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Research Article

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Viscoelastic or viscoplastic theory (vgt #115): a study of the us unemployment rates and covid-19 infection cases during the pandemic period from y2020q1 to y2022q1 based on gh-method: math-physical medicine, especially the vgt energy tool (no. 705)

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Introduction

The author is a mathematician and engineer who has conducted medical research work over the past 13 years. Thus far, he has written more than 700 medical research papers. Beginning with paper No. 578 dated 1/8/2022, he has written a total of 110 medical research articles and 5 economic research articles using the viscoelasticity and viscoplasticity theories (VGT). These papers aim to explore some hidden biophysical or physical behaviors and provide a quantitative understanding and interpretations of the relationships of a selected medical output (symptom) versus either selected singular input or multiple inputs (root causes, risk factors, or influential inputs). *The hidden biophysical behaviors and possible inter-relationships exist among lifestyle details, medical conditions, chronic diseases, and certain severe complications, such as heart attacks, stroke, cancers, dementia, and even longevity concerns. The chosen medical subjects with their associated data, multiple symptoms, and influential factors are* ***"time-dependent" which means that all biomedical variables change from time to time because body living cells are dynamically changing.*** *This is what* ***Professor Norman Jones****, the author's adviser at MIT, suggested to him in December 2021 and why he utilizes the VGT tools from physics and engineering to conduct his medical research work since then.*

From 1980 to 1981, the author attended a college in California for his MBA degree with an emphasis on finance and marketing. In addition, he spent many years managing a successful public-traded high-tech semiconductor business as the CEO in Silicon Valley, where it involved many key factors of economics and finance, such as gross domestic product (GDP), inflation rate, consumer price index (CPI), NASDAQ stock performance, price/earnings ratio (P/E ratio), various investment decisions, return on investments (ROI), unemployment rate, etc. As a result, he has plenty of opportunities to be involved with both finance and economic issues.

During his recent medical research work using the tool of viscoelastic or viscoplastic behavior theory, he suddenly realized a strong similarity between medicine and economics. The behaviors and patterns of economics variables (inputs and outputs) he observed are quite comparable to the behaviors and patterns of medical variables he studied and researched (causes and symptoms) in terms of their curve shape & waveforms, fluctuation patterns, and moving trends, physical behaviors, etc. ***Most importantly, variables in medicine and economics possessed the common "time-dependent" characteristics.***

The recent COVID-19 pandemic is a severe and unique experience for people worldwide that is comparable to the Spanish Flu that happened over a century ago. He wondered what type of economic impact or inter-relationship from this pandemic had on some of the current economic indices. Therefore, in this article, he selects the US unemployment rate % as the output variable and the US COVID-19 infection cases as the sole input variable to conduct his combined study of economics and disease.

The author conceived the idea of using mathematics, physics, and engineering in medical research while he was learning and practicing psychological care approximately 20 years ago. Due to the protection of his psychological patients' clinical data, requiring privacy and confidentiality, he cannot use their collected data in his research work. In addition, ***most published psychological papers are "subjective and language descriptive" rather than "objective and equation/number descriptive"*** like most papers in science and engineering. As a result, regarding the connections or relationships between economic indices, such as unemployment rate, GDP, Inflation, and CPI versus COVID infection cases, he can utilize the VGT equations and economics data from the public domain to conduct his research. It should be noted here that *the US unemployment ratio and US COVID infection data are rough "rounded-off" numbers that are directly extracted from the published graphic charts (not from data tables) from public institutions such as the Center for Disease*

Control (CDC) and Johns Hopkins University. The COVID data are simplified with rounded numbers to the millions for infection because using the precise digits would not improve the accuracy of results or change the observed physical characteristics. This study is of particular interest to him since it links the US national economy with severe infectious diseases in modern human history.

This article is one of five attempts to link COVID disease with key economic measurements. *The established theory of viscoelasticity and viscoplasticity from the physics branch of science* ***should not only be limited to a smaller scope of engineering applications.*** *Its ability to link certain variables' time-dependent characteristics and their associated energy estimation via the hysteresis loop area is equally powerful for applications in medicine, economics, psychology, and even certain social sciences.*

Method

6 steps of the Viscoelasticity & Viscoplasticity (VGT) process:

The author would like to ***describe the essence of the VGT in 6 simple steps using the English language instead of mathematical equations*** for readers who do not have an extensive academic background in engineering, physics & mathematics - *an excerpt from Wikipedia is still included in the Method section of the full-text article.*

