In recent years, there has been a significant increase in interest in research on physical phenomena occurring as a result of contact. Most of this research relates to the phenomena occurring in the structures with contact-type damage. For this type of damage can be include fatigue cracks and delaminations. The first attempts to determine the mechanisms that cause non-linear behavior of materials as a result of contact damage are dated to the early 60th. Then the study on material nonlinearities due to flaws in atomic bonds or their local absence, associated with e.g. microcracks started. Knowledge of these phenomena, however, led to the development of the first theories related to the dynamics of the contact damage. In the last 15 years the study on phenomena associated with asymmetric, thermo-elastic behavior generated by the dynamic interactions of damage edge began. Such nonlinearities are a group of local non-linearities. Those types of nonlinearities are more complex for analysis then the global nonlinearity. The above-mentioned phenomena can be activated as a result of non-linear mechanisms manifest themselves in the form of: generation of higher harmonics as well as sub- and super harmonics, frequency "mixing" effect, frequency shifting, response signal modulation, "slow dynamics" effect and many others. Despite the many studies conducted in this area, it is still not fully explained what the physical mechanisms associated with the above nonlinearities. Table 1 summarizes existing research on nonlinear phenomena associated with contact type damage.

Material Scale	Strain Level	Nonlinear Mechanisms	Nonlinearity Type	Material Examples
Atomic	10^{-10}-10^{-8}	Intrinsic elastic nonlinearity due to anharmonicity of interatomic potential	Elasticity	Homogeneous solids glass, cooper
	$<10^{-8}$	Non-friction and non-hysteretic dissipation locally enhanced by thermoelastic coupling (local concentration of stress and increased temperature gradient)	Dissipation	
		Local variation in the elasticity of the defect produced by either hysteretic or purely elastic (non-dissipative and nonhysteretic) nonlinearity of the defect (cascade mechanism)	Elasticity Dissipation	
	10^{-7}-10^{-6}	Drastic increase in nonlinear elasticity at defects (microcracks and microcontacts); strong strain concentration due to breaking interatomic bonds	Elasticity	Rocks with microcracks
		Hysteresis in stress-strain; amplitude dependent dissipation		
Mesoscopic	10^{-6}-10^{-5}	Friction, adhesion hysteresis	Elasticity	
		Stick-slip friction between crack surfaces, adhesion hysteresis	Dissipation	Rocks microstructured materials, fatigue-damaged metals
		Crack induced nonlinearity (variation in elastic moduli)	Dissipation	
		Hertzian type nonlinearity (contact between crack surfaces)	Dissipation	
	$> 10^{-6}$	High compliant elastic inclusion with an arbitrary weak deviation from the linear model (rheological model)	Elasticity	
	10^{-5}-10^{-3}	Local stiffness reduction leading to natural frequency shift	Elasticity	
Macroscopic	10^{-4}-10^{-2}	Bi-linear stiffness (closing-opening crack)	Elasticity	Rocks, micro-inhomogeneous materials, solids with cracks solids
		Clapping mechanism	Elasticity	
		Wave modulation due to Impedance mismatch (discontinuity due to closing-opening crack)	Elasticity Dissipation	

There are two major difficulties associated with these problems. The first one is the diversity of nonlinear mechanisms proposed. Similar nonlinear effects can be manifested by different mechanism and vice versa. For example energy dissipation can be modelled using frictional, hysteretic or thermoelastic mechanisms. Hysteresis in turn involves both elasticity and dissipation, and could be linear or nonlinear. The second difficulty is that various experimental evidence - related to these nonlinear mechanisms - have been observed. It is often very difficult – if not impossible - to separate all these mechanisms involved. It is also important to note that nonlinearities may result not only from contact surface damage but also from other non-damage related effects such as: friction between elements at structural joints or boundaries, overloads, material connections between transducers and monitored surfaces, electronics and instrumentation measurement chain.

The aim of this project is to analyze the physical phenomena occurring in the structures contact type nonlinearity. The most important research hypothesis to be confirmed / refuted is the theory on coupling of the temperature field generated due to harmonic excitation of structure with a strain field. Research conducted in the framework of the project will lead to:

- Search on theory describing relationship between the temperature gradient in the vicinity of the contact type damage and strain field
- Come to know on nonlinear mechanisms reveal as a result of contact and attempts to define the nature of those mechanisms depending on the type of contact.
- Develop a methodology on similar physical phenomena

Knowledge about the above mentioned phenomena is very important for two reasons. First, all existing research in this field are conducted on the basis of the hypotheses posed as a result of the partial research into these nonlinear effects. There is no comprehensive knowledge covering both theory, numerical modeling and experiments and validation. Additionally, the authors of the proposal on the basis of preliminary research proved, that there is a relationship between temperature field and the strain field in case of contact type damaged structure. The results of the work have been published in prestigious scientific journals and presented at international conferences theme. Secondly, understanding and analysis of these phenomena may in the future lead to a lot of interesting and useful methods for contact type damage detection. Currently, non-linear methods used for detection and location of damages are on the stage of experimental studies. Although these techniques have a very high potential due to their sensitivity on contact type damage, there is no consistent procedures for teststing. Another problem is the lack of unified field theory enabling the separation of non-linearity associated with the contact from the others non-linearity (e.g. material nonlinearities).