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# Evaluation of E-Glass / Epoxy Folded Composites

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***Abstract**:*

*In this study, properties of composite materials were investigated. Evaluations were made for the types of composite materials and their use. A detailed analysis was done by giving information about the studies about the composites in the scientific field.*

***Keywords***

*Composite materials, e-glass, epoxy,*

## 1. Introduction

Composite materials; In order to produce a suitable material in the design, it is the new materials obtained by combining two or more materials of macro size. A macro size means that the material is sized to be visible to the naked eye or magnifying glass. Composite material is a structure obtained by combining it in macro size to obtain better mechanical or thermal properties. Composite materials are composed of the main structure and the reinforcement material, usually called the matrix, to show the best properties of the materials that make them. Therefore, the determination of the mechanical properties of these materials is important for the determination of the usability of the materials in this class.

## 2. Composite Materials

Composite material is the new material obtained by combining two or more materials at the macro level to create a more suitable material that can give the desired properties in the design [1].

The main importance of composite materials in engineering is that the composite material composed of two or more different elements is superior to the characteristics of each element in the mixture [2].

In the 1940s, composite materials were developed to serve the aviation industry. The aim was to develop materials with lower weight but more strength and higher hardness, wear resistance and fracture toughness values instead of conventional materials such as steel and aluminum alloys [3].

When designing a composite part, a number of factors such as cost, raw material properties, and environmental impact of the component, manufacturing method and quality control methods should be considered together. One of the biggest challenges in design is that the composite materials do not show isotropic properties. Therefore, the designer must understand how much load will come from each direction in the direction of the part and the strength of the part at which point the strength is needed, and calculate the placement angles of the fibers accordingly.

As the core of the composite materials, there is a fiber material and a matrix material which constitutes the majority in volume around this material. Here, the fiber material provides the strength and load bearing property of the composite material. The matrix material prevents crack propagation in the transition to plastic deformation and delays the breakage of the composite material. Another object of the material used as matrix is to keep the fiber materials together under load and to distribute the load homogeneously between the fibers. In this way, when the plastic deformation occurs in the fiber materials, the crack propagation event will be prevented [4].

Composite materials, parts integrity, light weight, high strength, impact resistance and long life, such as features, provides advantages in wide-use areas [5].

## 3. Advantages and Disadvantages of Composite Materials

The low specific gravity of composite materials provides a great advantage in lightweight structures. In addition, corrosion-resistant, heat, sound and electrical insulation of fiber-reinforced composite materials provide an important advantage for their respective applications [6].

Composite materials can replace metallic materials if theoretical studies to eliminate the disadvantages of composite materials result in a positive result. The advantages of composite materials can be listed as follows [7-11].

### *3.1. High strength*

The tensile and bending strengths of composite materials are much higher than many metallic materials. In addition, due to the coating properties, composites can be given the required strength in the desired direction and in the desired area. Thus, by saving material, lighter and cheaper products can be obtained.

### *3.2. Easy forming*

Large and complex parts made using composite material can be molded into one piece in one operation. This results in material and labor.

### *3.3. Electrical specifications*

By selecting suitable materials, composite products with very high electrical properties can be obtained.

### *3.4. Resistance to heat and fire*

The heat-resistant properties of composites composed of low heat transfer coefficients allow to be used under high temperatures. Heat resistance of composite material can be increased with some special additives.

### *3.5. Vibration damping*

Due to the ductility of the composite materials, it has a natural vibration damping and shock absorption feature. This prevents cracking.

### *3.6. Resistance to corrosion and chemical effects*

Composite materials are not damaged by weather effects, corrosion and most chemical effects. Due to these properties, composite materials, chemical tanks, pipes and aspirators, boats and sea vehicles are used safely.

### *3.7. Permanent coloring*

Composite materials can be given the desired color thanks to the pigments added to the resin during molding. This does not require additional cost and labor. Composite materials have many advantages over steel and aluminum despite the disadvantages mentioned below. For this reason, composites are a material that can be used in many industrial areas such as chemical tanks, road tankers, building facades and boards, automobile body and bumpers, sea boats, complete bath units, household items, agricultural vehicles.

### *3.8. Disadvantages of composite materials*

1. The raw material is expensive.

2. The properties of the laminated composites are not always ideal, they have low strength in thickness direction and low shear strength between the layers.