The first step of VGT is to collect the output data (strain or ε) on a time scale, e.g. quarterly GDP, inflation rate, CPI, or unemployment rate. The second step is to calculate the output change rate with time (***dε/dt***), e.g. the change rate of US unemployment rate % for each quarter. The third step is to collect the input data (viscosity or ***η***) on a time scale such as quarterly numbers of COVID infections. The fourth step is to calculate the time-dependent input (time-dependent stress or ***σ***) by multiplying dε/dt and ***η*** together. ***(This "time-dependent input equation" is stress σ = strain change rate of*** *dε/dt* **** viscosity η).*** The fifth step is to plot the input-output (i.e. stress-strain or cause-symptom) curve in a space domain or SD (x-axis versus y-axis) with strain (output or symptom) on the x-axis; and stresses (time-dependent inputs, causes, or stresses) on the y-axis. The sixth step is to calculate the total enclosed area within this input-output curve (or hysteresis loop area) which is also the indicator of associated energy (either created energy or dissipated energy during the process) of this dataset of input and output. At this stage, he can calculate the areas associated with different periods to examine their associated energies or degrees of influence.

After providing this description, he would like to use the following re-defined ***VGT equation*** from engineering and physics to address the unique ***"time-dependency characteristic"*** of both economics and medical variables. He can then establish a ***stress-strain diagram*** in SD where:

Strain
= ε
= individual strain value at the present quarter

Stress
= σ (based on the change rate of strain multiplying with a chosen viscosity factor η, e.g. COVID infection case)
= η * (dε/dt)
= η * (d-strain/d-time)
= (viscosity factor η using individual viscosity factor at present quarter) * (strain at present quarter - strain at previous quarter)

These inputs (causes or viscosity factors) are further ***normalized by dividing them by the average viscosity factors.*** *This normalization process can remove the dependency of the individual unit or certain characteristics associated with each viscosity factor.* ***For example, he uses 150 for TG and 100 for FPG as their respective "break-even lines" or "healthy state vs. unhealthy state".*** *This process allows him to modify the variables into a set of* ***"dimensionless variables"*** *for easier comparison and interpretation of results.*

Elasticity, Plasticity, Viscoelasticity, and Viscoplasticity (LEGT & VGT):

The Difference Between Elastic Materials and Viscoelastic Materials
(from "Soborthans, innovating shock and vibration solutions")

What are elastic materials?

Elasticity is the tendency of solid materials to return to their original shape after forces are applied to them. When the forces are removed, the object will return to its initial shape and size if the material is elastic.

Medical analogy

The medical counterpart is "when cause or risk factors are reduced or removed, the symptoms of the certain disease would be improved or ceased".

What are viscous materials

Viscosity is a measure of a fluid's resistance to flow. A fluid with large viscosity resists motion. A fluid with low viscosity flows. For example, water flows more easily than syrup because it has a lower viscosity. High viscosity materials might include honey, syrups, or gels – generally, things that resist flow. Water is a low viscosity material, as it flows readily. Viscous materials are thick or sticky or adhesive. Since heating reduces viscosity, these materials don't flow easily. For example, warm syrup flows more easily than cold.

What is viscoelastic

Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Synthetic polymers, wood, and human tissue, as well as metals at high temperatures, display significant viscoelastic effects. In some applications, even a small viscoelastic response can be significant.

Medical analogy

Viscoelastic behavior means the material has "time-dependent" characters. Biomedical data, i.e. biomarkers, are time-depen-

dent due to body cells being organic which changes with time constantly.

Elastic behavior versus viscoelastic behavior

The difference between elastic materials and viscoelastic materials is that viscoelastic materials have a viscosity factor and elastic ones don't. ***Because viscoelastic materials have the viscosity factor, they have a strain rate dependent on time.*** Purely elastic materials do not dissipate energy (heat) when a load is applied, then removed; however, a viscoelastic substance does.

Medical analogy

Most of the biomarkers display time-dependency, therefore they have both change-rate of time and viscosity factor behaviors. Viscoelastic biomarkers do dissipate energy when a causing force is applied to it.

The following brief introductions are excerpts from Wikipedia

"Elasticity (physics)" Physical property is when materials or objects return to their original shape after deformation

In physics and materials science, elasticity is the ability of a body to resist a distorting influence and to return to its original size and shape when that influence or force is removed. Solid objects will deform when adequate loads are applied to them; if the material is elastic, the object will return to its initial shape and size after removal. This is in contrast to plasticity, in which the object fails to do so and instead remains in its deformed state.

Hooke's law states that the force required to deform elastic objects should be directly proportional to the distance of deformation, regardless of how large that distance becomes. This is known as perfect elasticity, in which a given object will return to its original shape no matter how strongly it is deformed. This is an ideal concept only; in practice, most materials that possess elasticity remain purely elastic only up to very small deformations, after which plastic (permanent) deformation occurs.

