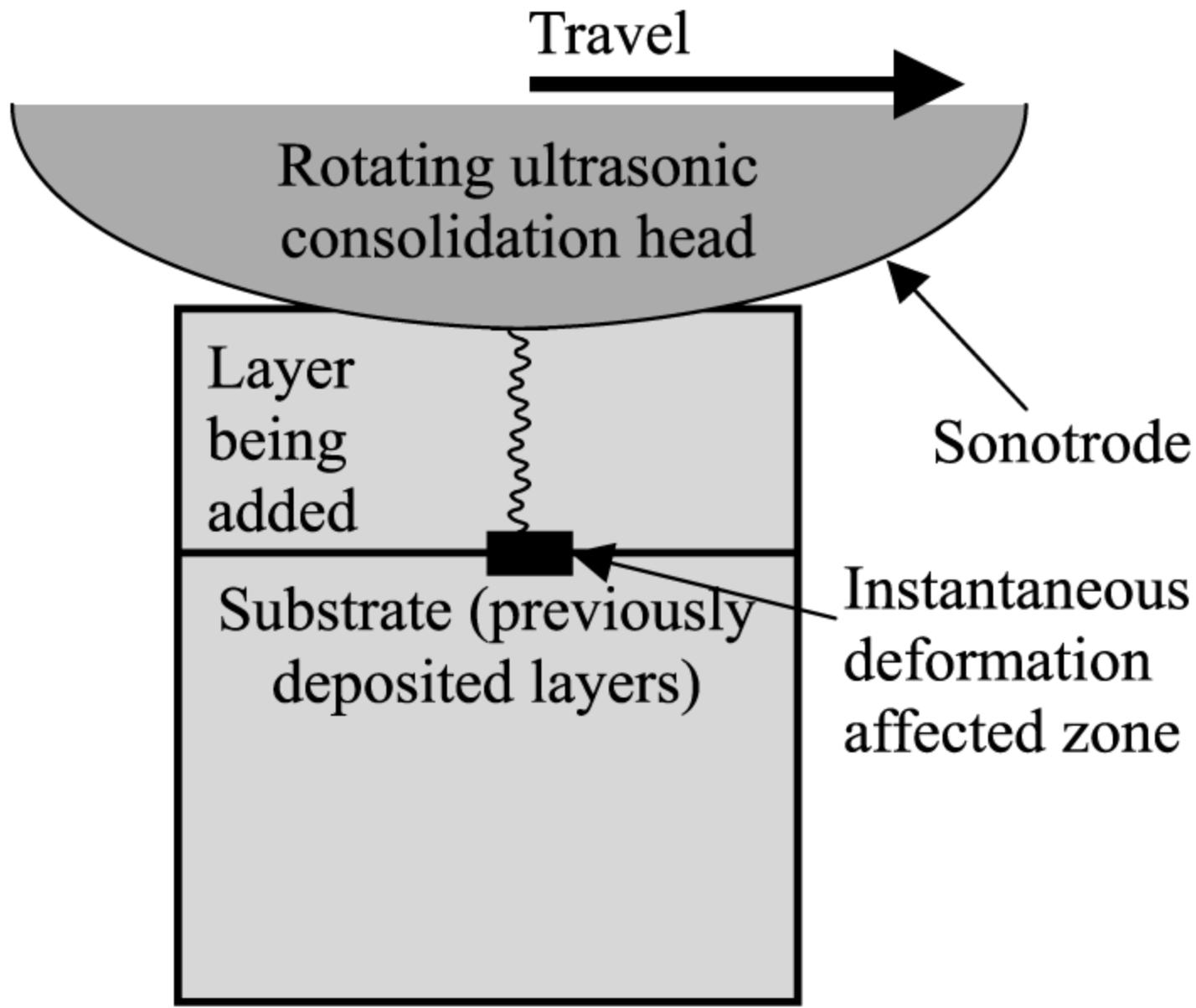


Figure 10





Finally, a key assumption in the lumped parameter model is no slip between the sonotrode and the top of the foil. During normal operation of the sonotrode damages the top surface (Ram Janaki *et al.*, 2006). Ram Janaki *et al.*, 2006 conclude that the no slip assumption is valid under moderate sonotrode wear and texture loss. Li and Soar (2007) further strengthen this finding by noting excessive sonotrode wear resulted in slip with the foil. They noted several phenomena that occurred when slip existed between the sonotrode and tape. Specifically, slipping resulted in shifting, overlapping and crinkling of foils. Contradicting these findings are the work of Johnson (2008), he concluded that most of ultrasonic energy used for bonding, i.e. energy due to slip, is between the build feature and tape and not at the interface between the tape and the substrate. He bases this conclusion on observing the presence of sub-grain refinement at the sonotrode foil interface. In the context of lumped parameter model the “ideal” case is assuming the no slip condition and using this condition to quantify slip at the tape feature interface.

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