3. Quality of material production depends on the quality of the methods, there is no standardized quality.

4. Composites are easily damaged due to their brittle material and their repair can create new problems.

## 4. Classification of Composite Materials

Although it is not possible to draw certain boundaries in the grouping of composites that can be used in many different materials in their structures, it is possible to classify the structures and constituents of the structures in two ways according to their shapes.

### *4.1. Composites According to Materials Forming Structures*

4.1.1 Fiber Composites

This composite type is formed by the presence of fine fibers in the matrix structure. The placement of fibers in the matrix is an important factor affecting the strength of the composite structure. While the long fibers are placed parallel to each other in the matrix, high strength is obtained in the direction of the fibers, while very low strength is obtained in the direction perpendicular to the fibers, while two-dimensional fiber reinforcements provide equal strength in both directions, while it is possible to form an isotropic structure with homogeneously distributed short fibers in the matrix structure. The strength of the fibers is very important for the strength of the composite structure. Further, as the length / diameter ratio of the fibers increases, the amount of charge delivered to the fibers by the matrix increases. The error-free structure of the fiber structure is also very important in terms of strength [12-15].

Another important factor in the strength of the composite structure is the structure of the bond between the fiber matrix. Contact with the fibers will be reduced if there are voids in the matrix structure. Moisture absorption is a negative feature that disrupts the bond between fiber and matrix.

#### *4.1.2 Particle Composites*

A matrix is obtained by the presence of another material in the material in the form of particles. Isotropic structures. The strength of the structure depends on the hardness of the particles. The most common type is the metal particles in the plastic matrix. Metal particles provide thermal and electrical conductivity. Structures containing ceramic particles in metal matrix have high hardness and high temperature resistance. They are preferred in the production of aircraft engine parts.

***4.1.3 Layered Composites***

The laminated composite structure is the oldest and most widely used area. Very high strength values are obtained by the composition of layers having different fiber orientations. Heat and moisture resistant structures. They are preferred materials because they are lightweight and also resistant to metals. Continuous fiber-anneal layered composites are widely used in aircraft structures, as a surface coating material in the wing and tail group.

In addition, sandwich structures with widespread use in aircraft structures are also examples of layered composite materials. Sandwich structures are obtained by adhering to the lower and upper surfaces of a low density core material which has only isolation property without carrying load.

***4.1.4 Hybrid Composites***

It is possible that two or more types of fibers are present in the same composite structure. Such composites are called hybrid composites. This area is suitable for the development of new type of composites. For example, Kevlar is a cheap and tough fiber, but its compressive strength is low. Graphite is a low toughness but expensive but with good compressive strength. In the composite structure of these two fibers, the toughness of the hybrid composite is better than the graphite composite, the cost is low and the compressive strength is higher than the kevlar fiber composite.

***4.2 Composites according to the shape of building components***

4.2.1 Polymer Composites

Fiber-reinforced polymer composites have a wide range of applications in the industry. Glass, carbon kevlar and boron fibers are used as reinforcement.

The most important binding material used in polymer composites is polyester and epoxy. As the amount of reinforcing fibers increases, the strength of the composite increases. The most important properties of polymer composites are high specific strength (strength / specific gravity) and specific modulus of elasticity. Therefore, they are superior to other materials due to these properties. For example, although the specific strength in high strength steels is 110 Nm / g, glass fiber polyester is 620 Nm / g in polyesters. On the other hand, the carbon fiber epoxy is also 700 Nm / g and the kevlar epoxy is 886 Nm / g. On the other hand, the specific modulus of elasticity of carbon fibers is 5 times that of aluminum. Due to these advantages, polymer composites are preferred to aluminum alloys in aircraft and aerospace industries.

***4.2.2 Metal Composites (Metal Matrixed Composite Materials MMC)***

MMCs are obtained by applying advanced techniques such as melting vacuum impregnation, hot pressing and diffusion welding with some reinforcing materials of a metallic phase. MMCs are mainly used in space and aerospace, such as space telescope, platform carrier parts, reflectors and support parts of space communication devices. used in places.