In engineering, the elasticity of a material is quantified by the elastic modulus such as Young's modulus, bulk modulus, or shear modulus which measure the amount of stress needed to achieve a unit of strain; a higher modulus indicates that the material is harder to deform. The material's elastic limit or yield strength is the maximum stress that can arise before the onset of plastic deformation.

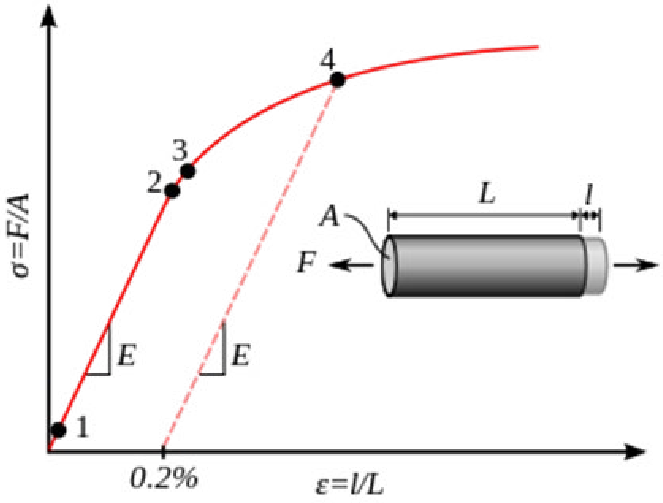
Medical analogy

The elastic behavior analogy in medicine can be expressed by the metal rod analogy for the postprandial plasma glucose (PPG). Consuming carbohydrates and/or sugar acts like a tensile force to stretch a metal rod longer, while post-meal exercise acts like a compressive force to suppress a metal rod shorter. If lacking food consumption and exercise, the metal rod (analogy of PPG) will remain in its original length, similar to a non-diabetes person or less-severed type 2 diabetes (T2D) patient.

Plasticity (physics)

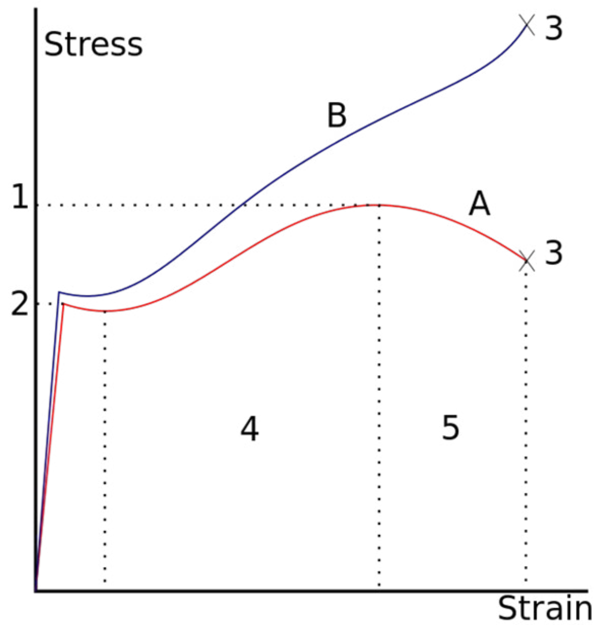
Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

In physics and materials science, **plasticity**, also known as **plastic deformation**, is the ability of a solid material to undergo permanent deformation, a non-reversible change of shape in response to applied forces. For example, a solid piece of metal being bent or pounded into a new shape displays plasticity as permanent changes occur within the material itself. In engineering, the transition from elastic behavior to plastic behavior is known as yielding. Plastic deformation is observed in most materials, particularly metals, soils, rocks, concrete, and foams.



A stress-strain curve showing typical yield behavior for nonferrous alloys.

1. True elastic limit
2. Proportionality limit
3. Elastic limit
4. Offset yield strength



A stress strain is typical of structural steel.

• 1: Ultimate strength
• 2: Yield strength (yield point)
• 3: Rupture
• 4: Strain hardening region
• 5: Necking region
• A: Apparent stress (F/A0)
• B: Actual stress (F/A)

For many ductile metals, tensile loading applied to a sample will cause it to behave in an elastic manner. Each increment of the load is accompanied by a proportional increment in extension. When the load is removed, the piece returns to its original size. However, once the load exceeds a threshold – the yield strength – the extension increases more rapidly than in the elastic region; now when the load is removed, some degree of the extension will remain.

Medical analogy

A plastic behavior analogy in medicine is the PPG level of a severe T2D patient. Even consuming a smaller amount of carbs/sugar, the patient's PPG will rise sharply which cannot be brought down to a healthy level of PPG even with a significant amount of exercise. This means that the PPG level has exceeded its "elastic limit" and entered into a "plastic range".

Viscoelasticity

Property of materials with both viscous and elastic characteristics under deformation.

In materials science and continuum mechanics, viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like water, resist shear flow and strain linearly with time when a stress is applied. Elastic materials strain when stretched and immediately return to their original state once the stress is removed.

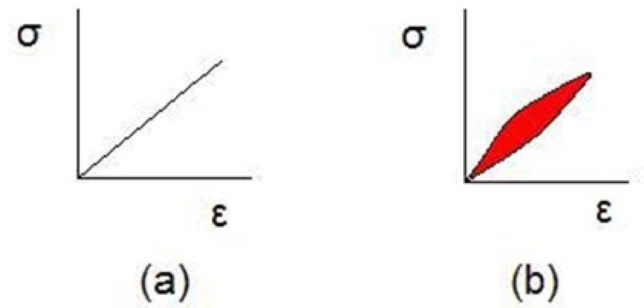
Viscoelastic materials have elements of both of these properties and, as such, exhibit time-dependent strain. Whereas elasticity is usually the result of bond stretching along crystallographic planes in an ordered solid, viscosity is the result of the diffusion of atoms or molecules inside an amorphous material.

In the nineteenth century, physicistssuch as Maxwell, Boltzmann, and Kelvin researched and experimented with the creep and recovery of glasses, metals, and rubbers. Viscoelasticity was further examined in the late twentieth century when synthetic polymers were engineered and used in a variety of applications. **Viscoelasticity calculations depend heavily on the viscosity variable, η. The inverse of η is also known as fluidity, φ. The value of either can be derived as a function of temperature or as a given value (i.e. for a dashpot).**

Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit rubber-like behaviors explained by the thermodynamic theory of polymer elasticity.

Cracking occurs when the strain is applied quickly and outside of the elastic limit. Ligaments and tendons are viscoelastic, so the extent of the potential damage to them depends both on the rate of the change of their length as well as on the force applied.

A viscoelastic material has the following properties:
• hysteresis is seen in the stress-strain
• stress relaxation occurs: step constant strain causes decreasing stress
• creep occurs: step constant stress causes increasing strain
• its stiffness depends on the strain rate or the stress rate.
Elastic versus viscoelastic behavior:



Stress-strain curves for a purely elastic material (a) and a viscoelastic material (b). The red area is a hysteresis loop and shows the amount of energy lost (as heat) in a loading and unloading cycle. It is equal to $\oint \sigma d\varepsilon$ where σ is stress and ε is strain. In other words, the hysteresis loop area represents the amount of energy during the loading and unloading process.

Unlike purely elastic substances, a viscoelastic substance has an elastic component and a viscous component. **The viscosity of a viscoelastic substance gives the substance a strain rate dependence on time.** Purely elastic materials do not dissipate energy (heat) when a load is applied, then removed. However, **a viscoelastic substance dissipates energy when a load is applied, then removed. Hysteresis is observed in the stress-strain curve, with the area of the loop being equal to the energy lost during the loading cycle.** Since viscosity is the resistance to thermally activated plastic deformation, a viscous material will lose energy through a loading cycle. Plastic deformation results in lost energy, which is uncharacteristic of a purely elastic material's reaction to a loading cycle.

Viscoplasticity

Viscoplasticity is a theory in continuum mechanics that describes the rate-dependent inelastic behavior of solids. Rate-dependence in this context means that the deformation of the material depends on the rate at which loads are applied. The inelastic behavior that is the subject of viscoplasticity is plastic deformation which means that the material undergoes unrecoverable deformations when a load level is reached. Rate-dependent plasticity is important for transient plasticity calculations. The main difference between rate-independent plastic and viscoplastic material models is that the latter exhibit not only permanent deformations after the application of loads but continue to undergo a creep flow as a function of time under the influence of the applied load.