***4.2.3 Ceramic Composites (Ceramic Matrices United Materials CMC)***

For this purpose, high-tech ceramics with structural and functional qualities are used. $Al_2O_3$, SIC, $Si_3N_4$ , $B_4C$, CbN, TiC, TIB, TIN, AIN. These compounds are in different constructions and one or more of them are used together to obtain CMCs. Sandwich armors, space vehicles with various military purpose parts are the main areas of use of these products.

***4.2.4 Basic Materials in Composite Material Making***

***4.2.4.1 Matrix Materials***

The matrix has three basic functions in composite structures. These are to keep the fibers together, distribute the charge to the fibers and protect the fibers from environmental influences. An ideal matrix material should initially have a low viscosity structure and then be able to easily pass the solid to the solid form, which can be firmly and appropriately surrounded by the fibers.

In composite structures, the mechanical properties of the matrix are very important in order to perform the functions of the carrying fibers. Considering a fiber bundle without, for example, a matrix material, the charge will be carried by one or more fibers. The presence of the matrix will provide equal distribution of the load to all fibers. Resistance to a stress under shear load requires a good adhesion between the fibers and the matrix and the high shear strength properties of the matrix. The mechanical properties of the matrix and the bond forces between the fiber and the matrix in the direction perpendicular to the fiber directions are important considerations that determine the strength of the composite structure. The matrix is weaker and more flexible than fiber. This feature should be considered in the design of composite structures [16].

If the shear strength of the matrix and the bond strength between the matrix and the fiber are too high, it is possible that a crack in the fiber or matrix can proceed without changing direction. In this case, the composite acts as a brittle material and the rupture surface is clean and bright. If the bond strength is too low, the fibers behave like a fiber bundle in the space and the composite weakens. In the case of a medium bond strength, a crack can proceed in the fiber direction by turning to a cracked fiber / matrix interface in the transverse direction starting from the fiber or matrix. In this case, the composite shows a fibrous surface, such as the breakage of ductile materials [16-18].

***4.2.4.2 Resins and their Properties***

Epoxy Resins; Epoxy resins are the reaction product of biphenol A with epichlorohydride and when mixed with the curing agent (catalyst), it hardens at a certain temperature and firing (70°-90°) for a certain period of time and takes on a plastic appearance. Important features of the liquid, viscous liquids or solids can be found in the presence of electricity, heat, chemical resistance and mechanical properties are high, is not affected by weather conditions. Storage times are 24 months at room temperature.

Polyesters; They are obtained from the reaction of dibasic acids with polyalcohols such as glycerin and glycol. Solid, liquid thermostat, thermoplast are found in such species. Liquid polyesters are cured using catalyst and accelerator. Resistance to hard, chemical and weather conditions is very high. Solid polyesters (such as LPET) are impact resistant.

Urethane Resins; The urethanes obtained by addition of an isocyanate with a polyalcohol at room temperature are more commonly used in making foam rubber (flexible and rigid). Chemical resistance is good. Software features are high.

Phenolic Resins; Phenol is the condensation product of formaldehyde, sometimes used in derivatives of these raw materials. There are solid and liquid types. Our country has liquid resin production.

Types of Fibers and Their Properties; The fiber reinforcements in the matrix material are the basic strength elements of the composite structure. High density modulus and hardness, as well as low density, are resistant to chemical corrosion. Glass fibers are the oldest fiber types used in technology. Boron, carbon, silicon carbide and aramid fibers developed in recent years are fiber types used in advanced composite structures. Due to the small diameter of the fibers, structural error possibilities are minimized compared to large masses [19-25]. Therefore they show superior mechanical properties. In addition, the reasons for the fact that fibers are high-performance engineering materials also depend on the following:

1. Superior microstructural properties, small particle size and small diameter production.
2. As the length / diameter ratio increases, the amount of charge delivered to the fibers by the matrix material increases.
3. Too high a modulus of elasticity.

## 5. Glass Fiber

Glass fibers are manufactured in many types from ordinary bottle glass to high purity quartz glass. Glass is an amorphous material and has a polymeric structure. In a three-dimensional molecular structure, a silicon atom is surrounded by four oxygen atoms. Silicium is a non-metallic lightweight material, usually in the form of silica ($SiO_2$) with oxygen . The silica sand for the glass production is heated to about 1260 ° C in the dry state with the additive materials and a hard structure is obtained when allowed to cool [23-26].

Some properties of glass fibers can be summarized as follows:

1. Tensile strength is high, higher than k Cel strength per unit weight.
2. Their thermal resistance is low. They do not burn, but soften at high temperatures.
3. They are resistant to chemical materials.
4. They do not have moisture absorbing properties, but in glass fiber composites there may be a dissolution with the effect of moisture between the matrix and the glass fiber. This effect can be eliminated by special fiber coating processes.
5. They don't transmit electricity. This feature allows the use of glass fiber composites in cases where electrical insulation is important.

When various additives are added to silica sand in glass fiber production, the structure gains different properties with the effect of these materials. Four different types of glass fibers are available.

A (Alkaline) Glass: A glass is a highly alkaline glass. This therefore, the electrical insulating property is poor. It is the most common glass type with high chemical resistance.

C (Corrosion) Glass: Resistance to chemical solutions is very high.

E (Electric) Glass: Due to its low alkali ratio, its electrical insulation is very good compared to other types of glass. The strength is quite high. Its resistance to water is also very good. Composites generally developed for humid environments E glass is used.

B i is an epoxy resin binder with woven fiberglass fabric composite materials, this product is. Resistant to fire. It has extinguishing capability. Mainly used as raw materials for electrical components or PCBs. They are used for insulation at high temperatures.

S (Strength) Glass: High strength glass. Pull strength is 33% higher than E glass. It also has a very good fatigue resistance at high temperatures. Due to these properties, it is preferred in aerospace industry. Glass fibers are generally used with plastic or epoxy resins.

Boron Fiber; Boron fibers are actually composite within themselves. They are manufactured by boring on a thin filament called core. The core is usually tungsten. Carbon core can also be used but this is a new application.

Bor-Tungsten fibers, hot tungsten filament hydrogen and boron chloride ($BC1_3$) are produced by passing gas. So the tungsten filament outside the boron Plate consists of. Boron fibers can be produced in different diameters (0.05 mm to 0.2 mm).

The tungsten core is always produced with a diameter of 0.01 mm. Boron fibers have high tensile strength and elastic modulus. Tensile strengths are 2758 MPa to 3447 MPa. The modulus of elasticity is 400 GPa. This value is five times higher than the modulus of elasticity of the S glass. Boron fibers with superior mechanical properties have been developed for use in aircraft structures. However, due to their high costs, they have been replaced by carbon fibers in recent years. Boron fibers are coated with Silicon Carbide (SiC) or Boron Carbide ($B_4C$) to increase the resistance to high temperatures. In particular, the tensile strength of boron carbide coating can be increased significantly. The melting temperatures of boron fibers are around 2040°C [22-26, 28, 29].

Silicon Carbide Fibers; Boron, silicon carbide on the tungsten core is obtained by coating. They are produced with diameters from 0.1 mm to 0.14 mm. High temperature properties are better than boron fibers. Silicon carbide fiber loses only 30% of its strength at 1370°C. For boron fibers, this temperature is 640°C. These fibers are generally used with Titanium matrix. They are used in Jet engine parts with Titanium, Aluminum and Vanadium alloy matrix. However, silicon carbide fibers have higher density than boron fibers. The density of the fibers produced by coating the silicon carbide onto the carbon core is low [18-23].

Alumina Fibers; Alumina is Aluminum oxide ($A1_2O_3$). The alumina in the form of fibers is obtained by coating the silicon dioxide ($SiO_2$) of 0.02 mm diameter alumina filament. The tensile strength of the alumina fibers is not high enough, but their compressive strength is high. For example, the compressive strengths of alumina epoxy composites are 2275 to 2413 MPa. They are also used in aircraft engines due to their high temperature resistance.

Graphite (Carbon) Fibers, Carbon is a crystalline material with a density of 2.268 g/cm$^3$. Carbon fibers are a widely used fiber group that is developed later on from glass fibers. Both carbon and graphite fibers are produced from the same base material. These materials are known as raw materials. This raw material is heated to 1000 - 3000 ° C in an inert atmosphere and at the same time pulling force is applied. This process provides strength and toughness. However, due to the high cost, rayon fibers are not suitable.