Medical analog

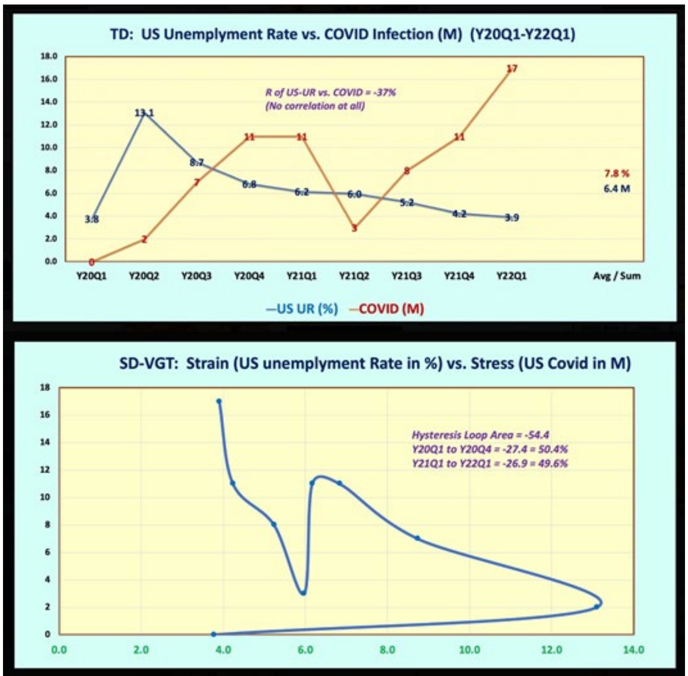
In viscoelastic or viscoplastic analysis, the stress component equals the strain change rate of time multiplying with the viscosity factor, or:

Stress (σ)
= strain (ε) change rate * viscosity factor (η)
= dε/dt * η

The hysteresis loop area
= the integrated area of stress (σ) and strain (ε) curve
= $\oint \sigma d\varepsilon$

Results

Figure 1 shows the time-domain (TD) correlation analysis result, SD VGT analysis of unemployment rates versus COVID infection cases, and the data table.



	Unemployment	Infection		Strain	Stress			
7/22/20-22	US UR (%)	COVID (M)	Strain Rate	US-UR %	Covid (M)	Height	Area	Time-periods
Y20Q1	3.8	0	0.0	3.8	0	0	0.0	
Y20Q2	13.1	2	9.3	13.1	2	1	9.3	
Y20Q3	8.7	7	-4.4	8.7	7	4.5	-19.7	
Y20Q4	6.8	11	-1.9	6.8	11	9	-17.1	-27.4
Y21Q1	6.2	11	-0.7	6.2	11	11	-7.3	
Y21Q2	6.0	3	-0.2	6.0	3	7	-1.4	
Y21Q3	5.2	8	-0.7	5.2	8	5.5	-4.0	
Y21Q4	4.2	11	-1.0	4.2	11	9.5	-9.5	
Y22Q1	3.9	17	-0.3	3.9	17	14	-4.7	-26.9
Avg / Sum	6.4	7.8	0.0	6.4	7.8	6.8	-54.4	
Correlation	100%	-37%						

Figure 1: TD correlation, SD-VGT energy, and data table of the US unemployment rate vs. COVID infection cases

Conclusions

In summary, there are 3 observations listed from this simple study of the unemployment rate versus the COVID infection cases:

(1) From the time domain analysis results, the correlation between unemployment rate ***vs. COVID infection cases is -37% which is no correlation at all.*** This correlation finding is not surprising to the author at all since a pandemic may impair the employee's work attendance but it should not have anything to do with the gain or loss of job opportunities. Of course, the pandemic may have caused many business shutdowns, particularly small business entities.

(2) Researching the part of strains from the SD-VGT diagram, we have seen that the unemployment rate has risen sharply from 3.8% in Y20Q1 to 13.1% in Y20Q2 due to the "initial shock" from the pandemic. After that quarter, the unemployment rate has been steadily dropping from 13.1% down to ~4% in Y22Q1. However, the COVID infection cases have gone through rising, flattening, dropping, and then rising again due to multiple reasons, such as vaccine availability, new COVID variants, etc. ***The strain (unemployment) change rate pattern and the viscosity (COVID infection) magnitude and pattern are influencing the final movement pattern of the strain-stress curve which can be observed and interpreted from the hysteresis loop in this diagram.***

(3) Further researching the stress-strain diagrams, the hysteresis loop area size is -54.4 which has no specific meaning since it lacks multiple inputs for a comparison study. However, ***the associated energies of its 2 different periods are almost equal to each other: Y20Q1-Y20Q4 = 50.4% and Y21Q1-Y22Q1 = 49.6%.*** This means that ***both Y2020 and Y2021 have almost equal amounts of complications from unemployment and COVID.***

Relatively speaking, this study of 1 output (unemployment rate) versus 1 input (COVID infection cases) is "too simple"; therefore, it fails to utilize the power of the VGT energy analysis which can usually provide some interesting clues or useful interpretation of results with multiple variables from this type of research subject.

References

1. For editing purposes, the majority of the references in this paper, which are self-references, have been removed for this article. Only references from other authors' published sources remain. The bibliography of the author's original self-references can be viewed at www.eclairemd.com.

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