In fiber manufacturing, polyacrylonitrile (PAN) is used instead of rayon. PAN-based fibers have a tensile strength of 2413 to 3102 MPa and are low in cost. The pitch-based fibers obtained by the refining of petroleum have tensile strength of 2069 MPa. Mechanical properties are not as good as PAN-based fibers but they are low in cost.

The most important properties of carbon fibers are low density as well as high strength and toughness values. Carbon fibers are not affected by moisture and their creep resistance is very high. Wear and fatigue strength is quite good.

Aramid Fibers; Aramid is the abbreviated name of "Aromatic polyamide". Polyamides are long chain polymers, in the molecular structure of the aramid, six carbon atoms are bonded to each other by hydrogen atoms. Two different types of aramid fibers are available. These are the Kevlar 29 and Kevlar 49 developed by DuPont. The mechanical properties of aramid are very good in the direction of fiber axis as in graphite fibers and very weak in vertical direction to fibers. Aramid fibers have low weight, high tensile strength and low cost properties. It has a high impact resistance, its friability is about half of the graphite's brittleness. Therefore, it can be easily shaped. It is resistant to natural chemicals but is affected by acids and alkalis [14-21, 28, 29].

Both Kevlar have a tensile strength of 2344 MPa and the elongation at break is 1.8%. Kevlar 49's elastic modulus is twice as high as Kevlar 29. The density of Kevlar fiber is lower than that of glass and graphite fibers. The impact strength of Kevlar49 / Epoxy composites is seven times higher than graphite epoxy composites and four times better than boron/epoxy composites. Due to their low compressive strength, they are used as hybrid composites with carbon fibers on the control surfaces. Aramid fibers do not have electrical conductivity. Besides the inadequate compressive strength, Kevlar epoxy composites have poor moisture absorption properties [28, 29].

There are many studies on the energy efficiency of composite materials or different materials. For example, instead of using uniform materials in a heating pipe for a stirling engine, up to 32% more energy can be produced using different materials. The advantages of different heating coefficients and the ability to conduct heat are provided here. More energy is produced from a product of the same nature [30, 31].

## 6. Conclusion

Composites cover a lot of subjects which are suitable for theoretical and experimental studies in many fields. For example, composite plates' response to impact, different plate thickness of the composite plate design, the impact of the thickness of the wall thickness, the impact of composite plate sizes on the impact can be examined.

## References

[1] Şahin, Y., 2000. Kompozit Malzemelere Giriş. *Gazi Kitapevi, Ankara*

[2] Smith, W.F., 2001. Malzeme Bilimi ve Mühendisliği. Üçüncü basım. Çeviri Editörü, Nihat G. Kırıkoğlu, *Literatür Yayınları*, İstanbul, 724.

[3] Kayrak, M.A., 1999. Havacılık Kompozitleri ve Mukavemet-Maliyet Analizleri. *Sivil Havacılık Yüksek Okulu Yayınları, No.09*, Eskişehir, 1, 12-13, 69.

[4] Lal, K.M., 1983.Low Velocity Transverse Impact Behavior of 8-Ply Graphite-Epoxy Laminates. Journal of Reinforced Plastics and Composites, 2, 216-225.

[5] Belingardi, G. and Vadori, R., 2002. Low Velocity Impact Tests of Laminate GlassFiber-Epoxy Matrix Composite Material Plates. *International Journal of Impact Engineering*, 27, 213-229.

[6] Mitrevski, T., Marshall, I.H., Thomson, R., Jones, R. and Whittingham, B., 2004. The Effect of Impactor Shape on the Impact Response of Composite Laminates. *Composite Structures*, 67, 139-148.

[7] Rotem, A. and Lifshitz, J.M., 1971. Longitudinal Strength of Unidirectional Fibrous Composite under High Rate of Loading. Proc. 26th Annual Tech. *Conf. Soc. Plastics Industry Reinforced Plastics, Composites Division*, Washington, DC, Section 10-G: pp. 1-10.

[8] Whitney, J.M. and Pagano, N.J., 1970. Shear Deformation in Heterogeneous Anisotropic Plates. *Journal of Applied Mechanics*, 37, 1026-1031.

[9] Şenel, M.and Kurşun, A., 2011. Investigation of the Effect of Low-Velocity Impact on Composite Plates with Preloading. *Society for Experimental Mechanics.*

[10] Gong, S.W. and Lam, K.Y., 1999. Transient Response of Stiffened Composite Plates Subjected *to Low Velocity Impact. Composites*, *Part B*, 30, 473-484.

[11] Kara, M., 2006. Düşük Hızlı Darbeye Maruz Tabakalı Kompozitlerin Dinamik Cevabı. *Yüksek Lisans Tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü,* Konya.

[12] Karakuzu, R., İçten, B.M., Aktaş, M., Toparlı, M., Ataş, C. ve Arman, Y., 2007.

[13] Kompozit Plakalarda Sıcaklığın Darbe Davranışına Etkisi. *TÜBİTAK, Proje No; 104M426*, İzmir, 6-8, 23-26.

[14] Lifshitz, J.M., 1976. Impact Strength of Angle Ply Fiber Reinforced Materials. *Journal of Composite Materials*, 10, 92-101.

[15] Aslan, Z., Karakuzu, R. and Okutan, B., 2003. The Response of Laminated Composite Plates under Low-Velocity Impact Loading. Composite Struc., 59, 119-127.

[16] Abrate, S., 1998. Impact on Composite Structures. *Cambridge University Press*, Cambridge, 135-160.

[18] Metin, M., 2008. E-Camı/Epoksi Tabakalı Kompozitlerde Düşük Hızlı Darbe Hasarının Burkulma Özelliklerine Etkisi. *Yüksek Lisans Tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü*, Konya.

[19] Mili, F. and Necip, B., 2001. Impact Behavior of Cross-Ply Laminated Composite Plates under Low Velocities. Composite Structures, 51, 237-224.

[20] Aslan, Z. and Karakuzu, R., 2002. Transient Dynamic Analysis of Laminated Composite Plate Subjected to Low-Velocity Impact. *Mathematical and Computational Applications*, Vol. 7, No.1, 73-82.

[21] Baucom, J.N. and Zikry, M.A., 2005. Low Velocity Impact Damage Progression in Woven E-glass Composite Systems. *Composites*, 36, 658-664.

[22] Sankar, B.V., 1992. Scaling of Low Velocity Impact for Symmetric Composite Laminates. *Journal of Reinforced Plastics Composites*, 11, 297-305.

[23] Güvensoy, S., 2010. Filaman Sarım Kompozit Boruların Düşük Hızlı Darbe Davranışının Simülasyonu. *Yüksek Lisans Tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü*, Konya

[24] Sayman, O., 2007. Kompozit Malzemeler Ders Notları. *Dokuzeylül Üniversitesi, Makine Mühendisliği Bölümü*, İzmir.

[25] Sierakowski, R.L. and Chaturvedi, S.K., 1997. Dynamic Loading and Characterization of Fiber-Reinforced Composites. *New York, Wiley*.

[26] Abatan, A., Hu, H. and Olowokere, D., 1998. Impact Resistance Modeling of Hybrid Laminated Composites. *Journal Thermoplastic Composite Materials*, 11, 249-260.

[27] Sun, C.T. and Chattopadhyay, S., 1975. Dynamic Response of Anisotropic Laminated Plates under Initial Stress to Impact of a Mass. *ASME Journal of Mechanics*, 42, 693-698.

[28] Uyaner, M., Kara, M. ve Ataberk, N., 2007. E-camı/epoksi Tabakalı Kompozitlerin Düşük Hızlı Darbe Davranışına Numune Boyutlarının Etkisi. *8. Uluslar Arası Kırılma Konferansı Bildiriler Kitabı,* İstanbul.

[29] Ünal, O., 2004. Yapı Malzemesi Ders Notları. *Afyon Kocatepe Üniversitesi, Makine Mühendisliği Bölümü*.

[30] Cengiz, MS., Mamiş, MS., Yurci, Y. 2018. Providing electrical power increase by stimulating temperature difference at low temperatures in Stirling motors, *Sigma Journal of Engineering and Natural Sciences*, 36 (1), 87-97

[31] Cengiz, MS., Mamiş, MS., 2016. Analysis of Electrical Efficiency in Stirling Engine for Temperature Increase, *International Workshop on Special Topics on Polymeric Composites*, February 24, 2016.

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